Australian Government
Cotton Research and Development Corporation

FINAL REPORT 2013

Part 1 - Summary Details

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

CRDC Project Number: **DAQ1104**

Project Title: **Silverleaf whitefly insecticide resistance monitoring 2010-2013**

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CRDC Program: Farming Systems

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Introduction

Bemisia tabaci B-biotype (Middle East – Asia Minor 1), commonly known as silverleaf whitefly (SLW), is a major pest of cotton. Silverleaf whitefly has a high reproductive rate and short generation time, which can result in pest outbreaks occurring in cotton growing regions in some seasons (e.g. Emerald 2001–02). Silverleaf whitefly nymphs and adults feed on phloem and produce sticky honeydew that contains the sugar trehalulose. Sticky cotton contaminated with honeydew causes significant interference during processing of lint for textiles (due to the low melting point of trehalulose) leading to honeydew-contaminated lint being severely discounted or rejected by end users. Therefore, widespread use of insecticides may be necessary in situations where SLW populations approach threshold levels, particularly late season, in order to avoid lint contamination.

Silverleaf whitefly has the ability to rapidly develop resistance to many insecticide groups. Worldwide, SLW has developed resistance in regions where it has been extensively exposed to conventional insecticides (synthetic pyrethroids, organophosphate and carbamates), neonicotinoids and insect growth regulators (IGR). In Australia, resistance has been recorded for several insecticides in horticulture, including synthetic pyrethroids, organophosphates, carbamates and pyriproxyfen, an IGR. Pyriproxyfen (Admiral®) is currently viewed as the most important insecticide for SLW management in Australian cotton due to its ability to control high density infestations. Due to the heavy dependence on Admiral® and the limited range of effective chemistry available to Australian cotton growers, it is important that the longevity of these products is maintained. Proactive resistance monitoring is imperative for the Transgenic and Insect Management Strategies (TIMS) committee to make informed decisions as part of yearly updates to the insecticide resistance management strategy (IRMS).

Methodology

Species identification: morphological and molecular diagnostics

Researchers, growers and consultants collected whitefly infested leaves from cotton fields throughout the 2010-11 and 2011-12 seasons for species identification and parasitism levels. Leaves were collected by moving at least 20 metres into the field and collecting whitefly infested leaves randomly throughout the field. Leaves were returned to the laboratory and initially inspected using a stereo microscope to differentiate greenhouse whitefly (GHW) *Trialeurodes vaporariorum* (Westwood) from the *B. tabaci* species complex and record parasitism levels. Where possible, a minimum of 30 leaves and 50 fourth instar whiteflies were inspected. A subsample of *B. tabaci* specimens was then subjected to a molecular diagnostic test to confirm their biotype identification.

The molecular procedure used was a polymerase chain reaction (PCR) based method optimised from existing methodologies using operon primers with OPH16 used to distinguish east Australian native (EAN) and B biotypes (Boukhatem *et al*., 2007, DeBarro and Driver, 1997). A microsatellite method using primers Bem23F and Bem23R was enhanced from established methodologies to distinguish B and Q biotypes using positive controls of Q biotype from Israel, USA and Spain (Chu *et al*., 2009).

The operon primers, OPA10 and OPH16 were not reliable for identification of Q biotype. Both the OPA10 and the OPH16 primers identified variations within Q biotype which were

possibly haplotypes of the biotype. Microsatellites were used for identification of Q biotype because it produced a strong band for Q biotype from different regions including Spain, USA and Israel (Figure 1). The SU07-1 strain (*B. tabaci* B biotype, susceptible strain) was used as a positive control for B biotype. GHW positive controls were provided by *Biological Services*, Loxton, South Australia. EAN positive controls were collected off *Euphorbia cyathophora* (Painted Spurge), Bargara, Queensland. Samples of Q biotype whiteflies were supplied by Rami Horowitz (Gilat Research Centre, Israel), Paul De Barro (CSIRO) and Xiachun Li (University of Arizona, USA).

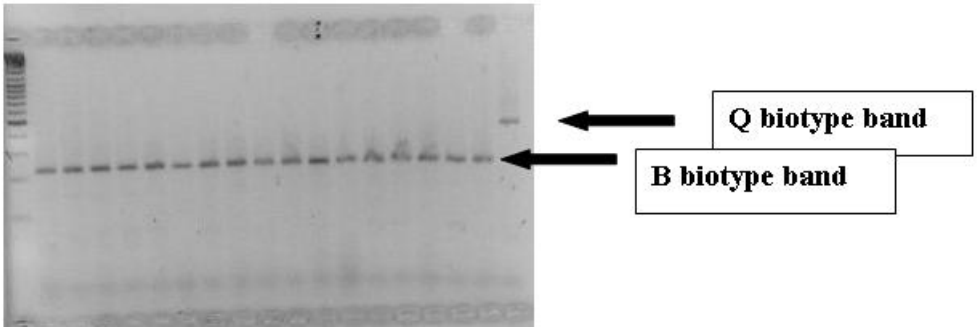

Figure 1. Gel image from PCR using microsatellite primers Bem23 for whiteflies collected from Warburn, NSW. On the far left is the DNA ladder, followed by the bands for the field collected SLW which were all B biotype. The positive control bands for B and Q biotypes are on the far right.

Insecticide resistance monitoring

Collections and colony maintenance

Collections of SLW obtained off cotton from 34 locations at Emerald, Theodore, St George, Mungindi, Moree and Narrabri were bioassayed between 2010-13 and are detailed in Table 1. Several collections were also derived from horticultural crops at Ayr, Bowen and Gatton so that SLW strains that are resistant to key insecticides could be developed and maintained. Collections of adult whiteflies off cotton were made with a petrol powered blower/vac fitted with a muslin sock in the vacuum tube. The procedure used was to walk a distance of 50 -100 m into a sample crop with the vacuum running on idle and the entrance of the vacuum tube held in the inter-row at about the middle of the crop canopy height. In this way, disturbed SLW that take flight from the plants are caught and held by the vacuum sampler. The adults were transferred to cloth-sided cages containing a potted cotton plant and transported back to the laboratory in an air-conditioned vehicle for processing. A minimum of 1000 whiteflies per collection site were then aspirated into 60 cm L x 30 cm W x 60 cm H cloth-sided cages fitted with a perspex roof for colony maintenance (Figure 2). Caged colonies were maintained on potted cotton plants (variety: Sicot 71RRF) in a glasshouse for several generations so testing could be completed on a range of insecticides. Cages were cleaned between generations with plants replaced and old adults discarded after subsequent egg lay. This was done to ensure adult bioassays used newly emerged individuals from discrete generations.

