



FINAL REPORT 2018

For Public Release

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: UNE1404

Project Title: Semiochemical management for occasional pests of cotton and grains

Project Commencement Date: 1/7/2013 **Project Completion Date:** 30/6/2018

CRDC Research Program: 1 Farmers

Part 2 – Contact Details

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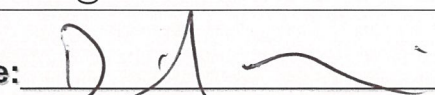
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A/Prof David Miron, Acting DVCR

Date Submitted:

9/10/18

Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Following extensive discussions since 2010, CRDC agreed to provide seed funding for a Centre for Biopesticides and Semiochemicals, to be developed by researchers from NSW DPI, the University of Western Sydney, and the University of New England. The aim of the Centre was to conduct basic research to identify new biopesticide and semiochemical solutions for use in integrated pest management in a range of Australian cropping systems, and to facilitate the commercial development of products based on these discoveries. It was anticipated that additional funding would be sourced from other rural R & D corporations and commercial partners in the future. However, CRDC eventually supported only some individual project applications that were submitted under the umbrella of the CBS, rather than the Centre itself, and no additional funding was available from other rural RDCs.

This application described a project led by UNE participants in the Centre. It focused on pheromones which might be used for monitoring, in early warning systems. Target pests were selected because existing monitoring and control methods were not adequate, and current GM technology did not provide management options. The targets are green mirids (*Creontiades dilutus*), affecting cotton and to a lesser extent grain legumes and the cotton leafworm or cluster caterpillar (*Spodoptera litura*), affecting cotton, vegetables and grain legumes. It had also been planned to include work on the common armyworm (*Mythimna convecta*), affecting winter cereals, but these aims were dropped when no funding was available from GRDC.

Following agreement from CRDC, the research component of this project was delayed until 1/7/2014, to enable us to focus on completing the larger project UNE1301. The administrative starting date of 1/7/2013 was retained to allow the project supervisor to participate in activities of the Centre for Biopesticides and Semiochemicals. For this reason many of the milestones were achieved at a later date than specified in the original project agreement.

Objectives

2. List the project objectives and the extent to which these have been achieved, with reference to the Milestones and Performance indicators.

The objectives and milestones with their due dates for the project are listed below:

1. Contribute to management of CBS

1.1 Attend meetings and teleconferences to discuss coordination of projects (1.10.13 to 30.6.18)

Achieved: There were a few meetings of participants in the Centre in 2013 and 2014, and these were attended by P. Gregg. The lack of funding for the Centre itself led to the abandonment

of formal meetings but informal contacts were continued between researchers from the three institutions.

2. Improve mirid pheromone lures

2.1 Investigate commercial options for producing slow-release lures (31/10/2014)

Achieved: The components of the mirid pheromone, hexyl hexanoate and (*E*)-2 hexenyl hexanoate, are very volatile compared with many moth pheromones, so it was necessary to develop slow release technology so the lures would have reasonable field life. Slow release pheromone lures had been first investigated by the UNE team in 2007, a part of Project 1502 in the Cotton Catchment Communities CRC. Rubber septa were coated with epoxy except for a small uncoated area at the tip through which the pheromone escaped. This enabled us to complete some early field trials, and the data from these trials have been re-analysed and included with this report. However it was concluded that these lures could be further improved.

After investigating the possibilities of producing slow release lures with a number of semiochemical companies, we contracted with Scentry Biologicals Inc. of the USA. Their initial solution was to enclose a large amount (7.5 g) of the active chemicals in a low density polyethylene pouch. We received a shipment of 100 of these lures for trial purposes, and established a field trial in cotton and pigeon pea near Breeza, NSW. Unfortunately the release rates of the highly volatile mirid pheromone components were much too variable with this dispenser. They were too high early in the life of the dispenser, and this proved to be repellent rather than attractive, and the life of the dispenser was much shorter than Scentry had predicted. In September 2015 P. Gregg attended the Asia-Pacific Association for Chemical Ecology Conference in Los Angeles, where he had the opportunity to further discuss the problems with representatives of Scentry, as well as other pheromone companies (Shin-Etsu of Japan, and ISCA Technologies of California). Following these discussions we decided to give Scentry another try, and they produced a novel dispenser in which the pheromone components are impregnated in polymer plugs. We conducted headspace GC-MS analyses with these lures and determined that the release rate profiles were much improved.

2.2 Trial lures with minor components (31/3/2017)

Achieved: In the original development of the pheromone, by PhD student Sam Lowor in the Cotton Catchment Communities CRC, a number of potential minor components of the pheromone were identified. In 2016/17 we tested a blend, in the Scentry polymer lures, which contained butyl hexanoate, suggested by Lowor as the most likely candidate for a minor component which might improve the blend. However, we found that catches were lower with this blend than the standard two-component blend. We then chose to focus on other aspects of the project and did not test any more potential minor components. There is scope for further work in this area.

3. Correlate mirid pheromone catches with field populations

3.1 First field trial of pheromone traps vs field populations (31/3/2015)

Achieved: We established two mirid pheromone traps, at each of four sites: “Kilmarnock” and “Milchengowrie” near Boggabri, “Ruvigne” near Gunnedah, and “Westend”, near Quirindi. One trap had the low dose loading (30 mg/lure) and the other had a high loading (60 mg/lure). We asked two consultants (Rob Weinthal, RAW Agriculture for Kilmarnock and Milchengowrie, and Adrian Nelson (NuRural) for Ruvigne and Westend) to check the traps at

regular intervals and to supply us with their data on mirid numbers in beat sheet samples. We made trips at approximately weekly intervals to sample all four sites using the D-vacs and clear the traps, adding to the consultants' data. The results are presented in the attached supplementary reports.

3.2 Second field trial of mirid pheromone traps vs field populations (31/3/2017)

Achieved: We conducted a second trial in which high-dose pheromone lures were deployed at two locations, "Kilmarnock" and "Milchengowrie". The 2015/16 trials had indicated major inconsistencies between the two consultants, due probably to differences in sampling techniques. There were also differences in interpretation of thresholds which led one consultant to spray much more than the other. For these reasons we did not use consultants in the second season's trials, relying entirely on our own data from suction samples.

We also had problems with the lures in this season. Problems in formulation in the US led to lower release rates, and lower mirid catches. We did not discover this until the trial was under way, and it was too late to replace the lures. Consequently the data from this trial were not used in the analysis of correlations between pheromone trap catches and field numbers of mirids. The results from suction sampling did however contribute to achieving Aim 4 (see below).

Following the failure of the second season of field trials we sought and were granted an extension from CRDC to conduct a third season of trials. On this occasion we tested the lures on receipt from the USA and found satisfactory release rates. We deployed pheromone traps on four fields at "Kilmarnock", "Nandewar" and "Brigadoon", near Boggabri.

The results from the 2015/16 and 2017/18 trials are presented in Supplementary Report #1 attached to this report. We also re-analysed some data from the old CRC project. In summary we found that there was a poor correlation between pheromone trap catches and mirid numbers in the field at any given time. However closer examination of the data revealed that peaks in pheromone catches often predicted peaks in field numbers, after a lag that was typically 1-3 weeks. We interpreted this as due to the female competition effect, where females compete with the traps during breeding, but males go to the traps when breeding has stopped and females are either lacking or not seeking mates. The field peaks arise when the next generation emerges. We used this information to develop ways of interpreting the catch to predict whether industry standard thresholds were likely to be exceeded in the near future, and use this information in conjunction with bug checking to assist management. Details are presented in Supplementary Report #1.

4. Investigate mirid reproductive biology

4.1 Describe seasonal trends in sex ratios and mated status (30/6/2017)

Achieved: We recorded mirid adults and nymphs separately in the suction samples for each site in the three years of sampling. We also sexed all the adults, and dissected females to determine if they had been mated. Previous attempts to study season-long mirid population dynamics have been hampered by the use of different sampling methods at different stages of crop development. We used suction sampling throughout the season. The results are described in Supplementary Report #2.

Briefly, the three seasons were very different. In 2015/16 and 2017/18 mirid numbers were low but built up during the season. In 2016/17, following a wet winter and spring both locally and in potentially distant source areas, early season numbers were very high, but there appeared

to be little breeding in cotton from this generation and numbers fell steadily for the rest of the season. Theoretical day-degree calculations indicated that three generations were possible in each of the seasons, with minor variation between seasons due to different temperatures. However, the suction sampling did not indicate that these generations actually occurred in cotton – patterns were inconsistent, with usually only one or two peaks in a season. The sex ratios and the proportions of nymphs were very inconsistent, suggesting that movement in and out of cotton is common, and may vary between the sexes, and immigration is not always followed by oviposition. There is a need for further detailed studies of mirid ecology in cotton, that also take into account nearby crop and non-crop vegetation, and potential long distance movement. Pheromone traps might assist in this, but there is a need for development of standardised sampling methods which might be different from those employed by cotton consultants.

5. Produce strategic review of future potential for attractants in insect pest management for Australian cotton

5.1 Write literature review for CRDC and possible publication (31/8/2017)

Achieved: P. Gregg wrote a 79 page review entitled “Applications for semiochemicals in the Australian cotton industry” that was submitted in October 2017. Topics covered included pheromones and kairomones and their roles in pest management such as monitoring, mass trapping, attract-and-kill, mating disruption and manipulation of natural enemies. The literature on semiochemicals for major and minor pests of cotton as well as exotic pests of quarantine concern was reviewed, and opportunities for research and development identified. The review was favourably received by CRDC and has been circulated to research colleagues for feedback before potential publication.

