CRDC 191C

Whitefly Study Tour
Texas, Arizona and California, July, 2002

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In season 2001-02, the Central Highlands area of Central Queensland experienced Australia's first major outbreak of Silverleaf Whitefly (*Bemisia tabaci* biotype B) in a cotton production system. The situation was managed to some degree with existing products, and whilst there is no indication that the quality of Central Highlands cotton was diminished this season, the industry realised that advances needed to be made for the effective management of this pest in the future.

Two key factors that made management of Silverleaf Whitefly (SLW) difficult in 2001-02 were a lack of suitable insecticides and knowledge of the pest and how it would react in cotton in the Australian environment.

To address the second issue, the Cotton Research & Development Corporation, Cotton Seed Distributors, and the cotton grower associations of the Central Highlands, Theodore and Biloela sponsored 12 people involved in the cotton industry in Central Queensland to visit regions in the United States of America that had experienced and managed problematic SLW populations.

The 12 day tour covered three distinct areas that shared similarities with the cotton production system of Central Queensland in terms of crop dynamics and climate; **Rio Grande Valley, Texas; Low Desert Areas, Arizona; Imperial Valley, California.**

In each of these areas the tour group spoke to producers, consultants, researchers, extension staff, and aerial operators to gain an understanding of the pest and its management.

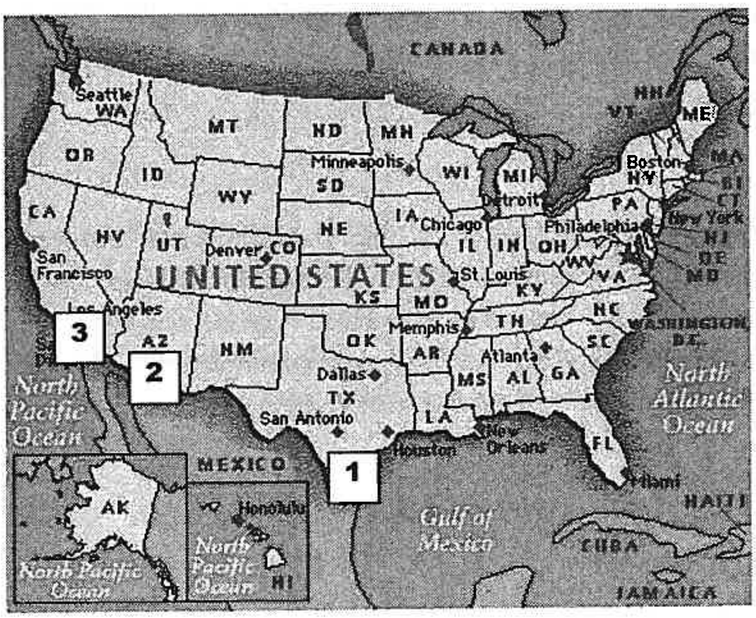

Figure 1: Tour Destinations

(1) Lower Rio Grande, **Texas**
(2) Low Desert Areas, **Arizona**
(3) Imperial Valley, **California**

Rio Grande Valley, TEXAS

The area and problem

The Rio Grande Valley of southern Texas is a long-term cotton producing area, which is characterised by its early production system. Traditionally this area of the US cotton belt is the first to commence harvest each season. The area includes a combination of irrigated and rain grown cotton, although restricted water allocation from the Rio Grande river, bordering Texas and Mexico has resulted in reduced irrigated cropping in the region during recent times.

The cropping system of the area comprises of spring melons, summer cotton, fall melons, and brassica crops during winter. This pattern of crop succession has been conducive to the build up of SLW populations in the Rio Grande.

It is speculated that the SLW (*Bemisia tabaci* biotype B) was introduced in the mid 1980's and gradually became the dominant species. Endemic whitefly species such as the Sweet Potato Whitefly (*Bemisia tabaci* biotype A) had been present in the area up to that point but had not previously presented a problem.

The first major outbreak of SLW occurred in 1991 with growers spending up to $100 per acre on control and losing up to one bale per acre in yield. It was recognised that the main cause of the problem in this season was the generation and movement of whitefly from abandoned winter cole crops onto spring melons and then cotton.

The problem occurred again in 1995, except on this occasion the blame was placed on the effect of the newly introduced boll weevil (*Anthonomus grandis*) eradication program. This program utilised regular applications of broad-spectrum insecticides, which decimated predator and parasitoid populations, allowing the uncontrolled reproduction of whitefly. The outbreak in the 1995 season also coincided with extensive beet armyworm populations that compounded yield losses.

In the Lower Rio Grande, SLW was associated more with yield declines rather than quality problems on cotton. Despite crops appearing to be heavily affected, very little cotton was actually classed as sticky from either major outbreak.

Management

The extent of the 1991 outbreak caused the cotton industry to form a collective taskforce including; growers, consultants, extension agents and researchers. This group produced extension material for the cotton industry but also engaged the local community to understand the ecology of the pest including the role played by ornamental host plants within the urban environment. This was done via regular radio segments targeting both the agricultural and wider communities.

In keeping with their low input production system, greater emphasis was placed on cultural control in the Rio Grande Valley. Insect Growth Regulators (IGRs) were not widely used due to their expense and resultant success of cultural methods. Many of the cultural controls that growers employ such as timely destruction of crop residues were also driven in part by the Boll Weevil control program, both mandatory and voluntary.

In both the cotton and rockmelon industries there has been a rapid move to smooth leafed crop cultivars. From 1991 to 1992, the use of smooth leafed cotton varieties increased from 55-91%.

Abandoned crops represented a medium level SLW threat. These crops were usually the result of low yielding cotton crops that had been abandoned under the Federal Government Farm Insurance Program and crop residue regrowth following share farmers who had finished their tenure. Cotton crop residue destruction is mandatory for the control of boll weevil although this is a medium term control in terms of SLW. Research for effective short-term control includes herbicide treatments at the time of slashing to prevent regrowth. Across the border in Mexico, post-harvest field gleaning of crop residues in all crops is thought to prevent continuous host availability for whitefly.
In Texas there was an emphasis on spatial distribution of alternate host crops by entomology researchers. The placement of cotton near adjacent late spring melons was avoided due to a high risk of cross-infestation. The recommendation was that there should be _ mile (400m) break between successive crops (eg spring melons and cotton).

Mandatory planting dates (which vary by location) exist for the control of boll weevil. This window is not adverse for the management of whitefly.