Figure 2. Colony cages used to rear silverleaf whitefly for resistance testing. The cages are made with light weight aluminium frames for ease of transport, insect proof netting for ventilation and a perspex top so that insects could be easily aspirated from the roof of the cage to minimise handling mortality.

Full dose response assays

Methodologies developed under CRDC project 03DAQ006 were refined and used to test insecticides registered for control of whitefly in cotton and other insecticides they may be exposed to. Insecticides tested included, pyriproxyfen (Admiral®), diafenthiuron (Pegasus®), bifenthrin (Talstar®), spirotetramat (Movento®) and clothianidin (Shield®).

Table 1. Field collection sites for silverleaf whitefly resistance testing

Year	Location	Region	Host	No. samples processed[#]	No. collections assayed
2010-11	Narrabri/Wee Waa	Namoi	Cotton	23	3
	Mungindi	McIntyre	Cotton	2	2
	St. George	Balonne	Cotton	8	5
	Jandowae	Darling Downs	Cotton	1	0
	Bundaberg*	Burnett	Cotton	1	0
	Griffith	Murrumbidgee	Cotton	3	0
	Hillston	Lachlan	Cotton	4	0
	Horticultural areas	NQ & Lockyer Valley	Melons	4	2
2011-12	Narrabri/Wee Waa	Namoi	Cotton	4	3
	Moree	Gwydir	Cotton	4	4
	St. George	Balonne	Cotton	3	3
	Emerald	Central Qld	Cotton	6	3
	Theodore	Central Qld	Cotton	1	1
	Chinchilla	Darling Downs	Cotton	1	0
	Horticultural areas	NQ & Lockyer Valley	Tomatoes/Melons	7	5
2012-13	Narrabri/Wee Waa	Namoi	Cotton	2	2
	Moree	Gwydir	Cotton	2	2
	St. George	Balonne	Cotton	3	3
	Emerald	Central Qld	Cotton	2	2
	Theodore	Central Qld	Cotton	1	1
	Horticultural areas	Lockyer Valley	Tomatoes	1	1

[#] includes samples submitted by consultants/researchers for biotype ID and parasitism levels

*Research station trial

Pyriproxyfen

An egg bioassay based on the Insecticide Resistance Action Committee (IRAC) method 016 (formally method 12c) was used to test the resistance status of SLW to pyriproxyfen. The bioassay method involved confining mated female adults overnight (18h) in clip cages (15/cage) on leaves of 5-7 node cotton plants (variety: Sicot 71RRF) to lay eggs. Adults were then removed, the leaves cut from the plant and with the aid of a stereo microscope, eggs were counted and their position on the leaf marked with a waterproof pen. Leaves were kept fresh by maintaining the petiole in a 20 mL vial of water. Six doses (treatments) of pyriproxyfen were tested: 0 (control), 0.003, 0.01, 0.03, 0.1, and 1 ppm. For each dose, 5 infested leaves (replicates) were treated. Serial dilutions of pyriproxyfen were mixed with distilled water plus 0.01% Agral® non-ionic surfactant. Leaves were dipped in the treatments for 20 seconds and allowed to dry. After the leaves had dried they were placed back into the vial and held in a constant temperature (CT) room at 27 ± 1ºC and 16:8 (L:D) for 10d. Egg mortality data was analysed using Probit 5 for Windows (Gillespie 1995). Probit regressions were calculated with LC_{50} and LC_{90} values estimated.

Spirotetramat

A nymph bioassay was used to test the resistance status of SLW to spirotetramat. This assay is based on IRAC method 016, except leaves were maintained on the potted plants for a further 10d after egg lay before removal so the eggs could hatch and 1st instar nymphs could develop and settle. At 10d, the leaves were cut off the plant and nymphs counted and marked (an ink dot was marked on the leaf adjacent to each nymph). Six doses (treatments) of

spirotetramat were tested: 0 (control), 1, 3, 6, 10 and 30 ppm. For each dose 5 leaves (replicates) were treated. Spirotetramat serial dilutions were mixed with distilled water plus 0.01% Agral® non-ionic surfactant. Leaves were dipped in the treatments for 20 seconds and allowed to dry, then the petiole placed into water filled vials. Leaves were kept in a CT room at 27 ± 1ºC and 16:8 (L: D) for a further 10d and then assessed for nymphal survival. Mortality data was assessed by probit analysis.

Diafenthiuron, Bifenthrin and Clothianidin

An adult bioassay was used to test the resistance status of SLW to diafenthiuron, bifenthrin and clothianidin. The methodology for this bioassay was based on IRAC method 008, however different cages with better ventilation were used to minimise control mortality (Figure 3). The following treatments were used:

- diafenthiuron and bifenthrin – 0 (control) 10, 30, 100 and 300 ppm mixed in distilled water with 0.01% Agral®
- clothianidin - 0, 3, 10, 30 and 300 ppm mixed in distilled water with 0.1% Maxx Organosilicone Surfactant™.

Treatments were replicated 5 times, with leaves being dipped in the treatment insecticide solutions for 20 seconds and then allowed to dry. Leaves were subsequently kept fresh by placing the petiole in water filled glass vials. Cages were clipped onto the treated leaves and 15 adult whiteflies were added to each cage. At 1h, handling mortality was assessed using a stereo microscope. Caged adults were kept in a CT room (27 ± 1ºC and 16:8 (L:D)) for 2d for bifenthrin or 3d for diafenthiuron and clothianidin. After the defined exposure period, whitefly mortality was assessed using a stereo microscope and data was subjected to probit analysis.

Figure 3. Clip cage used for adult Silverleaf whitefly bioassays

Discriminating dose tests

A discriminating dose (DD) bioassay was developed for pyriproxyfen and tested during the 2011-12 season. This procedure was deemed to be more efficient as fewer insecticide dilutions are required, and fewer whiteflies are needed for testing. A DD bioassay enables the testing of the F_0 generation whiteflies direct from the field. A discriminating dose of 0.3 ppm was used for testing based on previous results from full dose response bioassays.

Development of resistance colonies

Whitefly collections that showed elevated resistance to either full dose response bioassays or discriminating dose bioassays were pressured with a sub-lethal dose of insecticide and then assayed again to indentify shifts in resistance following selection pressure. Pressure tests were applied at rates that would kill approximately 70% of individuals (based on results from full dose response bioassays).

Pyriproxyfen

A potted cotton plant was added to a cage containing whitefly adults and they were allowed to oviposit for 48h before the adults were removed. To develop a resistant whitefly colony, whitefly eggs were exposed to a sublethal dose of pyriproxyfen by spraying the plant to run off. The resistance level of the survivors of this treatment was then determined by conducting a bioassay using a broad dose range.

