South African citrus thrips in Australia - identity, pest status and control

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Purpose

The purpose the research reported here was to assess the potential risk to Australian citrus (and other horticultural crops) posed by South African citrus thrips, *Scirtothrips aurantii*, a serious exotic pest first detected in Australia in Brisbane in March 2002, and to assess control and management options compatible with Queensland's longstanding citrus IPM system.

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FRONT COVER
Scirtothrips aurantii (ovipositing – top R; female & male – bottom L & R), a major citrus pest in Southern Africa, was detected for the first time in Australia in 2002 on the declared noxious exotic succulent plants *Bryophyllum delagoense* (top left), then the subject of a weed biocontrol program. Given its potential to damage citrus fruits for up to 12 weeks from petal fall, we conducted laboratory experiments to determine the potential host range of this thrips in Australia to assess the threat it posed to citrus and other crops, and evaluated insecticide and biocontrol options compatible with Queensland's long standing citrus IPM system.

MEDIA SUMMARY

South African citrus thrips (SACT), *Scirtothrips aurantii*, is a major pest of citrus in South Africa, banana in Yemen and grapes in Réunion; it also attacks mango, macadamia and tea. Control relies largely on pesticides, to which it rapidly develops resistance. First detected in Australia in Brisbane in March 2002 on mother of millions, weedy Madagascan succulents, SACT posed a serious threat to Queensland horticulture, including the $100M citrus crop.

If SACT behaved in Australia as it does in South African citrus, costs of production would increase, fruit pack-outs fall, and the longstanding IPM system, which relies heavily on a suite of biological control agents likely to be disrupted by increased insecticide usage, would be jeopardised. Climate matching indicted that the threat also extended to southern Australia.

SACT is reported from a very broad range of plants, however, in extensive surveillance in Brisbane it was found breeding only on mother of millions, and did not attack citrus, mango or native plants such as *Acacia* or *Grevillea*. This aroused speculation that SACT in Australia could be a host-restricted cryptic species, actually not *S. aurantii* but another species indistinguishable from it, that lives on *Bryophyllum* but does not attack citrus or other crops.

We tested the capacity of Australian *S. aurantii* to reproduce on 16 crop, 7 ornamental, 8 native and 5 weed species. To develop strategies to manage it in our horticultural crops we tested its susceptibility to insecticides registered in citrus, determined the capacity of the native predatory mite *Euseius victoriensis* to kill and survive on this thrips, conducted surveillance in the Sunshine Coast area and communicated our findings to Industry.

We found that Australian *S. aurantii* – 1) reproduced at very high levels on *Bryophyllum*, the traded succulent *Kalanchoe blossfeldiana*, macadamia and mango - 2) reproduced at moderate to good levels on Navelina orange, Tahitian lime, Eureka lemon, grapefruit, peach, grape, tea and the natives *Acacia sophorae*, *A. longifolia* and *Syzygium moorei* - 3) performed poorly or very poorly, but produced some offspring on many on the other plants tested.

We also found that Australian *S. aurantii* adults were highly susceptible to very low rates of all insecticides tested, and that the predatory mite *Euseius victoriensis* killed up to six first and small second instar larvae per day, and survived as well on a diet of SACT as on Typha pollen, the food used to mass rear the predator.

These findings suggest *S. aurantii* in Australia could attack important crops, and that natives such as Acacia may act as bridging hosts, allowing it to survive in the absence of its apparently preferred hosts, mother of millions. They also suggest, however, that if this thrips ever attacks Australian crops it should be easily controlled, as it was highly susceptibility to very low rates of a range of insecticides. The predatory mite *E. victoriensis* killed up to 6 larvae per day and should contribute to biological control if this thrips ever attacks citrus.

In the most recent surveys *S. aurantii* was found at numerous sites on the Darling Downs, the most northerly near Taroom, only 150 km west of Mundubbera in the Central Burnett, Queensland's largest citrus producing area. These detections indicate a rapid expansion in range of the thrips, previously known only from suburban Brisbane and Laidley, but again it was found only on mother of millions, to which it was causing significant damage.

If *S. aurantii* continues to prefer the widespread and weedy mother of millions, for which it will provide a degree of biological control, and refrains from attacking the valuable crops that overseas experience and our research has shown it can utilise as hosts, this may be one of those rare occasions when a potentially devastating exotic pest incursion turns out to be a good thing, and the Australian form of SACT can be renamed the 'Bryophyllum thrips'.

TECHNICAL SUMMARY

The problem

Scirtothrips aurantii, a major pest of citrus in South Africa, and a pest of mango, macadamia, banana and grape in the region, was found in Brisbane in 2002. This exotic thrips represented a threat to horticultural crops and a serious challenge to citrus IPM. It develops rapidly, has many generations yearly, a broad host range, readily develops resistance to insecticides, and is very damaging to citrus fruits for up to 12 weeks after petal fall. Extensive surveillance in Brisbane detected breeding populations on the exotic succulent weeds *Bryophyllum* spp., but not on any of the expected crop or native hosts such as citrus, mango, *Acacia* or *Grevillea*.

The science

We developed a rearing method for *S. aurantii*, determined its' potential to attack crop, native, ornamental and weed species; determined its' susceptibility to insecticides; assessed the capacity of the predatory mite *Euseius victoriensis* to kill and persist on larvae, surveyed *Bryophyllum* on the Sunshine Coast and communicated our findings to Industry.

We found that Australian *S. aurantii*:

1. Developed successfully on a range of hosts, but performed best on *Bryophyllum* spp., the traded succulent *Kalanchoe blossfeldiana*, on macadamia and mango, which we rated as very good hosts (performance 61-150% of the reference host *B. pinnatum*).
2. Performed well on Navelina orange and Tahitian lime, which we rated as good hosts (performance 31-60% of *B. pinnatum*, and similar to that on *B. delagoense*).
3. Performed moderately on Eureka lemon, grapefruit, peach, grape, tea, *Acacia sophorae*, *A. longifolia* and *Syzygium moorei*.
4. Performed poorly on *Caesalpinia pulcherrima*; very poorly on other species including sweet orange, avocado, banana, cotton, soybean, green bean pods, *Eucalyptus tereticornis*, *Grevillea robusta*, *S. australe*, *Murraya paniculata* and castor oil.
5. Damaged fruits of Kumquat nagami (tests on other varieties were inconclusive)
6. Is highly susceptible to insecticides at rates well below those registered in citrus
7. Is killed by *E. victoriensis*, which consumed up to 6 first & small second instar larvae per day and persisted for 19 days at levels comparable to mites fed Typha pollen.
8. Though not found near Nambour, now occurs on *B. delagoense* near Tewantin, from Laidley west to Toowoomba, and from Inglewood in the south to near Taroom in the north, less than 150 Km west of the Central Burnett citrus town of Mundubbera.

Recommendations & Future work

Resolution of the hypothesis of cryptic species within *S. aurantii* requires investigations in its native range of host utilisation and gene movement between citrus and major non-crop hosts including *Bryophyllum*. If this resolves that Australian *S. aurantii* is indeed an unrecognised host-restricted cryptic species, this will enable better understanding of the results of our host-testing trials and field survey observations. It may also allow us to conclude with greater confidence that this thrips does not pose the risk to crops in Australia that it does in South Africa. Further surveillance of infestations near potential hosts such as macadamia, mango, citrus, *Acacia* and *Grevillea* should be done to detect as early as possible indications of movement of the thrips onto hosts other than *Bryophyllum*. Research on new insecticides, mass rearing of natural enemies and the ecology of pest thrips in citrus, including the use of composting or other under-tree management options to enhance biological control, reduce water needs and improve fruit yield and quality should be undertaken.

EXTENSION

Publications

Freebairn CG. Progress reports on 'South African citrus thrips in Australia: identity, pest status and control' to the Queensland Citrus Growers Inc. (March & October 2004; March & October 2005; and October 2006 – meetings not convened March 06 or 07).

Freebairn CG. South African citrus thrips – to be or not to be (a pest of Australian citrus)? *Citrus Insight* - 2004/05 (**Appendix 2**).

Freebairn CG. A Thrips to watch closely. *Citrus Insight* - 2005/06 (**Appendix 2**).

Freebairn CG. South African citrus thrips in Australia – identity, pest status and control. *Citrus Insight* - 2006/07 (**Appendix 2)**.

Freebairn CG. South African citrus thrips – a pest of Australian citrus? *Australian Citrus News* – 2005/06 (**Appendix 3**).

Communications

Through this project extensive e-mail and/or phone communications were held with researchers and others in Australia, South Africa and California on various aspects of this research, its implications and consequences. These included QDPI&F Animal & Plant Health Service/Biosecurity Business Group (Brian Cantrell, James Planck, Peter Whittle, Cameron Tree, Grant Telford); Plant Science (Desley Tree, Roger Shivas); QDNR Alan Fletcher Research Station, Sherwood and Pretoria (Bill Palmer, Dhileepan, Andrew Manners, Martin Hannan-Jones); Agriculture Western Australia; Queensland University (Gimme Walter); CSIRO, (Laurence Mound); University of California Riverside (Joe Morse); in South Africa – QDNR (Arne Witt), Citrus Research International (Tim Grout), Letaba Estates (Martin Gilbert) and Merensky Holdings (Danielle Le Lagadec); with HAL, PHA/AFFA/OCCPO (Graham Hamilton), Queensland Citrus Growers Inc. (Chris Simpson), and citrus IPM consultants (Dan Papacek, Brian Gallagher, Malcolm Wallis).

ACKNOWLEDGMENTS

This project was initiated urgently to address the risk posed by SACT to Queensland citrus, and its longstanding IPM system. Dan Smith's awareness of the risk was critical, as was the support of the growers of the Central Burnett, represented at that time by the Central Burnett Horticultural Committee, more recently Queensland Citrus Growers Incorporated.

Australian Citrus Growers funding supported this project, with matching funds from HAL.

Alan Fletcher Research Station (AFRS) staff (formerly Dept of Natural Resources, Mines & Energy, now Natural Resources & Water), especially Bill Palmer, Andrew Manners and Dhileepan were always helpful and did what they could to assist; they were generous with their prior knowledge of mother of millions and SACT. Arne Witt (employed by NRW at their field station in Pretoria) provided useful background to the problem and details of his work in Madagascar and South Africa.

In South Africa, Dr Tim Grout, Citrus Research International, Nelspruit, and Dr Martin Gilbert, Letaba Estates, Tzaneen, provided valuable information through email discussions, provision of literature etc, and on the basis of our exchanges Tim conducted some host-switching experiments in South Africa which added interesting information on the behaviour of their SACT populations.

Dr Laurence Mound, Honorary Research Fellow, CSIRO Entomology, Canberra provided an invaluable breadth and depth of experience of thrips in general, and was always ready to assist with his time, identifications of thrips, provision of literature and discussions of the issues at play in this work.

Dr Joe Morse, University of California Riverside, provided useful discussion, information and reprints of literature from his long experience with their citrus thrips, *Scirtothrips citri*. Mark Hoddle's Californian work on *Scirtothrips perseae*, a relatively new pest of avocado from Mexico, provided current applied literature and an interesting new angle on *Scirtothrips* biocontrol – the use of the predatory thrips *Frankliniella orizabensis*.

My technical staff, Lindsay Smith and Jonathan Smith, gave invaluable support in the glasshouse, insectary and field, including many hours establishing, monitoring, assessing and entering data for the numerous experiments included in this research.

My Science Leader, Irene Kernot, showed sterling patience in dealing with the difficulties of managing my work load, and at HAL, Brad Wells and Ross Skinner generously accommodated the changing timelines for reports forced by the untimely death of Dan Smith and the early retirement of Geoff Waite, two very experienced entomologists at MRS Nambour. Other staff at MRS provided generously of their time in broad ranging discussions, often acting as sounding boards enabling clarification of what I was thinking.

Without the generous assistance of all of the above this work would not have been possible. I acknowledge and thank them all.

TECHNICAL REPORT

1. GENERAL INTRODUCTION

The exotic pest thrips *Scirtothrips aurantii* Faure, was first detected in Australia at the Queensland Department of Natural Resources and Mines' Alan Fletcher Research Station (AFRS) at Sherwood, in Brisbane in March 2002 (Anonymous 2003).

S. aurantii is a major pest of citrus in South Africa (**Figure 1**), where it causes serious rind blemishing resulting in fruit downgrading. Control requires the use of insecticides disruptive of IPM systems for up to 12 weeks after petal fall (Gilbert & Bedford 1998). It is also a pest of mango (Grové *et al*. 2000), especially near infested citrus (Gilbert, pers. comm. 2004), macadamia (van den Berg 1995), attacks tea in Malawi (Rattan 1992 & *et al.* 1996), causes fruit spotting on banana in Yemen (El Bashir & Al Zabidi 1985, Nasseh 1990), and is a pest of citrus (Quilici 1988) and the principal grape pest in Réunion (Dubois & Quilici 1999).

As at 2003, *S. aurantii* had been reported 17 times at US ports, arriving from Ghana, Israel, Kenya, Netherlands, South Africa and Zimbabwe (see Whittle 2003 – **Appendix 5**), but had not established anywhere in the world, nor been the subject or an eradication campaign.

S. aurantii is recorded from 83 crop and non-crop species in 33 plant families (**Table 1**). However, despite many years of research on this insect as a major indigenous pest of citrus and mango in southern Africa, as a result of which this extensive host list was developed, *S. aurantii* was not detected on *Bryophyllum* spp. until it was found on *B. delagoense* in surveys for weed biocontrol agents with potential for introduction to Australia in 2000-01. SACT was reported as one of the four most common insect species on *Bryophyllum* spp., though its actual level of importance may be less than this, since some damage to *Bryophyllum* attributed to *S. aurantii* was probably caused by *Thrips tabaci*, a species not known at the time from this host but subsequently found to cause similar damage (Palmer 2005). *S. aurantii* was not found in surveys in southern Madagascar - the centre of origin of *Bryophyllum*. Twenty three insect species were collected from 79 sites surveyed in August 1999, February and December 2000, and June 2001. The main target weed species, *B. delagoense,* was present at 48 of the 79 sites (Department of Natural Resources 1999 - 2006).

The *S. aurantii* infestation at Sherwood was detected on *B. delagoense* - common mother of millions. Native to Madagascar, species in the genus *Bryophyllum* are known as mother of millions because they produce tiny plantlets on their phyllodes (leaves modified to reduce water loss enabling survival in dry environments). Five species of *Bryophyllum* occur in Queensland; three are widespread noxious weeds that have invaded thousands of hectares of grazing land and are spreading rapidly down river drainage systems (Hannan-Jones & Playford 2002) and are responsible for numerous cattle deaths (DNRW 2006a). *B. delagoense* is the most widespread and abundant (DNRW 2006b), and has the potential to become even more so (DNRW 2006c). *B. pinnatum* has a more restricted current and predicted distribution (see **Figures 2-4).**

At the time of the detection of *S. aurantii* in Brisbane, mother of millions (i.e. *Bryophyllum* spp.), were the subjects of a weed biocontrol program which had imported into high security quarantine for host testing at Sherwood several promising insect species from Madagascar and South Africa via the AFRS quarantine facility at Pretoria. These included the weevil *Osphilia tenuipes* from Madagascar, shipped to AFRS Sherwood in May and July 2000

(AFRS Weed Research Projects, technical highlights 2000-01), and the wasp *Eurytoma* sp., which was shipped to AFRS in 2001-02, but destroyed after SACT was found in the quarantine premises at Sherwood in March 2002. A second weevil from Madagascar, *Rembastus* sp., and *Alcidodes sedi*, a native of southern Africa, also were reared, host tested and recognised as promising biocontrol agents of *Bryophyllum* spp. in South Africa, but were never shipped to Australia (AFRS Weed Research Projects 2001-02).

Upon confirmation of the identity of the thrips as *S. aurantii* by Dr Laurence Mound, an honorary CSIRO research fellow and internationally renowned thrips expert, AQIS immediately quarantined the station. A survey of AFRS and its surrounds was conducted and no further detections of *S. aurantii* were made. Mother of millions plants and other material suspected of being infested were destroyed and affected quarantine glasshouses were emptied and disinfested. *S. aurantii* was declared a pest under Queensland legislation (*Plant Protection Act 1989*) and the DPI (now DPI&F) assumed management of the outbreak.

The Consultative Committee on Emergency Plant Pests and Diseases (CCEPPD) reviewed the response to the outbreak in April 2002 and recommended intensive surveillance be maintained in areas within close proximity of AFRS for a further six months to determine if the initial eradication attempt was successful. This program included the inspection of sentinel mother of millions plants and the completion of trace back and trace forward investigations, as well as an intensive survey of high-risk sites conducted in December 2002.

From March 2002 to January 2003, DPI&F conducted over 650 property inspections at locations that posed a risk of thrips transfer from AFRS. No *S. aurantii* was found during the winter period, but the thrips was detected during the intensive December survey at Sherwood and subsequently was located in other suburbs in south-western Brisbane.

Following these detections, CCEPPD in January 2003 recommended that a delimiting survey be conducted for *S. aurantii* in southeast Queensland and other States, and requested that a cost-benefit (of eradication) paper be developed based on the value of listed host plants and potential impact on those plants. The survey was to include the inspection of at least 50 sites in the greater Brisbane area. This survey found *S. aurantii* at an additional twenty-eight of seventy-six sites inspected in Brisbane. No detections were made in other states, or in the Sunshine Coast area where 24 sites were surveyed (Anonymous 2003a&b – **Appendix 5**).

The Situation Assessment and Pest Risk Analysis paper, which considered citrus in the winter- and summer-dominant rainfall areas of Australia, took into account the likelihood of *S. aurantii* being introduced, establishing and spreading in the regions, and the economic consequences. The unrestricted risk estimates were determined to be *negligible* and *very low* respectively for the two regions; both estimates below the appropriate level of protection threshold, so further responses of containment or eradication were deemed unjustified. The likelihood of containment was determined to be negligible (Whittle 2003 – **Appendix 5**).

Annual losses, if *S. aurantii* became a pest on citrus, were estimated at 5.4% and 16.2% for winter-dominant and summer-dominant rainfall citrus areas respectively, with an overall estimated loss of 5.4%. The net present value of accumulated, indefinitely continuing control costs and residual losses was estimated at $13 million using a conservative discount rate that took into account the uncertainty of arrival and establishment of *S. aurantii* as a serious pest.

The estimated surveillance cost for *Bryophyllum* spp. was $9 million for an area of 1,700km^2, eradication of *Bryophyllum* spp. $30 million and treatment costs $17 million. Total cost of eradication was estimated to be $113.6 million, with a low likelihood of success.