Insecticide control of SLW in cotton appeared to be directed towards the knockdown of adults in a two-stage approach, mid and late season. The description of 10 to 12 adults per leaf early season then 30 to 40 adults per leaf late season reflects the irregular occurrence of outbreak populations, the effectiveness of the knockdown chemical control, and lack of sticky cotton (lint cotton contaminated with honeydew) produced in Texas. The standard control measure is a mixture of the pyrethroid Danitol® (fenpropathrin) and organophosphate Orthene® (acephate). The insect growth regulator (IGR) Applaud® (buprofezin) is registered in Texas but not routinely used as a control due to the generally late season nature of SLW infestations and the cost constraints.

Aerial application was generally the accepted method for insecticide use in the Rio Grande Valley. There was nothing extra-ordinary about application of insecticide treatments aside from an emphasis on good coverage. The optimum timing of sprays for whitefly was considered to be from dawn to mid-morning when adult SLW are typically exposed. All applications included cottonseed oil, which is thought supplement control by smothering insects.

The primary chemical control in cucurbit and cole crops is imidacloprid (Admire® or Confidor®), which is applied as a soil drench for seedlings or in-furrow at transplanting and then via the drip irrigation system. The application of imidacloprid systemically through the irrigation system provides a long residual within the plants (in terms of the crop period).

The preservation and utilisation of predators and parasitoids was highlighted very strongly in the Rio Grande Valley. In addition to this, agencies of the United States Department of Agriculture (USDA) responded to the devastating SLW outbreak of 1995 by commencing an intensive exotic parasitoid introduction program as well as a collaborative development (with industry) of bio-pesticides at a cost of approximately $US3 million. The technique of using Banker Plants to supplement the existing populations of parasitoids is utilised primarily in spring horticulture but may also be of use in a non-host crop period in areas of native vegetation and/or weed hosts. The most effective parasitoid species are a number of *Eretmocerus* and *Encarsia* species although equal importance was placed on predators such as lacewings and ladybird species.

Work had been conducted on the use of several bio-pesticides including Mycotrol® (*Beauveria bassiana*). This biopesticide was found to provide effective SLW control under laboratory and green house situations. However, under field conditions, fungal biopesticides were found to be largely ineffective due to application constraints and a requirement for high levels of relative humidity. Up to 80% infection of SLW had been achieved in rockmelon crops whereas tests in cotton were un-successful.

Summary:

A common attitude from growers in the lower Rio Grande regarding whitefly was; ***"we haven't seen many of them since '96"***. It appears that a number of strategic changes in cultural and insecticide management practices, and other outside influences has led to a situation where they are now able to co-exist with this pest.

Low Desert Areas (Maricopa), ARIZONA

The area and problem

Cotton production in Arizona is exclusively irrigated due to extremely low rainfall. The cotton acreage has declined during the last decade from approximately 800,000 acres to 220,000 acres due to decreased water allocation, pink bollworm, cost/price squeeze and urbanisation. Average yields for the area are generally around 2_ bales/acre which can vary significantly between districts and individual farms.

Whitefly species were first reported in the 1920s. Prior to 1990 the main concern was Cotton Leaf Crumple virus, which is commonly vectored by Sweet Potato Whitefly (*Bemisia tabaci* biotype A). In the 1960s yield reductions of up to 60% were attributed to this viral disease. Sweet Potato Whitefly was inadvertently controlled with synthetic pyrethriods used for the control of pink bollworm and the mandatory destruction of crop residues used to reduce the source of the virus. The unintentional introduction of SLW (*Bemisa tabaci* biotype B) on ornamental nursery plants from Florida is speculated to have occurred around 1985. The rapid development of a resistant population across the state suggests that the introduced insects were highly resistant to pyrethroids and carbamates used in Florida production greenhouses at that time.

During the late 1980's control problems were noticed when pyrethroids were used alone. The standard control progressed to pyrethroid organophosphate mixtures. By 1990, mixture of the specific pyrethroid Danitol® (fenpropathrin) and the organophosphate Orthene® (acephate) was the only chemical control option able to suppress whitefly populations.

Significant outbreaks of SLW occurred in 1991 and 1992. These outbreaks were attributed to the change in biotype (B), which was highly resistant to the available chemical control products. The combination of Danitol® and Orthene® remained the principal knockdown control despite declining efficacy.

In 1995, there was a severe outbreak of SLW and resistance to the above products had reached a level where control could no longer be achieved. In that season growers spent as much as $US200 /acre on insecticides. The situation was serious enough to potentially cripple the cotton industry in Arizona and resulted in EPA emergency use permits for the new Insect Growth Regulators (IGR's) Applaud® (buprofezin) and Knack® (pyriproxyfen).

In 1995 about 11% of the Arizona crop was downgraded for stickiness. Following the successful introduction of IGRs in 1996, this figure decreased to a level of 1%. Despite this change, Arizona growers are still burdened with the reputation of producing sticky cotton and receive on average 3-7c per pound less than growers in neighbouring California. As one grower put it; ***"facts are negotiable but perceptions are rock solid".***

ACPRC - Monitoring for Sticky Cotton

Sub sample of 1000 commercial bales annually for Thermodetector testing

Year	Non - light	Moderate	Heavy
1995	79%	11%	10%
1996	98%	1%	1%
2001	94%	2%	2%

Sticky points on Thermodetector test.

Non – light	0 – 13 points	(undetectable by spinning mills)
Moderate	14 – 24 points	(marginal for spinning)
Heavy	$\geq$ 25 points	(unusable)

The whitefly problem has also led to the demise of the bean crops from the farming system.

Management

The development and adoption of management strategies to curtail the whitefly problem was carried out collaboratively between the University of Arizona, United States Department of Agriculture (USDA), Cotton Incorporated, Arizona Cotton Research & Protection Council (ACRPC) and the Arizona Cotton Growers Association. The ACRPC was originally developed to act as an interface between cotton growers and researchers to manage the boll weevil eradication program. It has since maintained its structure after the completion of this program. It is a state agency supported by a bale tax, but is managed by growers.

With the introduction of the IGR products, a team from the University Arizona led by Drs Peter Ellsworth, Tim Dennehy, and Steve Naranjo (USDA), developed action thresholds and a resistance management strategy for SLW.

A sampling protocol for both nymphs and adult whitefly is found in the publication "Sampling Sweet potato Whitefly Nymphs in Cotton" by Peter Ellsworth, Jonathan Diehl, and Steve Naranjo, available on the University of Arizona website. Sampling should commence once adults are found to be present and involves 30 leaves from 2 sites in each 40-80 acre management unit. There is an extensive consultant or Pest Control Advisor (PCA) network in Arizona who undertake most of the sampling. When the sampling method was first developed an extensive training program was undertaken to ensure consistency.

