

■ A multi-targeted approach to management of fruitspotting bugs - major pests in tropical and subtropical horticulture in Australia

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SUMMARY

Fruitspotting bugs (FSB) *Amblypelta nitida* Stål and *Amblypelta lutescens lutescens* (Distant) (Hemiptera: Coreidae) are major native pests in subtropical and tropical horticultural crops in Australia and a key pest in avocado.

The pest is known to cause significant damage to more than 25 different tree fruit and nut crops and some vine fruits through the coastal and sub-coastal areas of Queensland, northern New South Wales, the Northern Territory and north-western Western Australia.

Current management is repeated applications of broad-spectrum insecticides, which is not sustainable in the long-term. This study, commenced in March 2011, is investigating an integrated approach including the following components:

1. Chemical control: A number of insecticides have been evaluated in laboratory and field trials. We are working towards availability of new chemicals for farmers.
2. Cultural control: Susceptibility of different cultivars and planting densities are investigated
3. Monitoring: Monitoring of FSB has been a challenge, but is crucial to strategic management. Two different monitoring tools have been investigated.
 - i) Trap crops: Investigation of small hedges of highly attractive host plants as a monitoring tool. A technique and monitoring protocol for *A. nitida* has now been developed.
 - ii) Pheromone traps: Pheromones have been investigated for both *Amblypelta* spp. A use pattern and a prototype of trap for *A.l. lutescens* have been developed and commercialisation of the trap is underway.
4. Biological control: Different natural enemies of FSB have been investigated including three species of FSB egg parasitoids to improve our understanding of their biology and ecology. Their biocontrol potential is being evaluated in small scale trials.
5. Area Wide Management (AWM): In order to allow management beyond farm level an area wide scale strategy is being developed and trialled with a pilot group of farmers.

This study is finishing in April 2016 and outcomes of different components to date and long-term benefits to industries involved will be presented.

Keywords: *Amblypelta lutescens lutescens*, *Amblypelta nitida*, Biological control, Chemical control, Crop monitoring, Pheromone traps, Trap crops, Integrated pest management.

INTRODUCTION

Fruitspotting bugs (FSB) *Amblypelta nitida* Stål and *Amblypelta lutescens lutescens* Distant (Hemiptera: Coreidae) are a major impediment to the successful production of most tree fruits and nuts and some vine fruits through the coastal and sub-coastal areas of Queensland, northern New South Wales (NSW), the Northern Territory (NT) and north-western Western Australia (WA).

Both species of *Amblypelta* have wide host ranges. *A. l. lutescens* has 111 recorded host species in 51 plant families and *A. nitida*, 56 recorded host species in 30 plant families. Both *Amblypelta* species have important hosts in 26 commercial crops including avocados, macadamias, mangoes, custard apples, papaya, cashews, guava, persimmons, lychees, longans, rambutans, kiwifruit, passionfruit, table grapes and many lesser grown tropical fruits including durians and mangosteens. Most damage shows as spots or cracks on developing or mature fruit, or as splits, water-soaked marks or wilting in the vegetative growth in papaya, mango, cashew and table grapes. Damage by this group of bugs can also facilitate the entry of diseases such as anthracnose.

The life-cycle from egg to adult takes about six weeks (Huwer, 1996). FSB are long-lived with adults recorded living for six months in a laboratory colony. Nymphs and adults cause damage and individuals are fairly mobile. Each feeding mark blemishes the fruit or nut and FSB cause substantial damage at very low population densities.

Crop losses to FSB are difficult to quantify accurately but are likely to amount to tens of millions of dollars annually. For example, more than 90% FSB damage has been recorded in unsprayed avocados in Southeast Queensland (Fay, 2002). For the Australian macadamia industry the economic impact of FSB is estimated at \$ 8.975M, per annum (Starkey, unpublished data), comprised of:

- Reduced farm gate production (10-15%)
- Increased production costs due to higher costs for crop protection (7%)
- Yield reduction in recovery of kernel in processing (25%)
- Increasing processing costs (5%)
- Impacting kernel quality, shelf life, and final product value due to increased handling during processing (5%)

The mainstay of FSB chemical control in virtually all crops mentioned had been endosulfan, which had its Australian registration withdrawn by the Australian Pesticides and Veterinary Medicines Authority (APVMA) in October 2010, removing it as an option for horticultural producers. There are few effective replacements for endosulfan, all of which are broad-spectrum, more expensive and potentially more disruptive to natural enemies. There are currently no registered narrow-spectrum insecticides for any of the true bugs in Australia. Reduction in the use of broad-spectrum insecticides is fundamental to the advancement of Integrated Pest Management (IPM), but in crops such as mangoes this has resulted in damage caused by FSB becoming a significant issue. Therefore research into alternative control techniques is required.