In March 2003, CCEPPD, in light of the fact that *S. aurantii* was then known to be distributed over an area of up to 1700 km^2 (primarily suburban Brisbane but also west to Laidley), and considering the Pest Risk Analysis paper, in consultation with Australian state department entomologists and citrus Industry representatives, declared that *S. aurantii* was established in Queensland, and that eradication was logistically and economically infeasible. Effectively, this meant that *S. aurantii* became an industry problem.

The Australian citrus industry is one of the largest horticultural industries in Australia, accounting for about 20% of the total value of horticultural production. With annual output of about 650,000 tonnes of fruit worth approximately $450M, it is potentially at risk from SACT. The main potential impacts are fruit downgrading, increased pesticide costs and disruption of the well-developed IPM system by heavy use of broad spectrum insecticides. Adverse impact on exports could also occur, as most of the 180,000 tonnes exported, worth $190M, are oranges, the variety most susceptible to SACT damage. The contingent annual loss (with control) to Australian citrus caused by SACT if it spread to its expected limits was estimated by to be $24.3M (Whittle 2003 – **Appendix 5**).

Given the potential risks to Australian horticulture posed by SACT, and its apparently unusual host utilisation behaviour (common on *Bryophyllum* spp, but not found citrus, mango, *Acacia* or *Grevillea*), it was important to research the potential host range of this thrips in Australia, especially with respect to citrus and other key crop hosts. On the assumption that *S. aurantii* behaved in Australia as it does in its home range, it was also appropriate to determine its susceptibility to pesticides, and to develop IPM strategies to manage the new thrips if and when it began to attack horticultural crops.

This report provides a summary of the research conducted during this project by the citrus IPM team located at Maroochy Research Station Nambour presented in 5 sections – 1) Thrips rearing and biology - 2) Host utilisation & performance - 3) Insecticide efficacy - 4) Predation by *Euseius victoriensis* and - 5) Surveillance & Pest risk analysis.

In the section, Surveillance & Pest risk assessment, reference is made to several key documents prepared by staff of the then DPI's Animal & Plant Health Service (now Biosecurity Queensland); these are included as **Appendix 5** in this report to provide insight into the effort made on behalf of Industry in response to this exotic pest thrips incursion.

Table 1: Plants (and families) on which citrus thrips, *Scirtothrips aurantii*, has been recorded.

Abutilon	(Malvaceae)	*Grevillea robusta*	(Proteaceae)
Acacia caffra	(Mimosaceae)	*Grewia cana*	(Tiliaceae)
Acacia karroo		Guava	(Myrtaceae)
Acacia nilotica kraussiana		*Gymnosporia buxifolia*	(Celastraceae)
Acacia polyacantha campylacantha		*Indigofera hedyantha*	(Fabaceae)
Acacia spp.		Lichen	n/a
Albizia	(Mimosaceae)	Litchi	(Sapindaceae)
Almond	(Rosaceae)	*Lopholaena randii*	(Asteraceae)
Burkea africana[1]	(Caesalpiniaceae)	Macadamia	(Proteaceae)
Amaranthus thunbergia	(Amaranthaceae)	Mango	(Anacardiaceae)
Apricot	(Rosaceae)	*Mucuna coriacea irritans*	(Fabaceae)
Avocado	(Lauracea)	Mulberry	(Moraceae)
Bauhinia sp.	(Caesalpiniaceae)	Mung bean	(Fabaceae)
Bauhinia galpinii		*Nicandra physaloides*[1]	(Solanaceae)
Bean	(Fabaceae)	*Ochna pulchra*[1]	(Ochnaceae)
Bryophyllum sp.	(Crassulaceae)	Olinia	(Oliniaceae)
Buddleia salviaefolia	(Scrophulariaceae)	*Osyris compressa*[1]	(Santalaceae)
Caesalpinia pulcherrima	(Caesalpiniaceae)	Pea	(Fabaceae)
Cassia delagoensis	(Fabaceae)	Peach	(Rosaceae)
Cassia occidentalis		*Phyllanthus reticulatus*	(Euphorbiaceae)
Cissus	(Vitaceae)	Plum	(Rosaceae)
Citrus	(Rutaceae)	Pomegranate	(Lythraceae)
Combretum spp.	(Combretaceae)	Privet	(Oleaceae)
Combretum guienzii		Protea	(Proteaceae)
Combretum imberbe petersii		*Prunus amygdalus*	(Rosaceae)
Combretum kraussii		*Rhoicissus cuneifolia*[1]	(Vitaceae)
Combretum microphyllum		*Rhoicissus erythrodes*	(Vitaceae)
Combretum suluensis		*Rhus sp.*	(Anacardiaceae)
Combretum zeyheri		*Rhus vimanalis*	
Croton gratissimum	(Euphorbiaceae)	*Rhus zeyheri*	
Dichrostachys cinerea	(Mimosaceae)	*Ricinus communis*	(Euphorbiaceae)
Dichrostachys cinerea nyaccana		Rose	(Rosaceae)
Dodonaea viscosa	(Sapindaceae)	*Royena pubescens*	(Ebenaceae)
Dombeya rotundifolia	(Sterculiaceae)	*Royena lucida*[1]	
Erythrina caffra	(Fabaceae)	*Sclerocarya birrea*	(Anacardiaceae)
Eucalyptus robusta	(Myrtaceae)	Syzygium sp.	(Myrtaceae)
Eucalyptus sideroxylon[1]	(Myrtaceae)	*Tagetes minuta*	(Asteraceae)
Jacaranda mimosaefolia	(Bignoniaceae)	*Terminalia sericea*	(Combretaceae)
Ficus sp.	(Moraceae)	*Trichilia dregeana*	(Meliaceae)
Fluggea macrocarpa	(Euphorbiaceae)	*Vitex rehmanni*	(Verbenaceae)
Grape	(Vitaceae)	*Waltheria indica*	(Sterculiaceae)
Grass (in orchard)	(Poaceae)		

Sources: Faure 1929; Hall 1930; Bedford 1943; Gilbert 1990; Gilbert & Bedford 1998; PPRI 2002.
[1] Wentzel et al. (1978) report *S. aurantii* does not breed on these hosts (this is certain also to apply to others).

2. THRIPS REARING & BIOLOGY

2.1 INTRODUCTION

The development of a reliable rearing method to produce the numbers of insects necessary for experimental purposes is a significant component of most research on insects. Thrips of many species have been reared using a variety of methods (eg Lewis 1973, Murai & Loomans 2001, Hoddle 2002a) some of which utilise excised plant parts like green bean pods. *S. aurantii* has been reared on various plant hosts including potted Pride of Barbados *Caesalpinia pulcherrima* and citrus, however plant based methods are laborious or unreliable; the use of citrus for example relies on management of the plants such that flush growth is always available (Grout pers. comm. 2004), since *S. aurantii* is incapable of utilising hard leaf tissue. The phyllodes of succulents such as *Bryophyllum* spp., adapted to survive in dry environments, can survive for extended periods in tubs, offering the potential to develop a simple rearing method.

Observations of the utilisation of *B. pinnatum* in the field, and of the attractiveness of excised leaves of this species to *S. aurantii* adults on field collected *B. delagoense* terminals held in Ziploc® bags led to the development of a simple rearing system enabling production of the thrips required for the host performance, insecticide susceptibility and predatory mite experiments reported here. Excised *B. pinnatum* leaves remained viable for months, and produced plantlets on their leaf margins, hence the name 'air plant'. Plants were readily grown from leaf sections placed onto the surface of moist potting mix (**Plate 2**).

Adult thrips were added to excised *B. pinnatum* leaves in plastic tubs (750 ml takeaway food containers - Castaway® CA-C25; base diameter 9 cm, lid 12 cm - were most commonly used; **Plate 2**), but any size was acceptable. Polystyrene tubes (30 ml) with 2 cm wide *B. pinnatum* strips including the midrib were used for smaller numbers of thrips or to maintain cultures from multiple sources. Security of the lid, preventing thrips escape through small gaps commonly found between lid and container, was provided by a piece of 100 µm nylon mesh over which the lid was placed. Container lids must snap on firmly over the mesh, which is quite slippery - poorly fitting lids pop up allowing thrips to escape. A hole cut in the lid (~ 50% of lid area) provided ventilation.

Late second instar larvae ceased feeding and pupated beneath leaves or where they touched the sides of containers (**Plate 2**). No pupation substrate was required (see **Table 2**). Prior to the addition of new leaves the container was tapped lightly several times on a bench to knock adults or roaming second instar larvae down from the sides to minimise escapes; if this was over-vigorous high pupal mortality resulted and culture performance was poor. Thousands of *S. aurantii* per week were produced using this simple method.

A single average sized *B. pinnatum* leaf supported development of large numbers of *S. aurantii* larvae, however, if thrips numbers used to start a culture cycle were excessive, severe leaf damage occurred, eggs failed to hatch and larvae starved. Periodic addition of new leaves or splitting of the culture by removing a heavily infested leaf to a new container with new leaves overcame this problem; larvae readily relocated to new leaves. Severely damaged *B. pinnatum* leaves turned black (**Plate 2**), and hungry larvae and adults moved off them and wandered around containers, both ready observable indications that new leaf was required.

S. aurantii was cultured continuously on *B. pinnatum* from January 2004 to the present. During this time various problems were encountered and solutions developed. *B. delagoense*

(the main source of our thrips), the most common species of MoM in the Brisbane area, is utilised by several species of thrips, the most common of which was *Thrips tabaci* Lindeman (Anonymous 2003 – see **Appendix 5**).

It was important, therefore, to ensure the thrips used to establish cultures were *S. aurantii*. Males of this species are readily distinguished from other *Scirtothrips*, and from the other thrips recorded on MoM in Australia, by a comb of stout setae on the posterior margin of their hind femorae. Also, abdominal tergite IX bears a pair of long curved dark lateral processes called drepanae (**Plate 1)**. Both characters are readily discerned with a stereomicroscope.

Other insects, including, aphids, scales, and predatory mites and thrips also utilise *B. pinnatum* and *B. delagoense*, and leaves used for culturing must be free of contaminants. Aphids can be very numerous on *B. pinnatum*, and predatory mites brought into culture tubs on leaves occasionally significantly reduced thrips culture performance.

In winter the fungus *Exosporium bryophylli* T.S. Ramakr. was increasingly apparent on *B. pinnatum* in the field and glasshouse (**Plate 8**). This fungus, which is restricted to *Bryophyllum*, and is probably a primary pathogen, has been recorded previously only twice in Australia (Shivas, pers. comm. 2004). It caused accelerated breakdown of leaves leading to loss of thrips eggs, accumulation of free water in tubs, and necessitated more frequent provision of new leaves. Another factor causing accelerated leaf breakdown was poor leaf quality; plants grown with excessive water and/or nutrients produced thin soft leaves more readily damaged by thrips.

When leaf breakdown occurred, free water accumulation drowned pupae. Provision of a paper or other absorbent substrate beneath the leaves assisted in reducing or preventing this, and could be used to remove pupae from the culture to obtain adults of known age, however when cultures were well maintained free water did not accumulate. Thrips of known age were easily obtained by clearing rearing tubs and collecting newly emerged larvae or adults. Synchronisation of populations was readily achieved in this way, or by restricting the time allowed for oviposition by adults to one or two days.

Other Bryophyllum species, though they also supported *S. aurantii* development and could be used as rearing hosts, were less suitable than *B. pinnatum*. The phyllodes of *B. delagoense*, are cylindrical and tightly appressed at the growing tip favoured by the thrips (**Plates 3, 7)**, making them difficult to observe and extract. *B. proliferum* (**Plates 4, 8**) and the hybrid *B. delagoense* x *B. daigremontianum* (**Plate 3)** have more suitable phyllode structure, but were more severely damaged by thrips feeding and broke down more quickly.

2.2 BIOLOGY, MATING ETC

Australian *S. aurantii* eggs hatched in 6 - 7 days, the 2 larval stages took 3 - 4 days, the propupal stage 1 - 2 days, and the pupal stage 3 - 4 days, giving a total, at summer room temperatures of 14 - 19 days. These development times are similar to those reported for SACT in South Africa. General aspects of the biology of Australian *S. aurantii* were determined in the course of culturing the insect.

Mating was readily observed. Males were more active generally than females; they attempted to mate with nearby females, but also occasionally with other males, with pupae or even the squashed remains of larvae and pupae, though they were not very persistent with dead individuals. If the female was unresponsive she vigorously flicked up her abdomen, ran about

or otherwise attempted to dislodge the male, which was carried around on her back for a short time but usually soon gave up. With responsive females the male placed his abdominal tip beneath hers, inserted his aedeagus then stood over or beside her for several minutes as sperm was transferred with conspicuous pumping movements of his abdomen. The female's ovipositor was exserted throughout, presumably to enable insertion of the aedeagus. The drepanae of the male were not involved in copulation. Mating events were frequently observed when adults were aspirated from the culture into 30 ml containers, where they were in close proximity to one another.

Adults lived for about one month on *B. pinnatum* in culture and survived for several days on a broad range of hosts, including 30% survival over 11 days on bean pods on which no damage and only minimal egg hatch (3 x L1 larvae produced from 150 - 200 adults) was observed. Unmated females on *B. pinnatum* produced 1.3 - 1.6 eggs per female per day (recorded as hatching larvae: 9 females produced 148 larvae in a 10 - 13 day hatching period). As expected, all adults reared from larvae produced by unmated females were males, indicating arrhenotoky, i.e. haplo-diploid sex determination with diploid females produced from fertilised eggs and haploid males parthenogenetically from unfertilised eggs.

2.3 ATTRACTION TO LIGHT

During the course of culturing *S. aurantii* on *Bryophyllum*, observations were made of the behaviour of the adults with respect to light. When large numbers of thrips were present in a rearing tub and the *Bryophyllum* leaves degraded as a result of heavy feeding, the thrips moved off the leaves and were readily visible moving about in the area of the tub above the leaves. In undisturbed tubs it was apparent that these thrips were responding very strongly to the ambient light from a nearby window; all of the thrips were on the lighted side of the tub. When the tub was turned through 180 degrees, so that the thrips were on the dark side of the tub, they rapidly moved to the lighted side, and all had done so within 5 - 10 seconds. Many flew across the tub, others walked across the underside of the lid.

Efforts to rear *S. aurantii* in South Africa have reportedly been hampered on occasions by strong phototaxis, with colonies apparently failing because the adults were strongly attracted away from the host plants towards room lights (Grout, pers. comm. 2004). In our host performance trials we did not use artificial light specifically to avoid this potential problem.

2.4 PREDATORS & PARASITOIDS

Two species of very small wasps, almost certainly thrips parasitoids, were observed in *S. aurantii* cultures newly established from field collected plant material; they persisted for only one or two generations, and appeared responsible for low levels of parasitism.

Predatory mites were commonly observed and persisted in our thrips culture tubs, where little other than thrips was available as food. These were identified to be *Amblyseius longispinus*, a local coastal species usually not seen in the main Queensland citrus production areas of Emerald and Central Burnett, which are much drier than the coastal zone around Nambour.

2.5 PLANT HOST AND PUPATION SUBSTRATE COMPARISON EXPERIMENT

Introduction

Initial attempts to rear SACT for experimental work utilised excised parts of the most common *Bryophyllum* species, *B. delagoense* (terminals), and the hybrid *B. delagoense* x *B. daigremontianum* (phyllodes). Green bean pods and *B. pinnatum* terminal stems also were tried, and finally *B. pinnatum* leaves, which subsequently became the standard rearing host. *B. proliferum* leaves appeared to have potential to be an even better rearing host. Most early comparisons were based on qualitative observations, however, data from a single experimental comparison for excised *B. proliferum* and *B. pinnatum* leaves in tubs are given here. In rearing *Scirtothrips citri* on laurel sumac, Morse (pers. comm. 2004) used folded paper as a pupation site for the thrips. In this experiment we added folded paper towel to the bottom of half of the tubs for each *Bryophyllum* species. Host performance comparisons for growing potted plants with on-plant cages can also be derived from the experiments reported in Section 3, host utilisation and performance.

Materials & methods

Approximately 20 adult thrips (15 females, 5 males) were aspirated from *B. pinnatum* culture and placed into each of 5 tubs (ventilated, with 100 μm mesh) with 3 - 4 *B. pinnatum* leaves or *B. proliferum* composite leaves per treatment. Folded paper towel as a pupation substrate was placed in the bottom of an additional 5 tubs per Bryophyllum species. Adult thrips and first instar larvae (L1) were counted by treatment and adults removed at 1 week; numbers of L1, L2, pupae (i.e. including propupae & pupae) and new adults were counted at 14 days.

Results & Discussion

At 7 days the numbers of adult thrips removed by treatment were: Bp – 83, Bp + paper – 87, Bpf – 79, Bpf + paper – 84, giving estimates of 11.9 - 13.1 female and 4.0 - 4.4 male adults per tub (based on 75% females), i.e. a total of 15.8 - 17.4 thrips per tub. Small numbers of L1 larvae were present at 7 days: Bp – 5, Bp + paper – 10, Bpf – 6, Bpf + paper – 23, indicating an egg hatch period of 6 - 7 days.

A total of 5185 offspring (49% were pupae or adults at 14 days) was produced by an estimated 250 female SACT, a mean of 259 ± 10 from 12 - 13 female thrips per tub (**Table 2**). This equates to a mean (or rate of increase, RI) of 20.8 ± 0.8 offspring per female for one week of oviposition, or 2.6 - 3.0 ± 0.1 offspring per female per day based on a 7 or 6 day egg hatch period. This can be considered a reasonable estimate of the maximum oviposition rate, based on the assumption of zero egg mortality.

These egg production estimates are substantially higher than those reported by (Gilbert & Bedford 1998) for *S. aurantii* in African studies of 1.2 per female per day.

There were no treatment differences in the number of offspring at 14 days following a 7 day oviposition period on *B. pinnatum* or *B. proliferum*, with or without paper. Similarly, no significant difference in development time between *Bryophyllum* species was apparent based on the relative proportions of offspring in each stage (**Table 2**).

Table 2: Comparison of offspring at 14 days from *S. aurantii* adults allowed to oviposit for one week on *B. pinnatum* or *B. proliferum* leaves in tubs with and without paper as a pupation substrate (~15 female & 5 male thrips were added to each of 5 tubs per treatment[1]).