Diafenthiuron and bifenthrin

For each insecticide, a potted cotton plant was treated with a sublethal dose and adults were exposed to the insecticide for 48h. The treated plant was then removed and an untreated plant was added to the cage so the surviving adults could oviposit on it for 72h before removal. Resultant adult offspring were bioassayed with a broad dose range.

Data analysis

Bioassay mortality data were analysed using Probit 5 for Windows. Mortality data were adjusted using Abbott's formula (Abbott 1925) to correct for any control mortality. Probit regressions were calculated and LC_{50} and LC_{90} values were estimated. The slope of the line was also calculated. A resistance factor (RF) was calculated by dividing the LC_{50} value of the tested strain by the LC_{50} value of the susceptible strain (SU07-1) for the same insecticide. Field collections were considered significantly different to the susceptible strain if the fiducial limits did not overlap.

Results and discussion

Species identification: morphological and molecular diagnostics

During 2010-11, 542 individuals were subjected to DNA analysis using the OPH16 primer with 80% identified as Silverleaf whitefly, 7% eastern Australian native, 6% greenhouse whitefly, 0% Q biotype and 7% unknown.

While the test used identifies Q biotype using the positive controls that were available, Q biotype is considered to be genetically highly variable. There are more reliable methods for testing Q biotype based on the PhD results of Sharon van Brunschot (UQ, Brisbane). It would

be highly desirable for future threats of Q biotype to be run through this system. Sharon's method also has been tested against far more worldwide samples of Q biotype.

All samples identified from cotton regions were predominantly SLW with very little EAN identified in any samples. Greenhouse whiteflies were also uncommon in cotton except in situations where they were in close proximity to sunflowers. There was very little GHW reproduction in cotton crops near sunflowers based on nymphal population assessments.

Insecticide resistance monitoring

Mortality results

Pyriproxyfen bioassays from 2011 to 2013 suggest relatively little change in resistance levels to this product across all cotton regions (Figure 4).

Bifenthrin bioassays from 2011 to 2013 suggest there are low levels of resistance to bifenthrin in most cotton regions, but overall the product should remain efficacious when used as a late season clean up or pre-defoliation salvage spray option (**Figure 5**).

Results from the diafenthiuron bioassays suggest whitefly populations in cotton regions remain susceptible to diafenthiuron (**Figure 6**).

Spirotetramat bioassay results indicate that whitefly populations are susceptible to this product (**Figure 7**).

Clothianidin bioassay results suggest that due to prior incidental exposure of SLW to other neonicotinoids in seed dressings and/or sprays has resulted in SLW populations developing low levels of resistance to clothianidin. Late seasons sprays using clothianidin to control GVB and cotton aphid may increase the likelihood of SLW developing resistance to clothianidin and other neonicotinoids (**Figure 8**).

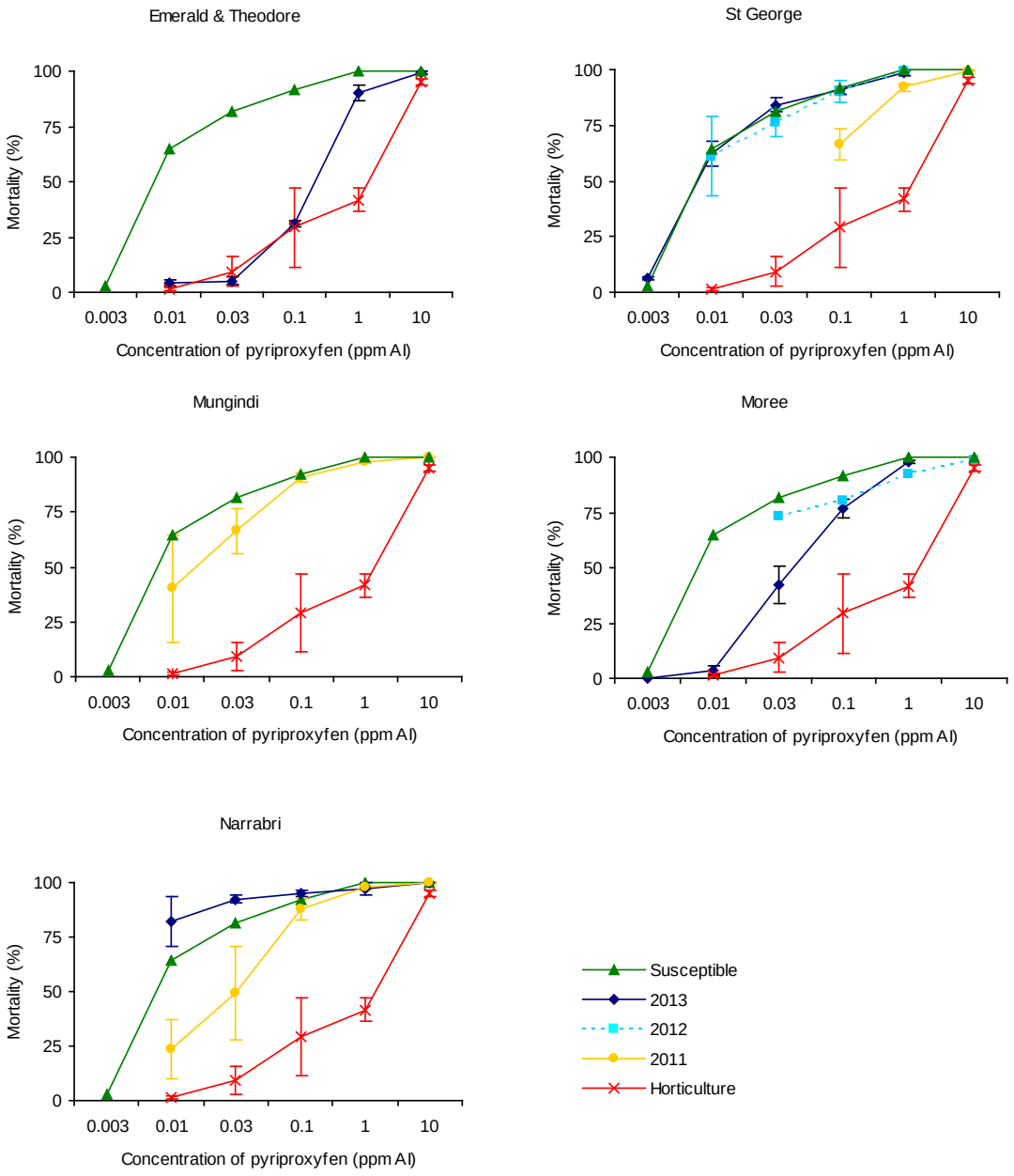

Figure 4. Pyriproxyfen bioassay results for Emerald & Theodore, St George, Mungindi, Moree and Narrabri for 2011 to 2013. Note: in some regions testing was not conducted in each year. Discriminating dose testing of Pyriproxyfen was conducted in 2012 so there is a limited data set for that year. Horticulture results are derived from limited testing of whiteflies from the Bowen and Gatton regions.