The resistance management strategy for whitefly is based on three stages, promoting the use of IGRs early, followed by other compounds. The stages are not governed by dates, but in most situations, the threshold for IGR application will be reached in the period between first and peak flower. It takes time for the effect of the IGR products to be seen but they have strong residual activity. This is enhanced by ensuring that these products are applied first while there is still a presence of natural enemies. The combined effect of these two forces was termed **'bio residual'**. The strategy appears below.

Stage I: Insect Growth Regulators

Threshold: 0.5-1 large nymph per leaf disk AND 3-5 adults per leaf

IGR	Use Rate	Restrictions	Mode of action
Applaud (70WP)	8 oz./ac	Use only once per season. Apply no sooner than 21 days after Knack	Chitin synthesis inhibitor; effective against nymphs
Knack (0.86EC)	8 fl. oz./ac	Use only once per season. Apply no sooner than 14 days after Applaud	Juvinoid; sterilises adults and eggs; prevents adult emergence

Stage II: Non- Pyrethroids

Threshold: 5 adults per leaf

1. When populations average more than 5 adults per leaf, use stage II materials at least once before using Stage III materials, in order to delay the need for pyrethroids.
2. Rotate among classes of insecticides and among different insecticides within classes
3. Do not use mixtures of more than 2 compounds
4. Use no active ingredient more than twice per season

Stage III: Pyrethroid Mixtures

Threshold: 5 adults per leaf

1. Delay Pyrethroid use until the end of the control season approaches
2. Plan to use the pyrethroid class no more than twice per season.
3. Rotate the classes of the compounds tank-mixed with the pyrethroids and amongst pyrethroids.

From: The 1996 Whitefly Resistance Management Program for Arizona Cotton. Tim Dennehy, Peter Ellsworth and R Nichols.

The full effects of IGR products are only realised when they are applied across a large area, and hence only treating the field edges was discouraged. This is not to say that all fields in Arizona are treated with IGRs every year. The need to treat with these products is dependant on SLW density thresholds. Some fields will get through the season without using either, whilst some will require two applications, although this was estimated to be a very small number of fields (10-15%). Pyriproxifen (Knack®) was the more popular of the two IGR products with it being utilised in approximately 75% of first treatments.

The use of pyrethroids is still necessary in some situations. It was noted that since the introduction of the IGR products, the efficacy of the pyrethroids and their mixes has begun to improve.

Although the adoption of IGR use in the broad management strategy has resulted in a significant reduction of the whitefly problem, current low market prices has led to complacency with some growers trying to manage the situation with cheaper products such as endosulfan. It was stressed that this scenario is fraught with danger, often only delaying the problem when it becomes too late for IGRs to be effective and more applications of stage II and III chemistry is required resulting in equivalent costs being incurred as if the IGR had been used first. This factor has also been attributed to a slightly higher proportion of sticky bales in 2001 up from 1% to 2%.
Good SLW control in melon crops has been attributed as a major factor for reducing populations in cotton. Control has been achieved through the systemic application of imidacloprid (Confidor®) through drip systems or as an in-furrow planting treatment in melon crops. The superior efficacy of imidacloprid on melons compared to cotton has prevented this product from being used on multiple crops, which would potentially pose a resistance management problem. This may be complicated to some degree in the future through the introduction of new neonicatinoid products for use on cotton.

Although the introduction of the IGRs seems to be the centrepiece of the Arizona whitefly management strategy, a number of **cultural and biological practices** are also deemed very important.

The adoption of smooth leaf cotton varieties has been widespread. Some growers still choose to plant hairy leafed varieties but tend to have more problems. There was generally not much difference in attractiveness of whitefly to Upland or Pima cotton although Pima was deemed to be more susceptible due to longer maturation period.

Biocontrol plays an important role in the Arizona production system, however due to the rapid reproductive ability of SLW, the pest generally overwhelms the predators by peak season. The release of parisitoids had been trialed in Arizona but their effectiveness was limited due to the difficulty in getting adequate dispersion. It was stressed however that the effectiveness of bio-control would vary with every situation. The effect of predator insects such as predatory bugs, flies, and lacewings was found to be more pronounced.

The fungal biopesticides *Beauveria bassiana* (Naturalis-I™), *Beauveria bassiana* (Mycotrol™), and *Paecilomyces fumosoroseus* (PFR-97 ™) again had been investigated for their potential for SLW management but under local conditions were found to be largely ineffective due to inadequate relative humidity and practical problems with targeting nymphs on leaf undersides during application.

The vast majority of insecticide applications using both IGR and knockdown products are undertaken using aircraft fitted with CP nozzles. A general comment was that higher water rates can give better results. Aerial applications were generally done using 3-10 gallons/acre (approx 30-100 L/ha) whilst ground rig applications were done at 5-15 gallons/acre (approx 50- 150 L/ha).

The mandatory destruction of cotton crop residues and compulsory planting window in place due to the pink bollworm eradication program have also proven beneficial for the management of SLW.

The USDA had trialed the application of oil and detergent formulations as an early season tactic for delaying SLW population development. Although some success had been found in domestic and glasshouse situations, this has not been replicated in the field.

Summary

Whitefly seems to have moved from the status as a major to mediocre pest in the last five years. Central to their management strategy in the use of the IGR products supported by a rigorous sampling and cultural control program.

Imperial Valley, CALIFORNIA

The area and problem

The cotton area in the Imperial Valley of California has experienced a steady decline from 140,000 acres in 1980 to 1,400 acres in 2002, mainly due to pink bollworm, SLW and low cotton prices. This has resulted in major changes in the cropping system with a large increase in the lucerne (40% of area) and horticulture (vegetables) areas.

The Sweet Potato Whitefly (*Bemisia tabaci* biotype A) has been a pest of cotton in the area since the 1920's primarily as a vector of the Cotton Leaf Crumple virus. The introduction of pyrethroid resistant SLW (*Bemisia tabaci* biotype B) in the late 1980's caused control problems and yield losses in cotton and cucurbit crops. In 1991 it was estimated that whitefly caused a $US250 million crop loss, mainly due to the 98% annihilation of the melon crop. Interestingly the new biotype has been a less effective vector of Cotton Leaf Crumple virus.

Severe yield loss and sticky cotton resulted from infestations in cotton in 1991, 1992 and 1995. Approximately 5% of Californian bales were classed as sticky cotton in 2001 although this was partly attributed to a Banded Wing Whitefly outbreak in the San Joaquin Valley.

Management

Predominant chemical control in the area remains adult knockdown utilising synthetic pyrethroid and organophosphate mixtures. The high proportion of lucerne in the cropping system that is unsprayed for whitefly seems to help maintain susceptibility in the SLW population.

As in the other areas, the effective use of neonicatinoid products in melons has reduced the problem in cotton.