Research on different aspects of FSB management has been conducted for quite some time (Aldrich *et al.*, 1993; Fay and Huwer, 1993; Huwer, 1993; Waite *et al.*, 1993; Huwer, 1996a; Huwer, 1996b; Huwer, 1997; Fay *et al.*, 1998; Waite *et al.*, 2000; Huwer *et al.*, 2003; Huwer and Maddox, 2004a; Huwer and Maddox, 2004b; Waite, 2004; Drew, 2005; Huwer and Maddox, 2005; Huwer and Maddox, 2006; Huwer *et al.*, 2007; Huwer *et al.*, 2008; Huwer *et al.*, 2011). Previous research on FSB management in macadamia suggests that a multi-faceted management approach is necessary to achieve sustainable and long-term management.

METHODS

The project is taking a multi targeted approach towards FSB management in order to maximise pest management. A comprehensive literature review was undertaken in the first instance (Danne *et al.*, 2014) to develop a database of research and practices of FSB management, related insects and technologies considered in the program. The different components of the management approach are the following:

- Chemical control
- Cultural control
- Development of monitoring tools
- Trap hedges
- Pheromone traps
- Biological control
- Industry Adoption
- Area Wide Management (AWM)

Chemical Control

The aim of the chemical control component was to investigate integrated pest management (IPM) compatible alternatives to endosulfan. Laboratory screening of insecticides on FSB eggs, nymphs and adults is currently underway. Eggs are positioned on the sticky surface of a post-it note and dipped in the insecticide solution. Nymphs and adults are tested in a topical application test to establish contact toxicity (1µl of insecticide solution applied to the back of individual insects) and a feeding test (food source is dipped in insecticide solution) to establish ingested toxicity. Promising insecticides will then be tested in a small scale field trial at the Centre for Tropical Horticulture CTH), Alstonville, Australia. Insecticides that perform well in this small scale field trial will be tested on a small number of commercial macadamia and avocado farms.

Monitoring

Monitoring FSB is challenging as the insects are cryptic and hard to find in orchards. Monitoring of FSB prior to damage would enable growers to target management of this pest more efficiently. In avocados, monitoring mostly relies on visual observation of damage and is reactive rather than proactive. To be commercially effective, monitoring protocols need to be developed in consultation with crop consultants.

1. Trap Hedges

FSB are known to show host preference to certain species and also host cultivars. The principle of a trap crop is based on the 'Push and Pull' strategy (Cook *et al.*, 2007). Host plants used in a trap hedge need to be more attractive than the main crop, particularly while the crop is most vulnerable to damage. In our trials, hedges with different host plant species are planted at the edge of an orchard. On commercial farms, no more than 6 plants in a strip were used. Once fruiting, trap plants are visited weekly and numbers of FSB nymphs and adults observed within 30 min are recorded.

2. Pheromone Traps

Pheromone compounds for *Amblyopelta* spp., were identified by Geoff Waite and Chris Moore (formerly of Queensland Department of Primary Industries) and Jeff Aldrich (United States Department of Agriculture) in the early 1990s (Aldrich *et al.*, 1993). Further development of the *A. lutescens* lure is detailed in Khirmian *et al.* (2012).

The *A. lutescens* lure was optimised by testing mixes of two and three chemical components identified in previous research. Different isotopes of one of the compounds were also tested for effectiveness. The optimum trap density needed to be established by installing 10, 22 or 36 traps per hectare vs a control at 22 traps/ha (sticky panel traps without lure) on commercial farms.

A threshold was established by tagging small undamaged custard apple or avocado fruit and checking it every two weeks for new damage and correlating this with the trap catches.

For *A. nitida* chemical components identified in previous research were tested in the field. One component was tested against three components and a control (no lure). Chirality and dose were tested using different isotopes at 1x and 10x concentration of the main compound vs a control (no lure).

Biological Control

A number of egg parasitoids are recorded as natural enemies of *Amblyopelta* spp. (Huwer, 1996; Danne *et al.*, 2014).

Anastatus sp. was selected as a potential candidate for commercialisation by BioResources Pty. Ltd., as a related species, *Anastatus japonicas* (Ashmead) (Hymenoptera: Eulophidae) is successfully mass-reared and released for management of the lychee stink bug (*Tessaratoma papillosa* (Dury) (Hemiptera: Pentatomidae) (Li *et al.*, 2014) in China. BioResources developed a technique to mass-rear *A. lutescens* in a previous study (Llewellyn, 2011). A mass-rearing technique using eggs of the Chinese oak silkworm *Antheraea pernyi* (Guérin-Méneville) (Lepidoptera: Saturniidae) pasted in strips on corrugated cardboard cards placed in boxes with adult *Anastatus* sp. Field releases were made on over 20 commercial farms, with 8-10 releases per farm from spring to late autumn.