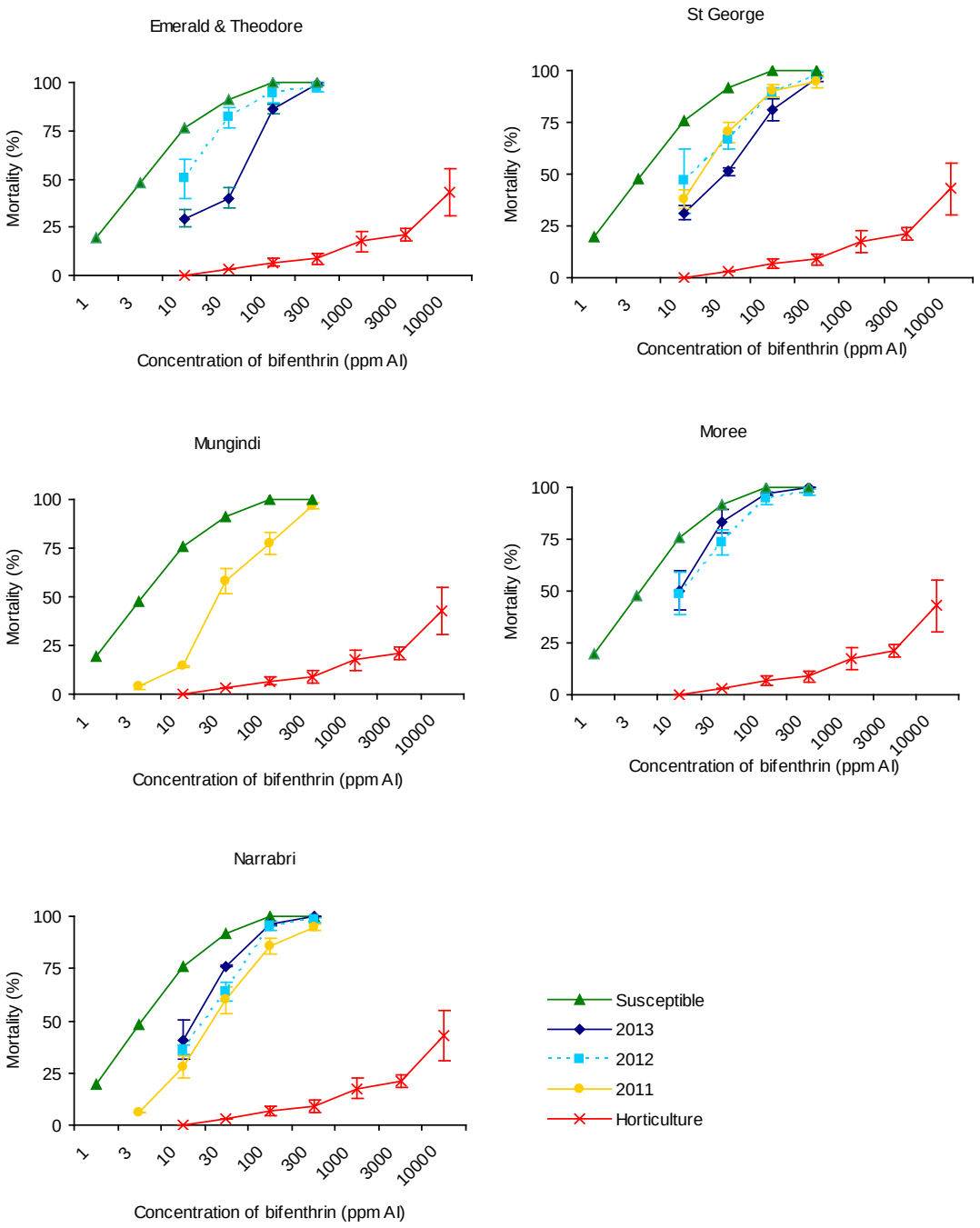

Figure 5. Bifenthrin bioassay results for cotton regions 2011 to 2013. Note: in some regions testing was not conducted in each year. Horticulture results are derived from limited testing of whiteflies from the Bowen region.