Host plant resistance (HPR) research has identified both smooth leaf and okra leaf types in cotton as effective in delaying the build up of damaging populations. The CSIRO variety Siokra L-23 has consistently been the top performer in HPR trials for whitefly. Commercially, the transgenic (Bollgard®) derivative of Deltapine 5415, Deltapine 33b, is commonly preferred due to the Bt trait and smooth leaf. Work is being carried out with a native *Gossypium* species that shows a reduced susceptibility to SLW.

Considerations For Central Queensland

The Central Queensland cotton industry is fortunate in the respect that many have gone before us in dealing with SLW. Each of the areas that the tour group visited had experienced a problem equal to or worse than that experienced in the Central Highlands and had since managed it to some degree.

The fundamental key to each of the strategies we viewed was the development of a management plan that was widely adopted. It was painfully clear that fragmented strategies or adoption do not work. The strategy needs to be developed at a 'grass roots' level with all affected stakeholders included at the onset. As Dr Peter Ellsworth put it; ***"the strategy was built around people".***

Silverleaf whitefly is a pest that attacks many crops, and poor control in one crop only creates a problem in another. A link of communication regarding whitefly needs to be forged between the cotton, horticulture and grain industries of Central Queensland. These groups will have to work together in developing cultural management protocols (ie. planting windows and crop residue destruction) and insecticide resistance management strategies.

It is also important that everyone is 'talking the same language' in regards to SLW populations. The sampling protocol developed by the University of Arizona has been extensively researched, is simple and is well adopted.

Most current commercial cultivars grown in Central Queensland are smooth leaved.

Given that the silverleaf whitefly population in Central Queensland is already resistant to pyrethroids, the availability of the IGR products pyriproxifen and buprofezin will be extremely important to the management of the pest in cotton. Already this pest has shown an amazing ability to rapidly develop resistance and the use strategy for these and neonicatinoid products across all crops will be essential. This will be especially applicable to the neonicatinoid chemical group, which will be available for use on both melons and cotton. To give early warning to any resistance situations to IGR and other knockdown products, judicious resistance monitoring will be essential.

Conclusions:

The whitefly situation in the Central Highlands in 2001-02 was a very overwhelming one for those involved. Lack of tools for control and knowledge of how the pest would develop in the local cotton production system left us in a somewhat helpless situation.

This study has gone a long way in improving the knowledge of the pest and the tools that are available in its management. The challenge is now to use this knowledge to develop strategies to effectively manage the pest.

Tour Participants

Brett Austin, Chairman Theodore Cotton Growers Association, Theodore
Duane Evans, Cotton Consultant, Emerald
Paul Grundy, Australian Cotton CRC, Research Entomologist, QDPI, Biloela
Greg Jensen, Chairman Emerald Cotton Growers Association, Emerald
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David Kelly, Development Extension Officer, QDPI/ Australian Cotton CRC, Emerald
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Hamish Millar, ACGRA grower representative, Emerald
David Parlato, Cotton and Horticulture Consultant, Emerald
Wayne Reeves, Cotton Grower, Emerald
Richard Sequeria, Australian Cotton CRC, Research Entomologist, QDPI, Emerald
Simon Struss, Cotton Consultant, Biloela

Funding

Cotton Research & Development Corporation: David Kelly, Richard Sequeria, Paul Grundy, Hamish Millar and David Parlato.

Emerald Cotton Growers Association, Theodore Cotton Growers Association and Cotton Seed Distributors: Greg Jensen, Wayne Reeves, Duane Evans, Brett Austin, Simon Struss, John Marshall and Greg Kauter.

Key Internet sites (re: silverleaf whitefly)

Texas A & M University, Weslaco, Texas http://primera.tamu.edu/
USDA ARS – Subtropical Agricultural Research Centre http://weslaco.ars.usda.gov/
University of Arizona http://ag.arizona.edu/crops/cotton/insects/
USDA ARS - Western Cotton Research Laboratory http://www.wcrl.ars.usda.gov
University of California http://ipm.ucdavis.edu

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Cotton tarnished with SLW honeydew

To address the second issue, the Cotton Research & Development Corporation, Cotton Seed Distributors, and the cotton grower associations of the Central Highlands, Theodore and Biloela sponsored 12 people involved in the cotton industry in Central Queensland to visit regions in the United States of America that had experienced and managed problematic SLW populations.

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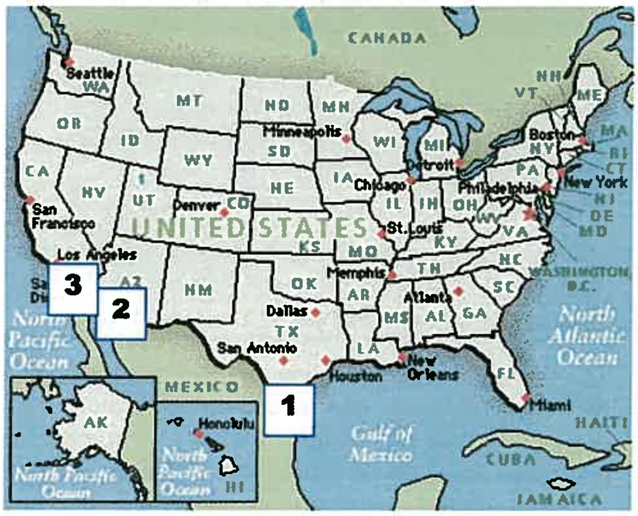

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Tour group at the Texas A&M Weslaco, TX

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Tour group discussing importance of predators and parisitoids in SLW management with Dr Walker Jones, USDA, Weslaco TX.

In keeping with their low input production system, greater emphasis was placed on cultural control in the Rio Grande Valley. Insect Growth Regulators (IGRs) were not widely used due to their expense and resultant success of cultural methods. Many of the cultural controls that growers employ such as timely destruction of crop residues were also driven in part by the Boll Weevil control program, both mandatory and voluntary.

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Tour group discussing SLW management with crop consultant, Dr Webb Wallace, Lower Rio Grande, TX

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Cotton Boll Weevil

The preservation and utilisation of predators and parasitoids was highlighted very strongly in the Rio Grande Valley. In addition to this, agencies of the United States Department of Agriculture (USDA) responded to the devastating SLW outbreak of 1995 by commencing an intensive exotic parasitoid introduction program as well as a collaborative development (with industry) of bio-pesticides at a cost of approximately $US3 million.

The technique of using Banker Plants to supplement the existing populations of parasitoids is utilised primarily in spring horticulture but may also be of use in a non-host crop period in areas of native vegetation and/or weed hosts. The most effective parasitoid species are a number of *Eretmocerus* and *Encarsia* species although equal importance was placed on predators such as lacewings and ladybird species.
Work had been conducted on the use of several bio-pesticides including Mycotrol® (*Beauveria bassiana*). This biopesticide was found to provide effective SLW control under laboratory and green house situations. However, under field conditions, fungal biopesticides were found to be largely ineffective due to application constraints and a requirement for high levels of relative humidity. Up to 80% infection of SLW had been achieved in rockmelon crops whereas tests in cotton were un-successful.