6. Evaluate feasibility of trials of *Spodoptera litura* pheromones as monitoring tools

6.1 Location, logistics and design of a field trial to evaluate *S. litura* pheromones developed

Achieved: This milestone was substituted for more extensive work on *Spodoptera litura* that had been proposed subject to GRDC funding but not proceeded with when that funding did not happen. A trial in northern Queensland was proposed, but in the event an opportunity arose to conduct a trial in the Ord Valley, with a modified design (see Milestone 6.1 below).

6.1 Conduct field trial of *S. litura* pheromones if warranted

Achieved: An opportunity to test *S. litura* pheromones arose in conjunction with a trial conducted by Steven Yeates (CSIRO) and Paul Grundy (QDPI) in the Ord region in 2018. Pheromone lures were sourced from Alpha Scents in the USA for this species and also for *Spodoptera frugiperda* (fall armyworm). The latter species was included because it is an exotic pest of biosecurity concern, and it was thought useful to determine whether *S. litura* would come to its pheromones, which might cause false alarms if sentinel pheromone traps were deployed. Pheromone traps were set up at two sites, Ceres and KAI near Kununurra. As well as AgriSense universal traps, Trapview smart traps were supplied by their Australian distributor, Adama Pty Ltd, who also funded travel and operating costs for this component of the project.

The results are presented in Supplementary Report #3. Briefly, the conclusions were that the Asian pheromone blend for *S. litura* is highly effective for Australian *S. litura*, that this species does not come to *S. frugiperda* pheromones, and that both AgriSense and Trapview smart traps

are potentially suitable for monitoring for *S. litura*, though some modifications to the Trapviews would be needed. Attempts to correlate field numbers of larvae with pheromone catches were limited by the low numbers of larvae, which were likely due to high efficacy of the Bollgard III cotton compared to earlier observations by other researchers working with Bollgard II. However some evidence of peaks in larval numbers following pheromone peaks was obtained.

7. Engage commercial partners

7.1 Hold discussions with potential commercial partners (30/6/2018)

Achieved: Following the analysis of the trials relating pheromone trap catches to field numbers (Supplementary Report #1) and interest expressed by growers and consultants, we decided to commercialise the lures ourselves, through our private company EcoKimiko IPM Pty Ltd. This company licensed the technology for the pheromone blend from UNE, which had patented it following the PhD project of Sam Lowor. CRDC, which had some background IP as a legacy from the last Cotton CRC, agreed to this arrangement. EcoKimiko has negotiated a commercial supply of lures from Scentry and is marketing them to growers and consultants for the coming season. Details can be found on the EcoKimiko website, www.ecokimiko.com.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

The methods used in the project have generally been standard ecological techniques and are described in the Supplementary Reports.

The technique for incorporating the mirid pheromones in polymer lures is proprietary information of Scentry and not available to us, but it has potential for use with other highly volatile pheromones,

Suction sampling is not widely used by cotton consultants, though it once was. It is however a common research technique, and we made an advance by using electric rather than petrol suction samplers. We investigated the performance of a 36 volt electric D-vac (Ryobi Model RBV3650) compared to a petrol D-vac (Ryobi PBV30) similar to those used by researchers and consultants in the past. Four replicate samples were made with each type at each of four sites on two occasions. The numbers of mirid adults and nymphs, along with red & blue beetles and coccinellids (ladybirds, all species) were counted in 50 m samples. Results are shown in Fig. 1.

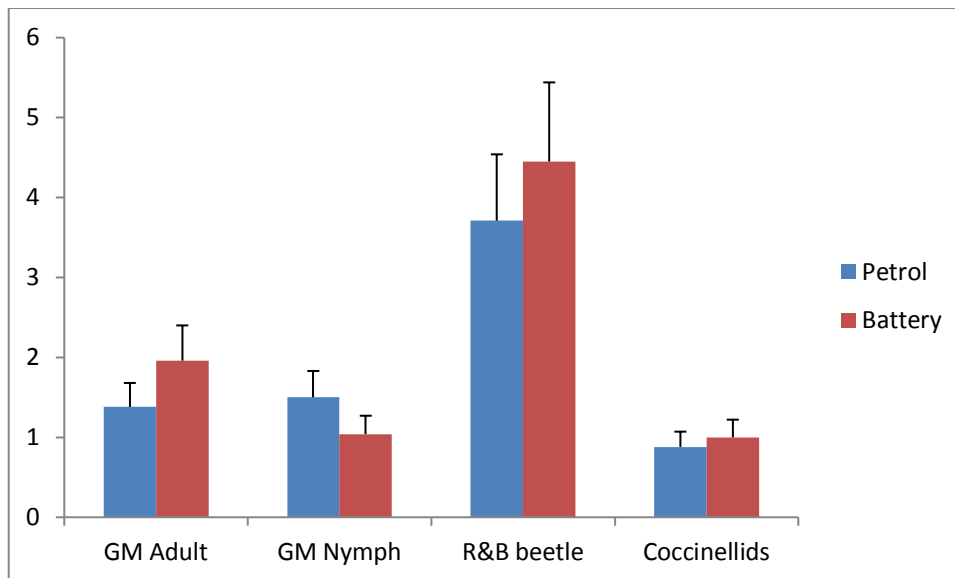


Fig. 1. Numbers of four types of insects in 50 m suction samples using battery and petrol powered D-vacs.

There were no significant differences in any of these categories, even though the measured airspeeds generated by the D-vacs were slightly different (41 m/s for the battery D-vac compared with 44 m/s for the petrol). The battery version was much quieter than the petrol one, and it is likely that any effects of lower suction levels were compensated for by less disturbance of the insects ahead of the operator. Since the battery-powered version was more reliable and more comfortable for operators, we recommend its use for other researchers.

We also made advances in the design of traps for mirids. We found that it was necessary to put the traps within the crop, rather than on roads or ditches nearby, as is done for *Helicoverpa* spp. This is probably because mirids are weaker flyers and less likely to leave the crop. It was also necessary to locate the traps at canopy height, and adjust them during the season. We developed modified universal trap supports for this purpose, that pose less risk to machinery such as pickers if they are accidentally left in the field. Details can be found on the EcoKimiko website.

We also investigated the use of Trapview smart traps with mirid pheromones. This component of the work was supported by Adama, and data are being prepared for a confidential report to them. However it is clear that the Trapview traps can be used for mirids, albeit with certain modifications, some of which have already been made. It is likely that many of the lures supplied by EcoKimiko this season will be used in Trapviews, which offer the advantage that catches can be viewed daily online, thus providing more timely information without the need to physically service the traps. We also investigated the effects of combining *Helicoverpa armigera* pheromone with mirid pheromone, which would enable the traps to be used to monitor both species at once. It appears that *Helicoverpa* pheromones do not affect mirid responses, and mirid pheromones may potentiate *Helicoverpa* pheromones. Further work is needed, and there is an issue with the sticky surfaces of the Trapviews clogging up with scales if large numbers are present.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

Detailed results and analyses are presented in the three Supplementary Reports (attached)

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

The main outputs from the project are a stable formulation of green mirid pheromone that can be used for monitoring, and knowledge of how to use mirid pheromones to support decisions on mirid management. The main outcome is that the cotton industry will have access to improved methods of monitoring for green mirids. At present mirid management in cotton is complicated by lack of confidence in thresholds, due partly to difficulties with sampling and partly to lack of understanding of how numbers in the field relate to damage levels. This leads to poor spray decisions, including unnecessary spraying. We do not suggest that mirid pheromones are a substitute for bug checking, but a supplement to it, and a way of providing early warning of potential problems. They may also be a useful tool in understanding mirid ecology.

Another output is knowledge of the effectiveness of *Spodoptera litura* pheromones, and the lack of cross-attraction to *Spodoptera frugiperda*. This may be useful if sentinel traps are used for this exotic species.

6. Please describe any:-

- a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);**
- b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and**
- c) required changes to the Intellectual Property register.**

(a) EcoKimiko has an exclusive license for the mirid pheromone blend from UNE and has contracted with Scentry for the manufacture of lures – see www.ecokimiko.com.

(b) Advances in methodology for suction sampling and using universal traps for mirids are described in Section 3 above, and may be useful for future research in mirid ecology. We have also evaluated the Trapview smart traps for use in cotton to monitor mirids, *Helicoverpa* spp. and *Spodoptera litura*. This information will be provided in a confidential report to Adama, who funded this component of the project.

(c) There are no changes to the IP register.

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

The main impact for the industry is likely to be improved methods for monitoring green mirid populations in cotton, and consequently better decisions on spraying. This will contribute to overall improvements in IPM. An important take-home message is that semiochemical methods for monitoring and control of insect pests have potential for commercial development, and this can contribute to better pest management in cotton.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:

(a) to further develop or to exploit the project technology.

(b) for the future presentation and dissemination of the project outcomes.

(c) for future research.

(a) The project technology will be developed through sales of lures and traps by EcoKimiko. Depending on feedback from the industry we may increase stocks of lures and traps being imported from the USA, and we may advertise these products in trade publications such as *Australian Cottongrower*.

(b) We applied for a place in the “Startup Alley” initiative promoted by CRDC in the 2018 Australian Cotton Conference, but were unsuccessful. However, we were given space for a display by Adama on their trade stand, and about 20 consultants expressed interest in trying the mirid pheromones this season. We will apply again if this initiative is repeated in the next Cotton Conference, and will also present at CCA meetings and grower association meetings as opportunities arise. We also anticipate presenting results at the next Australian Cotton Research Association conference.

(c) We are asking for feedback, including data from pheromone traps and mirid populations in the field, to guide further research. One self-funded project we will undertake through EcoKimiko is to compare universal traps of different colours (yellow, white and green) to see if colour affects trap catches. Also, it is unfortunate that in 2016 we were unable to monitor the large early season immigrations of mirids due to the substandard lures we had that year, so we do not know how the pheromones perform in this situation. When a similar year occurs we would like to repeat the trials correlating trap catches with field numbers.