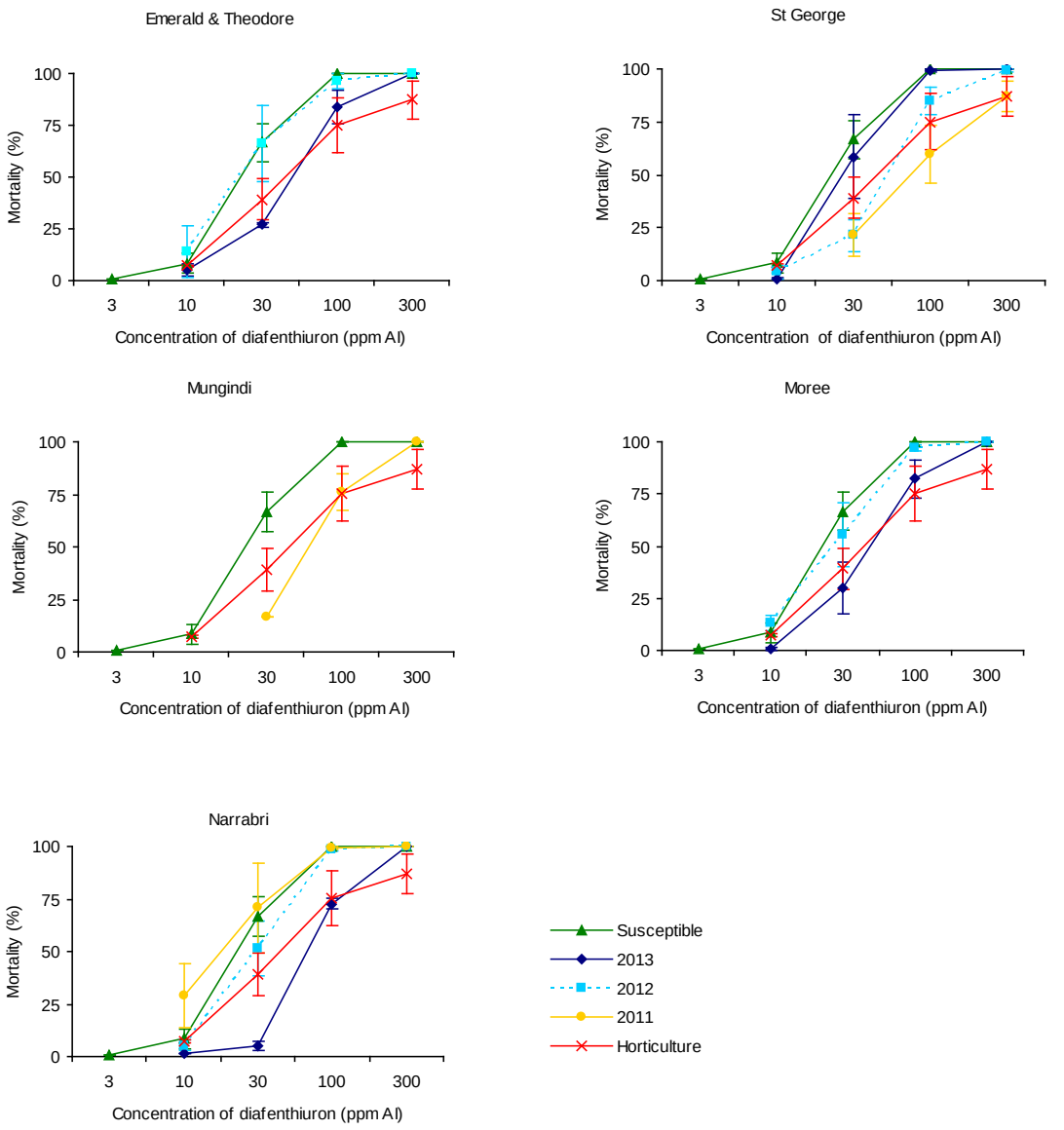

Figure 6. Diafenthiuron bioassay results from cotton regions 2011 to 2013. Note: in some regions testing was not conducted in each year. Horticulture results are derived from limited testing of whiteflies from the Bowen and Gumlu regions.

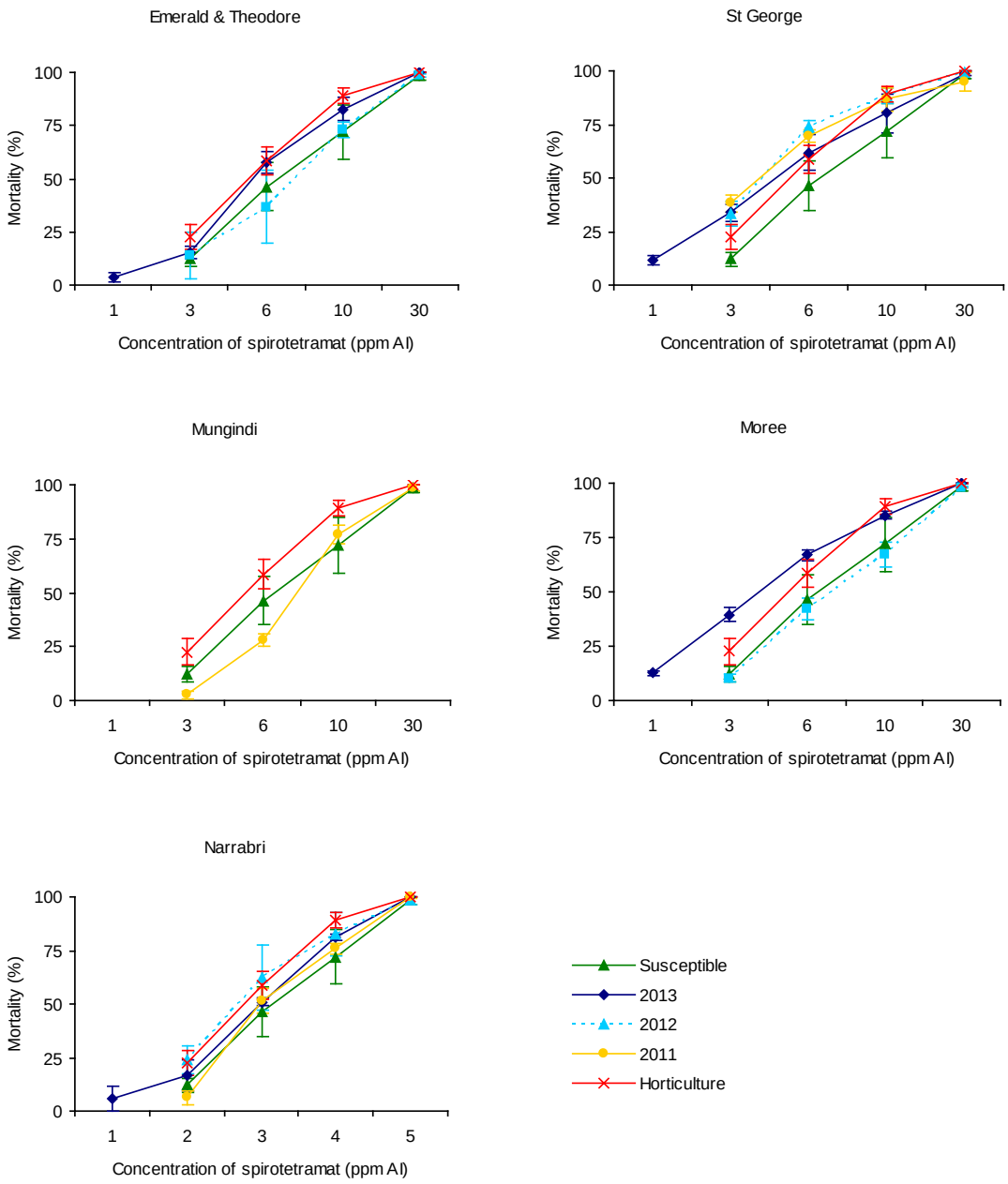

Figure 7. Spirotetramat results for cotton regions 2011 to 2013. Note: in some regions testing was not conducted in each year. Horticulture results are derived from limited testing of whiteflies from the Bowen region.