Summary:
A common attitude from growers in the lower Rio Grande regarding whitefly was; ***"we haven't seen many of them since '96"***. It appears that a number of strategic changes in cultural and insecticide management practices, and other outside influences has led to a situation where they are now able to co-exist with this pest.

Low Desert Areas, ARIZONA:

The area and problem
Cotton production in Arizona is exclusively irrigated due to extremely low rainfall. The cotton acreage has declined during the last decade from approximately 800,000 acres to 220,000 acres due to decreased water allocation, pink bollworm, cost/price squeeze and urbanisation. Average yields for the area are generally around 2½ bales/acre, which can vary significantly between districts and individual farms.

Tour group with Dr Tim Dennehy at the University of Arizona Arthropod Resistance Management Laboratory

Whitefly species were first reported in the 1920s. Prior to 1990 the main concern was Cotton Leaf Crumple virus, which is commonly vectored by Sweet Potato Whitefly (*Bemisia tabaci* biotype A). In the 1960s yield reductions of up to 60% were attributed to this viral disease. Sweet Potato Whitefly was inadvertently controlled with synthetic pyrethriods used for the control of pink bollworm and the mandatory destruction of crop residues used to reduce the source of the virus. The unintentional introduction of SLW (*Bemisa tabaci* biotype B) on ornamental nursery plants from Florida is speculated to have occurred around 1985. The rapid development of a resistant population across the state suggests that the introduced insects were highly resistant to pyrethroids and carbamates used in Florida production greenhouses at that time.

During the late 1980's control problems were noticed when pyrethroids were used alone. The standard control progressed to pyrethroid organophosphate mixtures. By 1990, mixture of the specific pyrethroid Danitol® (fenpropathrin) and the organophosphate Orthene® (acephate) was the only chemical control option able to suppress whitefly populations.

Significant outbreaks of SLW occurred in 1991 and 1992. These outbreaks were attributed to the change in biotype (B), which was highly resistant to the available chemical control products. The combination of Danitol® and Orthene® remained the principal knockdown control despite declining efficacy.

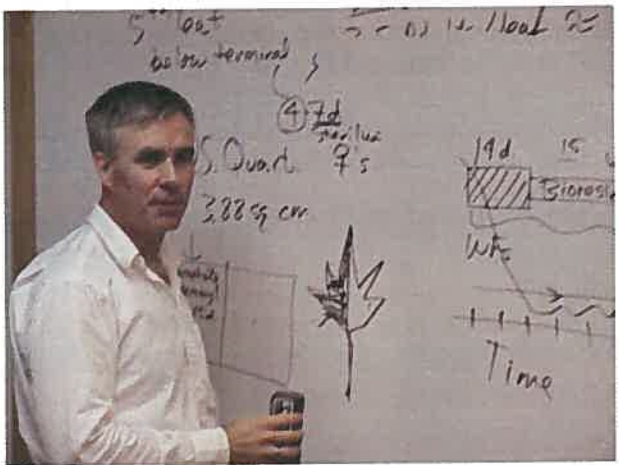
In 1995, there was a severe outbreak of SLW and resistance to the above products had reached a level where control could no longer be achieved. In that season growers spent as much as $US200 /acre on insecticides. The situation was serious enough to potentially cripple the cotton industry in Arizona and resulted in EPA emergency use permits for the new Insect Growth Regulators (IGR's) Applaud® (buprofezin) and Knack® (pyriproxyfen).

In 1995 about 11% of the Arizona crop was downgraded for stickiness. Following the successful introduction of IGRs in 1996, this figure decreased to a level of 1%. Despite this change, Arizona growers are still burdened with the reputation of producing sticky cotton and receive on average 3-7c per pound less than growers in neighbouring California. As one grower put it; ***"facts are negotiable but perceptions are rock solid"***.

The whitefly problem has also led to the demise of the bean crops from the farming system.

Management

The development and adoption of management strategies to curtail the whitefly problem was carried out collaboratively between the University of Arizona, United States Department of Agriculture (USDA), Cotton Incorporated, Arizona Cotton Research & Protection Council (ACRPC) and the Arizona Cotton Growers Association. The ACRPC was originally developed to act as an interface between cotton growers and researchers to manage the boll weevil eradication program. It has since maintained its structure after the completion of this program. It is a state agency supported by a bale tax, but is managed by growers.



Dr Peter Ellsworth, University of Arizona discussing SLW thresholds and sampling

ACPRC - Monitoring for Sticky Cotton

Sub sample of 1000 commercial bales annually for Thermodetector testing

Year	Non - light	Moderate	Heavy
1995	79%	11%	10%
1996	98%	1%	1%
2001	94%	2%	2%

Sticky points on Thermodetector test.

Non – light	0 – 13 points	(undetectable by spinning mills)
Moderate	14 – 24 points	(marginal for spinning)
Heavy	≥ 25 points	(unusable)

With the introduction of the IGR products, a team from the University Arizona led by Drs Peter Ellsworth, Tim Dennehy, and Steve Naranjo (USDA), developed action thresholds and a resistance management strategy for SLW.

A sampling protocol for both nymphs and adult whitefly is found in the publication "Sampling Sweet potato Whitefly Nymphs in Cotton" by Peter Ellsworth, Jonathan Diehl, and Steve Naranjo, available on the University of Arizona website. Sampling should commence once adults are found to be present and involves 30 leaves from 2 sites in each 40-80 acre management unit. There is an extensive consultant or Pest Control Advisor (PCA) network in Arizona who undertake most of the sampling. When the sampling method was first developed an extensive training program was undertaken to ensure consistency.

Brett Austin sampling for SLW

The resistance management strategy for whitefly is based on three stages, promoting the use of IGRs early, followed by other compounds. The stages are not governed by dates, but in most situations, the threshold for IGR application will be reached in the period between first and peak flower. It takes time for the effect of the IGR products to be seen but they have strong residual activity.

This is enhanced by ensuring that these products are applied first while there is still a presence of natural enemies. The combined effect of these two forces was termed **'bio residual'**. The strategy appears at the bottom of this page.

The full effects of IGR products are only realised when they are applied across a large area, and hence only treating the field edges was discouraged. This is not to say that all fields in Arizona are treated with IGRs every year. The need to treat with these products is dependant on SLW density thresholds. Some fields will get through the season without using either, whilst some will require two applications, although this was estimated to be a very small number of fields (10-15%). Pyriproxifen (Knack®) was the more popular of the two IGR products with it being utilised in approximately 75% of first treatments.