More generally, we see a need for fundamental studies on mirid ecology. The variability in sex ratios and apparent variable breeding success in cotton between years and sites, the suggestion of variation in mobility between the sexes, the lack of understanding of mirid movement and migration, and our inability to identify discrete mirid generations all indicate there is much we do not understand about mirid ecology, and management will be hamstrung without such understanding.

9. A. List the publications arising from the research project and/or a publication plan.

(NB: Where possible, please provide a copy of any publication/s)

The discovery and potential uses of mirid pheromones were described in two publications in 2009, following the PhD project of Sam Lowor:

Lowor ST, Gregg PC & Del Socorro AP (2009). Sex pheromones of the green mirid *Creontiades dilutus* (Stal) (Hemiptera: Miridae). *International Journal of Agricultural Research* **4**, 137-145

Lowor ST, Gregg PC & Del Socorro AP (2009). Potential for pheromone-based attract and kill and mating disruption of the green mirid *Creontiades dilutus* (Stal) (Hemiptera: Miridae). *International Journal of Agricultural Research* **4**, 153-162.

The work in the current project has been largely commercial-In-confidence so there are no publications yet, but we hope to publish in the future, in the light of commercial experience with the mirid pheromone.

Publication of a modified version of the semiochemical review (Milestone 6) is being considered.

B. Have you developed any online resources and what is the website address?

The EcoKimiko website www.ecokimiko.com contains information about the mirid pheromone as well as the company, and information about our past research and publications, and about semiochemicals generally.

The website also contains a document on Frequently Asked Questions about the mirid pheromone which can be downloaded from <https://www.ecokimiko.com/products-and-services/i9kup043tmz0h6ic4unk3etuzwugtt> and is being included with all mirid pheromones distributed by us.

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

This project aimed to investigate the potential for monitoring two pests in cotton using sex attractant pheromones. One target pest was the green mirid *Creontiades dilutus*, which is an emerging pest that is not controlled by current transgenic cotton varieties. The other was the cluster caterpillar, *Spodoptera litura*, an occasional pest of cotton in northern Australia for which transgenic varieties available at the time the project commenced had limited efficacy.

The green mirid work built on research done by a postgraduate student in the Cotton Catchment Communities CRC a decade ago. That research identified the sex attractant pheromone for this species. While the active components were readily available and cheap, the use of the pheromone was restricted by its high volatility which meant it was rapidly lost from lures. This problem was overcome through collaboration with a semiochemical manufacturer in the USA, Scentry Biologicals Inc., who produced a lure based on their proprietary polymer formulation. We tested these lures in standard universal pheromone traps and new Trapview smart traps, the latter in collaboration with Adama Australia Pty. Ltd. This work was done in collaboration with cotton consultants who checked for field populations. It also included some re-analysed data from the old Cotton CRC project. We found that while the correlation between mirid trap catches and field numbers at any one time was poor, there was a good correlation between peaks in trap catches and subsequent peaks in field numbers, and that this could be related to thresholds used to make decisions on insecticide treatments.

We also studied mirid ecology and reproductive biology by determining the sex and mated status of field populations. We found extensive variation in sex ratio and mated status between areas and times, and suggest there is extensive movement of mirids in and out of cotton fields, and there may be variation in this between the sexes. Further research on mirid ecology is needed.

The mirid pheromone is being produced commercially by a company set up by the principal researchers in this project, EcoKimiko IPM Pty Ltd. This company has licensed the technology for the pheromone and marketing lures and traps to consultants and growers in the cotton

industry from the current season. It is expected that information from these traps will supplement current checking methods and lead to improved decision making for control of mirids, facilitating IPM for other pests for which mirid sprays often disrupt natural enemies.

Studies on *Spodoptera litura* were conducted in the Ord River area in collaboration with CSIRO, Ordco Pty Ltd and Adama Pty Ltd. We found that the pheromone, originally developed for Asian *S. litura*, also worked for Australian moths. Monitoring using universal traps was effective, but the smart traps could also be used, though a few modifications were required. We also deployed the pheromone for *Spodoptera frugiperda* (fall armyworm), an exotic pest of potential biosecurity importance. This pheromone did not attract *S. litura*, but did attract a few *Helicoverpa punctigera* moths. This knowledge may be useful if sentinel traps are deployed to monitor possible incursions of fall armyworm.

Project UNE1404 Supplementary Report #1

Correlations between pheromone traps and mirid numbers in the field

The aim of this work was to determine whether pheromone trap catches reflected the numbers of mirids in the field, either now or at some time in the future. This would determine whether pheromone traps might have a role in mirid management, for example in determining the necessity for, and helping prepare for, insecticide sprays.

Background

Many factors determine the extent to which pheromone catches reflect field numbers. These factors are best understood for moths. Due to the relative newness of bug pheromones, there are few comparable studies for them, and none for mirids.

In moths weather can affect pheromone catches. High wind speeds can reduce catches, and very still conditions can also do so since moths have better flight control and can approach a lure more closely without risk of capture. Trap design can affect these relationships. Low temperature also reduces pheromone catches, though many moths will come to pheromones at lower temperatures than to light traps. Moonlight may also be a factor, though there are conflicting reports on what effects it has. Perhaps the most significant factor affecting correlations with field numbers is the female competition effect. Most synthetic pheromone blends are only approximations of the blends released by females, and males can tell the difference. When there are many females calling, males go to them, not the traps. When there are few females calling, either because they are mostly mated and not seeking mates or because they have left an area, leaving a male-dominated population, more males will go to the traps. This can mean that in predicting egg lays pheromone traps are a better guide to what has happened rather than what is now happening.

For these reasons the use of pheromone traps to predict the level of oviposition by *Helicoverpa* spp. was abandoned many years ago (Gregg & Wilson 1991). Pheromone traps are also unreliable guides to the ratio of eggs between the two *Helicoverpa* species (Daly & Fitt 1993). There was an obvious need to understand the relationship between trap catches and the biology of mirids if the pheromones were to be useful in pest management.

Methods

Our initial approach was to seek correlations by regression analysis between mirid catches (number per night per trap for the preceding catch interval, usually one week, and the numbers of mirids found per D-vac sample. We also drew on consultant data from this project, and re-analysed data from an old Cotton Catchment Communities CRC project (UNE 1502).

In UNE 1502 we provided several consultants in different areas from Goondiwindi to Hay with mirid pheromone lures. These were the older resin-coated rubber septa that we had developed, and while not as good as the polymer lures made for us by Scentry in this project, we considered them reliable enough to re-use the data here. We also provided the consultants with suction samplers similar to those we used in this project, and asked them to use suction sampling in conjunction with their normal sampling methods (visual, beat sheet or sweep net). We conducted similar studies ourselves at two sites, Auscott Narrabri and "Brigadoon", Boggabri.

We first sought correlations between the different sampling methods, to determine which data could be used for correlating with pheromone catches. Where correlations existed we used them to convert data from other methods (including suction sampling) to the equivalent in beat sheets, since

this is the industry-recommended sampling method. After examining the sampling data for direct correlations with mirid numbers, we plotted the two over time for each study where suction sampling was used, to see if any delayed correlations might be present.

Results

1. Comparisons of sampling methods

We found no correlation between suction samples and visual sampling by the consultants (Fig. 1). In fact the line of best fit was negative, although not statistically significant.

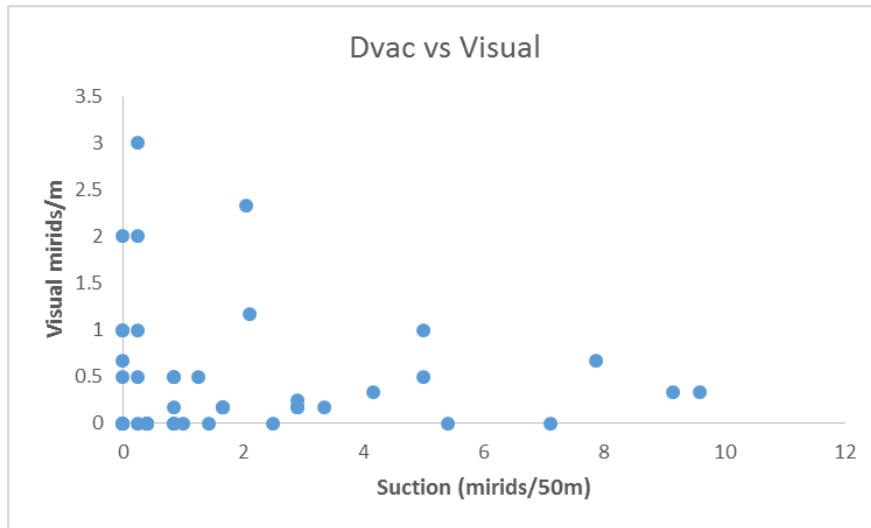


Fig. 1. Relationship between visual counts and suction samples. All data from consultants and ourselves in 2007, and from the Boggabri sites in this project, are combined. The regression is $\text{Visual} = 0.494 - 0.0221 * \text{Dvac}$, $P=0.59$, $R^2 = 0.7$.

Various explanations can be put forward for the lack of correlation between these two methods, but for our purposes it meant that visual samples had to be discarded from our comparisons with pheromone traps. There was a better correlation between beat sheets and suction samples (Fig. 2).