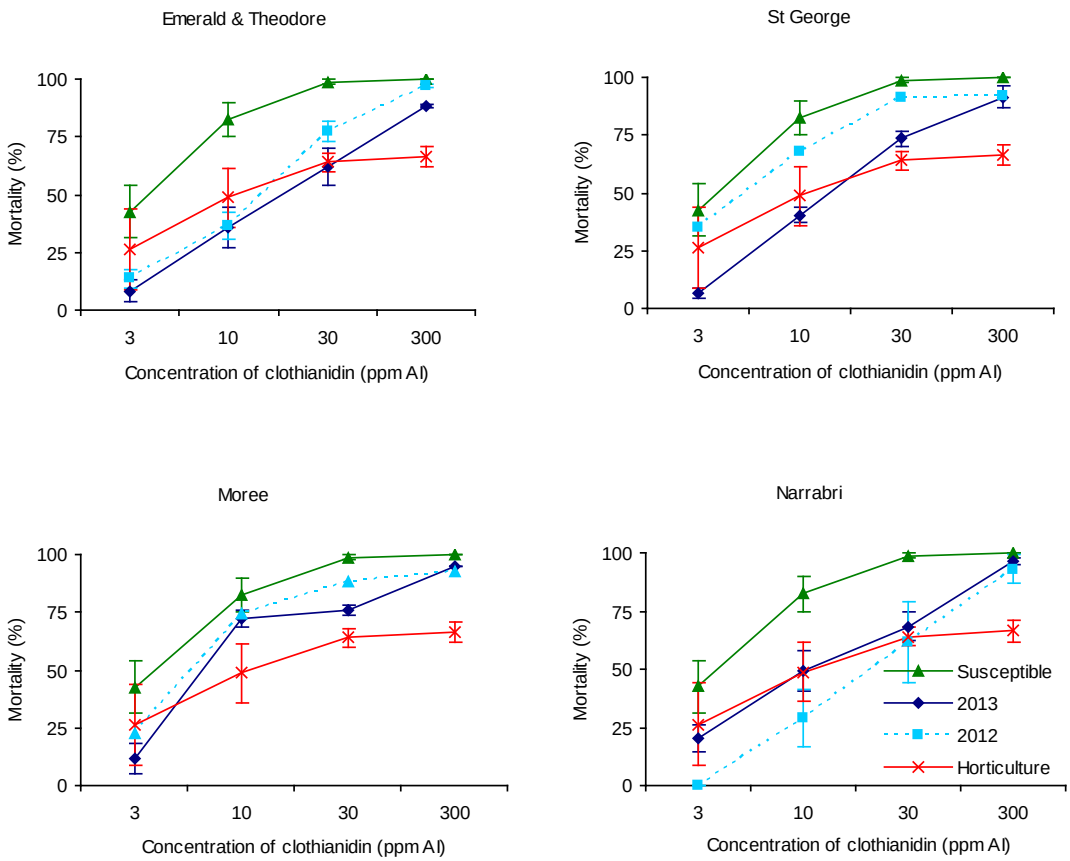

Figure 8. Clothianidin bioassay results for 2012 to 2013. Horticulture results are derived from limited testing of whiteflies from the Gatton region.

LC50

The lethal concentration to kill 50% of the population was calculated for each insecticide tested for SLW collected from cotton regions and compared to the LC50 to kill susceptible whitefly (**Figure 9**). The concentration of bifenthrin required to kill 50% of SLW was elevated in each region compared to the susceptible population.

Results of clothianidin suggest there are some populations of SLW that have elevated levels of neonicotinoid resistance; this is particularly evident in 2013 for central Queensland regions of Theodore and Emerald as well as St George and Narrabri.

Pyriproxyfen and spirotetramat bioassay results indicate whitefly populations in cotton remain susceptible to these two products. However, there has been very limited usage of spirotetramat in cotton since its registration in 2011/12 due to low levels of aphid and SLW activity.

Diafenthiuron results for 2011-12 were compromised by an inferior batch of test product. Subsequent testing and results from 2012-13 suggest whitefly populations in cotton remain susceptible to diafenthiurion.