Treatment (Female thrips/treatment)	**Rep.**	**Offspring by stage: L1**	**L2**	**Pupae**	**Adults**	**Total**
B. pinnatum	1	14	141	121	14	290
(83 x 0.75 = 62.3 ff)[1]	2	17	138	175	4	334
Mean 12.5 ff per tub[1]	3	12	114	108	6	240
	4	15	135	115	15	280
	5	20	111	132	23	286
B. pinnatum + paper	1	14	77	108	10	209
(87 x 0.75 = 65.3 ff)	2	19	104	89	15	227
Mean 13.1 ff per tub	3	15	137	128	27	307
	4	12	106	118	21	257
	5	9	165	102	18	294
B. proliferum	1	14	78	41	14	147
(79 x 0.75 = 59.3 ff)	2	19	183	102	18	322
Mean 11.9 ff per tub	3	28	141	163	21	353
	4	16	89	77	11	193
	5	23	73	104	19	219
B. proliferum + paper	1	8	85	121	16	230
(84 x 0.75 = 63.0 ff)	2	10	124	89	21	244
Mean 12.6 ff per tub	3	18	118	127	4	267
	4	17	116	104	18	255
	5	7	89	121	14	231
B. pinnatum						
- total	5	78	639	651	62	1430
- mean ± se		16 ± 1.4	128 ± 6.3	130 ± 11.9	12 ± 3.4	286 ± 15
- % in stage		5.5	44.7	45.5	4.3	
B. pinnatum + paper						
- total	5	69	589	545	91	1294
- mean ± se		14 ± 1.7	118 ± 15.2	109 ± 6.7	12 ± 2.9	259 ± 19
- % in stage		5.3	45.5	42.1	7.0	
B. proliferum						
- total	5	100	564	487	83	1234
- mean ± se		20 ± 2.5	113 ± 21.3	97 ± 20	17 ± 1.8	247 ± 39
- % in stage		8.1	45.7	39.5	6.7	
B. proliferum + paper						
- total	5	60	532	562	73	1227
- mean ± se		12 ± 2.3	106 ± 8.1	112 ± 7.0	15 ± 2.9	245 ± 7
- % in stage		4.9	43.4	45.8	5.9	
All						
- total	20	307	2324	2245	309	5185
- mean (se)	20	15 ± 1.0	116 ± 6.0	112 ± 5.7	16 ± 1.2	259 10
- % in stage	20	5.9	44.8	43.3	6.0	-
- per female (se)	250 ff					20.8 ± 0.8
- per female per day (se)	250/7					3.0 ± 0.1

[1] Based on the numbers of adults extracted at 7 days, mean female thrips per tub was 11.9 - 13.1
[2] Based on egg hatch period of 7 days; if 6 days is used = 2.6 ± 0.1

3. HOST UTILISATION & PERFORMANCE

3.1 INTRODUCTION

S. aurantii reportedly occurs on 83 plant species in 33 families (Table 1). The 2002 surveys in Brisbane, because of uncertainty about how the insect would behave here, sampled all potential thrips hosts but found breeding populations only on *Bryophyllum* (Anonymous 2003). This led to the suggestion that *S. aurantii* in Australia comprised a host restricted subset of the gene pool of this species in Africa, with the potential consequence that the risk to citrus and other horticultural crops may have been less than anticipated.

To assess the potential of Australian *S. aurantii* to attack hosts other than *Bryophyllum* we ran a series of no-choice experiments on potted plants using on-plant cages. We considered the use of off-plant enclosures commonly used for thrips research such as Petri dishes using leaves or leaf discs (eg Kogel *et. al* 1997ab) or Munger cells (eg Morse 1986) and did preliminary tests with other designs of our own, or very small on-plant cages, using individual or very low numbers of thrips as the experimental unit, but these methods were labour intensive and subject to the risk of false negatives because of the low numbers of thrips used.

We concluded that the most practical and representative method was to use on-plant cages with 20 - 100 thrips, and designed cages for this purpose. Our tests were no-choice trials, with adult thrips from *B. pinnatum* culture added at the start, and were terminated usually at 14 days but some after periods as long as 42 days. The 14 day period was chosen because this allowed for 7 - 8 days of egg hatch and larval development, by which time pupae and often small numbers of F_1 adults were present in cages on *B. pinnatum,* the reference host.

In this section of the report the general methods, and a summary and discussion of the results is given first, followed by the details of each experiment.

3.2 GENERAL MATERIALS & METHODS

Cage design and utilisation

The ends were cut off clear 1L PET bottles, one or two ventilation holes (~ 15 cm diameter) cut into the sides, and a ventilated lid made by cutting a clear plastic cup so that it fitted tightly into the top of the bottle. The mouth of the cup (the cage lid) and side ventilation holes were covered with 100 µm nylon mesh glued on with contact cement. A plastic freezer bag (24 x 32 cm) was cut across one corner and glued with contact cement over the other end of the bottle. The cage was placed over twigs or a branch end with soft flush leaves or fruit and the freezer bag skirt closed with 6 mm flat elastic over the branch or twig (**Plates 5 & 6).**

At the start of each experiment the on-plant cages were set up on test plants using bamboo stakes to support them with their skirts open. The required numbers of adult *S. aurantii* were aspirated from *B. pinnatum* culture into clear 30 ml polystyrene tubes, one for each cage. The tubes were capped and held until all thrips required for the experiment were accumulated (less than 1 hour); the thrips tubes were taken to a controlled temperature room (~ 25ºC with an ambient light regime) where all experiments were conducted. A small piece of blue-tac® was attached to the side of each tube, the thrips displaced to the bottom of the tube by tapping it firmly on a bench, the lid removed and the tube stuck with the open end up with the blue-tac to the inside of the cage just above the skirt which was then quickly closed with 6 mm elastic.

Plants were randomised and placed radially next to a floor to ceiling window in the CT room to achieve good ambient lighting; overhead lights were turned off to minimise possible attraction towards them of caged thrips.

At the conclusion of the experiment (14 days for most trials) the cage was removed by cutting the branch below the cage skirt, taken to the laboratory and thrips counted by stage (1st or 2nd instar larvae – L1 or L2, pupae or adults; teneral adults, because they are very pale, could sometimes be distinguished from surviving F_0 adults). The fine plastic skirt was cut above the elastic holding it onto the plant stem; the folds around the stem were carefully inspected under a stereomicroscope, as were small cavities where the skirt was glued to the cage base, all favoured pupation sites. The skirt was then removed and the cage tapped downwards firmly to dislodge thrips onto a large piece of white paper from which they were aspirated and counted. The plant material was then removed from the cage and inspected for thrips.

We did not routinely examine test plants for thrips damage. This was done initially, but added significantly to the time to process trials. Additionally, the growth of test plants during trials resulted in contact between foliage and cage sides, providing atypical locations for thrips to feed, and thus potentially unnatural damage. We chose to increase numbers of plants, replicates and thrips, and focused on performance as measured by offspring thrips. Occasional observations were made when damage was conspicuous.

Thrips were never returned to our culture from test hosts, so none of the thrips used in our trials experienced hosts other than *Bryophyllum*. The only variation from this was the trial in which thrips were passaged through mango prior to use on other hosts (Experiment 5) and the continuous culture trials on citrus (Experiment 16).

Plant species tested

Twenty nine experiments were conducted on 16 crop 'species' (all citrus varieties used are hybrids - see Mabberley 1997, 1998), 8 natives, 7 exotic ornamentals and 5 exotic weed species - a total of 36 'species' (**Table 3**). Green mother of millions, ***B. pinnatum,*** was used as the reference host in 18 trials. ***B. delagoense***, the most common mother of millions species in Queensland, was used to determine its productivity relative to ***B. pinnatum*** in 5 trials, and the less common ***B. proliferum*** was included in one on-plant trial.

Data handling

In most experiments there were no, or few, F_1 adult thrips, enabling estimates of survival rates of F_0 adults (those used to start the experiment), and clear delineation of offspring thrips. For these trials the number of non-adult offspring was divided by the number of F_0 female thrips placed into cages to give a rate of increase per female thrips, abbreviated as RI.

Where numbers of F_1 adults prevented discrimination of F_0 & F_1 adults (indicated by the numbers of pupae or numbers of live adults substantially exceeding the F_0 number), the numerator for calculation of the RI value was total thrips minus the total number of F_0 adults.

Because most, but not all, experiments ran for 14 days, RI values were standardised to offspring per female per 14 days (RI_{14}) by multiplying offspring number by 8 divided by the days in excess of the 6 day egg hatch time for which the trial was run (i.e. 14 days = 8 days of oviposition by the adults and 8 days of egg hatching, since eggs laid on day 1 begin to hatch on day 7, those laid on day 8 begin to hatch on day 14). For example, for a 10 day trial, RI_{14} = No. thrips offspring x 8/4, whereas for a 17 day trial RI_{14} = No. offspring x 8/11.

Relative performance compared with the reference host *B. pinnatum*, was calculated by dividing mean RI for the test host by RI for the reference host, converted to a percentage; thus relative performance on *B. pinnatum* was 100%; a test host producing half as many offspring thrips per female as *B. pinnatum* would have a relative performance (i.e. RRI%) of 50%. In trials with no *B. pinnatum*, relative performance was calculated against the mean RI_{14} value from 18 trials that did include the reference host (i.e. RI_{14} = 15.3; see **Table 6**).

In the 5 mango trials run for extended periods, the RI_{14} value for *B. pinnatum* run in the first set of trials was used, and the mean from 18 trials for the second; these are indicated in **Table 5** by shading and the numbers are shown in bold italics to distinguish them.

F_0 adult thrips mortality data recorded in 5 experiments was used to estimate the degree to which calculated RI values (based on the estimated female proportion of F_0 adults added to cages) underestimate the true RI values (**Table 7**). To prevent the introduction of bias in comparisons with experiments for which no correction for mortality was made, the data presented for all trials uses the number of thrips added to each cage to calculate the RI values.

In summarising the results, the 36 species tested in 28 trials were allocated on the basis of maximum mean relative thrips performance into five categories – Very good hosts (RRI = 61 - 150%), Good (31 - 60%), Moderate (21 - 30%), Poor (11 - 20%) and Very poor (0 - 10%).

3.3 RESULTS SUMMARY & DISCUSSION

Overview

Relative performance of *S. aurantii* in 26 no-choice experiments on plants and 2 tub trials is summarised in **Table 4**. Details by trial are shown in **Table 5**, the number of replicates in **Table 6**, and the mean rate of increase, or RI values, for the 18 plant and two tub trials for the reference host *B. pinnatum*, 5 plant trials for *B. delagoense* and 2 tub trials for *B. proliferum* in **Table 7**. Rate of increase values corrected for trials in which an estimate of the mortality of the adult thrips introduced at the start of the trial are shown in **Table 8**. Detailed methods and data for each experiment are presented in **Tables 9-36** in section 3.4 Experiments.

S. aurantii performance was assessed in 106 trials with 336 replicates on 16 crop, 8 native, 7 exotic ornamental and 5 exotic weed species from April 2004 to November 2006. Of these, 30 trials with 92 replicates were on citrus (orange - 8, lemon - 7, Tahitian lime - 8, grapefruit - 4), and 8 trials with 32 replicates on mango. In fruit damage trials, almost all fruit aborted in all trials on lemon and lime; typical thrips damage was evident on Kumquat fruit, most of which remained on the plants for the duration of the trial (**Table 27**, **Plate 6**).

The *Bryophyllum* species, the traded ornamental *Kalenchoe blossfeldiana* and macadamia were rated very good hosts – i.e., mean maximum offspring thrips numbers per female added to test cages were 61 - 150% of those on the reference host *B. pinnatum* (**Table 4**). Navelina, lime and mango were good hosts (RRI 31 - 60%), lemon, grapefruit, peach, grape, tea, *Acacia sophorae*, *A. longifolia* and *Syzygium moorei* were moderate hosts (RRI 21 - 30%).

C. pulcherrima was a poor host (RRI 11 - 20%). Hickson, sweet orange, Kumquat nagami fruit, avocado, banana, cotton, soybean, castor oil, *Holarrhena pubescens*, *Eucalyptus tereticornis*, *Callitris columellaris*, *Grevillea robusta*, *Syzygium australe*, *Kalanchoe longiflora*, *Crassula ovata*, *Murraya paniculata*, Poinciana and bean pods were very poor hosts (RRI 0 - 10%).

Bryophyllum
On the reference host *B. pinnatum*, *S. aurantii* performance, as measured by the rate of increase (RI_{14} = offspring per F_0 female over 14 days), was 7.1 - 28.3 (mean 15.3, n = 18), for *B. delagoense* 2.6 - 11.2 (mean 5.8, n = 5), representing performance relative to mean reference host performance from 18 trials (**Table 7**) of 38% (or 44% using the trial data - **Table 5**). In the single on plant trial on *B. proliferum*, RI_{14} was 15.6 (**Table 7**), 107% of the reference host. In two trials with excised leaves in tubs, the RI_{14} values for *B. pinnatum* were 18.1 and 21.6, and for *B. proliferum* 15.4 and 16.2.

Macadamia
Macadamia, in 4 trials, produced 58%, 139%, 132% and 127% (mean 114%) as many thrips per female as *B. pinnatum*.

Kalanchoe blossfeldiana
This traded ornamental succulent in a single tub trial (10 replicates) produced an RI_{14} of 6.3, 61% of *B. pinnatum* performance (5 cages on plants, RI_{14} 10.3). Relative to *B. delagoense* (5 cages on plants, RI_{14} 3.3), Kalanchoe produced almost 191% as many thrips per female. Potted plants in a glasshouse were observed to be heavily damaged by *S. aurantii* (**Plate 8**); leaves and stems were heavily scarred, internodes shortened and the plants unthrifty.

Citrus
Performance on citrus in general was poor, with mean performance relative to the reference host of 7 - 20%. Occasional trials, were much more productive of thrips, however, with per trial mean maxima relative to *B. pinnatum* of 44% for navelina and 41% for lime (**Table 5**).

Four experiments provide examples of better performance. In experiment 6, one lemon cage produced 133 offspring from 20 F_0 females in 14 days, including 10 pupae, an RI_{14} of 6.7, performance relative to *B. pinnatum* of 46%, and to *B. delagoense* of 60% (**Table 13**).

In experiment 10, a lime cage produced 188 offspring from 35 F_0 females in 12 days, an RI_{14} of 7.2. *B. pinnatum* produced an RI_{14} of 26.6 (458 & 472 offspring thrips in 10 days from two cages with 35 F_0 females). Because of the high RI_{14} on *B. pinnatum*, this represents a relative performance of 12%, however, compared with mean performance on the reference host (in 18 trials, RI_{14} 15.3), relative performance of this lime cage was 54% (**Table 17**). In experiment 12, one lime cage produced 461 offspring from 70 females (including 334 L2's & 40 pupae), an RI_{14} of 6.6 and RRI of 43% of mean *B. pinnatum* performance (**Table 19**).

In experiment 25, two of the three cages on limes and three of four on navelina had 95 - 138 offspring thrips at 17 days from 20 females, a mean RI_{14} of 3.5, 42% of *B. pinnatum* (RI_{14} 8.3), and a replicate maximum of 5.0 for a cage on Tahitian lime, an RRI of 60% (**Table 34**).

Continuous culture on citrus
S. aurantii was maintained in continuous culture on flush growth on potted citrus trees – mostly Eureka lemon and Tahitian lime, in five trials over a period of five months, with 3 - 7 cycles or generations (mean 4.6) per trial, in experiment 16 (**Table 23**).

From a total of 4400 F_0 adult thrips (100 per cage to start 44 cages in five trials), ~ 3080 of which were females (70% per cage), a total of 6567 juvenile thrips (1684 L1's, 4591 L2's and 292 pupae) and 2755 adults were produced, 9322 thrips in total. Although some adults would

have been counted more than once, as survivors between cycles, this provides an estimate over the five trials of the rate of increase per female (RI) of 3.0 (i.e. 9322/3080).

Mean total thrips per cage per cycle peaked at 308, 209, 113, 172 and 179, with corresponding maxima per cage per cycle of 333, 219, 377, 497 and 349. The maximum numbers of larvae and pupae produced per cage per cycle were 235, 176, 94, 159 and 171, with corresponding cage maxima of 242, 183, 324, 461 and 346.

Maximum RI values for the F_0-F_1 generation, the one for which the F_0 number was most reliably known (100 per cage, ~70% female) were 2.1, 2.0, 5.4, 7.7 and 4.0 for the five trials. For three of the five trials these were also the maximum RI values; in the other two trials, maximum RI's were 6.0 in cycle two of trial one, and 5.7 in cycle three of trial two. Based on comparison with the mean RI for 18 *B. pinnatum* trials (i.e. 15.3, see **Table 7**), these maxima correspond to performance on citrus of 39%, 37%, 35%, 50% & 26% of that on *B. pinnatum*.

Mango

In the first trial, a single cage started with ~ 15 adult females and 5 males produced 132 thrips at 15 days, an RI_{14} of 8.8, and RRI 31% of *B. pinnatum* (**Table 10**). In the second trial, four of five cages produced a mean RI_{14} of 3.9, the fifth 237 offspring thrips at 13 days, a mean RI_{14} of 13.5, an RRI 92% of *B. pinnatum* (RI_{14} 4.6). Performance on *B. delagoense* was poor, with a mean RI_{14} of 2.6 (**Table 12**).

In experiments 2b, 2c, 2d, 7 and 8, cages on mango flush leaves initiated with adult thrips from culture on *B. pinnatum* were run for extended periods, from 20 to 42 days. In experiment 2b (2 reps x 20 days) (**Table 10**) mean RI_{14} for the two cages was 9.2 (6.0 & 12.5), and the RRI was 31% of the very productive *B. pinnatum* (mean RI_{14} 28.3).

In experiment 2c (3 reps x 41 days) performance was very poor (RI_{14} 0.6, RRI 2%), and in experiment 2d (3 reps x 42 days) the cage mean was 272 thrips, mean RI_{14} 4.5, and RRI 16% of *B. pinnatum* (**Table 10**). However, at 41 & 42 days most leaves in 5 of the 6 cages in these were unsuitable for thrips breeding, all soft terminal leaves (up to 3 - 4 cm long) were black and severely damaged, and thrips age distribution adult dominated (88 - 93%; **Table 11b**). The one cage with viable leaves had 545 thrips, 95% were juveniles. The mean RI_{14} for the 6 cages was 2.5 (for the best cage 9.0), giving a trial RRI of 9% (32% for the best cage). Relative to mean *B. pinnatum* performance in 18 trials (**Table 7**, RI_{14} 15.3), the best mango cage produced 59% as many thrips per F_0 female as the reference host.