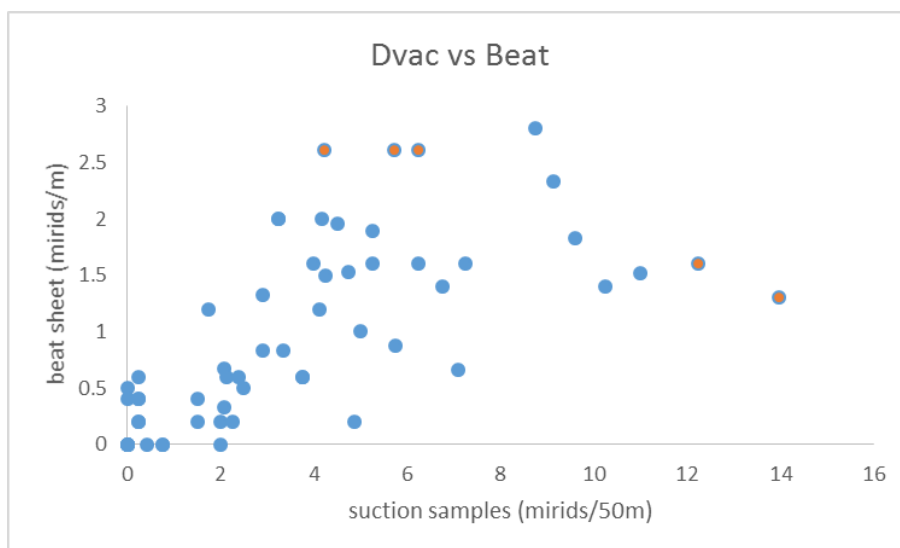


Fig. 2. Relationship between beat sheet counts and suction samples. All data from consultants and ourselves in 2007, and from the Boggabri sites in this project, are combined. The regression is $\text{Beat} = 0.163 + 0.244 * \text{Dvac}$, $P < 0.001$, $R^2 = 0.58$.

There was a similarly good correlation between suction samples and sweep netting, but as very few consultants used this method we did not include the results in subsequent analyses.

These results highlight the variability of sampling methods for mirids, and the inadequacy of visual sampling. When cotton is small, mirids see the checker before he/she sees them, so numbers are underestimated. When the cotton is larger more mirids than really exist can be seen, as checkers count any briefly glimpsed green insect as a mirid.

We view suction sampling as the most reliable indicator of mirid numbers, but it is time consuming and few consultants use it. Beat sheeting is more reliable but cannot be used in small cotton - most consultants do not begin beat sheeting until the crop is about 5-6 nodes.

2. Direct correlations between suction samples and pheromone catches

After converting all the beat sheet data to suction equivalents using the relationship in Fig. 2, we plotted mirid numbers (nymphs plus adults) against the pheromone catch (mirids/trap/night) in the interval preceding the sampling. We excluded our data from 2016/17 from this analysis because of the low release rates of the lures in that year, but included relevant data from the 2007 studies. Results are shown in Fig. 3.

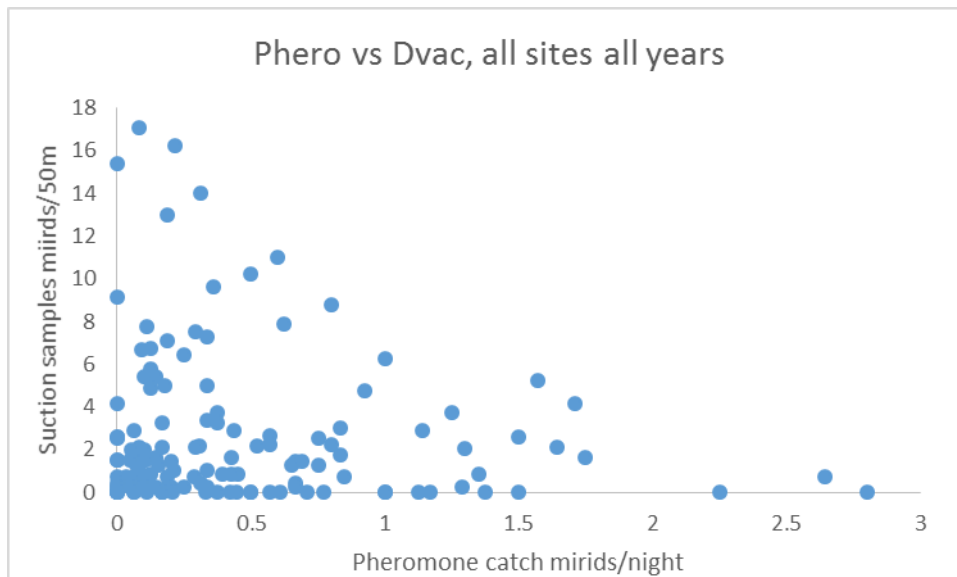


Fig. 3 Relationship between pheromone catches in the preceding trapping interval and mirid numbers (suction equivalents). All data from consultants and ourselves in 2007, and from the Boggabri sites in this project, are combined. The regression is $Dvac/50m = 2.79 - 0.167 * Mirids/trap/day$, $P = 0.76$ $R^2 = 0.01$.

This lack of correlation suggests that pheromone catches cannot be used as indicators of mirid numbers in the field at the time of trapping. This is similar to the situation with *Helicoverpa* spp. and some other moths.

3. Lagged comparisons between beat sheets and pheromone catches.

When we plotted pheromone catches and suction samples or beat sheets against time on the same graphs, it appeared that a peak in the field samples often followed a peak in the pheromone catch, with a lag of 1 to 3 weeks. Examples are shown in Fig. 4. There were occasions on which peaks in field numbers were not predicted by the pheromone traps, but these were all after Day 120 (end of January) – see Kilmarnock 2015 in Fig. 4. Most consultants have stopped sampling for mirids at this time because square loss is unlikely to cause yield loss.

We therefore plotted the peak pheromone catch against the peak field numbers (this time converted to beat sheet equivalents as this is what the consultants generally use)

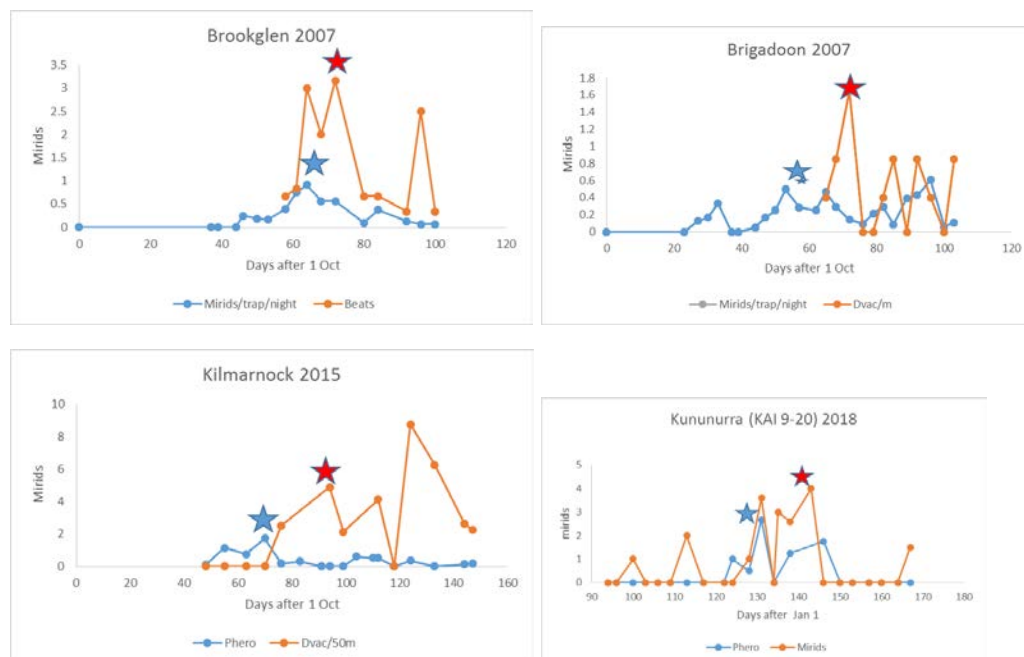


Fig. 4. Pheromone catches and mirid numbers over time at four sites. Blue stars indicate peak pheromone catches, red stars indicate peak field numbers (suction samples or beat sheets)

A summary of 15 trials conducted over the three years of this study plus the 2007 study is presented in Table 1. There were two cases when the peak pheromone trap catch coincided with the peak in field numbers, but in the other 13 cases there was a lag ranging from 8 to 24 days.

Table 1. Summary of pheromone trap trials showing the peaks in pheromone catches and field numbers, and the lag between peaks.

Site	Year	Operator	peak trap mirids/night	peak beat equivalent/m	Lag (days)
Brigadoon	2017/18	P. Gregg/A. Del Socorro	1	1.78	23
Nandewar	2017/18	P. Gregg/A. Del Socorro	1.375	0.79	8
Airstrip	2017/18	P. Gregg/A. Del Socorro	1	0.43	0
Lateral	2017/18	P. Gregg/A. Del Socorro	0.85	0.98	8
Kununurra KAI 9.20	2018	Consultant P. Goldsmith	2.67	4.0	12
Kununurra KAI 5.11	2018	Consultant P. Goldsmith	1.67	3.25	0
Milchengowrie	2015/16	P. Gregg/A. Del Socorro	1.5	0.55	10
Kilmarnock	2015/16	P. Gregg/A. Del Socorro	1.71	1.19	24
Auscott Narrabri	2007	P. Gregg/A. Del Socorro	2.25	1.92	10
Avalon	2007	Consultant S. Ceeney	2.64	4.18	21
Brigadoon	2007	P. Gregg/A. Del Socorro	0.47	0.40	9
St. George Brookglen	2007	Consultant D. King	0.91	0.40	16
Hay	2007	Consultant J. Hill	1.54	0.71	15
Goondiwindi Korolea	2007	Consultant R. Gordon	1.75	2.35	7
St. George Thomas	2007	Consultant D. King	1.5	2.24	15

We then plotted the peak trap catch against the peak (lagged) field numbers (Fig. 5.)