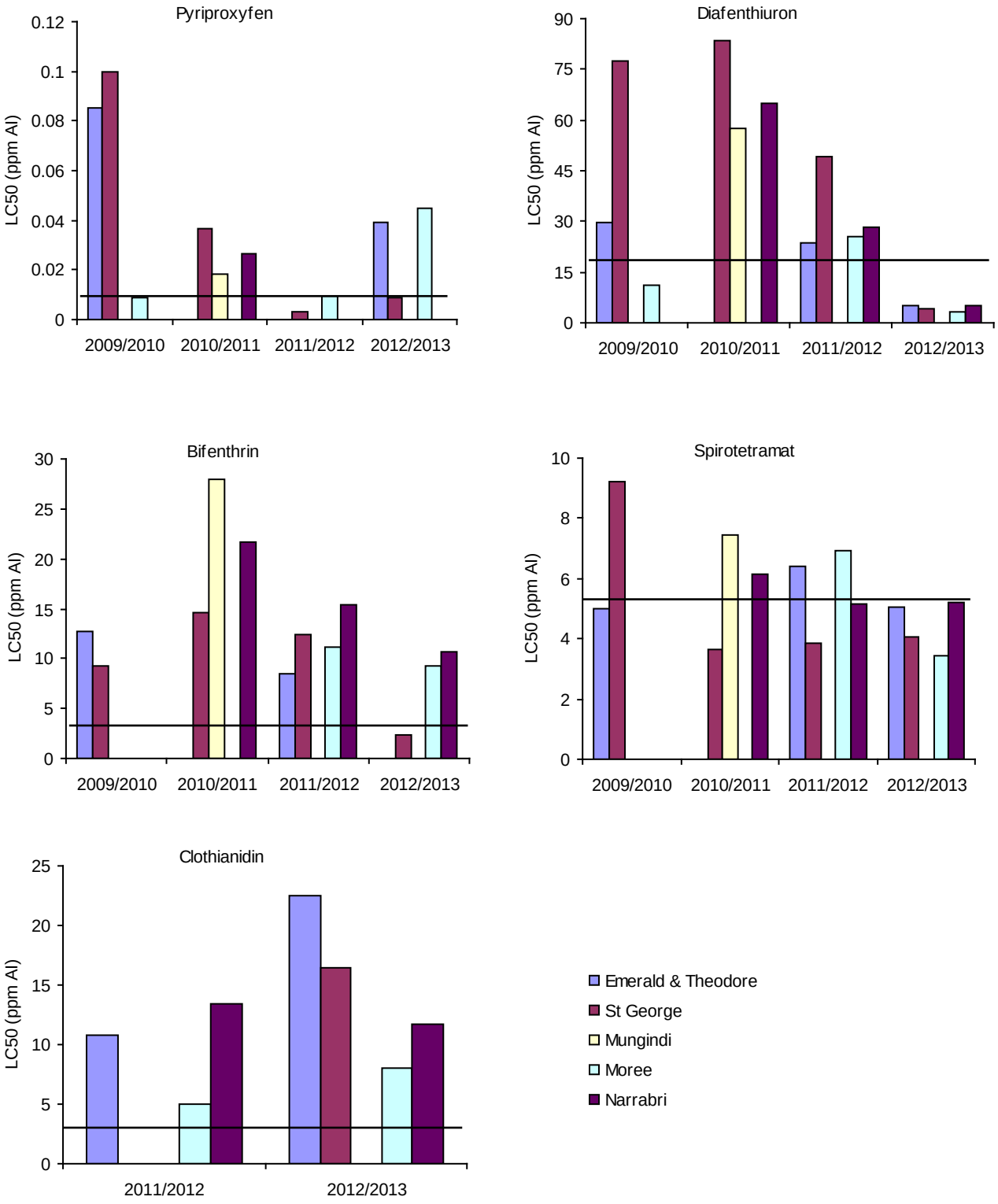

Figure 9. LC_{50} for pyriproxyfen, diafenthiuron, bifenthrin, spirotetramat, and clothianidin for each cotton region tested for 2010 to 2013. The black line represents the LC_{50} required to kill 50% of a susceptible whitefly population

Discriminating dose bioassays

Project staff visited resistance expert, Grant Herron, at his Sydney facilities in 2012 to review the 2010-11 data and discuss the development of discriminating doses. Grant's advice was that the discriminating dose that had been selected was not functional because 100% mortality had not been achieved in the full dose response bioassays and the slope of the lines were flat which would make it difficult to extrapolate the results. Based on this information, it was decided to continue to perform full dose response bioassays for the foreseeable future. Bioassay dose selection has since been changed so that 100% mortality is achieved with the top dose.

Resistance colonies

By 2011-12, pyriproxyfen and bifenthrin resistant colonies derived from horticultural areas had achieved resistance frequencies (RF) (LC_{90}) of 1065 and 2527, respectively. These colonies are now considered to be homozygous resistant. An increase in the RF for a diafenthiuron colony could not be achieved after pressuring for three generations. The elevated resistance frequencies for the whiteflies tested in 2011-12 that initiated the diafenthiuron test colony have since been attributed to a faulty batch of test product. This colony has subsequently been discarded.

The results achieved with these colonies perfectly demonstrate the capacity that SLW has to develop extreme levels of resistance. The rapid ability of SLW to develop resistance is the main threat posed to the cotton industry and this information reinforces the need to manage the use of available chemistry proactively. The resistant colonies are being maintained as a resource for possible future research into fitness costs associated with insecticide resistance and as a source of resistance markers for DNA research.

Parasitism and predation

Samples submitted by growers and consultants have primarily been for whitefly species identification (*B. tabaci* biotypes B, EAN and Q, and greenhouse whitefly) to assist with control decision making. Parasitism levels were provided as part of the service in order to provide evidence of beneficial activity and to promote the avoidance of disruptive insecticides.

There was little interest in the species diagnostic or parasitism by crop consultants from 2010-2013. A total of 21 leaf samples from Hillston (7), St. George (6), Moree (4), Narrabri (3) and Emerald (1) were microscopically examined and the results conveyed to the consultants. In the previous project (03DAQ006), 60 samples were received for the diagnostic, mostly from locations around Narrabri, Darling Downs and St George. The samples from St. George had the highest parasitism levels, ranging from 19 to 56%. Very low parasitism levels (max 7%) were recorded from the Hillston samples. The reduced interest in the diagnostic service over time can be attributed to several events. During the seasons of the initial outbreak of SLW in Queensland and NSW cotton regions, accurate identification was important, as populations were a mixture of SLW, EAN and GHW. EAN and GHW have since been displaced by SLW in all the warmer regions (Darling Downs and southern NSW regions still have composite populations of GHW and SLW). During the previous project there was a suspected incursion of the exotic Q biotype which created interest in whitefly species identification and parasitism; it has since been confirmed as being absent. There has

been increased confidence by consultants in their ability to distinguish between SLW and GHW which has made the diagnostic service less relevant.

A poster was developed and an A4 PDF (see **Figure 10**) has been made available under the resources section of the QDAFF Beatsheet blog to assist consultants with SLW parasitism identification.

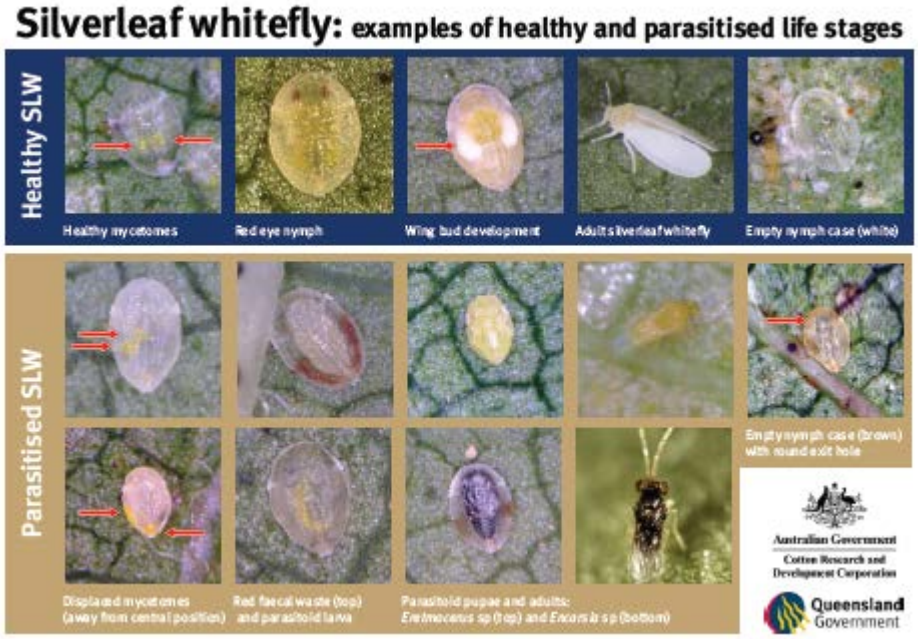

Figure 10. Poster showing SLW life stage features used to assist with parasitism identification.

Train extension officers and consultants in the differentiation of GHW and *Bemisia tabaci*

Project staff have delivered the following extension presentations at conferences and grower/agronomist meetings. Several online extension articles were produced and published on the QDAFF entomology blog site.

Conference papers:

Ludgate, Z. (2010). Three years of monitoring insecticide resistance to Silverleaf whitefly in cotton. *Proceedings of the 15th Australian Cotton Conference*, Gold Coast.