Experiments 7 (33-34 days) and 8 (20-26 days) each had 9 replicates. In experiment 7, the 6 cages with foliage suitable for thrips feeding and breeding produced 2257 thrips, a mean of 376 per cage; two cages produced less than 50 thrips, two more than 300, and the best 1337, giving RI values for 33-34 days of 1.3, 1.8, 17, 18 & 67, with a cage mean of 18.8. Adjusted to per female per 14 days, the RI_{14} for the best cage was 19.8, for the next two 4.5 & 5.1, and the mean 5.5 (**Table 14**). When compared with the mean for *B. pinnatum* (from 18 trials, RI_{14} 15.3), the best cage is 129%, and the mean 36% of performance on the reference host.

In experiment 8, the nine cages produced 4942 thrips, a cage mean of 549; three cages produced less than 200 thrips, one produced 358, and the remaining five 593 - 1074, giving RI values for 20 - 26 days of 2.6 - 35.8. Adjusted, the RI_{14} values were 1.0 - 2.3 for the worst three cages, 6.8 and 7.9 for two cages, and 13.1 - 17.7 for the remaining four cages; mean RI_{14}

per cage was 7.7 (**Table 15**). When compared with mean performance on *B. pinnatum* in 18 trials (RI_{14} 15.3), relative performance of the best cage was 116% and the mean 50%.

The same correlation between variance in host suitability and thrips performance observed in experiments 2b, 2c & 2d was observed in experiments 7 and 8, because the extended period of these experiments was long enough for the original leaves to harden and new ones to be produced. In cages in which most leaves had hardened and few soft leaves were available the thrips were mostly adults, the terminals and small new leaves were severely damaged by their feeding and few larval thrips able to be produced. In cages with sufficient soft young leaves to sustain the numerous adults, breeding was maintained and the thrips population comprised predominantly of juveniles (**Table 11b,** last replicate compared with 5 others).

Based on these 5 extended trials (total of 23 replicates), which produced large numbers of thrips in cages on plants with suitable leaves, and in which damage to new leaves was severe where adult numbers were high relative to the available soft leaves, mango qualifies as a very good host, and is included in **Table 4** in brackets to indicate this.

Mango-reared thrips
In experiment 5, adult *S. aurantii* reared on potted mango were added to cages (20 per cage, ~ 15 females & 5 males) on potted *B. pinnatum*, *B. delagoense*, mango and orange; thrips reared in *B. pinnatum* culture were caged on plants of the same species (**Table 12**).

Relative performance of mango-reared thrips on the reference host *B. pinnatum* was 95% of that of *B. pinnatum*-reared thrips. On *B. delagoense*, the RRI for 'mango thrips' was 43%. For '*B. pinnatum* thrips' it was 18%; on mango RRI was 55% for 'mango thrips' and 26% for '*B. pinnatum* thrips'. On flush leaves of potted orange plants (cv Navelina), adult thrips reared on *B. pinnatum* and mango performed equally poorly with RRI values of 5% and 0.7%.

To compare thrips performance on mango with *B. delagoense* (the most common mother of millions), the data for mango and *B. pinnatum* reared thrips was pooled (excluding the two worst cages for each, which had almost no thrips). Mean RI_{14} for *B. delagoense* (n = 4) was 4.5, for mango (n = 6) 7.1, i.e. performance on mango was 173% of that on *B. delagoense*.

Peach, grape and tea
S. aurantii performance on these crop species was rated as moderate (21-30% of performance on the reference host). Relatively few trials were done on these species (five replicates in two trials on peach, three replicates in one trial on tea, and one replicate in one trial on grape).

On peach, the two cages in experiment 9 produced a mean RI_{14} of 3.0, relative performance 26% of trial reference host performance (RI_{14} 11.6), 20% of mean reference host performance (RI_{14} 15.3), and 53% of performance on *B. delagoense* (**Table 16**). The 3 cages in experiment 21 produced a mean RI_{14} of 3.1, relative performance 14% of trial reference host performance (RI_{14} 22.8), and 20% of mean reference host performance (RI_{14} 15.3) (**Table 29**).

One of three cages on tea produced almost no thrips, the other two 3.5 and 2.4 times the ~15 females added to start each cage, giving a mean RI_{14} of 2.1, and relative performance 21% of the reference host (**Table 32**). The single grape cage produced 121 offspring thrips, an RI_{14} of 3.6, a relative performance 24% of the reference host mean RI_{14} of 15.3 (**Table 27**).

Acacia sophorae, A. longifolia* and *Syzygium moorei

The performance of *S. aurantii* on these natives was rated as moderate. In two trials on *A. sophorae* (**Tables 10 & 16**), one on *A. longifolia* (**Table 10**) and one on *S. moorei* (**Table 31**), mean RI_{14} values were 6.8 & 2.6, 5.9 and 3.4 (with species replicate maxima 8.2, 8.8 and 4.6), performances 24% & 22%, 21% and 25% of trial reference host performance. In experiment 9, the RI_{14} for *B. delagoense* was 5.7, giving performance on *A. sophorae* of 46% of that on common mother of millions. Some larvae successfully completed development in the 15 day trial period (**Table 11a**); on *A. sophorae* 16% of thrips were pupae and on *A. longifolia* 13%.

Caesalpinia pulcherrima

Pride of Barbados is a 3m shrub native to tropical America known to Amazon forest medicine men as *ayoowiri*, and is commonly used today in traditional Indian and Chinese medicine. After perhaps thousand of years of traditional use for similar purposes, recent studies have shown extracts of leaves and flowers to prevent virus replication of the human herpes viruses and adenoviruses, which cause the common cold. Other studies showed efficacy against wheezing, bronchitis, malaria, tuberculosis, other bacteria, fungi, and some parasites, and that 4 grams of the active ingredients of this plant caused vomiting, and can induce abortion in the first trimester of pregnancy (Counter 2006).

An occasional garden or street planting in Queensland, in South Africa *C. pulcherrima* is a favoured host of *S. aurantii,* and has been used to rear this thrips (Gilbert pers. comm. 2004), including for pesticide trials (Georgala 1968).

In a single trial (3 replicates), potted *C. pulcherrima* was found to be a poor host of Australian *S. aurantii*; producing a mean RI_{14} of 1.5, performance compared with the trial reference host (RI_{14} 13.7) of 11%, less than half that on *Syzygium moorei* in experiment 23 (**Table 31**).

Very poor hosts

The traded ornamentals *Kalanchoe longiflora*, *Crassula ovata* and *Syzygium australe* were very poor host, as was *Grevillea robusta*, *Eucalyptus tereticornis*, castor oil, soybean cotton, banana (plants, not fruit) and avocado. Sweet orange seedlings, Hickson mandarin leaves and Kumquat fruit also produced very few offspring thrips (**Table 4**).

Many of these, however, produced reasonable adult thrips survival, and a few larvae which appeared to be developing normally, with some pupating during the trial period eg *E. tereticornis* (**Table 11a**). For example, cage maxima for *Eucalyptus tereticornis* was 30 larvae, *Grevillea robusta* 11, *Crassula ovata* 26, avocado 5, soybean 9, cotton 7 and green bean pods in tubs 3 larvae. Mock orange, *Murraya paniculata*, a common ornamental citrus relative (F: Rutaceae), was a very poor host, producing only 5 larval thrips from 12 cages in 3 trials (**Tables 13, 21 & 31**). No offspring thrips were produced by banana, castor oil, *Callitris columellaris, Kalenchoe longiflora, Grevillea lanigera* and *Holarrhena pubescens*.

Fruit trials

In trials on citrus and mango fruits on potted plants, most fruit were aborted by the plants before the completion of the trial. Very low levels of thrips production and no fruit damage were noted on those fruit that did remain on trial plants, except for one trial in which damage typical of thrips was noted on Kumquat nagami fruit (**Plate 6**). In three field trials in which *S. aurantii* reared on *B. pinnatum* were released into navel orange trees there was no evidence of establishment on or damage to fruit or flush leaves.

Table 3: Details of the 36 plant 'species' used in experimental performance testing of *S. aurantii*.

Latin name – No. 'species'	Common name	Authority	Family	Origin
Crop hosts - 16				
Citrus x aurantium[1]	Sweet orange (r/stock)	(L.) Osbeck	Rutaceae	SE Asia/China
(or *C. sinensis*)	Navelina (cv)	(L.) Osbeck	Rutaceae	SE Asia/China
C. x limon	Lemon (cv Eureka)	(L.) Burm. F.	Rutaceae	SE Asia/China
C. x latifolia	Tahitian lime	(Yu. Tanaka)	Rutaceae	SE Asia/China
C. x paradisi	Grapefruit	Macfad.	Rutaceae	SE Asia/China
C. reticulata	Hickson mandarin	Blanco	Rutaceae	SE Asia/China
Fortunella margarita	Kumquat nagami	(Lour.) Swingle	Rutaceae	China
Mangifera indica	Mango	(L.)	Anacardiaceae	India
Macadamia integrifolia	Macadamia	Maiden & Betche	Proteaceae	Australia
Prunus persica	Peach	(L.) Batsch	Rosaceae	China
Vitis vinifera	Grape	(L.)	Vitaceae	Europe/Near East
Persea americana	Avocado	Mill.	Lauraceae	Mexico
Camellia sinensis	Tea	(L.) Kuntze	Theaceae	China
Gossypium hirsutum	Cotton	(L.)	Malvaceae	Mexico
Glycine max	Soybean	(L.) Merr.	Fabaceae	China
Musa acuminata	Banana	Colla	Musaceae	SE Asia
Phaseolus vulgaris	Green bean	(L.)	Fabaceae	Sth America
Natives – 8				
Eucalyptus tereticornis	Forest red gum	Sm.	Myrtaceae	Australia
Acacia sophorae	Coastal wattle	(Labill.) Court	Fabaceae	Australia
A. longifolia	Sydney golden wattle	(Andrews) Willd	Fabaceae	Australia
Callitris columellaris	Bribie Is pine		Cupressaceae	Australia
Syzygium australe	Brush cherry	(J.C. Wendl. ex Link) B. Hyland	Myrtaceae	Australia
S. moorei	Coolamon	(F. Muell.) L.A.S. Johnson	Myrtaceae	Australia
Grevillea robusta	Silky oak	Cunn. Ex R. Br.	Proteaceae	Australia
G. lanigera	Woolly grevillea	A.Cunn. ex R. Br.	Proteaceae	Australia

Table 3: Details of the 36 plant 'species' used in experimental performance testing of *S. aurantii* (continued).

Latin name – No. 'species'	Common name	Authority	Family	Origin
Exotic ornamentals – 7				
Kalanchoe blossfeldiana	Widow's thrill	Poelln.	Crassulaceae	Madagascar
K. longiflora	n/a	Schltr. Ex Wood	Crassulaceae	South Africa
Crassula ovata	Jade plant	(Miller) Druce	Crassulaceae	South Africa
(*C. argentea* - syn. *C. ovata*)	Coral plant	n/a		
Murraya paniculata	Mock orange	(L.) Jack	Rutaceae	China, India, Australia
Caesalpinia pulcherrima	Pride of Barbados	(L.) Sw.	Fabaceae	Central America,
Delonix regia	Poinciana	(Boj. Ex Hook) Raf.	Fabaceae	Madagascar
Holarrhena pubescens[2]	Bitter oleander	(L.) Wall. ex G. Don	Apocynacea	Africa, Asia
Exotic weeds – 5				
Bryophyllum pinnatum	Green MoM/Air plant	(Lam.) Oken	Crassulaceae	Madagascar
B. delagoense	Mother of millions	(Eckl. & Zeyh.) Schinz	Crassulaceae	Madagascar
B. proliferum	Blooming boxes	Bowie	Crassulaceae	Madagascar
B. daigremontianum x delagoense	Hybrid MoM	n/a	Crassulaceae	Ornamental
Ricinus communis	Castor oil	L.	Euphorbiaceae	Africa

[1] Citrus names as per Mabberley (1997)

[2] This species is known worldwide, including in the Queensland nursery trade, as *Wrightia antidysenterica* Artic snow; other potentially correct names or synonyms are *Wallida antidysenterica*, *Echites antidysenterica* (eg Panigrahi 1987) or *Holarrhena antidysenterica*. Under the latter name, this species has been studied extensive for its medicinal properties, which derive largely from alkaloids.

Table 4: Summary of *S. aurantii* performance on potted plants of 36 'species' in no-choice trials. Inclusion in a category is based on *maximum* mean performance per trial as a proportion of the *B. pinnatum* standard. For trials in which a standard was not included, test host performance was compared with mean performance on *B. pinnatum* in 18 trials on plants (i.e. RI = 15.3 ± 1.4, means by trial shown last row of Table 5).

Very good 61 – 150 % x Bp	**Good** 31 – 60 %	**Moderate** 21 – 30 %	**Poor** 11 – 20 %	**Very poor** 0 – 10 %	
Macadamia integrifolia	Navelina	Lemon	*C. pulcherrima*	Hickson mandarin	*Eucalyptus tereticornis*
	Lime	Grapefruit		Sweet Orange[3]	*Callitris columellaris*
Bryophyllum pinnatum				Kumquat nagami (fruit)	*Grevillea robusta*
B. delagoense	Mango	*Prunus persica*			*G. lanigera*
B. proliferum		*Vitis vinifera*		Avocado	*Syzygium australe*
Kalanchoe blossfeldiana		*Camellia sinensis*		Banana (plantlets)	
				Cotton	*Kalanchoe longiflora*
(Mango)[1]		*Acacia sophorae*		Soybean	*Crassula ovata*
(*Bryophyllum* hybrid)[2]		*A. longifolia*		Green bean (pods)	(*C. argentea*)
		Syzygium moorei			
				Holarrhena pubescens	*Murraya paniculata*
				Ricinus communis	*Delonix regia*
5 (7)	3 (2)	8	1	-	19

[1] Mango trials run over extended periods (i.e. 20 – 26 & 33 – 34 days indicate that this species is potentially a good host
[2] *Bryophyllum daigremontianum* x *delagoense* data not reported; preliminary tub trials with excised plant parts indicate the hybrid is probably a 'Good' host
[3] Seedlings ~ 10 – 15 cm high

Table 5: Performance of *S. aurantii* relative to *B. pinnatum* (RRI%) on 36 'species' in 28 trials. (Trial mean RIs in the last row, *B. pinnatum* trials mean (n = 18, see Table 7) in italics; summary data by host - mean, maximum, No. trials, total reps - in last 5 columns; No. replicates per trial see Table 6).

		Trial # - on plants							
Latin name	**Common name**	**1**	**2a**	**2b[1]**	**2c[2]**	**2d[3]**	**3-4**	**5a**	**5b[4]**
Crop hosts (16)									
Citrus x aurantium	Sweet orange	0.4	0.6				0.02	5	1
C. x aurantium	Navelina (cv)								
C. x limon	Eureka Lemon		2						
C. x latifolia	Tahitian lime		3						
C. x paradisi	Grapefruit		3						
C. reticulata	Hickson mandarin								
C. x microcarpa	Kumquat nagami								
Mangifera indica	Mango		31					26	55
	- extended time			***50***	***10***	***60***			
Macadamia integrifolia	Macadamia						58		
Prunus persica	Peach								
Vitis vinifera	Grape								
Persea americana	Avocado								
Camellia sinensis	Tea								
Gossypium hirsutum	Cotton								
Glycine max	Soybean						0.7		
Musa acuminata	Banana						0		
Phaseolus vulgaris	Green bean (pods)						0		
Natives (8)									
Eucalyptus tereticornis	Forest red gum		3						
Acacia sophorae	Coastal wattle		24						
A. longifolia	Sydney golden wattle		21						
Callitris columellaris	Bribie Island pine						0		
Syzygium australe	Brush cherry						0.2		
S. moorei	Coolamon								
Grevillea robusta	Silky oak		1						
G. lanigera	Woolly grevillea	0							
Exotic ornamentals (7)									
Kalanchoe blossfeldiana	Widow's thrill								
K. longiflora	*K. longiflora*								
Crassula ovata	Jade plant								
C. argentea (= *C. ovata*)	Coral plant								
Murraya paniculata	Mock orange								
Caesalpinia pulcherrima	Pride of Barbados								
Delonix regia	Poinciana								
Holarrhena pubescens	Bitter oleander								
Exotic weeds (5)									
Bryophyllum pinnatum[5]	Green MoM	100	100	-	-	-	100	100	95
B. delagoense	Mother of millions							18	43
B. proliferum	Blooming boxes								
B. daigr. x delagoense	Hybrid MoM								
Ricinus communis	Castor oil		0						
	***B. pinnatum* mean RI**	15.4	28.3	<	28.3	>	21.5	14.6	13.8
	se	3.9	10.6	<	10.6	>	1.9	4.0	2.9

[1-3] Mango trials run for 20 (2b), 41 (2c) & 42 (2d) days; relative performance compared with *B. pinnatum* trials mean
[4] Thrips ex mango used in this trial; all others ex *B. pinnatum* laboratory culture. [5] Reference host

Table 5: *S. aurantii* relative performance on 36 plant 'species' (continued).

Common name	Trial # - on plants 6	7[6]	8[7]	9	10	11	12	13	14	15	19	21
Crop hosts (16)												
Sweet orange												
Navelina (cv)				3			14					
Lemon (cv Eureka)	26			3	4	0.1	11					
Tahitian lime	24			4	27	6	23					
Grapefruit	21			6	5							
Hickson mandarin	0				4							
Kumquat nagami											0.7	
Mango												
- extended time		***123***	***120***									
Macadamia	139											132
Peach				26								14
Grape											24	
Avocado				2								
Tea												
Cotton							0.3					
Soybean												
Banana												
Green bean (pods)												
Natives (8)												
Forest red gum				4	9							
Coastal wattle				22								
Sydney golden wattle												
Bribie Island pine												
Brush cherry									0.4	2		
Coolamon												
Silky oak				5								
Woolly grevillea												
Exotic ornamentals (7)												
K. blossfeldiana								61[8]				
K. longiflora												
Jade plant												
Coral plant												
Mock orange	0.3								0			
Pride of Barbados												
Poinciana										1		
Bitter oleander												
Exotic weeds (5)												
B. pinnatum	100	-	-	100	100	100	-	100	100	100	-	100
B. delagoense	77			49				32				
B. proliferum												
Hybrid MoM												
Castor oil	0											
***B. pinnatum* mean RI**	14.5	*15.3*	*15.3*	11.6	26.6	11.2	*15.3*	10.3	15.7	7.1	*15.3*	22.8
se	4.9	*1.4*	*1.4*	5.7	0.4	0.6	*1.4*	1.5	1.5	0.5	*1.4*	2.7

[6-7] Trials on mango run for 33 & 34 days (4 reps) and 20, 25 & 26 days (4, 2 & 3 replicates) respectively

[8] *K. blossfeldiana* in tubs, *B. pinnatum* & *B. delagoense* on plants

Table 5: *S. aurantii* performance on 36 plant 'species' (continued).