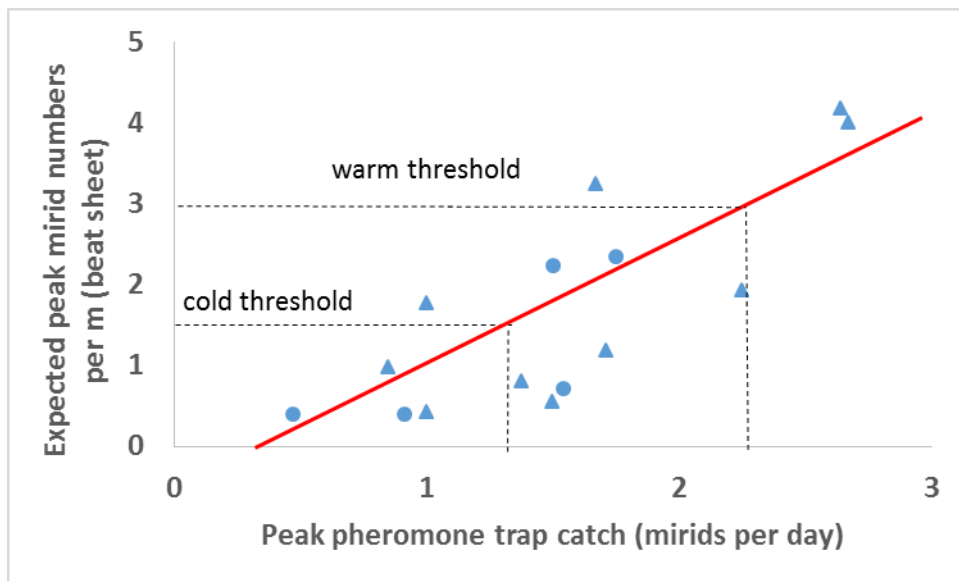


Fig. 5. Peak pheromone catches (mirids/trap/night) plotted against peak field numbers (beat sheet equivalents, total mirids/sample). Triangles are trials from this project, circles are from 2007. Regression equation is peak beat = - 0.791 + 1.62 * peak trap, $P < 0.001$, $R^2 = 0.61$. Peaks after Day 120 have been excluded.

There was a good correlation between trap numbers and future peak numbers, and superimposing thresholds on this graph indicated that average catches of more than 1.3 mirids per night indicated that cold area thresholds were likely to be exceeded, and more than 2.3 per night indicated that warm thresholds were likely to be exceeded (Fig. 5).

Our hypothesis to explain the lack of correlation between trap catches and field numbers at the same time, but a correlation with subsequent field numbers, centres on the female competition effect. It is possible that females compete with the traps when there is a breeding event, leading to low catches. However, after the females are mated they may leave, die, or not be interested in mating, leaving males nowhere to go except the traps. The lag is the time between when this occurs and when the next generation of nymphs emerges. This hypothesis would be consistent with the variation in sex ratios and mated status often seen in mirid populations in cotton.

This hypothesis still requires testing, but regardless of the mechanism, if pheromone traps can predict future mirid numbers, this may be more useful than if they just reflected current numbers. Knowing that a problem is likely within the next 1-3 weeks provides a warning that may enable growers to intensify their sampling and prepare for potential spraying. On an area-wide basis, it may provide resellers with an indication of future insecticide requirements.

Conclusions

While there is no correlation between mirid pheromone catches and numbers in the field at any given time, there is a correlation between peak mirid catches and peak field numbers after a lag, and this may be more useful for management as an indication of potential future problems.

Acknowledgements

We are grateful to Andrew Watson and Rod Smith for permission to work on their properties, and to Rob Weinthal and Adrian Nelson for supplying their bug checking data.

References

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Daly JC & Fitt GP (1993) The need to validate monitoring techniques for insect populations. In Corey S.A., Dall D.J. & Milne W.M. (eds.) *Pest control and Sustainable Agriculture*. CSIRO, Canberra. p. 414-6.

Project UNE1404 Supplementary Report #2

Mirid ecology and reproductive biology

1. Expected number and timing of generations

Methods

We calculated the expected number and timing of generations at Boggabri from data on degree-days required from egg to adult presented by Foley & Pyke (1985) and Khan *et al.* (2009). We used 280 day-degrees above 12, and obtained data from the Milchengowrie weather station from CottonInfo. To this we added a pre-reproductive period of 14 days (Khan 1999, the midpoint of the range of 8-21 days). Assuming the first adults arrive in the field on 1 November, the expected generations for each year are shown in Fig. 1.

Results and discussion

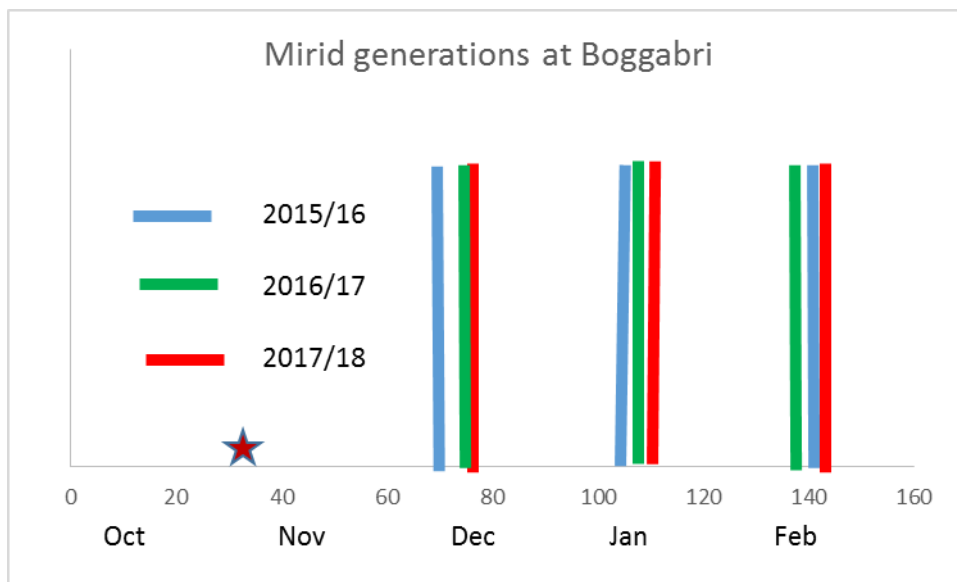


Fig. 1. Expected generations of mirid adults in the three years starting from 1 November (the star).

There were differences between the three seasons – 2015/16 had a warm start with a fairly normal summer, 2016/17 had a cool start but a hot summer, and 2017/18 also had a cool start. However all three years had the potential for three mirid generations starting from an infestation in early November. One occurred around days 70-80 (mid December), another around days 100- 110 (early to mid January) and the third around days 135-145 (mid to late February). Whether these generations actually occur will be influenced by the timing of initial infestations, the availability of alternative hosts, and the success of breeding in cotton (which may be affected by insecticides).

2. The 2015/16 season

Methods

In this season we suction sampled four sites: “Kilmarnock” and “Milchengowrie” near Boggabri, “Ruvigne” near Gunnedah, and “Westend” near Quirindi. We also obtained data from two consultants, one checking the Boggabri sites and the other checking “Ruvigne” and “Westend”.

Results and discussion

Numbers of mirid adults and nymphs from these sites are shown in Fig. 2.

In this season we did not begin suction sampling until mid-December, after the consultants had started checking. It is therefore possible that we missed the December generation (except possibly at “Kilmarnock”. There is however little indication of a December generation in the consultant’s data, and no real indication of two subsequent generations in our later counts. Rather the pattern is a more or less steady increase in both nymph and adult numbers to a peak in February.

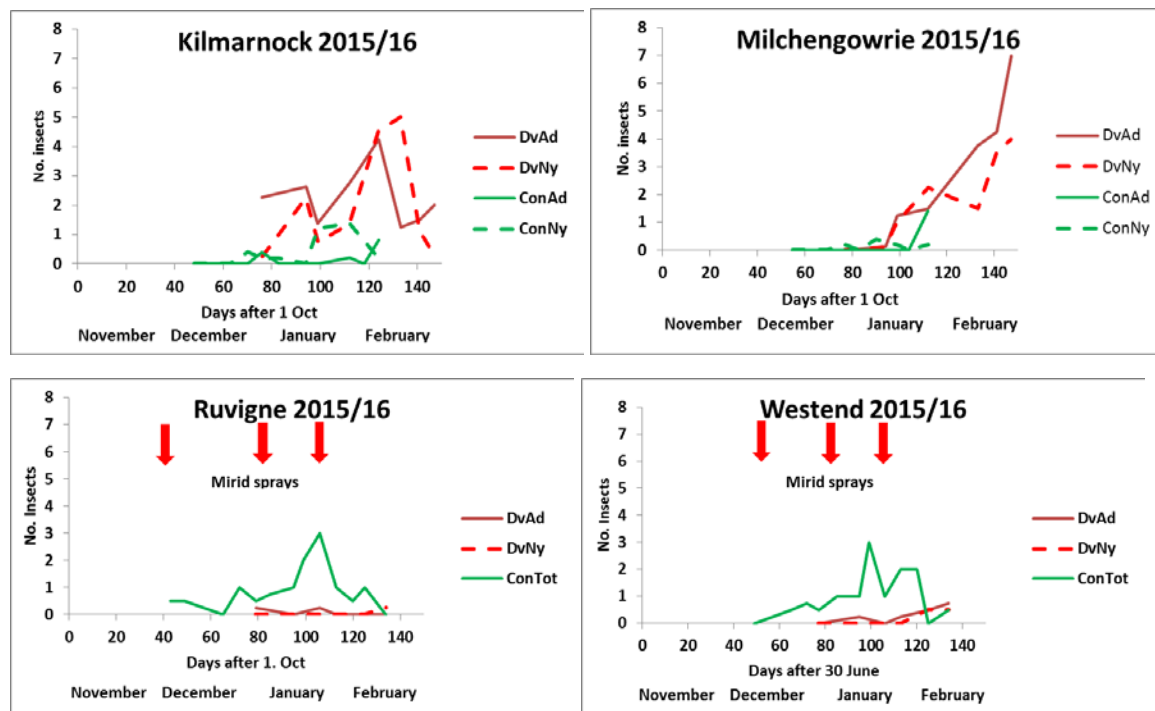


Fig. 2. Numbers of mirid adults and nymphs collected by suction samples, and recorded by consultants, at the four sites in 2015/16. DvAd = our suction sample counts of adults per 50 m, DvNy = our suction sample counts of nymphs per 50 m, ConsAd = consultant beat sheet counts of adults, ConsNy = consultant beat sheet counts of nymphs. ConsTot = consultant beat sheet counts of total mirids (the consultant for “Ruvigne” and “Westend” did not separate adults and nymphs).