Experiments with the tachinid fly *Trichopoda giacomellii* (Blanchard) (Diptera: Tachinidae), a parasite of *Nezara viridula* (L.) (Hemiptera: Pentatomidae) nymphs and adults, was also conducted, transferring fly eggs from *N. viridula* onto *A. nitida* adults and checking for establishment and development of the parasite.

The project also investigated the ecology and biology of biological control, conducting a survey of natural enemies of *Amblyopelta* spp. that could potentially be used as biological control agents. This component of the study is investigating the ecology, including life-cycle and investigation of flora of their environment, of these species. To identify potential species, FSB eggs were collected and checked for parasitism, live FSB were placed as bait on the sticky trap panels and checked for parasitism and yellow pan traps setup and checked them for other invertebrates.

Area Wide Management

New South Wales Department of Primary Industries (NSW DPI) will establish a small pilot AWM program for the 2015/16 season in the Rous/Alstonville district involving six farms, with three case study sites. Fortnightly monitoring data on damage levels and bug numbers will be collated by NSW DPI staff and two commercial consultants and be entered onto a database. These data will include dates of *Anastatus* releases (where relevant) and details of spray applications including date, chemical applied, rates and whether or not it is a “hotspot” or whole block application. The utility of the database information will be assessed by consultants and growers at the midpoint and at the end of the season.

Industry Adoption

An extension program runs in parallel with the research program. The initial focus of the extension program is to inform the industry of the project objectives and outline current control options for growers. It is important that industries are thoroughly consulted and well informed, have input into the project, that research is relevant across all contributing industries and project outcomes are accessible to all growers. The industry adoption component includes presentations to grower groups at conferences, industry journal articles, the Area Wide Management pilot program, a series of spray application workshops, a FSB management guide for growers and YouTube videos.

RESULTS

A literature review (Danne *et al.*, 2014) reviewing FSB biology and ecology (life cycles, dispersal and feeding behaviours, host plant relationships, and natural enemy complexes) and currently available management strategies has been published. The review identified gaps in current knowledge of the pests' biology and ecology. Recommendations for future research, including the development of effective laboratory rearing techniques required to underpin sustainable pest management strategies, are discussed.

Chemical Control

Thirteen chemicals were tested for their ovicidal effect. None of the chemicals tested stopped developing nymphs from hatching, indicating that chemicals have no direct effect on FSB eggs. This also shows that the chorion of the egg is a barrier and developing egg parasitoids are also protected inside the egg. This is positive for an integration of biological control.

A number of chemicals have been screened in the laboratory for their efficacy against FSB bugs including a number of new chemicals. Of the insecticides screened in laboratory tests, small scale trials in a research orchard and small field trials on commercial farms there are, at this stage, three chemical compounds that consistently have given good results.

Chemical 1(1ml/L), Chemical 2 (1ml/L), and Chemical 3 (0.8ml/L), Chemical 4 and 5 combined and Chemical 6 have achieved 90 – 100% mortality in laboratory tests and results from field trials are comparable with the current standard chemical treatment options (trichlorfon (2ml/L) and beta-cyfluthrin (0.5ml/L). Chemical 3 and Chemical 6 have been tested in a commercial farm trial in macadamias and gave good results. In avocados, a rotation of trichlorfon and beta-cyfluthrin is still giving the best results. By the end of the project we expect to have the registration process finalised for at least one new chemical registered and minor use permits for two further chemicals.

Monitoring tools

1. Trap Hedges

The initial selection of suitable trap hedge species has been completed. The combination of trap crops will depend on the crop grown. For macadamias, ribbonwood *Euroschinus falcata*, *Macadamia ternifolia*, and *Murraya paniculata* are considered to have the greatest potential.

The long-term data from the trial at CTH Alstonville together with data from a commercial avocado farm and two custard apple farms give us confidence that we can identify the main flights and when FSB are invading the orchards. *Murraya paniculata* is particularly suitable for monitoring as its berries are a preferred food source, it fruits most of the year and FSB can be easily seen on the host. A treatment threshold, when the population on the trap hedge has > 30% 5th instar nymphs, has been established. This leaves a 10-14 day window, to apply a treatment to the main crop, before the 5th instar nymphs turn into adults and leave the monitoring hedge. For a 12 month monitoring program, longans are a good indicator from December to February, *Murraya* is suitable from March to September and *Macadamia ternifolia* from August to February. Trap crops themselves produce chemicals that attract the bugs naturally and trap crops are also important refugia for parasitoids.