Common name	22	23	24	25b	26b	In tubs 18a	In tubs 18b	Mean	se	Max	Total Trials	Total reps
Crop hosts (16)												
Sweet orange								**1**	1	5	5	26
Navelina (cv)				44				**20**	12	**44**	3	8
Lemon (cv Eureka)					2			**7**	3	26	7	15
Tahitian lime				41	0			**16**	5	**41**	8	20
Grapefruit								**9**	4	21	4	16
Hickson mandarin								**2.0**	2.0	4	2	4
Kumquat nagami								**0.7**	-	1	1	3
Mango								**37**	9	**55**	3	9
- extended time								**73**	22	**123**	5	23
Macadamia	127							**114**	19	**139**	4	8
Peach								**20**	6	26	2	5
Grape								**24**	-	24	1	1
Avocado								**2**	-	2	1	3
Tea			21					**21**	-	21	1	3
Cotton								**0.3**	-	0.3	1	10
Soybean								**1**	-	1	1	4
Banana								**0**	-	0	1	6
Green bean (pods)								**0**	-	0	1	1
Natives (8)												
Forest red gum								**5**	2	9	3	7
Coastal wattle								**23**	1	24	2	4
Sydney golden wattle								**21**	-	21	1	3
Bribie Island pine								**0**	-	0	1	3
Brush cherry								**1**	-	2	3	8
Coolamon		25						**25**	-	25	1	3
Silky oak								**3**	2	5	2	4
Woolly grevillea								**0**	-	0	1	2
Exotic ornamentals (7)												
K. blossfeldiana								**61**	-	61	1	10
K. longiflora							0	**0**	-	0	1	3
Jade plant						2		**2**	-	2	1	3
Coral plant						2		**2**	-	2	1	3
Mock orange		0.4						**0.2**	0.1	0.4	3	12
Pride of Barbados		11						**11**	-	11	1	3
Poinciana		0.4						**1**	0.3	1	2	8
Bitter oleander					0			**0**	-	0	1	3
Exotic weeds (5)												
B. pinnatum	100	100	100	100	100	100	100	**100**	0	**100**	20	60
B. delagoense								**44**	10	**77**	5	17
B. proliferum	107					71	90	**89**	10	**107**	3	9
Hybrid MoM							75[9]	**75**	-	75	(1)	-
Castor oil								**0**	0	0	2	6
***B. pinnatum* mean RI**	14.6	13.7	9.9	8.3	15.4	21.6	18.1	**15.3**	1.4	**28.3**	106	336
se	2.0	0.2	1.8	1.2	1.4	2.0	0.8	**15.8**	1.3	**7.10**		

[9] Qualitative estimate - data not recorded; excluded from trials & replicate totals

Table 6: Number of replicates for the *S. aurantii* performance trials data shown in **Table 5**.

		Trial # - on plants							
Latin name	**Common name**	**1**	**2**	**2b[1]**	**2c[2]**	**2d[3]**	**3-4**	**5a**	**5b[4]**
Crop hosts (16)									
Citrus x aurantium	Sweet orange	7	3				10	3	3
C .x aurantium	Navelina (cv)								
C. x limon	Eureka Lemon		3						
C. x latifolia	Tahitian lime		3						
C. x paradisi	Grapefruit		3						
C. reticulata	Hickson mandarin								
C. x microcarpa	Kumquat nagami								
Mangifera indica	Mango		1					5	3
	- extended time			***2***	***3***	***3***			
Macadamia integrifolia	Macadamia						1		
Prunus persica	Peach								
Vitis vinifera	Grape								
Persea americana	Avocado								
Camellia sinensis	Tea								
Gossypium hirsutum	Cotton								
Glycine max	Soybean						4		
Musa acuminata	Banana						6		
Phaseolus vulgaris	Green bean (pods)						1		
Natives (8)									
Eucalyptus tereticornis	Forest red gum		3						
Acacia sophorae	Coastal wattle		3						
A. longifolia	Sydney golden wattle		3						
Callitris columellaris	Bribie Island pine						3		
Syzygium australe	Brush cherry						2		
S. moorei	Coolamon								
Grevillea robusta	Silky oak		3						
G. lanigera	Woolly grevillea	2							
Exotic ornamentals (7)									
Kalanchoe blossfeldiana	Widow's thrill								
K. longiflora	*K. longiflora*								
Crassula ovata	Jade plant								
C. argentea (= *C. ovata*)	Coral plant								
Murraya paniculata	Mock orange								
Caesalpinia pulcherrima	Pride of Barbados								
Delonix regia	Poinciana								
Holarrhena pubescens	Bitter oleander								
Exotic weeds (5)									
Bryophyllum pinnatum[5]	Green MoM	2	3	-	-	-	3	5	2
B. delagoense	Mother of millions							5	1
B. proliferum	Blooming boxes								
B. daigr. x delagoense	Hybrid MoM								
Ricinus communis	Castor oil		3						
	Total replicates by trial	11	31	2	3	3	30	18	9

Table 6: Number of replicates for *S. aurantii* performance trials (continued).

Common name	Trial # - on plants											
	6	**7[6]**	**8[7]**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**19**	**21**
Crop hosts (16)												
Sweet orange												
Navelina (cv)				4			1					
Lemon (cv Eureka)	3			1	3	1	4					
Tahitian lime	1			5	1	3	2					
Grapefruit	1			3	9							
Hickson mandarin	3				1							
Kumquat nagami											3	
Mango												
- extended time		***6***	***9***									
Macadamia	1											3
Peach				2								3
Grape											1	
Avocado				3								
Tea												
Cotton							10					
Soybean												
Banana												
Green bean (pods)												
Natives (8)												
Forest red gum				2	2							
Coastal wattle				1								
Sydney golden wattle												
Bribie Island pine												
Brush cherry									3	3		
Coolamon												
Silky oak				1								
Woolly grevillea												
Exotic ornamentals (7)												
K. blossfeldiana								10[8]				
K. longiflora												
Jade plant												
Coral plant												
Mock orange	2								7			
Pride of Barbados												
Poinciana										5		
Bitter oleander												
Exotic weeds (5)												
B. pinnatum	5	-	-	3	2	3	-	5	2	2	-	3
B. delagoense	3			3				5				
B. proliferum												
Hybrid MoM												
Castor oil	3											
Total reps by trial	22	*9*	*9*	28	18	7	17	20	12	10	4	9

[6-7] Trials on mango run for 33 & 34 days (4 reps) and 20, 25 & 26 days (4, 2 & 3 replicates) respectively
[8] *K. blossfeldiana* in tubs, *B. pinnatum* & *B. delagoense* on plants

Table 6: Number of replicates for *S. aurantii* performance trials (continued).

Common name	Trial # - on plants 22	23	24	25b	26b	In tubs 18a	18b	Totals Trials	reps	- by host type Trials	reps
Crop hosts (16)											
Sweet orange								5	26		
Navelina (cv)				4				3	8		
Lemon (cv Eureka)					2			7	15		
Tahitian lime				3	2			8	20		
Grapefruit								4	16		
Hickson mandarin								2	4		
Kumquat nagami								1	3		
Mango								3	9		
- extended time								5	20		
Macadamia	3							4	8		
Peach								2	5		
Grape								1	1		
Avocado								1	3		
Tea			3					1	3		
Cotton								1	10		
Soybean								1	4		
Banana								1	6		
Green bean (pods)								1	1	**51**	**165**
Natives (8)											
Forest red gum								3	7		
Coastal wattle								2	4		
Sydney golden wattle								1	3		
Bribie Island pine								1	3		
Brush cherry								3	8		
Coolamon		3						1	3		
Silky oak								2	4		
Woolly grevillea								1	2	**14**	**34**
Exotic ornamentals (7)											
K. blossfeldiana								1	10		
K. longiflora							3	1	3		
Jade plant						3		1	3		
Coral plant						3		1	3		
Mock orange		3						3	12		
Pride of Barbados		3						1	3		
Poinciana		3						2	8		
Bitter oleander					3			1	3	**11**	**45**
Exotic weeds (5)											
B. pinnatum	3	3	3	3	2	3	3	20	60		
B. delagoense								5	17		
B. proliferum	3					3	3	3	9		
Hybrid MoM							*	(1)	*		
Castor oil								2	6	**30**	**92**
Total reps by trial	9	15	6	10	9	12	9	**106**	**336**		

* Qualitative assessment - data not recorded; excluded from trial and replicate totals

Table 7: Performance of *S. aurantii* adults (mean offspring thrips per female = RI) as recorded, and standardised to per 14 days (RI_{14}) on *B. pinnatum* (Bp), *B. delagoense* (Bd) and *B. proliferum* (Bpf) in 20 trials (18 on plants, 2 in tubs) conducted from April 2004 to November 2006.

			Mean RI - as recorded						RI_{14}		
Trial	**End date**	**Days**	**Bp**	**se**	**Bd**	**se**	**Bpf**	**se**	**Bp**	**Bd**	**Bpf**
Plants											
1	30/4/04	14	**15.4**	3.9					**15.4**		
2	30/4/04	15	**31.8**	11.9					**28.3**		
3	15/6/04	12	**16.2**	1.4					**21.5**		
5a	28/7/04	13	**12.8**	3.5	**2.3**	0.7			**14.6**	**2.6**	
5b	Ex mango	13	**12.1**	2.6	**5.5**	0.4			**13.8**	**6.3**	
6	13/8/04	14	**14.5**	4.9	**11.2**	1.4			**14.5**	**11.2**	
9	9/9/04	13	**10.2**	5.0	**5.0**	1.3			**11.6**	**5.7**	
10	30/9/04	10	**13.3**	0.2					**26.6**		
11	10/12/04	17	**15.4**	0.8					**11.2**		
13	23/2/05	13	**9.0**	1.3	**2.9**	0.5			**10.3**	**3.3**	
14	7/3/05	13	**13.7**	1.3					**15.7**		
15	24/3/05	14	**7.1**	0.5					**7.1**		
21	16/12/05	14	**22.8**	2.7					**22.8**		
22	6/1/06	14	**14.6**	2.0			**15.6**	2.3	**14.6**		**15.6**
23	3/2/06	14	**13.7**	0.2					**13.7**		
24	1/9/06	14	**9.9**	1.8					**9.9**		
25	11/9/06	14	**8.3**	1.2					**8.3**		
26	15/11/06	14	**15.4**	1.4					**15.4**		
Tubs											
18a	10/8/05	12	**16.2**	1.5			**11.5**	0.9	**21.6**		**15.4**
18b	30/08/05	14	**18.1**	0.8			**16.2**	1.3	**18.1**		**16.2**
Mean – on plants			**14.1**		**5.4**		**15.6**		**15.3**	**5.8**	**15.6**
se			1.3		1.6		-		1.4	1.5	-
Max			31.8		11.2		15.6		28.3	11.2	15.6
Min			7.1		2.3		-		7.1	2.6	-
n			**18**		**5**		**1**				
Mean – all			**14.4**		**-**		**14.4**		**15.8**	**5.8**	**15.7**
se			1.2		-		1.5		1.3	1.5	0.2
Max			31.8		-		16.2		28.3	11.2	16.2
Min			7.1		-		11.5		7.1	2.6	15.4
n			**20**		**-**		**3**				

Table 8: RI values uncorrected, corrected for adult thrips mortality[1], and standardised to RI_{14} for five trials in which assessment of adult mortality was made.

		Uncorrected		Corrected[1]		RI_{14} Uncorrected		RI_{14} Corrected[1]	
Trial	**Days**	**Bp**	**Bd**	**Bp**	**Bd**	**Bp**	**Bd**	**Bp**	**Bd**
5a	13	**12.8**	2.3	**17.3**	3.9	**14.6**	2.6	**18.6**	4.2
5b	13	**12.1**	5.5	**14.4**	5.5	**13.8**	6.3	**15.5**	5.9
6	14	**14.5**	11.2	**17.2**	13.9	**14.5**	11.2	**17.2**	13.9
9	13	**10.2**	5.0	**13.2**	8.0	**11.6**	5.7	**14.2**	8.6
10	10	**13.3**		**14.6**		**26.6**		**20.4**	
Mean		**12.6**	6.0	**15.3**	7.8	**16.2**	6.5	**17.2**	8.2

[1] Estimated by counting dead adult thrips remaining in inoculation tubes in cages at the end of the trial

3.5 EXPERIMENTS

Introduction

The details of 29 experiments are presented in this section in chronological order. The methods for each experiment are provided without a specific methods subhead.

Experiment 1

S. aurantii adults were placed into cages on potted *B. pinnatum* (25 thrips on each of 2 plants), sweet orange seedlings (25, 40 & 50 thrips on each of 4, 1 & 2 plants - a total of 240 thrips on 7 plants) and woolly grevillea *Grevillea lanigera* (50 thrips on each of two plants). Surviving adults and offspring larvae were counted at 14 days (on 30.4.04).

Results & Discussion

Seventy percent of F_0 adult thrips survived for the 14 days of this trial on *B. pinnatum*, whereas less than 1 and zero percent survived on sweet orange seedlings or *G. lanigera*.

The two *B. pinnatum* cages produced 517 offspring thrips (all L1s & L2s), giving RI_{14} values of 11.5 and 19.3, with a mean 15.4. *G. lanigera* produced no offspring thrips, and 7 sweet orange seedlings only 16 larvae. The mean RI_{14} for citrus was less than 1%, for *G. lanigera* it was zero.

Table 9: Performance of *S. aurantii* on *B. pinnatum*, sweet orange & woolly grevillea at 14 days. Rate of increase (RI) & standard error (se) values assume 67% of F_0 thrips were female.

		F_0	Offspring			Surviving adults				
Test host	**Rep.**	**thrips**	**L1**	**L2**	**Pupae**	**No.**	**%**	**RI_{14}**	**se**	**RRI (%)**
B. pinnatum	1	25	>	324	0	20	80	19.3		
	2	25	>	193	0	15	60	11.5		
	Total	50	>	517	0	**35**	**70**	**15.4**	**3.9**	**100**
C. sinensis	1	25	0	0	0	0	0	0		
	2	25	0	0	0	0	0	0		
	3	25	0	0	0	0	0	0		
	4	25	0	0	0	0	0	0		
	5	40	3	2	0	0	0	0.15		
	6	50	7	4	0	3	6	0.3		
	7	50	0	0	0	0	0	0		
	Total	240	10	6	0	**3**	**1**	**0.06**	**0.04**	**0.4**
G. lanigera	1	50	0	0	0	0	0	0		
	2	50	0	0	0	0	0	0		
	Total	100	0	0	0	**0**	**0**	**0**	**0**	**0**

Experiments 2, 3 & 4

In experiments 2 & 3, *S. aurantii* adults were caged on potted plants of 17 species, 20 - 25 adults per cage on 1 - 10 cages per species (26.5 - 15.6.04) (**Table 10)**. In experiment 4, three green bean pods were washed, dried and exposed to150 adults in a ventilated plastic container (19 - 30.4.04). Larvae, pupae and surviving adults were counted at 11 - 18 days for most treatments; two sets of 3 replicates on potted mango were assessed at 41 - 42 days (6 & 7.7.04).

Results & Discussion

In experiments 2, 3 & 4, no F_0 adult thrips survived on sweet orange seedlings, castor oil, *Callitris* or soybean. Survival was < 10% on forest red gum, red grapefruit, lemon, lillypilly and banana, 15 - 33% on golden and coast wattles, silky oak, lime and bean pods; on mango, macadamia and *B. pinnatum* F_0 adult thrips survival was 45 - 73%.

B. pinnatum was the most productive host in experiment 2, with 746 offspring thrips in the best cage at 15 days, and a mean of 426 per cage. RI_{14} values were 16.8 - 49.5, mean 28.3. The RI_{14} for the single 15 day mango cage was 8.8, for the cages run for 20 days 6.0 - 12.5, mean 9.2, with the best cage producing 293 offspring. *Acacia longifolia* and *A. sophorae* had means of 88 and 103 offspring thrips per cage, maxima of 133 and 123, and RI_{14} values of 3.3 - 8.8.

The natives, forest red gum *Eucalyptus tereticornis* and silky oak *G. robusta* produced very few offspring (cage maxima 30 & 11); sweet orange, grapefruit, lime and lemon also produced very few thrips (cage maxima 8-38); castor oil produced no offspring. In the extended mango trials, one set of 3 cages produced few thrips (cage max. 42), the other produced a mean of 271; the best cage had 545 offspring thrips, an uncorrected RI 40.7 times the estimated F_0 inoculum of 13 female thrips. RI_{14} values for the extended mango trial were 0.3 - 9.0.

Relative to *B. pinnatum*, performance in experiment two was 31-33% and 16% for mango trials run for 15, 20 and 41 - 42 days; 21-24% for the two Acacia species, and < 3% for the remaining species. If these data are compared with mean reference host performance (RI_{14} = 15.3), they become 57 - 61% and 30% for mango for 15, 20 & 41 - 42 days; and 39 - 44% for the Acacias.

In experiment 3, *B. pinnatum* was again the most productive (RI_{14} = 17.8 - 23.6, mean 21.5). The single macadamia cage produced 157 thrips (RI_{14} = 12.5; or 81.2% of mean *B. pinnatum* performance). Lillypilly, soybean and sweet orange produced cage maxima of 1 - 9 thrips; *Callitris* and banana produced no offspring. In Experiment 4, despite adult thrips survival on green bean pods of 33% (50 of 150 thrips alive at 11 days), no offspring thrips were produced.

In experiments 2 & 3 the age distribution of offspring thrips (**Table 11a**) was slightly retarded on macadamia compared with *B. pinnatum* at 12 days; at 15 days, mango was slightly ahead (48% cf 28% pupae). Development on the Acacias, red gum and citrus was slightly retarded, but only by a day or two. On mango at 20 days, 19% of the thrips population were adults.

On mango at 6 weeks most leaves in 5 of the 6 cages were hard and unsuitable for thrips feeding or breeding, the age distribution was adult dominated (88-93%), and all soft terminal leaves (up to 3 - 4 cm long) were black and severely damaged. The one cage with soft, viable leaves had 545 thrips, 95% of which were juveniles (**Table 11b**). The mean mango RI_{14} was 2.5; for the best cage 9.0, and compared with the *B. pinnatum* trial mean, relative performance was 32%. Using mean *B. pinnatum* performance in 18 trials (**Table 7**, RI 15.3), the best two mango cages produced 27 & 59% as many thrips per F_0 female as the reference host.

Table 10: *S. aurantii* performance on 17 plant species exposed to adult thrips in on-plant cages (F_0).
Rate of increase (RI) & standard error (se) values calculated on the assumption that 67% of F_0 adults were female. RRI is % of the reference host, *B. pinnatum*.