It is clear that there was a major discrepancy between the consultants, relative to our counts. The consultant at “Kilmarnock” and “Milchengowrie” saw fewer mirids than we were seeing, and did not spray. The consultant at “Ruvigne” and “Westend” saw far more mirids than we did, and sprayed three times (the red arrows in Fig. 2). Perhaps as a result of these sprays we found very few mirids in the suction samples from these sites. This discrepancy dramatically illustrates the difficulties of sampling for mirids, and the variation between operators that can arise even when they are supposedly using industry standard methods. In consequence we did not use consultant data for the remainder of the project and worked only with the Boggabri grower, who generally did not spray for mirids.

The proportions of the adult catch that were female, and the proportions of females that were mated, are shown for the Boggabri sites in Fig. 3. For “Ruvigne” and “Westend” we found so few mirids that the data were unreliable so they are not shown.

The two Boggabri sites were different in regard to the percentage of females. At “Kilmarnock” the sex ratio of the mirids in December was about 1:1, and it fluctuated around this for the rest of the season. At “Milchengowrie” there were initially no females, but their numbers built up steadily during the season. This shows that the sex ratio of mirid populations can vary substantially from 1:1 depending on location and stage of the season. Given the late start to sampling it is difficult to determine whether our initial samples represented a colonising generation or part of a local one, but in either case it may reflect differences between the sexes in regard to immigration and emigration in cotton fields.

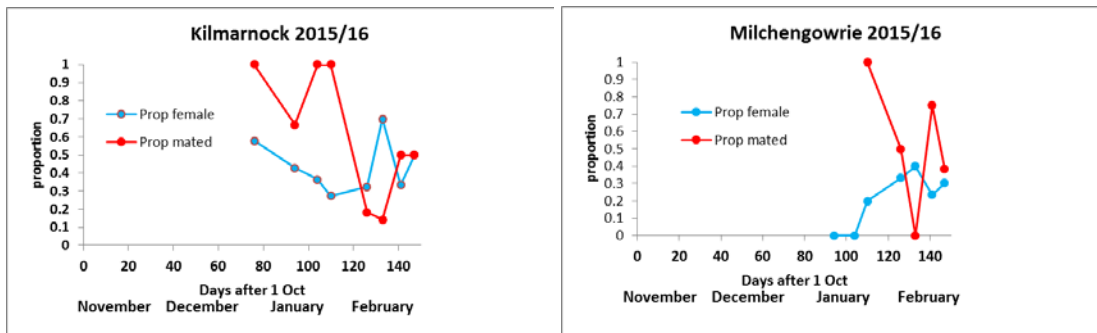


Fig. 3. The proportion of adult mirids that were female, and the proportion of females that were mated, at the two Boggabri sites in 2015/16.

However, in both sites all the females were mated when we started sampling, and this proportion fluctuated, with a declining trend, as the season progressed. This suggests recruitment of unmated females to the population from local breeding.

3. The 2016/17 season

Methods

In this season we only had two sites, at Boggabri. The season was in marked contrast to 2015/16. The winter and early spring had been wet and cool, leading to abundant growth of alternative hosts both locally and in distant non-cropping areas such as western Queensland.

Results and discussion

High numbers of mirid adults, but no nymphs, were found when we began sampling in late November (earlier sampling was not possible because the cotton was too low, and suction samples contained mostly dirt). The absence of nymphs suggests that these adults were first generation immigrants, and we just caught the end of a large generation.

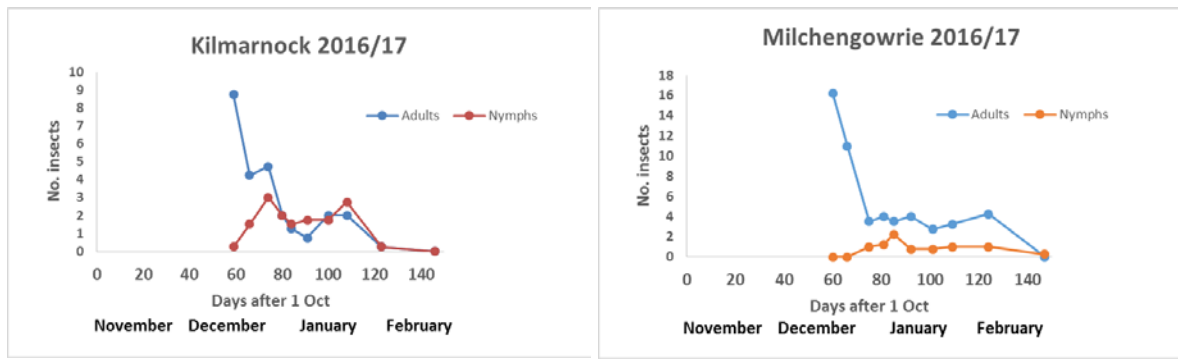


Fig. 4. Numbers of adults and nymphs in the suction samples at the two Boggabri sites, 2016/17.

The numbers of adults steadily declined through the rest of the season although there were weak indications of another generation in late January/early February. The numbers of nymphs remained low, comparable with the previous season, which suggests that the immigrants did not breed extensively in cotton. Many growers in the upper Namoi sprayed for mirids in December and January, some several times. They were concerned by square losses, though the extent to which mirids were implicated rather than physiological causes remains unclear. The Boggabri grower did not spray, and the outcome suggests this decision was wise. Our results indicate that early season mirid invasions are not always followed by problems later in the season.

The proportion of females and proportion mated in 2016/17 are shown in Fig. 5. The sex ratios were about 1:1 and did not change much during the season. The proportion mated was about 50% in both sites at the start of the season, but rose to 100% by about day 80 (the same time at which we had found 100% mating in 2015/16). Thereafter it fluctuated, with a suggestion of a second generation peak at “Milchengowrie” in late January.

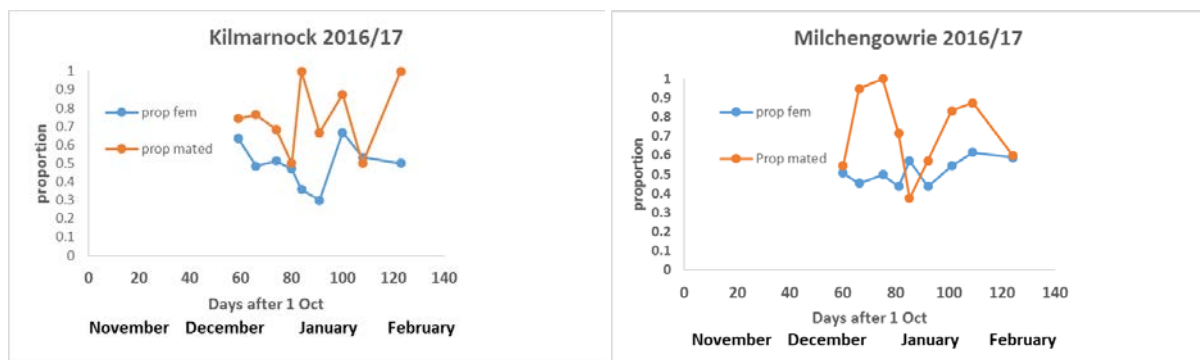


Fig. 5. The proportion of adult mirids that were female, and the proportion of females that were mated, at the two Boggabri sites in 2016/17.

4. The 2017/18 season

Methods

In 2017/18 we sampled four fields within a radius of about 2 km, all in the “Kilmarnock” area.

Results and discssion

The numbers of mirid adults and nymphs are shown in Fig 6.

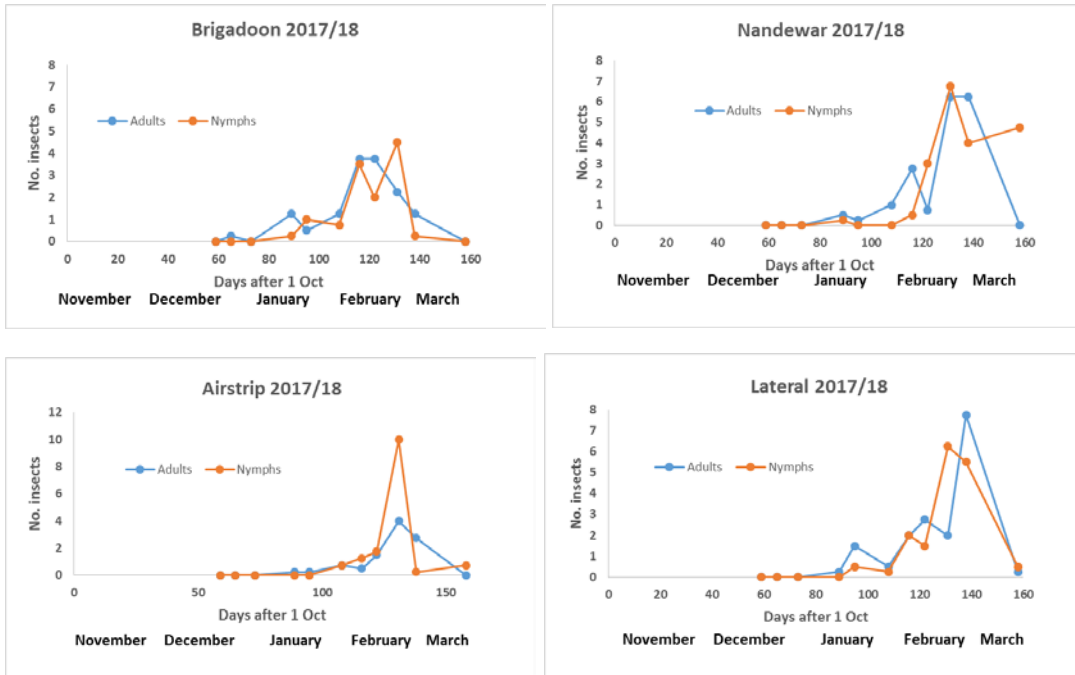


Fig. 6. Numbers of adults and nymphs in the suction samples at the four Boggabri sites, 2017/18.