2. Pheromone Traps

The lure for the *A. l. lutescens* pheromone is fully optimised with regard to chemical compounds, quantities and ratios. A trap prototype using a sticky Coreflute panel has been developed and the commercialisation process for this product has commenced. Preliminary use patterns and thresholds have been developed for avocados and custard apple with action required at 0.4 bugs/trap/fortnight or 4 bugs/10 traps/fortnight.

A. nitida research trials have been inconclusive so far and need to be confirmed with laboratory trials, including electroantennogram, windtunnel and olfactometer assays.

Biological Control

A rearing system for both *Amblypelta* spp., was maintained to provide material for experimentation and maintaining an *Anastatus* sp. culture on the target host. Antheraea pernyi eggs were imported from China to mass-rear *Anastatus* and a larger mass rearing system capable of providing significant numbers of wasps, for case study sites and to assess the feasibility of commercial scale production, was developed.

Experiments in the greenhouse and field confirmed that mass reared *Anastatus* would find and parasitise eggs of both *Amblypelta* spp., and 22 case study sites were initially set up for *Anastatus* releases and evaluation. *Anastatus* were mass produced and regularly released for up to 24 months at some of these sites. After two years of releases a downward trend in bug damage has been observed.

Main releases of *Anastatus* have stopped as part of the project but smaller releases are still being evaluated.

The egg parasitoid, *Gryon* sp., was tested in the CTH macadamia orchard and on a commercial macadamia farm. We were able to recapture *Gryon* sp. with sentinel cards and detect some parasitism. The egg parasitoid *C. darwini*., was also released on a small scale.

Experiments with *Trichopoda giacomellii* showed that fresh fly eggs can be transferred from *N. viridula* to FSB. The fly larvae kill FSB, but development was incomplete, stopping at the pupal stage.

None of the FSB collected from the field (*Murraya*) or used as bait on sticky traps with FSB (adults and nymphs) as bait were parasitised. The collection of a number of insects from yellow pan traps located next to *Murraya* hedges is still to be sorted and classified.

Area Wide Management

The AWM pilot will be established in the 2015/16 season. The newly developed control strategies will be integrated and tested at farm level and across a small region, and include coordinated monitoring and data sharing and a coordinated management strategy. This study will involve two macadamia farms, two avocado and macadamia farms and a custard apple farm.

DISCUSSION

This study has been a very complex and challenging. New chemicals to manage FSB have been identified. The field activity of these new chemicals however is not as persistent as some of the old chemistry and under high pest pressure, efficacy of some of the new chemicals is lower.

The investigations for suitable monitoring tools gave us two different options. The data from the trap hedges gave a good option for both FSB species, but particularly for *A. nitida*. To use this tool, a good understanding of the life-cycle of the pest is required. The pheromone trap is currently only developed for *A. lutescens* and the trap design still needs improvement. The adhesive used in the prototype is efficient in capturing bugs, but not very UV stable, requiring traps to be replaced frequently. It is an easy tool to use, but in the absence of an effective *A. nitida* lure, in areas where both species are present, the trap hedge is needed as well. Investigations for chemical compounds and composition for *A. nitida* lures are ongoing.

Biological control has been the most difficult component of the program and at this stage, no viable biological control options have been discovered. Of the four egg parasitoids, only one, *Anastatus* sp., has been considered suitable for commercialisation. Due to wide host range of the pest it can be assumed that the main action of the pest and natural enemies is outside the main crop and the effectiveness of the egg parasitoid has been very difficult to evaluate.

CONCLUSIONS

This project has identified new insecticides to be recommended for registration. These new chemicals will complement or replace existing chemicals. By the end of the project we are expecting to have an application for registration of one chemical submitted, and minor use permits for two further chemicals.

Pheromone research has progressed. The lure for the *A. l. lutescens* pheromone is fully optimised, a trap prototype has been developed, and the commercialisation process for this product has commenced. The *A. nitida* pheromone research still needs further work, including laboratory bioassays and electroantennogram studies.

Trap hedge investigations on commercial farms have confirmed long term data from trials at CTH. These data now give us confidence that FSB flights and timing for and threshold for treatments have been identified. The next step is commercial evaluation in collaboration with crop consultants and growers.

The downward trend in FSB damage at *Anastatus* release sites is a promising result with further work required to confirm this trend. Any biological control option will be long-term and difficult to assess.

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