Test host	Common name	Reps x thrips	Days	% adult survival Mean	(se)	Offspring Mean	(se)	Range Min	Max	RI_{14} range Min	Max	Mean/14dd[1] RI	se	RRI (%)
Experiment 2														
B. pinnatum	Green MoM	3 x 20	15	73	(3)	426	(160)	254	746	16.8	**49.5**	**28.3**	10.6	**100**
Mangifera indica	Mango	1 x 20	15	45	(0)	132	(0)	---	132	-	**8.8**	**8.8**	-	**31**
M. indica	Mango	2 x 20	20	---	---	217	(77)	140	293	6.0	**12.5**	**9.2**	3.3	**33**
A. sophorae	Coast wattle	3 x 20	15	17	(4)	103	(14)	77	123	5.1	**8.2**	**6.8**	0.9	**24**
Acacia longifolia	Golden wattle	3 x 20	15	30	(9)	88	(24)	49	133	3.3	**8.8**	**5.9**	1.6	**21**
Eucalyptus tereticornis	Forest red gum	3 x 20	15	3	(3)	13	(9)	4	30	0.3	**2.0**	**0.9**	0.6	**3**
Citrus sinensis	Navelina	3 x 20	15	0	---	3	(3)	0	8	0	**0.5**	**0.2**	0.2	**0.6**
C. x paradisi	Red grapefruit	3 x 20	15	2	(2)	15	(6)	5	26	0.3	**1.7**	**1.0**	0.4	**3**
C. x latifolia	Tahitian lime	3 x 20	15	15	(5)	14	(12)	0	38	0	**2.5**	**1.0**	0.8	**3**
C. x limon	Eureka lemon	3 x 20	15	8	(2)	10	(2)	7	15	0.5	**1.0**	**0.7**	0.2	**2**
Grevillea robusta	Silky oak	3 x 20	15	17	(17)	5	(3.2)	0	11	0	**0.7**	**0.3**	0.2	**1**
Ricinus communis	Castor oil	3 x 20	15	0	---	0	---	0	---	0	**0**	**0**	0	**0**
M. indica	Mango	3 x 20	**41**	---	---	34	(7)	19	42	0.3	**0.7**	**0.6**	0.1	**2**
M. indica	Mango	3 x 20	**42**	---	---	271	(151)	24	545	0.4	**9.0**	**4.5**	2.5	**16**
Experiments 3 & 4														
B. pinnatum	Green MoM	3 x 25	12	57	(16)	271	(24)	223	297	17.8	**23.6**	**21.5**	1.9	**100**
Macadamia integrifolia	Macadamia	1 x 25	12	56	---	157	---	---	157	-	**12.5**	**12.5**	-	**58**
Syzygium australe	Lillypilly	2 x 25	16	6	(6)	1	(1)	0	2	0	0.1	**0.05**	0.05	**0.2**
Glycine max	Soybean (Dragon)	4 x 25	16	0	---	3	(2)	0	9	0	0.4	**0.2**	0.09	**0.7**
C. sinensis	Sweet orange	10 x 25	16	0	---	0	---	0	1	0	0.05	**0.01**	0.01	**0.02**
Callitris columellaris	Bribie Is. pine	3 x 25	18	0	---	0	---	0		0	0	**0**	0	**0**
Musa acuminata[1]	Banana	6 x 25	16	5	(5)	0	---	0	---	0	0	**0**	0	**0**
Phaseolus vulgaris	Green beans pods	1 x 150	11	33	---	0	---	0	---	0	0	**0**	0	**0**

[1] Means standardised to RI per 14 days, except 2 mango trials (shaded) run for 41 & 42 days; RRI values calculated by comparison with Bp at 14 days
[2] Musa – 2 x cv. Lady Finger, 1 x cv. Williams, 3 x cv. GF

Table 11a: Cage mean offspring age distributions (% in each stage) by days after inoculation.

Common name	Days	Reps	No. thrips	L1	se	L2	se	Pupae	se	F_1 adults	se
B. pinnatum	**12**	3	812	**69**	2.9	**30**	2.9	**1**	0.9	**0**	0
Macadamia	**12**	1	157	**89**		**11**		**0**		**0**	
B. pinnatum	**15**	3	1279	**40**	5.0	**26**	2.6	**28**	8.4	**5**	4.9
Mango	**15**	1	132	**38**		**14**		**48**		**0**	
Acacia (2 species)	**15**	6	573	**52**	3.7	**33**	2.3	**15**	2.8	**0**	
Forest red gum	**15**	3	39	**58**	13.1	**32**	14.8	**11**	7.5	**0**	0
Citrus (3 varieties)	**15**	8	118	**66**	11.6	**21**	6.9	**13**	10.0	**0**	0
Mango	**20**	2	433	**29**	5.0	**18**	0.9	**34**	2.2	**19**	3.7
Means by DAI											
B. pinnatum & Mac	**12**	4	969	**79**	9.9	**21**	9.3	**1**	0.5	**0**	0.0
Bp - Citrus (8 var's)	**15**	21	2141	**51**	5.3	**25**	3.6	**23**	7.1	**1**	1.0
Mango	**20**	2	433	**29**	5.0	**18**	0.9	**34**	2.2	**19**	3.7

Table 11b: Performance by replicate of *S. aurantii* in cages on potted mango at 6 weeks.
Note that in 5 of the 6 cages (reps 4 - 8) the thrips population was adult dominated, with almost no juvenile thrips. All leaves in these cages were heavily damaged by thrips feeding and unsuitable for breeding; the one cage with leaves suitable for breeding (replicate 6) had large numbers of juvenile thrips.

		Offspring thrips						As recorded[1]		cf trial Bp[2]		cf mean Bp[3]
Days	Rep	L1	L2	Pupae	Adults	Total	% A's	RI	RRI%	RI_{14}	RRI%	RRI%
41	4	0	2	2	**36**	40	**90**	3.0	9	0.7	2	5
	5	1	1	0	**17**	19	**89**	1.4	5	0.3	1	2
	6	1	2	1	**38**	42	**90**	3.1	10	0.7	3	5
42	7	0	3	0	**21**	24	**93**	1.8	6	0.4	1	3
	8	0	9	7	**229**	245	**88**	18	58	4.1	**14**	**27**
	9	10	492	17	**26**	545	**5**	41	128	9.0	**32**	**59**
Total		12	509	27	367	915						
Mean		**2**	**85**	**5**	**61**	**153**	**76**	**11.4**	**35.8**	**2.5**	**9.0**	**16.6**
se		2	81	3	34	86	14.3	6.4	20.2	1.4	5.0	9.3

[1] total thrips at 41 - 42 dd divided by No. female thrips (20 x 0.67), RRI compared with trial Bp at 15 dd
[2] Bp & mango production standardised to per 14 days, RRI compared with Bp trial mean RI (= 28.3)
[3] RRI compared with mean of 18 trials (15.3), since Bp RI this trial is the highest of all 18 trials

Experiment 5

S. aurantii reared on *B. pinnatum* (~ 20 females & 10 males; sexed by size – females are bigger than males - and aspirated from culture leaves under a stereo microscope) were added to on-plant cages on potted mango (5 reps), sweet orange seedlings (3 reps), *B. delagoense* (5 reps) and *B. pinnatum* (5 reps). Thrips adults (20 female, 10 male) reared on mango were placed into cages on mango (3 reps), sweet orange (3 reps), *B. pinnatum* (2 reps) and *B. delagoense* (1 rep) (on 13 - 15.7.04).

Dead adults remaining in the inoculation tube, and offspring larvae, pupae and adult thrips were counted at 13 days (on 26 - 28.7.04). RI values were calculated for uncorrected and corrected numbers of adult thrips; i.e. offspring numbers divided by 20 for uncorrected, divided by 20 minus 0.67 times the number dead in the inoculum tube for corrected.

Results & Discussion

In this trial adult survival was corrected for F_0 mortality estimated by the number of dead adults remaining in inoculum tubes at the end of the trial. Mean survival was 50% for adults reared on *B. pinnatum* caged on *B. pinnatum* and citrus (orange 68 - 74%, Kumquat 0%), and for adults reared on mango caged on mango 57%, and on *B. pinnatum* 50%. Survival on *B. delagoense* and mango of adult thrips reared on *B. pinnatum* was 41 and 30%, and 16% of adult thrips reared on mango survived for 13 days caged on flush leaves on potted citrus.

Mean offspring per cage for thrips reared on *B. pinnatum* and on mango caged on *B. pinnatum* was 256 & 242; on *B. delagoense* 46 & 110; on mango 67 & 141; and on citrus 13 & 2.

Performance relative to the reference host *B. pinnatum* for thrips reared on *B. pinnatum* and on mango caged on *B. pinnatum* was 100% & 95%; on *B. delagoense* 18% & 43%; on mango 26% & 55%; and on citrus 5% & 0.7%.

Table 12: Performance of *S. aurantii* reared on *B. pinnatum* (Bp) and mango at 13 days.

Host		Larvae & pupae			Adults		Total		% A's			RRI
Origin	**Test**	**L1**	**L2**	**Pupae**	**Live**	**Dead**	**L&P**	**All**	**Dead**	**Live**	**RI_{14}**	**(%)**
Bp	Bp 1	59	181	0	12	11	240	**252**	37	63	13.7	
	2	44	128	0	15	9	172	**187**	30	71	9.8	
	3	140	325	65	12	6	530	**542**	20	50	30.3	
	4	23	108	0	7	8	131	**138**	27	32	7.5	
	5	48	160	0	13	6	208	**221**	20	54	11.9	
	Total	314	902	65	59	40	1281	1340				
	Mean	**63**	**180**	**13**	**12**	**8**	**256**	**268**	**27**	**54**	**14.6**	**100**
	se	20.2	38.3	13.0	1.3	0.9	71	71	3.2	6.7	4.0	
	Propn	**25**	**70**	**5**			**100**					
Bp	Bd 1	2	9	0	3	16	11	**14**	53	21	0.6	
	2	14	62	0	14	10	76	**90**	33	70	4.3	
	3	10	43	0	3	12	53	**56**	40	17	3.0	
	4	2	12	0	10	8	14	**24**	27	45	0.8	
	5	17	57	0	8	14	74	**82**	47	50	4.2	
	Total	45	183	0	38	60	228	266				
	Mean	**9**	**37**	**0**	**8**	**12**	**46**	**53**	**40**	**41**	**2.6**	**18**
	se	3.1	11.1	0.0	2.1	1.4	14	15	4.7	9.8	0.8	
	Propn	**20**	**80**	**0**			**100**					
Bp	Mango 1	108	129	0	11	6	237	**248**	20	46	13.5	
	2	0	0	0	5	6	0	**5**	20	21	0.0	
	3	6	29	0	11	4	35	**46**	13	42	2.0	
	4	0	14	0	6	3	14	**20**	10	22	0.8	
	5	8	43	0	5	0	51	**56**	0	17	2.9	
	Total	122	215	0	38	19	337	375				
	Mean	**24**	**43**	**0**	**8**	**4**	**67**	**75**	**13**	**30**	**3.9**	**26**
	se	21.0	22.7	0.0	1.4	1.1	43	44	3.7	6.0	2.5	
	Propn	**36**	**64**	**0**			**100**					
Bp	Orange 1	1	1	0	16	8	2	**18**	27	73	0.1	
	2	2	20	0	14	11	22	**36**	37	74	1.3	
	3	5	21	0	15	8	26	**41**	27	68	1.5	
	Kumquat	1	1	0	0	18	2	**2**	60	0	0.1	
	Total citrus	9	43	0	45	45	52	97				
	Mean	**2**	**11**	**0**	**11**	**11**	**13**	**24**	**38**	**54**	**0.7**	**5**
	se	0.9	5.6	0.0	3.8	2.4	6.4	8.9	7.9	17.9	0.4	
	Propn	**17**	**83**	**0**			**100**					
Mango	Bp 1	46	145	0	14	6	191	**205**	20	58	10.9	
	2	82	211	0	11	4	293	**304**	13	42	**16.7**	
	Total	128	356	0	25	10	484	509				
	Mean	**64**	**178**	**0**	**13**	**5**	**242**	**255**	**17**	**50**	**13.8**	**95**
	se	18.0	33.0	0.0	1.5	1.0	51	50	3.3	8.0	2.9	
	Propn	**26**	**74**	**0**			**100**					
Mango	Bd	38	72	0	12	0	110	**122**	0	40	**6.3**	**43**
Mango	Mango 1	35	104	0	10	11	139	**149**	37	53	7.9	
	2	26	82	0	7	0	108	**115**	0	23	6.2	
	3	49	110	18	24	5	177	**201**	17	96	10.1	
	Total	110	296	18	41	16	424	465				
	Mean	**37**	**99**	**6**	**14**	**5**	**141**	**155**	**18**	**57**	**8.1**	**55**
	se	6.7	8.5	6.0	5.2	3.2	20	25	10.6	21.1	1.1	
	Propn	**26**	**70**	**4**	**-**	**-**	**100**					
Mango	Orange 1	0	0	0	5	10	0	**5**	33	25	0.0	
	2	0	5	0	2	15	5	**7**	50	13	0.3	
	3	0	0	0	2	11	0	**2**	37	11	0.0	
	Total	0	5	0	9	36	5	14				
	Mean	**0**	**2**	**0**	**3**	**12**	**2**	**5**	**40**	**16**	**0.1**	**0.7**
	se	0	1.7	0.0	1.0	1.5	1.7	1.5	5.1	4.4	0.1	

Experiment 6

S. aurantii adults (~ 20 female & 10 male) reared on *B. pinnatum* were added to cages on *B. delagoense* (3 reps), citrus (3 reps Hickson, 3 lemon, 1 lime & 1 grapefruit), macadamia (1 rep), mock orange (2 reps), castor oil (3 reps) and *B. pinnatum* (5 reps) (on 29 - 30.7.04). Dead adults remaining in the inoculation tube, and offspring larvae, pupae and adult thrips were counted 14 days post-establishment (on 12 - 13.8.04).

Results & Discussion

One of the *B. pinnatum* cages produced only 116 offspring thrips, compared with 299 and 454 in the other two; mean offspring thrips per cage was 314; mean RI_{14} 14.5. *B. delagoense* produced a mean of 223 offspring thrips, with RI_{14} values 9.4 - 14.0, a mean of 11.2 and performance relative to *B. pinnatum* of 77% (**Table 13**).

The single macadamia cage produced 417 offspring thrips, an RI_{14} of 20.2 and relative performance compared with *B. pinnatum* of 139%.

No adult *S. aurantii* survived on *Murraya* or *Ricinus*; the former produced only 2 larvae.

Survival of F_0 adults on citrus was greater than 60% in individual cages on lemon, grapefruit and Hickson mandarin, with a mean over the 8 cages of 39%. The Hicksons produced no offspring thrips; 4 of the 5 cages on the other varieties produced 25 - 70; the fifth cage, on lemon, had 133 offspring thrips, including 10 pupae, an RI_{14} of 6.7, and performance relative to *B. pinnatum* of 46%, and compared to *B. delagoense* of 60%.

The age distributions of offspring thrips on *B. pinnatum*, *B. delagoense*, macadamia and the best lemon cage were comparable, with 52 - 72% of populations as L2's and 5 - 13% pupae; those in the remaining citrus cages were slightly retarded, with more L1's and no pupae.

Table 13: *S. aurantii* performance on *B. pinnatum*, *B. delagoense*, Macadamia, citrus of 4 varieties, mock orange and castor oil.

Test host		L1	L2	Pupae	Adults Live	Adults Dead	Total L&P	Total All	% Adults Dead	% Adults Live	RI_{14}	RRI (%)
B. pinnatum	1	34	80	2	21	3	116	**137**	10	-	5.8	
	2	169	201	84	27	6	454	**481**	20	-	22.7	
	3	96	170	33	24	3	299	**323**	10	-	15.0	
	Total	299	451	119	72	12	869	941		-		
	Mean	**100**	**150**	**40**	**24**	**4**	**290**	**314**	**13**	**-**	**14.5**	**100**
	se	39.0	36.3	23.9	1.7	1.0	98	99	3.3	-	4.9	
	Propn	**34**	**52**	**14**	**-**	**-**	**100**					
B. delagoense	1	61	202	17	21	8	280	**301**	27	-	14.0	
	2	50	135	3	16	6	188	**204**	20	67	9.4	
	3	46	144	12	14	2	202	**216**	7	50	10.1	
	Total	157	481	32	51	16	670	721				
	Mean	**52**	**160**	**11**	**17**	**5**	**223**	**240**	**18**	**58**	**11.2**	**77**
	se	4.5	21.0	4.1	2.1	1.8	29	31	5.9	8.3	1.4	
	Propn	**23**	**72**	**5**	**-**	**-**	**100**					
Macadamia	1	**68**	**284**	**52**	**13**	**4**	**404**	**417**	**13**	**50**	**20.2**	**139**
	Propn	**17**	**70**	**13**	-	-	**100**					
Lemon	**1**	**45**	**78**	**10**	**14**	**6**	**133**	**147**	**20**	**58**	**6.7**	**46**
	2	33	37	0	16	6	70	**86**	20	67	1.3	
	3	7	18	0	5	0	25	**30**	0	17	3.5	
Lime	1	27	43	0	1	4	70	**71**	13	4	3.5	
Grapefruit	1	16	44	0	17	3	60	**77**	10	63	3.0	
Hickson	1	0	0	0	6	2	0	**6**	7	21	0	
	2	0	0	0	6	0	0	**6**	0	20	0	
	3	0	0	0	12	11	0	**12**	37	63	0	
	Total	128	220	10	77	32	358	435				
	Mean	**16**	**28**	**1**	**10**	**4**	**45**	**54**	**13**	**39**	**2.2**	**15**
	se	6.1	9.9	1.3	2.1	1.3	17	18	4.3	9.2	0.8	
	Propn	**36**	**61**	**3**	**-**	**-**	**100**					
Mock orange	1	0	2	0	0	6	2	**2**	20	0	0.1	
	2	0	0	0	0	5	0	**0**	17	0	0.0	
	Total	0	2	0	0	11	2	2				
	Mean	**0**	**1**	**0**	**0**	**6**	**1**	**1**	**18**	**0**	**0.1**	**0.3**
	se	0	1.0	0	0	0.5	1.0	1.0	1.7	0	0.1	
Castor oil	1	0	0	0	0	10	0	**0**	33	0	0	
	2	0	0	0	0	4	0	**0**	13	0	0	
	3	0	0	0	0	2	0	**0**	7	0	0	
	Total	0	0	0	0	16	0	0				
	Mean	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**18**	**0**	**0**	**-**
	se	0	0	0	0	2.4	0.0	0.0	8.0	0.0	0	

Experiments 7 & 8

Thirty adult thrips (~ 20 female & 10 male) reared on *B. pinnatum* were placed into single cages on 9 potted Kensington mango trees with new leaves on 15.7.04; 40 adults (30 female & 10 male) were placed into another 9 cages on 30.7.04. Dead adults in inoculation tubes, offspring larvae, pupae and adult thrips were counted at 33 & 34 days (on 17 - 18.8.04) for the first nine cages, and at 20, 25 & 26 days (on 19, 24 & 25.8.04) for the second nine.