The 2017/18 winter and spring were dry, as in 2015/16, but cooler. Mirid numbers (both adults and nymphs) were initially very low, and built up to only moderate numbers by the end of the season. At “Brigadoon” (the earliest planted cotton) there was evidence for two generations, one in late December and another in February but at the other sites there was only a single peak in mid to late February. This suggests that mirids were slow to colonise the fields in this year, perhaps due to a shortage of alternative hosts in the spring. In this regard the pattern was similar to 2015/16 for the Boggabri sites, especially “Milchengowrie”. It suggests that in such years mirid spraying can be delayed until late in the season, where because of higher thresholds it may not be needed at all. The Boggabri grower did not spray.

Since the sites were in close proximity and the numbers of mirids were low, especially early in the season, we pooled the data for all fields to calculate the proportion of females and the proportion mated (Fig. 7).

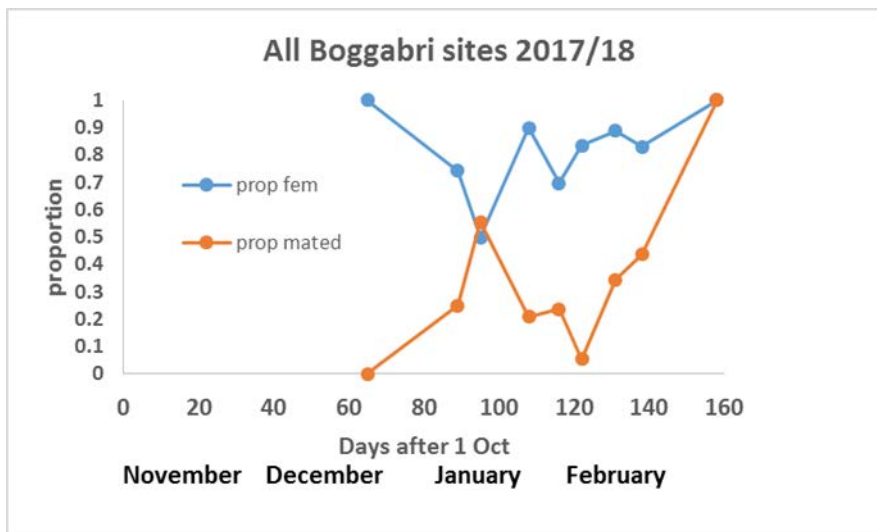


Fig. 7. The proportion of adult mirids that were female, and the proportion of females that were mated, at all four Boggabri sites combined, in 2017/18

The patterns were almost the reverse of 2015/16, despite the climatic similarity of these two years and the similarity in overall numbers of adults and nymphs. The early populations were all unmated females, and the sex ratio was generally female-biased throughout the season. There were two clear peaks of mating, one in early January and another in late February-early March. This further reinforces the conclusion that the sexes may differ in immigration/emigration behaviour, leading to variable sex ratios, and that reproductive behaviour in cotton is highly variable, so that immigration may or may not be followed by in-crop breeding.

Conclusions

The data over three different seasons indicate that it is not possible to recognise discrete generations that correlate with theoretical ones based on day-degree calculations. This is probably because of frequent movements to and from fields, and between cotton and alternative hosts. These movements may vary between sites, from year to year, and even between the sexes. This means that high numbers of adults may or may not be followed by high numbers of nymphs. This may contribute to the variable relationship between mirid numbers and subsequent damage, and the resulting lack of confidence that growers and consultants now have in the sampling methods and threshold recommendations for mirids. There is a need for further ecological studies to understand these variable relationships.

Acknowledgements

We are grateful to Andrew Watson and Rod Smith for permission to work on their properties

Project UNE1404 Supplementary Report # 3

Pheromone trapping for *Spodoptera* spp. in Kununurra

Background

One of the original aims of Project 1404 was to investigate the potential of pheromone-based monitoring for *Spodoptera litura*, the cluster caterpillar or cotton leafworm. This species was of concern because it was less susceptible than most caterpillars to the toxins in Bollgard II cotton. It is also a significant pest of grain legumes, and when the project was proposed as a cross-industry one we intended to work on it with GRDC funds. When GRDC funding was not forthcoming this milestone was dropped, but in the last year of the project an opportunity arose to do the work in cotton in conjunction with a trial of Bollgard III cotton in the Ord area being run by Steven Yeates (CSIRO) and Paul Grundy (QDPI), with local collaborators who were checking for *S. litura* larvae.

We also took the opportunity to include pheromone traps baited with lures for *Spodoptera frugiperda*, the fall armyworm. This is a pest of quarantine significance which, as a New World native, does not occur in Australia but has recently had a major range expansion into Africa. There may be a need to establish sentinel traps for it, in which case it is important to know whether there is cross-attraction to *S. litura* pheromone as the two species look similar and there might be a risk of false alarms.

Finally, we also took the opportunity to test the Trapview smart traps, distributed by Adama Australia Pty Ltd, as monitoring devices for this species. Adama provided operating expenses for the work.

Methods

Lures for *S. litura* and *S. frugiperda* were sourced from Alpha Scents Pty Ltd in the USA. Trapview and AgriSense universal traps were freighted to Kununurra and set up during a visit of 8 days by P. Gregg between 22 February and 2 March 2018. Thereafter the Trapview images were monitored daily from Armidale, and the AgriSense traps were serviced at approximately weekly intervals by staff from Ordco Pty Ltd. who were collaborating in the Yeates/Grundy trials. Two Trapview traps and two AgriSense traps for *S. litura* were established at Ceres, approximately 8 km south of Kununurra. Two AgriSense traps baited with *S. frugiperda* pheromone were also established here. Two AgriSense traps for *S. litura* were also established at Kimberley Agricultural Industries property (KAI) approximately 40 km NE of Kununurra. This property is outside mobile phone range so it was not possible to deploy Trapview traps there. Checking for *Spodoptera* larvae was done by Ordco staff and is based on a mean of 10 x one meter checks at each site, at approximately twice weekly intervals.

Results

1. Comparison of the Trapview and AgriSense traps

Catches of the Trapview and AgriSense traps at Ceres are shown in Fig. 1. The Trapviews gave daily data so for comparison the AgriSense trap data were converted to average moths/trap/night since the last check.

For the first 20 days after establishment the catches were similar between the two trap types, although the Trapviews better recorded the timing of individual peaks in catches, because they provided daily data. After about day 20 however the catches in the Trapviews were lower than the

AgriSense traps. This was accompanied by evidence from the uploaded images that indicated that some moths were being removed after capture. Patches of moth scales were sometimes found without the moths (Fig 2a). The mystery was eventually solved when one image revealed a frog inside the Trapview (Fig. 2b). It appears frogs were able to gain access to the Trapviews because they were relatively low to the ground and presented opportunities to climb up them and down the funnel. In contrast the AgriSense traps were higher, and held out from the post by a thin wire, which would have been more difficult for frogs to climb. It appears that the sticky surface of the Trapviews was not an obstacle to frogs entering or leaving the traps, or consuming insects stuck on it.

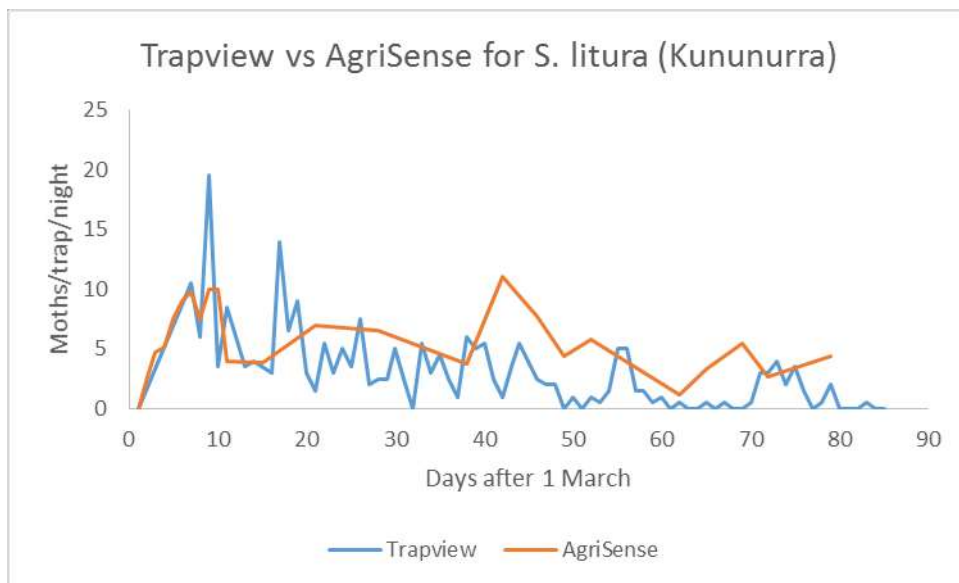


Fig. 1. Trap catches, nightly for the Trapviews and average nightly for the AgriSense traps, at Ceres.