The use of pyrethroids is still necessary in some situations. It was noted that since the introduction of the IGR products, the efficacy of the pyrethroids and their mixes has begun to improve.

Although the adoption of IGR use in the broad management strategy has resulted in a significant reduction of the whitefly problem, current low market prices has led to complacency with some growers trying to manage the situation with cheaper products such as endosulfan. It was stressed that this scenario is fraught with danger, often only delaying the problem when it becomes too late for IGRs to be effective and more applications of stage II and III chemistry is required resulting in equivalent costs being incurred as if the IGR had been used first. This factor has also been attributed to a slightly higher proportion of sticky bales in 2001 up from 1% to 2%.

Good SLW control in melon crops has been attributed as a major factor for reducing populations in cotton. Control has been achieved through the systemic application of imidacloprid (Confidor®) through drip systems or as an in-

Stage I: Insect Growth Regulators
Threshold: 0.5-1 large nymph per leaf disk AND 3-5 adults per leaf

IGR	Use Rate	Restrictions	Mode of action
Applaud (70WP)	8 oz./ac	Use only once per season. Apply no sooner than 21 days after Knack	Chitin synthesis inhibitor; effective against nymphs
Knack (0.86EC)	8 fl. oz./ac	Use only once per season. Apply no sooner than 14 days after Applaud	Juvinoid; sterilises adults and eggs; prevents adult emergence

Stage II: Non- Pyrethroids
Threshold: 5 adults per leaf

1. When populations average more than 5 adults per leaf, use stage II materials at least once before using Stage III materials, in order to delay the need for pyrethroids.
2. Rotate among classes of insecticides and among different insecticides within classes
3. Do not use mixtures of more than 2 compounds
4. Use no active ingredient more than twice per season

Stage III: Pyrethroid Mixtures
Threshold: 5 adults per leaf

1. Delay Pyrethroid use until the end of the control season approaches
2. Plan to use the pyrethroid class no more than twice per season.
3. Rotate the classes of the compounds tank-mixed with the pyrethroids and amongst pyrethroids.

Arizona SLW Resistance Management Strategy From: The 1996 Whitefly Resistance Management Program for Arizona Cotton. Tim Dennehy, Peter Ellsworth and R Nichols.

furrow planting treatment in melon crops. The superior efficacy of imidacloprid on melons compared to cotton has prevented this product from being used on multiple crops, which would potentially pose a resistance management problem. This may be complicated to some degree in the future through the introduction of new neonicatinoid products for use on cotton.

Although the introduction of the IGRs seems to be the centrepiece of the Arizona whitefly management strategy, a number of **cultural and biological practices** are also deemed very important.

The touring party with Larry Antilla at the Arizona Cotton Research and Protection Council

The adoption of smooth leaf cotton varieties has been widespread. Some growers still choose to plant hairy leafed varieties but tend to have more problems. There was generally not much difference in attractiveness of whitefly to Upland or Pima cotton although Pima was deemed to be more susceptible due to longer maturation period.

Biocontrol plays an important role in the Arizona production system, however due to the rapid reproductive ability of SLW, the pest generally overwhelms the predators by peak season. The release of parisitoids had been trialed in Arizona but their effectiveness was limited due to the difficulty in getting adequate dispersion. It was stressed however that the effectiveness of bio-control would vary with every situation. The effect of predator insects such as predatory bugs, flies, and lacewings was found to be more pronounced.

The fungal biopesticides *Beauveria bassiana* (Naturalis-I™), *Beauveria bassiana* (Mycotrol™), and *Paecilomyces fumosoroseus* (PFR-97 ™) again had been investigated for their potential for SLW management but under local conditions were found to be largely ineffective due to inadequate relative humidity and practical problems with targeting nymphs on leaf undersides during application.

The vast majority of insecticide applications using both IGR and knockdown products are undertaken using aircraft fitted with CP nozzles.

A general comment was that higher water rates can give better results. Aerial applications were generally done using 3-10 gallons/acre (approx 30-100 L/ha) whilst ground rig applications were done at 5-15 gallons/acre (approx 50- 150 L/ha).

The touring party inspecting the operations of Custom Farm Service (aerial operator), Stanfield, AZ.

The mandatory destruction of cotton crop residues and compulsory planting window in place due to the pink bollworm eradication program have also proven beneficial for the management of SLW.

The USDA had trialed the application of oil and detergent formulations as an early season tactic for delaying SLW population development. Although some success had been found in domestic and glasshouse situations, this has not been replicated in the field.

Summary

Whitefly seems to have moved from the status as a major to mediocre pest in the last five years. Central to their management strategy in the use of the IGR products supported by a rigorous sampling and cultural control program.

Imperial Valley, CALIFORNIA:

The area and problem

The cotton area in the Imperial Valley of California has experienced a steady decline from 140,000 acres in 1980 to 1,400 acres in 2002, mainly due to pink bollworm, SLW and low cotton prices. This has resulted in major changes in the cropping system with a large increase in the lucerne (40% of area) and horticulture (vegetables) areas.

The Sweet Potato Whitefly (*Bemisia tabaci* biotype A) has been a pest of cotton in the area since the 1920's primarily as a vector of the Cotton Leaf Crumple virus. The introduction of pyrethroid resistant SLW (*Bemisia tabaci* biotype B) in the late 1980's caused control problems and yield losses in cotton and cucurbit crops.

In 1991 it was estimated that whitefly caused a $US250 million crop loss, mainly due to the 98% annihilation of the melon crop. Interestingly the new biotype has been a less effective vector of Cotton Leaf Crumple virus.

The touring party at University of California Imperial County Cooperative Extension facility, Holtville, CA.

Severe yield loss and sticky cotton resulted from infestations in cotton in 1991, 1992 and 1995. Approximately 5% of Californian bales were classed as sticky cotton in 2001 although this was partly attributed to a Banded Wing Whitefly outbreak in the San Joaquin Valley.

Cotton Leaf Crumple virus.

Management

Predominant chemical control in the area remains adult knockdown utilising synthetic pyrethroid and organophosphate mixtures. The high proportion of lucerne in the cropping system that is unsprayed for whitefly seems to help maintain susceptibility in the SLW population.

As in the other areas, the effective use of neonicatinoid products in melons has reduced the problem in cotton.

Host plant resistance (HPR) research has identified both smooth leaf and okra leaf types in cotton as effective in delaying the build up of damaging populations. The CSIRO variety Siokra L-23 has consistently been the top performer in HPR trials for whitefly.