Hall, Z., Lloyd, R. and Grams, R. (2012). Five years of resistance monitoring for Silverleaf whitefly in cotton. *Proceedings of the 16th Australian Cotton Conference*, Gold Coast.

Presentations:

Hall, Z. (2010). Silverleaf whitefly biology and management. *Melon growers meeting*, Chinchilla.

Hall, Z. (2010). Future directions & challenges in resistance monitoring. *IPM Forum*, Toowoomba.

Lloyd, R. (2010). Silverleaf whitefly biology and management. *Landmark grower meeting*, Colonsay.

Lloyd, R. (2010). Silverleaf whitefly management – a cotton perspective. *IPM Forum*, Toowoomba.

Ludgate, Z. and Brier, H. (2010). Whitefly – the IPM Enforcer - 'How to avoid a $100/ha spray in cotton'. *Proceedings of GRDC Grains Research Update*, Dalby.

Hall, Z and Lloyd, R. (2011). Resistance testing for Silverleaf whitefly. *TIMS Technical Panel meeting*, (Teleconference)

Hall, Z. (2012). Five years of resistance monitoring for Silverleaf whitefly in cotton. *Epidemiology and management of whitefly-transmitted viruses workshop*, Brisbane.

Hall, Z. (2012). Resistance testing for Silverleaf whitefly. *TIMS Technical Panel meeting*, Goondiwindi.

Grundy, P. (2013). Resistance testing for Silverleaf whitefly *TIMS Technical Panel meeting*, Narrabri.

Other publications:

Contributions were made to articles pertaining to whitefly and sucking pest IPM published in the "Spotlight" magazine, Cotton CRC "Pest Profile" and annual reviews of the Cotton Pest Management Guide.

The Beatsheet blog postings

Four articles related to whitefly management and resistance monitoring were posted on the QDAFF Beat Sheet blog http://thebeatsheet.com.au/ between July 2010 and June 2013. There were 375,636 and 454 views of whitefly-related articles during the 2010-11, 2011-12 and 2012-13 financial years, respectively. The postings were:

- 2010-11 Annual Silverleaf Whitefly Resistance Testing Results and Implications for Management in the coming Season (November 14, 2011)
- Collecting to assess Silverleaf Whitefly susceptibility to insecticides (March 1, 2012)
- Managing Silverleaf Whitefly (SLW) – Wet conditions, late crops and immigrant populations (March 1, 2012)
- Whitefly resistance monitoring in Cotton (September 10, 2012).

Conclusion

Silverleaf whiteflies in cotton growing regions remain susceptible to the insecticides used against it. Increases in the LC_{50} of bifenthrin and clothianidin detected during the course of this project suggest whiteflies could potentially develop resistance to these products. Development of lab resistant whitefly colonies to bifenthrin and pyriproxyfen demonstrated the rapid capacity of silverleaf whitefly to develop resistance which reinforces the importance of the cotton industry having and adhering to an IRMS for whitefly.

Resistance of silverleaf whitefly to insecticides was tested from 2010-13. Levels of resistance in whitefly populations from the major cotton growing regions were monitored and reported to the cotton industry. Project staff participated in TIMS technical panel meetings and made recommendations on the IRMS for silverleaf whitefly. Results from the project provide the cotton industry reassurance that IRMS is protecting the industry from resistance

issues in SLW. This in turn is conserving the long term viability of insecticides registered for whitefly, particularly pyriproxyfen (Admiral®) and diafenthiuron (Pegasus®) which have a good IPM fit. Results from project provide the option to modify the IRMS if potential resistance issues develop.

References

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Chu, D., Zhang, Y., Gao, C. & Liu, G. (2009). Validity of microsatellite loci BEM06 and BEM23 to differentiate B*emisia tabaci biotypes* B and Q (Hemiptera: Aleyrodidae). *Acta Entomologica Sinica,* 52**,** 1390-1396.

Debarro, P. J. & Driver, F. (1997). Use of RAPD PCR to distinguish the B biotype from other biotypes of B*emisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae). *Australian Journal of Entomology,* 36**,** 149-152.

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Part 4 – Final Report Executive Summary

Silverleaf whitefly (SLW) is a major insect pest of the cotton industry. It is a pest because it excretes honeydew that contaminates cotton lint, causing problems during textile processing. Honeydew contaminated lint may receive price penalties or in extreme cases may be rejected from sale. Insecticides are an integral part of whitefly IPM, particularly products like Admiral® (pyriproxyfen) which are soft on natural enemies. However, SLW can rapidly develop resistance to insecticides as seen overseas (Israel and USA: Arizona) where resistance to pyriproxyfen has been reported. An insecticide resistance management strategy (IRMS) has been developed by the Australian cotton industry for SLW to prolong the life of insecticides like Admiral®. This project collected SLW insecticide resistance data so the performance of the IRMS can be evaluated and if necessary the IRMS can be adjusted to reduce the likelihood of SLW developing resistance to insecticides used against it.

The project has maintained and developed several important glasshouse colonies of SLW including a susceptible colony, and resistant colonies (bifenthrin and pyriproxyfen). These colonies demonstrate the potential that SLW has to develop resistance and are useful research resources.

Project staff presented results of resistance monitoring at field days and conferences, including the Australian cotton conference. Results were presented at TIMS technical panel meetings, and several postings were made on QDAFF's field crop entomology blog site thebeatsheet.com.au.

In 2009 it was suspected that Q biotype of SLW had arrived in Australia. Further testing indicated it was misidentified, however regular screening for Q biotype should be maintained as an essential component of the cotton industry's biosecurity precautions. Although a methodology that identified Q biotype was developed as part of the diagnostic services provided by this project, a more reliable method has since been developed by Sharon van Brunschot as part of a PhD research program.

During 2010-13, the insecticide resistance status of silverleaf whitefly populations in cotton growing regions (Emerald, Theodore, St George, Mungindi, Moree and Narrabri) was monitored. Insecticides tested included pyriproxyfen, diafenthiuron, bifenthrin, spirotetramat and clothianidin. Silverleaf whiteflies populations in each of these cotton regions remain susceptible to these products. A small increase in the LC_{50} for bifenthrin at Narrabri was detected in the 2010–11 season, but this has decreased in the subsequent seasons. Limited data on clothianidin indicate potential for resistance at Emerald but further testing over coming seasons is required. The elevated levels of resistance to clothianidin are likely to be the result of widespread usage of neonicotinoids in the form of seed coat dressings at planting as only minor amounts of clothianidin are utilised in foliar crop applications.