When the depreddations of frogs are taken into account, it is likely that the two trap types caught similar numbers of *S. litura*. We also learned some valuable lessons about operation of the Trapviews for large moths such as *S. litura*, in remote areas such as Kununurra, which have been reported to Adama.



Fig. 2. Images from a Trapview smart trap at Ceres, 2/6/2018 (left) and 3/6/2018 (right) showing a frog (top left) and patches of moth scales but no moth bodies, indicating the consumption of moths

2. *S. litura* trap catches and relationships with larval numbers

The numbers of *S. litura* caught per trap/night at Ceres and the two KAI sites are shown in Figs 3-5.

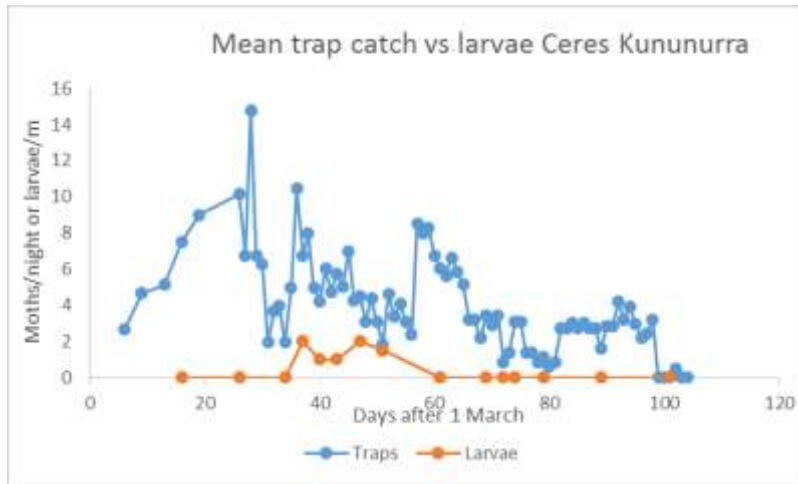


Fig. 3. Pheromone trap catches/night (average of all traps) and *S.litura* larvae/m at Ceres.

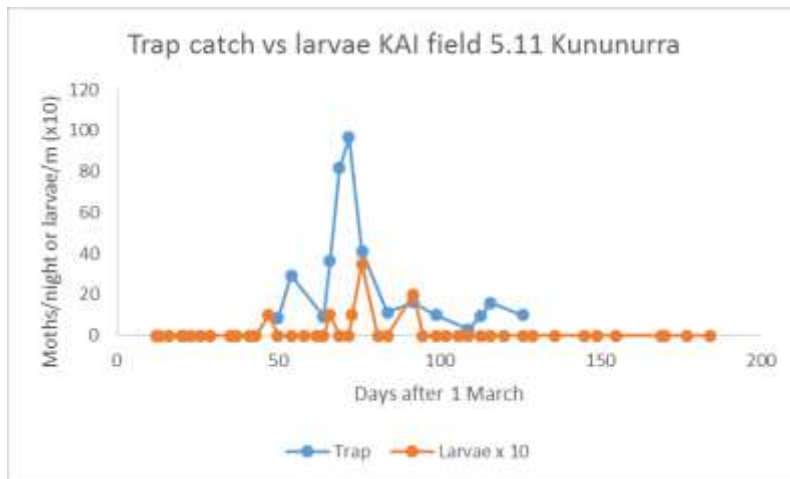


Fig. 4. Pheromone trap catches/night and *S.litura* larvae/m at KAI, field 5.11. Note the numbers of larvae have been multiplied by 10, to better show trends in relation to the high numbers of moths.

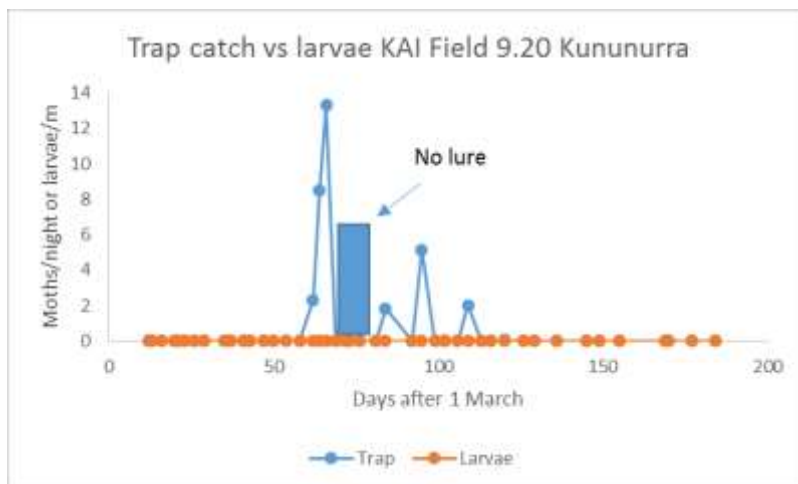


Fig. 4 . Pheromone trap catches/night and *S.litura* larvae/m at KAI, field 9.20. Blue bar indicates a period when the lure was missing from the trap.

There were differences in the size and time of the pheromone peaks between the three sites. At Ceres, which was the earliest planted cotton, the peak was around 10-15 moths/night and occurred around Day 25 (late March). At KAI, where the cotton was planted later, the peaks occurred about day 60-70 (early May). There were many more moths in Field 5.11 compared to Field 9.20 at KAI, which was the latest planted of the three.

Numbers of larvae were generally low. None were found at KAI, field 9.20. At the other two fields there were indications that the peak of larvae followed the pheromone peak by 2-3 weeks, which would fit with the time required for egg hatching and larval development. This suggests that pheromone traps could be useful in monitoring for *S. litura*, but this conclusion must be tentative because of the low numbers. These low numbers probably indicate that the Bollgard III cotton was efficacious against *S. litura*, in contrast to earlier reports about Bollgard II.

3. Moths found in *S. frugiperda* traps

The numbers of moths found in the two traps at Ceres baited with *Spodoptera frugiperda* lures are shown in Table 1:

Table 1. Numbers and species of moths found in traps baited with *S. frugiperda* pheromone at Ceres.

Date	Trap	Number and species
27/3/2018	1	3 <i>Helicoverpa punctigera</i>
28/3/2018	1	1 unknown noctuid
3/4/2018	2	1 <i>Helicoverpa punctigera</i>
16/4/2018	1	1 <i>Helicoverpa punctigera</i> + 1 unknown noctuid
24/5/2018	1	2 <i>Helicoverpa punctigera</i>
28/5/2018	1	1 <i>Helicoverpa punctigera</i>

A total of 8 *Helicoverpa punctigera* moths and two unknown noctuids (not *Spodoptera* spp. or any other major pest species) were found in the traps baited with *S. frugiperda* lures at Ceres. During this period the *Spodoptera litura* traps at the same site caught a total of 943 *S. litura*. This indicates that *S. litura* do not come to *S. frugiperda* lures, and if the latter are used in sentinel traps to detect incursions of *S. frugiperda* there should not be a problem with false alarms due to cross-attraction between the two species.

The main species found in the *S. frugiperda* traps was *Helicoverpa punctigera*. One component of the *S. frugiperda* pheromone is Z-11 hexadecanal acetate, which is also found in the pheromone lures for *H. punctigera* (but not for *H. armigera*, or *S. litura*). Since *H. punctigera* were found in the traps while *H. armigera* were not even though that species would have been present, it is likely that there is some attraction of the *S. frugiperda* pheromone to *H. punctigera*. However, it looks very different from either *S. litura* or *S. frugiperda*, and should not cause false alarms if the trap catch is inspected by experienced entomologists. The main risk for false alarms could have been *S. litura*, but none of these were found despite the capture of over 900 of them in nearby traps baited with their pheromone. However, there are always occasional non-target species caught in pheromone traps for any species, because they just blunder into the traps, or see them as potential sites for roosting during the day. This explains the two unknown noctuids that were captured, and indicates

that it would be unwise to assume that *S. litura* would never, ever be found in *S. frugiperda* sentinel traps – but they are unlikely to be found in significant numbers.

Conclusions

1. The pheromone for *Spodoptera litura*, which was initially developed in China and Japan, is highly effective for Australian *S. litura*. Large catches of moths can be obtained using AgriSense (universal) traps in the same way as they are used for *Helicoverpa* spp.
2. Pheromone catches broadly indicate likely larval populations in 2-3 weeks, though the low numbers of larvae in this study (probably due to the efficacy of Bollgard III cotton) makes this conclusion tentative
3. *Spodoptera frugiperda* pheromone does not attract *S. litura*, which means that there is little risk of false alarms from this species if it is deployed in sentinel traps. It does attract low numbers of *Helicoverpa punctigera*, though probably not *H. armigera*, and this is likely due to the presence of a common pheromone component, Z-11 hexadecenal acetate.
4. Trapview smart traps can be used for *S. litura*, and will catch similar numbers as AgriSense traps. However, when large numbers are present the traps will quickly clog up, requiring frequent changes of the sticky surface. Also, there is a potential problem with frogs gaining access to the traps and consuming moths, in environments where frogs are common. Both these issues could be overcome with design modifications.

Acknowledgements

We are grateful to Steven Yeates and Paul Grundy, and to the growers at Ceres and KAI, for allowing us to work on their trial sites. Penny Goldsmith and Carolyn Palmer from Ordco provided checking data and serviced pheromone traps, and Adama Australia provided travel and operating costs for the project.