Commercially, the transgenic (Bollgard®) derivative of Deltapine 5415, Deltapine 33b, is commonly preferred due to the Bt trait and smooth leaf. Work is being carried out with a native *Gossypium* species that shows a reduced susceptibility to SLW.

John Marshall and David Kelly looking at a 'Host Plant Resistance' trial conducted by University of California in the Imperial Valley, CA.

Considerations For Central QLD:

The Central Queensland cotton industry is fortunate in the respect that many have gone before us in dealing with SLW. Each of the areas that the tour group visited had experienced a problem equal to or worse than that experienced in the Central Highlands and had since managed it to some degree.

The fundamental key to each of the strategies we viewed was the development of a management plan that was widely adopted. It was painfully clear that fragmented strategies or adoption do not work. The strategy needs to be developed at a 'grass roots' level with all affected stakeholders included at the onset. As Dr Peter Ellsworth put it; ***"the strategy was built around people".***

SLW Adults

Silverleaf whitefly is a pest that attacks many crops, and poor control in one crop only creates a problem in another. A link of communication regarding whitefly needs to be forged between the cotton, horticulture and grain industries of Central Queensland. These groups will have to work together in developing cultural management protocols (ie. planting windows and crop residue destruction) and insecticide resistance management strategies.

It is also important that everyone is 'talking the same language' in regards to SLW populations. The sampling protocol developed by the University of Arizona and United States Department of Agriculture has been extensively researched, is simple and is well adopted.

Most current commercial cultivars grown in Central Queensland are smooth leaved.

Given that the silverleaf whitefly population in Central Queensland is already resistant to pyrethroids, the availability of the IGR products pyriproxifen and buprofezin will be extremely important to the management of the pest in cotton. Already this pest has shown an amazing ability to rapidly develop resistance and the use strategy for these and neonicatinoid products across all crops will be essential. This will be especially applicable to the neonicatinoid chemical group, which will be available for use on both melons and cotton. To give early warning to any resistance situations to IGR and other knockdown products, judicious resistance monitoring will be essential.

Conclusions:

The whitefly situation in the Central Highlands in 2001-02 was a very overwhelming one for those involved. Lack of tools for control and knowledge of how the pest would develop in the local cotton production system left us in a somewhat helpless situation.

This study has gone a long way in improving the knowledge of the pest and the tools that are available in its management. The challenge is now to use this knowledge to develop strategies to effectively manage the pest.

The success of the tour has been a result of the collaborative effort between the Cotton Research & Development Corporation, Cotton Seed Distributors, Central Highlands Cotton Growers Association, Theodore Cotton Growers Association, and Biloela Cotton Growers Association.

Tour party members meeting with Texan growers in the Lower Rio Grande, TX

Key Internet sites (re: silverleaf whitefly):

- **Texas A & M University**, Weslaco, Texas http://primera.tamu.edu/
- **USDA ARS** – Subtropical Agricultural Research Centre http://weslaco.ars.usda.gov/
- University of Arizona http://ag.arizona.edu/crops/cotton/insects/
- **USDA ARS** - Western Cotton Research Laboratory http://www.wcrl.ars.usda.gov
- **University of California,** http://ipm.ucdavis.edu

Key Contacts (re: silverleaf whitefly):

Mr. John Norman, Extension Agent IPM, TAMU, Agriculture Research and Extension Centre Cooperative Extension Service, Weslaco, Texas j-norman@tamu.edu (pictured below)

Dr. Tong-Xian (TX) Liu, Assoc. Professor Entomology, Agriculture Research and Extension Centre, TAMU, Weslaco, Texas tx-liu@tamu.edu

Dr. Walker Jones, Research Leader, USDA, Agriculture Research Service, Beneficial Insects Research Unit, Weslaco, Texas wjones@weslaco.ars.usda.gov

Dr. Webb Wallace, Consultant, Weslaco, Texas Bywebbwall@aol.com

Professor Timothy Dennehy, Extension Arthropod Resistance Management Laboratory, Department of Entomology, University of Arizona, Tucson, Arizona tdennehy@ag.arizona.edu

Professor David Byrne, Department of Entomology, College of Agriculture and Life Sciences, University of Arizona, Tucson byrne@ag.arizona.edu

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Jessie Hardin, Department of Entomology, University of Arizona jhardin@ag.arizona.edu

Vanessa Jacobs-Lorena, Department of Entomology, University of Arizona

Dr. Peter Ellsworth, Integrated Pest Management Specialist, University of Arizona, Maricopa Agricultural Centre, Maricopa, Arizona peterell@ag.arizona.edu

Dr. Richard Percy, Research Geneticist, USDA, ARS, Maricopa Agricultural Centre, Maricopa, Arizona rpercy@ag.arizona.edu

Mr. Larry Antilla, Director, Arizona Cotton Research and Protection Council, Phoenix, Arizona lantilla@azcotton.com (pictured below)

Mr. Joe Kramer, Custom Farm Service (aerial operator), Stanfield, Arizona

Mr. Paul Ollerton, Cotton Grower, Maricopa County, Arizona

Dr. Tom Henneberry, Laboratory Director, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona thenneberry@wcrl.ars.usda.gov

Dr. Chang-Chi Chu, Plant Physiologist, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona cchu@wcrl.ars.usda.gov

Dr. David Akey, Research Entomologist, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona dakey@wcrl.ars.usda.gov

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Dr. James Hagler, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona jhagler@wcrl.ars.usda.gov

Dr. Don Hendrix, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona dhendrix@wcrl.ars.usda.gov

Dr. Steve Naranjo, Research Entomologist, USDA, Agriculture Research Service, Western Cotton Research Centre, Phoenix, Arizona snaranjo@wcrl.ars.usda.gov

Dr. Eric Natwick, Entomologist, University of California: Agriculture and Natural Resources Cooperative Extension, Imperial County, Holtville, California etnatwick@ucdavis.edu

Mr. Herman Mizcher, Agronomist, University of California: Agriculture and Natural Resources Cooperative Extension, Imperial County, Holtville, California

Study Tour Funding:

Cotton Research & Development Corporation:

- David Kelly, Richard Sequeria, Paul Grundy, Hamish Millar and David Parlato.

Cotton Seed Distributors
Central Highlands Cotton Growers Association
Theodore Cotton Growers Association
Biloela Cotton Growers Association

- Greg Jensen, Wayne Reeves, Duane Evans, Brett Austin, Simon Struss, John Marshall and Greg Kauter.