Results & Discussion

Three of the first batch of 9 cages produced almost no thrips, and the foliage was clearly unsuitable for thrips utilisation; these data are not shown in **Table 14**. Because these trials ran for an extended period, RI values are shown as recorded, as well as adjusted to per 14 days, and are based on total thrips.

In experiment 7, the 6 cages produced a total of 2257 thrips, with a mean of 376 per cage; two cages produced less than 50 thrips, two more than 300, and the best 1337 thrips, giving RI values for 33 - 34 days of 1.3, 1.8, 17, 18 & 67, with a cage mean of 18.8.

Adjusted to thrips per female per 14 days, the best cage's RI_{14} was 19.8, the next two 4.5 & 5.1, and the mean 5.5. When compared with mean performance from 18 trials on *B. pinnatum* (RI_{14} 15.3), the best cage represents performance of 129%, and the mean 36% of the performance of *S. aurantii* on the reference host.

Table 14: Performance of *S. aurantii* on mango at 33 & 34 days.

					Adults		Total		% dead		
Cage	**DAI**	**L1**	**L2**	**Pupae**	**Live**	**Dead**	**L&P**	**All**	**adults**	**RI**	**RI_{14}**
1	**33**	437	649	162	89	0	1248	**1337**	0	67	19.8
2	**34**	104	216	17	23	6	337	**360**	15	18	5.1
3	**34**	6	21	4	5	8	31	**36**	20	1.8	0.5
4	**34**	5	11	3	146	0	19	**165**	0	8.3	2.4
5	**34**	3	19	0	4	0	22	**26**	0	1.3	0.4
6	**34**	31	82	16	204	0	129	**333**	0	17	4.8
	Total	586	998	202	471	14	1786	2257			
	Mean	**98**	**166**	**34**	**79**	**2**	**298**	**376**	**6**	**18.8**	**5.5**
	se	70	102	26	34	2	197	201	4	10	3
	Propn	**26**	**44**	**9**	**21**	**-**	**-**	**100**			

In experiment 8, the nine cages produced 4942 thrips, a mean per cage of 549; three cages produced less than 200 thrips, one produced 358, and the remaining five 593 - 1074, giving RI values of 2.6 - 35.8.

Adjusted, the RI_{14} values were 1.0 - 2.3 for the worst three cages, 6.8 & 7.9 for two cages, and 13.1 - 17.7 for the remaining four cages; the RI_{14} mean per cage was 7.7 (**Table 15**). When compared with performance from 18 trials on *B. pinnatum* (RI_{14} 15.3), the best cage represents performance of 116%, and the mean 50% of that on the reference host.

The variability in these two experiments was high; some cages produced few thrips, others very large numbers. The age distribution also was highly variable; some cages had a high proportion of juveniles (Experiment 7 – cages 1 & 2), others a high proportion of adults and few juveniles (Experiment 7 - cages 4 & 6, Experiment 8 - all except cages 4 & 5).

This variability reflected the state of the leaves during the course of these experiments, which were run for long enough for the original leaves to harden and new ones to be produced. In cages in which most leaves had hardened and few soft leaves were available, the thrips population was skewed towards adults, and the terminals and small new leaves were severely damaged. The predominance of juveniles occurred in cages in which soft young leaves were available, as was the case in experiment 2 in which mango trials were run for 41 - 42 days.

Table 15: Performance of *S. aurantii* on mango at 20, 25 & 26 days.

					Adults		Total		% dead		
Cage	**DAI**	**L1**	**L2**	**Pupae**	**Live**	**Dead**	**L&P**	**All**	**adults**	**RI**	**RI_{14}**
1	**20**	11	117	82	478	0	210	**688**	0	22.9	13.1
2	**20**	3	46	25	284	0	74	**358**	0	11.9	6.8
3	**20**	45	121	82	645	0	248	**893**	0	29.8	17.0
4	**20**	58	288	143	442	6	489	**931**	15	31.0	17.7
5	**25**	16	70	9	68	0	95	**163**	0	5.4	2.3
6	**25**	36	95	31	912	0	162	**1074**	0	35.8	15.1
7	**26**	0	3	0	161	0	3	**164**	0	5.5	2.2
8	**26**	0	5	0	73	3	5	**78**	8	2.6	1.0
9	**26**	0	16	10	567	0	26	**593**	0	19.8	7.9
	Total	169	761	382	3630	9	1312	4942			
	Mean	**19**	**85**	**42**	**403**	**1**	**146**	**549**	**3**	**18.3**	**7.7**
	se	7	30	16	95	1	52	125	2	4.2	2.9
	Propn	**3**	**15**	**8**	**74**	**-**	**-**	**100**			

Experiment 9

Thirty adult thrips (~ 20 female & 10 male) reared on *B. pinnatum* were placed into cages on potted plants with soft new leaves of 11 test hosts including *B. pinnatum* and *B. delagoense* (3 reps each), peach (2 reps), *Acacia sophorae* and *Grevillea robusta* (1 rep each), *Eucalyptus tereticornis* (2 reps), avocado (3 reps) and 4 species of citrus (Navelina – 4 reps, grapefruit – 3 reps, lime – 5 reps, lemon – 1 rep) (on 25 & 26.8.04). Dead adults remaining in the inoculation tube, and offspring larvae, pupae and adults were counted for the 2 *Bryophyllum* species 13 and 15 days post-establishment for the remainder (on 8 & 9.9.04).

Results & Discussion

Survival of the F_0 adult thrips for *B. pinnatum* and *B. delagoense* was 56% & 53%, for peach 88%, for *A. sophorae* and *G. robusta* 44% and 8%, for *E. tereticornis* and avocado 10% and 4% and for citrus 15%, though in three cages survival on citrus was 39 - 56% (**Table 16**).

Two of the three *B. pinnatum* cages performed poorly, producing only 50 and 152 offspring thrips, the third produced 373, and the cage mean was 192. *B. delagoense* and peach produced means of 91 and 45, and the single *A. sophorae* cage 46 offspring thrips per cage. *Grevillea*, Eucalyptus, avocado and citrus produced very few thrips.

By comparison with *B. pinnatum*, *B. delagoense* produced 49% as many offspring thrips, peach 26% and *A. sophorae* 22%; the other tested species less than 6% of the numbers on the reference host.

Table 16: Performance of *S. aurantii* on 11 test host species.

					Adults		Total		% Adults			RRI
Test host	**Rep**	**L1**	**L2**	**Pupae**	**Live**	**Dead**	**L&P**	**All**	**Dead**	**Live**	**RI_{14}**	**(%)**
B. pinnatum	1	153	220	0	20	6	373	**393**	20	83	22.5	
	2	6	18	26	4	17	50	**54**	57	31	3.1	
	3	41	101	10	12	8	152	**164**	27	55	9.4	
	Total	200	339	36	36	31	575	611				
	Mean	**67**	**113**	**12**	**12**	**10**	**192**	**204**	**34**	**56**	**11.6**	**100**
	se	44	59	8	5	3	95	100	11	15	5.7	
	Propn	**35**	**59**	**6**	**-**	**-**	**100**					
B. delagoense	1	16	38	0	7	15	54	**61**	50	47	3.5	
	2	36	44	4	8	15	84	**92**	50	53	5.3	
	3	58	72	6	12	10	136	**148**	33	60	8.5	
	Total	110	154	10	27	40	274	301				
	Mean	**37**	**51**	**3**	**9**	**13**	**91**	**100**	**44**	**53**	**5.7**	**49**
	se	12	11	2	2	2	24	26	6	4	1.5	
	Propn	**40**	**56**	**4**	**-**	**-**	**100**					
Peach	1	20	35	0	21	8	55	**76**	27	95	3.4	
	2	14	21	0	24	0	35	**59**	0	80	2.6	
	Total	34	56	0	45	8	90	135				
	Mean	**17**	**28**	**0**	**23**	**4**	**45**	**68**	**13**	**88**	**3.0**	**26**
	se	3	7	0	2	4	10	9	13	8	0.4	
	Propn	**38**	**62**	**0**	**-**	**-**	**100**					
A. sophorae	1	12	34	0	12	3	46	**58**	10	44	**2.6**	**22**
G. robusta	1	0	10	0	2	5	10	**12**	17	8	0.5	**5**
Eucalyptus	1	0	3	0	6	5	3	**9**	17	24	0.4	
	2	0	10	0	2	0	10	**12**	0	7	0.5	**4**
Avocado	1	0	2	0	0	0	2	**2**	0	0	0.1	
	2	0	0	0	0	0	0	**0**	0	0	0.0	
	3	0	5	0	4	0	5	**9**	0	13	0.4	**2**
Navelina	1	1	0	0	0	5	1	**1**	17	0	0.0	
	2	0	0	0	5	0	0	**5**	0	17	0.2	
	3	0	0	0	11	2	0	**11**	7	39	0.5	
	4	0	0	0	15	3	0	**15**	10	56	0.7	**3**
Grapefruit	1	2	19	1	3	2	22	**25**	7	11	1.1	
	2	3	7	0	2	0	10	**12**	0	7	0.5	
	3	0	7	0	2	0	7	**9**	0	7	0.4	**6**
Lime	1	0	4	0	1	0	4	**5**	0	3	0.2	
	2	0	6	0	0	10	6	**6**	33	0	0.3	
	3	0	0	0	0	16	0	**0**	53	0	0.0	
	4	3	27	0	3	0	30	**33**	0	10	1.5	
	5	1	5	0	3	23	6	**9**	77	43	0.4	**4**
Lemon	1	0	5	0	2	0	5	**7**	0	7	0.3	3
Total – all citrus		10	80	1	47	61	91	138				
	Mean	**1**	**6**	**0**	**4**	**5**	**7**	**11**	**16**	**15**	**0.5**	**4**
	se	0.3	2	0.1	1	2	3	3	7	5	0.1	
	Propn	**11**	**88**	**1**	**-**	**-**	**100**					

Experiment 10

S. aurantii adults (~ 35 females, 15 males per cage) reared on *B. pinnatum* were added to single cages on potted *B. pinnatum* (2 replicates), lemon (3 reps), grapefruit (9 reps), lime, Hickson mandarin (1 rep each) and *Eucalyptus tereticornis* (2 reps) with soft leaves (on 10 & 17.9.04).

On a single potted mango with 5-6 mm long fruitlets, 20 thrips were added to each of 4 cages with 2 or 3 fruitlets (n = 4), and 40 thrips (~25 females & 15 males) to each of 3 cages with 4, 5 and 12 fruitlets (n = 4).

Dead adults remaining in the inoculation tube, and offspring larvae, pupae and adults were counted for the 2 reps of Bryophyllum and 4 reps of citrus (3 x lemon, 1 x grapefruit) after 10 days (on 20.9.04), for the remaining citrus and the Eucalyptus at 12 & 13 days (29 & 30.9.04) and for the mango at 14 days (on 27.9.04).

Results & Discussion

Mean survival of F_0 adults on *B. pinnatum* was 56%, citrus 50% and *E. tereticornis* 41%. The proportion of inoculated adults dead in the inoculation tubes was 9%, 18% and 8%.

The two *B. pinnatum* cages produced 930 offspring thrips (excluding surviving F_0 adults) in 10 days, a mean of 465 per cage, giving an RI_{14} of 26.6 (the 2nd highest of our trials). The mean for all 15 citrus cages was 40 offspring thrips per cage, an RI_{14} of 1.5 and relative performance compared with *B. pinnatum* of 6%, however, 1 cage on lime produced 188 offspring thrips at 12 days, an RI_{14} of 7.2. Because of the high RI_{14} on the reference host in this trial, this represented a relative performance of only 12% of *B. pinnatum*; however, if compared with mean performance in 18 trials on the reference host (**Table 7**, RI_{14} 15.3) the relative performance of this single lime cage is 54%.

In 5 of the 8 mango cages all fruitlets had aborted and were dry and black; 1 cage had 1 surviving adult thrips, another had a single adult and a single second instar larva; in the last cage there were 4 surviving adults and 7 thrips larvae.

Table 17: *S. aurantii* performance on *B. pinnatum*, citrus and *Eucalyptus tereticornis*.

Test host					**Adults**		**Total**		**% adults**			**RRI**
DAE	**Rep**	**L1**	**L2**	**Pup.**	**Live**	**Dead**	**L&P**	**All**	**Dead**	**Live**	**RI_{14}**	**(%)**
B. pinnatum	1	271	201	0	27	6	472	**499**	12	61	27.0	
10 days	2	237	221	0	24	3	458	**482**	6	51	26.2	
	Total	508	422	0	51	9	930	981				
	Mean	**254**	**211**	**0**	**26**	**5**	**465**	**491**	**9**	**56**	**26.6**	**100**
	se	17	10	0	2	2	7	9	3	5	0.4	
	Propn	**55**	**45**	**0**	**-**	**-**	**100**					
Lemon	1	27	12	0	19	5	39	**58**	10	42	2.2	
10 days	2	0	1	0	7	8	1	**8**	16	17	0.1	
	3	3	12	0	9	6	15	**24**	12	20	0.9	**4**
GF	1	16	12	0	8	7	28	**36**	14	19	1.6	**6**
Red GF	1	3	12	0	31	4	15	**46**	8	67	0.6	
12 days	2	4	25	0	29	8	29	**58**	16	69	1.1	
	3	9	36	0	30	10	45	**75**	20	75	1.7	**4**
Lime	**1**	**60**	**122**	**6**	**34**	**11**	**188**	**222**	**22**	**87**	**7.2**	**12**
Hx	1	0	2	0	4	15	2	**6**	30	11	0.1	**4**
Red GF	1	2	18	0	26	12	20	**46**	24	68	0.7	
13 days	2	16	51	0	27	5	67	**94**	10	60	**2.2**	
	3	0	0	0	15	16	0	**15**	32	44	0.0	
	4	13	49	0	33	7	62	**95**	14	77	2.0	
	5	12	43	0	27	12	55	**82**	24	71	1.8	
	6	7	22	3	12	8	32	**44**	16	29	1.0	**5**
Total – All citrus		172	417	9	311	134	598	909				
	Mean	**11**	**28**	**1**	**21**	**9**	**40**	**61**	**18**	**50**	**1.5**	**6**
	se	4	8	0.4	3	1	12	14	2	7	0.4	
	Propn	**29**	**69**	**2**			**100**					
Eucalyptus	1	7	26	0	18	8	33	**51**	16	43	1.1	
13 days	2	2	115	0	20	0	117	**137**	0	40	3.8	
	Total	9	141	0	38	8	150	188				
	Mean	**5**	**71**	**0**	**19**	**4**	**75**	**94**	**8**	**41**	**2.4**	**9**
	se	3	45	0	1	4	42	43	8	1	1.4	
	Propn	**6**	**94**	**0**	**-**	**-**	**100**					

Experiment 11

S. aurantii adults reared on *B. pinnatum* were added to 1 cage each on 3 potted *B. pinnatum* plants (~ 20 female & 10 male per cage), 1 on a lemon and 3 on limes (with ~70 female & 30 male thrips per citrus cage) (on 23.11.04). Larvae, pupae & adults were counted for the citrus at 14 days (on 7.12.04) and 17 days after establishment for the *B. pinnatum* (on 10.12.04).

Results & Discussion

In one of the *B. pinnatum* cages the plant was so severely damaged all leaves had dropped; thrips were counted only from two cages. Adult survival on *B. pinnatum* was not able to be estimated as both cages contained significant numbers of new F_1 adults; on citrus it was 3%.

On *B. pinnatum* RI_{14} was 11.2, on citrus 0.7, giving relative performance of 5%.

Table 18: *S. aurantii* performance on *B. pinnatum*, lemon and lime.

Test host					**Live**	**Total**		**% S**		**RRI**
DAE	**Rep**	**L1**	**L2**	**Pupae**	**Adults**	**L&P**	**All**	**Adults**	**RI_{14}**	**(%)**
B. pinnatum	1	39	185	25	73	249	**322**	-	10.6	
17 days	2	28	221	15	89	264	**353**	-	11.7	
	Total	67	406	40	162	513	675	-		
	Mean	**34**	**203**	**20**	**81**	**257**	**338**	**-**	**11.2**	**100**
	se	6	18	5	8	8	16	-	0.6	
	Propn	**10**	**60**	**6**	**24**	**-**	**100**	**-**		
Lemon	1	1	0	0	0	1	**1**	0	0.01	**0.1**
Lime	1	0	64	0	7	64	**71**	7	0.9	
14 days	2	42	84	0	2	126	**128**	2	1.8	
	3	0	18	0	3	18	**21**	3	0.3	**6**
	Total	43	166	0	12	209	221			
	Mean	**11**	**42**	**0**	**3**	**52**	**55**	**3**	**0.7**	**5**
	se	10	20	0	1.5	28	28	1.5	0.4	
	Propn	**21**	**79**	**0**	**-**	**100**				

Experiment 12

S. aurantii adults reared on *B. pinnatum* were added to a single cage on each of 10 actively growing potted cotton plants *Gossypium hirsutum* (sourced from Emerald QDPI&F) (~ 20 female & 10 male per cage) and 7 flushing citrus – i.e. 4 lemons, 2 limes & 1 navelina (~70 female & 30 male thrips per citrus cage; on 11.1.05). Larvae, pupae and adults were counted for the citrus at 14 days (on 25.1.05) and 16 days for the cotton (on 27.1.05).

Results & Discussion

Cotton was a poor host, producing only 10 larvae and 1 pupa from 10 replicates and with mean adult survival of only 4%, though in 1 replicate it was 40%. Mean performance compared with the mean of 18 *B. pinnatum* trials (RI_{14} 15.3) was less than 1%.

Survival of F_0 adults on citrus was poor (13%). Four cages produced more than 100 larvae but because 100 F_0 thrips were put into these cages these represent only modest rates of increase. For 6 of the 7 cages RI_{14} was 0.5 - 2.3, and mean performance relative to *B. pinnatum* 15%, but one cage on lime produced 461 offspring thrips, 72% of which were second instar larvae (L2) and 9% pupae, values similar to the age distribution for the total of 1114 offspring thrips from 7 cages. The RI_{14} for the best cage (6.6), compared with mean performance on the reference host *B. pinnatum*, represents a relative performance of 43%, the third best single cage performance for all of our citrus trials.