US Whitefly Study Tour 2002 - ITINEARY

PHONE	0407 233044 (CSD direct dial tri-band with message bank – to call this number from the US first dial 011 then 61 then 407 233044)
BOOTS	Come clean – Go clean: Please clean boots before leaving home and before leaving the US
LUGGAGE	Duffel type bags are easier to pack in car boots
15 July Monday	Arrive Los Angeles 10:45am Accommodation: Sheraton Four Points Ph. 310 645 4600 Fx. 310 649 7047
16 July Tuesday	Los Angeles (CO685) 8:00am > Houston 1:29pm > Houston (CO3646) 2.20pm > Brownsville 4:05pm Car Rental: HERTZ 3 x Full size cars - 4 door Accommodation: Best Western Rose Garden Inn Ph. 956 546 5501 Fx. 956 546 6474
17 July Wednesday	**Webb Wallace**, Consultant - Home 956-423-1356 Office 956-423-6393 Mobile 956-491-1793 CRDC: Arrive LAX 9:00am > Los Angeles (CO305) 11:15am > Houston 4:32pm > Houston (CO3648) 5:30pm > Brownsville 6:45pm Accommodation: Best Western Palm Aire Motor Inn , 415 South International Blvd., Weslaco, Texas Phone: 956-969-2411 Fax: 956-969-2211
18 July Thursday	**John W. Norman**, Jr., Extension Agent-IPM Cameron, Hidalgo & Willacy Counties Texas A&M University Agricultural Research and Extension Center 2401 East Highway 83 Weslaco, Texas Office:956-968-5581 Mobile:956-330-0427 Fx 956 969-5639 Accommodation: Best Western Palm Aire Motor Inn 415 South International Blvd., Weslaco, Texas Phone: 956-969-2411 Fax: 956-969-2211
19 July Friday	**Tong-Xian (TX) Liu**, Agriculture Research and Extension Centre, TAMU, Weslaco **Walker Jones**, USDA, Agriculture Research Service, Beneficial Insects Research Unit **Larry**, Rio Grande Aviation **John Christian**, Consultant (by phone) Ph: 956 689 2352 Accommodation: Best Western Palm Aire Motor Inn 415 South International Blvd., Weslaco, Texas Phone: 956-969-2411 Fax: 956-969-2211
20 July Saturday	Write-up Texas visit Accommodation: Best Western Palm Aire Motor Inn 415 South International Blvd., Weslaco, Texas
21 July Sunday	CRDC: Harlingen, Tx. (CO3782) 4:30pm > Houston > Houston (CO202) 8:44pm > Tucson, Az. 9:04pm CSD: Brownsville, Tx. (CO3651) 4:24pm > Houston 6:10pm > Houston (CO202) 8:44pm > Tucson, Az. 9:04pm Car Rental: ALAMO 2 x Group LX – 7 seater Accommodation: Tucson Marriott, University Park Hotel. 880 E Second Street, Tucson Phone: 520-792-4100 Fax: 520-882-4100
22 July Monday	**University of Arizona campus** to visit the Extension Arthropod Resistance Management Laboratory (my group), Bruce Tabashnik, Yves Carrière and **Shai Morin** (resistance to Bt cotton and whitefly resistance), **David Byrne** (whitefly and parasitoid movement) and Judy Brown (whitefly biotypes and viruses transmitted by whiteflies). Accommodation: Tucson Marriott, University Park Hotel. 880 E Second Street, Tucson Phone: 1-520-792-4100 Fax: 1-520-882-4100
23 July Tuesday	**Maricopa Agricultural Center.** (90 minute drive from hotel in Tucson). **Peter Ellsworth**, IPM Specialist, has spearheaded efforts in Arizona to improve sampling of whiteflies in cotton as well as area-wide management of whiteflies. **Richard Percy**, Cotton Breeder. Drive to Hotel near Phoenix (40 minute drive) Accommodation: Fiesta Inn Resort, 2100 South Priest Drive, Tempe, AZ Phone: 480-967-1441
24 July Wednesday	**Larry Antilla**, Director of the Arizona **Cotton Research and Protection Council**, Visit with producers in the Buckeye, Salt River and Coolidge areas. Meet growers **Bill Scott and Paul Ollerton.** **Joe Karmer**, aerial operator. Accommodation: Fiesta Inn Resort, 2100 South Priest Drive, Tempe, AZ Phone: 480-967-1441

25 July Thursday	**USDA Western Cotton Research Laboratory.** **Tom Henneberry**, Director, has spearheaded the multi-state coordination of whitefly research over the past decade. A wide range of studies on whiteflies are conducted here including: physiology of sugars in honeydew (**Don Hendrix**), sampling bales for stickiness (**Steve Naranjo and Tom Henneberry**), biological control of whiteflies (**Hagler, Steve Naranjo**, and Gould), parasitoid behaviour (**Glen Jackson**), chemical control of whiteflies (**David Akey**) and monitoring techniques (**CC Liu**). PM Drive to El Centro/Holtville (4 hour drive) Accommodation: Barbra Worth Country Club Hotel, Holtville CA (Confirm: 153806 Cancel: 48hrs.) Phone: 760-356-2806. Fax: 760-356-4653.
26 July Friday	**Eric Natwick** – Entomologist, Imperial Valley - El Centro, California **Herman Mizcher** – Agronomist, Imperial Valley University of California Cooperative Extension - UC Desert Research & Extension Centre 1050 East Holton Road, Holtville, CA 92250-9615 Tel: (760) 352-9474 Fax: (760) 352-0846 PM Drive El Centro, California – San Diego, California (2 hours) Accommodation: Holiday Inn, SAN DIEGO (OLD TOWN), CA 2435 Jefferson Street, SAN DIEGO, CA 92110 Local Phone: 619-2608500, Reservations: 800-255-3544 (Confirm: 63772111 Cancel 48hrs.)
27 July Saturday	San Diego, California Write up Arizona visit Accommodation: Holiday Inn, SAN DIEGO (OLD TOWN), CA 2435 Jefferson Street, SAN DIEGO, CA 92110 Local Phone: 619-2608500, Reservations: 800-255-3544 (Confirm: 63772111 Cancel 48hrs.)
28 July Sunday	Drive San Diego – LAX (124 miles) CRDC: Depart LAX 11:30 PM CSD: Depart LAX 10:30pm
29 July Monday	Missed day
30 July Tuesday	CRDC: Arrive Auckland 7:15am CSD: Arrive Sydney 6:10am > Brisbane (QF508)8:05am > Arrive Brisbane 9:30am > Various Emerald (QF2404) / Gladstone (QF2336) / Rockhampton (QF1864)
31 July Wednesday	CRDC: Auckland 11:30am > Brisbane 1:15pm

Touring Party (L-R) John Marshall, Greg Jensen, Duane Evans, Hamish Millar, David Parlato, Brett Austin, Paul Grundy, Wayne Reeves, David Kelly, Simon Struss, Richard Sequeira.