Table 19: *S. aurantii* performance on cotton, lemon, lime and navelina.

Test host					**Adults**	**Total**		**% S**		**RRI[1]**
DAE	**rep**	**L1**	**L2**	**Pupae**	**Live**	**L&P**	**All**	**Adults**	**RI_{14}**	**(%)**
Cotton	1	0	0	0	0	0	**0**	0	0	
16 dd	2	0	0	0	0	0	**0**	0	0	
	3	0	1	0	0	1	**1**	0	0.04	
	4	0	0	0	0	0	**0**	0	0	
	5	0	0	0	0	0	**0**	0	0	
	6	0	0	0	12	0	**12**	40	0	
	7	0	0	0	0	0	**0**	0	0	
	8	0	7	0	0	7	**7**	0	0.28	
	9	1	0	0	0	1	**1**	0	0.04	
	10	0	1	1	1	2	**3**	3	0.08	
	Total	1	9	1	13	11	24			
	Mean	**0**	**1**	**0**	**1**	**1**	**2**	**4**	**0.04**	**0.3**
	se	0.1	0.7	0.1	1.2	0.7	1.3	4.0	0.03	
	Propn	**9**	**82**	**9**	**-**	**100**				
Lemon	1	18	72	3	4	93	97	4	1.3	
14 dd	2	27	129	8	12	164	176	12	2.3	
	3	33	113	2	5	148	153	5	2.1	
	4	12	51	1	6	64	70	6	0.9	**11**
Navelina	1	18	123	5	16	146	162	16	2.1	**14**
Lime	1	5	33	0	10	38	48	10	0.5	
Lime	**2**	**87**	**334**	**40**	**36**	**461**	**497**	**36**	**6.6**	**43**
Total - all citrus		200	855	59	89	1114	1203			
	Mean	**29**	**122**	**8**	**13**	**159**	**172**	**13**	**2.3**	**15**
	se	10	38	5	4	53	57	4	0.8	
	Propn	**18**	**77**	**5**	**-**	**100**				

[1] RRI calculated by comparing RI values with the *B. pinnatum* mean from 18 on-plant trial (i.e. 15.3)

Experiment 13

S. aurantii adults reared on *B. pinnatum* were added to 10 tubs (~ 20 females & 10 males per tub) containing several leaves each of the traded succulent *Kalanchoe blossfeldiana* (on 8.2.05) and (on 10.2.05) to a single cage on each of 5 potted *B. pinnatum* and *B. delagoense*. Larvae, pupae and adults were counted at 9 days for the Kalanchoe (on 17.2.05) and for the Bryophyllum species at 13 days (on 23.2.05).

Results & Discussion

Survival of *S. aurantii* at 13 days on *B. pinnatum*, *B. proliferum* and *K. blossfeldiana* was low, at 24 - 27% **(Table 20**). Mean offspring thrips per cage were 180, 58 & 47, and RI_{14} values 10.3, 3.3 & 6.3. Performance relative to *B. pinnatum* was 32% for *B. delagoense* and 61% for *K. blossfeldiana*. Development on the three species was comparable with 16-25% of offspring populations as L1, 68 - 70% as L2 and 5 - 15% as pupae.

Table 20: *S. aurantii* performance on *B. pinnatum*, *B. delagoense* and *K. blossfeldiana*.

Test host					**Live**	**Total**				**RRI**
DAE	**rep**	**L1**	**L2**	**Pupae**	**Adults**	**L & P**	**All**	**%A S**	**RI_{14}**	**(%)**
B. pinnatum	1	32	158	40	8	230	**238**	27	13.1	
13 days	2	39	165	28	3	232	**235**	10	13.3	
	3	13	82	12	0	107	**107**	0	6.1	
	4	31	140	35	10	206	**216**	33	11.8	
	5	33	77	16	15	126	**141**	50	7.2	
	Total	148	622	131	36	901	937			
	Mean	**30**	**124**	**26**	**7**	**180**	**187**	**24**	**10.3**	**100**
	se	4	19	5	3	27	27	9	1.5	
	Propn	**16**	**69**	**15**		**100**				
B. delagoense	1	19	64	5	10	88	**98**	33	5.0	
13 days	2	9	36	3	5	48	**53**	17	2.7	
	3	15	41	8	7	64	**71**	23	3.7	
	4	6	19	1	8	26	**34**	27	1.5	
	5	17	39	8	11	64	**75**	37	3.7	
	Total	66	199	25	41	290	331			
	Mean	**13**	**40**	**5**	**8**	**58**	**66**	**27**	**3.3**	**32**
	se	3	7	1	1	10	11	4	0.6	
	Propn	**23**	**68**	**9**		**100**				
K. blossfeldiana	1	0	0	0	0	0	**0**	0	0.0	
9 days	2	0	43	10	7	53	**60**	23	7.1	
	3	3	26	0	13	29	**42**	43	3.9	
	4	5	20	0	3	25	**28**	10	3.3	
	5	5	33	0	5	38	**43**	17	5.1	
	6	31	65	6	9	102	**111**	30	13.6	
	7	21	40	0	18	61	**79**	60	8.1	
	8	37	57	10	15	104	**119**	50	13.9	
	9	12	31	0	10	43	**53**	33	5.7	
	10	2	15	0	0	17	**17**	0	2.3	
	Total	116	330	26	80	472	552			
	Mean	**12**	**33**	**3**	**8**	**47**	**55**	**27**	**6.3**	**61**
	se	4	6	1	2	11	12	7	1.4	
	Propn	**25**	**70**	**5**		**100**				

Experiment 14

S. aurantii adults (~ 20 female & 10 male per cage) reared on *B. pinnatum* were added to 2 cages on *B. pinnatum*, 7 on mock orange *Murraya paniculata* and 3 on *Syzygium australe* (on 22.2.05). Larvae, pupae and adults were counted at 13 days (on 7.3.05).

Results & Discussion

B. pinnatum produced a mean of 275 offspring thrips per cage and an RI_{14} of 15.7. No thrips were produced on *Murraya*; *S. australe* produced only 4 larvae and 3 adults (**Table 21**).

Table 21: *S. aurantii* performance on potted *B. pinnatum*, mock orange and *S. australe*.

Test host	rep	L1	L2	Pupae	Live Adults	Total L & P	Total All	RI_{14}	RRI (%)
B. pinnatum	1	63	189	48	23	300	**323**	17.1	
	2	47	163	39	16	249	**265**	14.2	
	Total	110	352	87	39	549	588		
	Mean	**55**	**176**	**44**	**20**	**275**	**294**	**15.7**	**100**
	se	8.0	13.0	4.5	3.5	25.5	29.0	1.5	
	Propn	**19**	**60**	**15**	**6**		**100**		
M. paniculata	1	0	0	0	0	0	**0**	0	
	2	0	0	0	0	0	**0**	0	
	3	0	0	0	0	0	**0**	0	
	4	0	0	0	0	0	**0**	0	
	5	0	0	0	0	0	**0**	0	
	6	0	0	0	0	0	**0**	0	
	7	0	0	0	0	0	**0**	0	
	Total	0	0	0	0	0	0		
	Mean	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
S. australe	1	0	2	0	1	2	3	0.1	
	2	1	0	1	0	2	2	0.1	
	3	0	0	0	2	0	2	0	
	Total	1	2	1	3	4	7		
	Mean	**0.3**	**0.7**	**0.3**	**1.0**	**1.3**	**2.3**	**0.07**	**0.5**

Experiment 15

Cages were set up over young growing leaves of Poinciana *Delonix regia*, *S. australe* and on *B. pinnatum* (on 10.3.05). Thirty adult *S. aurantii* (~ 20 female, 10 male) were added to each of 2 cages for *B. pinnatum* 3 cages for *S. australe* and 5 cages for Poinciana; offspring were counted by stage at 14 days (on 24.3.05).

Results & Discussion

S. aurantii performance on the reference host *B. pinnatum* was poor in this experiment, with a mean of 154 thrips per cage and an RI_{14} of 7.1, the lowest of all of our trials. Performance on Poinciana and *S. australe* was poor, with only 6 larvae produced in 3 cages on the former, and 6 larvae and 1 pupa on the latter (**Table 22**).

Table 22: *S. aurantii* performance on *B. pinnatum*, Poinciana and *S. australe*.

Test host	Rep	L1	L2	Pupae	Adults	Total	%A S	RI_{14}	RRI (%)
B. pinnatum	1	36	77	18	14	**145**	70	6.6	
	2	48	89	15	11	**163**	55	**7.6**	
	Total	84	166	33	25	308			
	Mean	**42**	**83**	**17**	**13**	**154**	**63**	**7.1**	**100**
	se	6.0	6.0	1.5	1.5	9.0	7.5	0.5	
	Prop'n	**30**	**59**	**12**	**-**	**100**			
Poinciana	1	0	0	0	0	**0**	0	0	
	2	0	3	0	11	**14**	55	**0.2**	
	3	0	0	0	1	**1**	5	0	
	4	2	1	0	1	**4**	5	0.2	
	5	0	0	0	0	**0**	0	0	
	Total	2	4	0	13	19			
	Mean	**0**	**1**	**0**	**3**	**4**	**13**	**0.06**	**1**
	se	0.4	0.6	0	2.1	2.7	10.6	0.04	
S. australe	1	1	0	0	4	5	13	0.1	
	2	0	2	0	1	3	3	0.1	
	3	3	0	1	0	4	0	0.2	
	Total	4	2	1	5	12			
	Mean	1.3	0.7	0.3	1.7	4.0	5.6	**0.12**	**2**

Experiment 16

S. aurantii was reared exclusively on flushing potted citrus through as many cycles as could be sustained. Adult thrips reared on *B. pinnatum* were put into cages (100 per cage, ~70 female, 30 male) on lemon, lime, navelina or grapefruit trees (~1 m high); ~ 2 weeks later all cages were removed, the thrips counted by stage and transferred to a new set of cages (apportioned equally between cages – the shaded, bold Totals column in **Table 23** shows the number of thrips that were divided between the cages of the next cycle). This process was continued until thrips numbers declined to zero. A total of 102 cages were used, 54 on lemon, 44 on lime, 3 on navelina and 1 on grapefruit.

A total of about 12 plants of the two main varieties (lemon & lime) were used. These were pruned as needed to produce the soft flush growth required for each cycle, and several cages per plant per cycle were used, depending on the numbers of thrips from the prior cycle, and the availability and number of flushing terminals on plants.

Five experiments were carried out from 23.11.04 to 21.4.05. The numbers of generations for which thrips were sustained, and the number of cages on each variety are shown in **Table 23**, as well as the total number of thrips per generation by stage, cage means, standard errors and the maximum number per cage for total thrips, and for larvae and pupae only.

The rate of increase was calculated for larvae and pupae only. In the first generation ($F_0 - F_1$) ~ 70% of the adult *S. aurantii* added to each cage were female; in subsequent generations, since larvae were included and the sex ratio of adults was not determined, a ratio of 60% females was used for calculations of the rates of increase, RI. The data were not standardised to RI_{14} values (most cycles were run for 14 days), but are presented as recorded, with the number of days for each cycle or generation shown.

Results & Discussion

S. aurantii was maintained in continuous culture on flush growth on potted citrus trees in five trials over a five month period, with 3 - 7 cycles of ~14 days (mean 4.6) per trial (**Table 23**).

From a total of 4400 adult thrips (100 per cage to start 44 x F_0 cages in five trials), ~ 3080 of which were females (70% per cage), a total of 6567 juvenile thrips (1684 L1's, 4591 L2's and 292 pupae) and 2755 adults were produced, 9322 thrips in total. Though some adults would have been counted more than once (as survivors between cycles), this provides an estimate over the five trials of the rate of increase per female - RI, of 3.0 (i.e. 9322/3080).

The mean total thrips per cage per cycle peaked at 308, 209, 113, 172 and 179, with corresponding maxima per cage per cycle of 333, 219, 377, 497 and 349. The maximum numbers of larvae and pupae produced per cage per cycle were 235, 176, 94, 159 and 171, with corresponding cage maxima of 242, 183, 324, 461 and 346.

Maximum RI values for the $F_0 - F_1$ generation, the one for which the F_0 number was most reliably known (100 per cage, ~70% female) were 2.1, 2.0, 5.4, 7.7 and 4.0. For three of the five trials these were also the maximum RI values; in the other two trials, the maximum RI's were 6.0 in cycle two of trial one, and 5.7 in cycle three of trial two. Based on comparison with the mean RI for 18 *B. pinnatum* trials (i.e. 15.3, see **Table 7**), these maxima correspond to performance on citrus of 39%, 37%, 35%, 50% and 26% of that on the reference host.

Table 23: Performance of *S. aurantii* in continuous culture on potted citrus in 54 cages on lemon, 44 on lime, 3 on Navelina and 1 on grapefruit.

		No.		Variety				Total thrips by stage & by cycle:					Per cage:			Total	Per cage (L&P only):			RI - L&P only		
Trial	**Cycle**	**Cages**	**Days**	Lemon	Lime	Navel	GF	L1	L2	P	Adults	**Totals**	**Mean**	se	Max	**L&P**	**Mean**	se	Max	**Mean**	se	Max
1	F_0 - F_1	4	14	1	3			43	166	0	12	**221**	**55**	28.4	128	209	**52**	28.0	126	0.9	0.5	2.1
	F_1 - F_2	6	16		6			137	228	11	345	**721**	**120**	28.8	215	376	**63**	25.3	132	2.8	1.1	**6.0**
	F_2 - F_3	2	14		2			110	339	20	146	**615**	**308**	25.5	333	469	**235**	7.5	242	2.1	0.7	2.8
	F_3 - F_4	1	14		1			31	26	0	80	**137**	**137**	-	137	57	**57**	-	57	0.4	-	-
	F_4 - F_5	1	14			1		0	0	0	0	**0**	**0**	-	0	57	**0**	-	0	-	-	-
	Cage Mean	14		1	12	1	0	**23**	**54**	**2**	**42**	**121**				**79**						
	se							6.3	15.7	1.0	9.7	27.5				22.0						
	Max							58	176	12	106	333				242						
2	F_0 - F_1	9	10 & 13	7	2			139	210	7	183	**539**	**60**	17.0	168	356	**40**	12.8	120	0.7	0.2	2.0
	F_1 - F_2	2	14		2			29	24	0	54	**107**	**54**	14.5	68	53	**27**	3.5	30	0.3	0.1	0.4
	F_2 - F_3	2	14	1	1			136	210	5	66	**417**	**209**	10.5	219	351	**176**	7.5	183	**5.5**	0.2	**5.7**
	F_3 - F_4	2	14		2			15	41	1	102	**159**	**80**	16.5	96	57	**29**	1.5	30	0.2	0.0	0.2
	F_4 - F_5	1	11	1				5	20	0	46	**71**	**71**	-	71	25	**25**	-	25	0.3	-	-
	F_5 - F_6	1	14	1				12	35	0	8	**55**	**55**	-	55	47	**47**	-	47	1.1	-	-
	F_6 - F_7	1	14		1			0	0	0	1	**1**	**1**	-	1	57	**0**	-	0	-	-	-
	Cage Mean	18		10	7	0	0	**19**	**30**	**0.7**	**26**	**75**				**49**						
	se							5.2	7.6	0.3	4.1	14.7				12.7						
	Max							75	106	5	66	219				183						
3	F_0 - F_1	14	13 & 14	10	4			388	888	36	272	**1584**	**113**	28.3	377		**94**	24.1	324	1.6	0.4	**5.4**
	F_1 - F_2	7	13 & 14	5	2			61	90	0	403	**554**	**79**	8.7	101		**22**	6.9	58	0.2	0.1	0.4
	F_2 - F_3	5	14		4	1		0	0	0	9	**9**	**2**	1.8	9		**0**	0.0	0	0.0	0.0	-
	Cage Mean	26		15	10	1	0	**17**	**38**	**1**	**26**	**83**				**56**						
	se							3.9	11.1	0.8	5.2	17.3				15.3						
	Max							79	229	16	83	377				324						
4	F_0 - F_1	7	14	4	2	1		200	855	59	89	**1203**	**172**	57.2	497		**159**	53.3	461	2.7	0.9	**7.7**
	F_1 - F_2	7	10	6	1			1	6	1	120	**128**	**18**	2.4	31		**1**	0.6	4	0.0	0.0	0.0
	F_2 - F_3	1	10	1				2	6	0	7	**15**	**15**	0	15		**8**	-	8	-	-	-
	Cage Mean	15		11	3	1	0	**14**	**58**	**4**	**14**	**90**				**75**						
	se							6.0	23.4	2.6	2.2	32.8				31.8						
	Max							87	334	40	36	497				461						
5	F_0 - F_1	10	14	5	5			266	1294	147	83	**1790**	**179**	36.7	349		**171**	37.0	346	1.6	0.4	**4.0**
	F_1 - F_2	12	14	10	2			0	12	0	422	**434**	**36**	5	64		**1**	0.4	4	0.01	0	0.03
	F_2 - F_3	3	14		2		1	104	70	0	207	**381**	**127**	43.3	211		**58**	25.0	108	0.7	0.3	1.2
	F_3 - F_4	3	14	1	2			5	69	5	77	**156**	**52**	5.9	63		**26**	10.4	45	0.3	0.1	0.6
	F_4 - F_5	1	14	1				0	2	0	23	**25**	**25**	-	25		**2**	-	2	0.02	-	-
	Cage Mean	29		17	11	0	1	**13**	**50**	**5**	**28**	**96**				**68**						
	se							3.7	14.5	1.9	4.4	18				19.1						
	Max							70	269	39	103	349				346						

Trial 1 23.11.04 – 3.2.05; **Trial 2** 10.12.04 – 14.3.05; **Trial 3** 23.12.04 – 3.2.05; **Trial 4** 11.1.05 – 14.2.05; **Trial 5** 14.2.05 – 21.4.05

Experiment 17

To determine the capacity of Australian *S. aurantii* to survive for short periods on non-hosts, soft new leaves of 25 plant species (including 3 cultivars of banana) were placed into each of two clear 30 ml tubes and ~ 10 thrips aspirated into each; tubes were closed with unventilated lids to retard leaf desiccation; % survival of thrips was determined at 24 hours (on 14.5.05).

Results & Discussion

Survival of adult *S. aurantii* for 24 hours exceeded 50% for all plants tested; for 18 of the 27 plants survival was greater than 80% (**Table 24**). Of the citrus and other crop species, survival on sweet orange was 80%, navelina 76%, grapefruit 57%, mango 89% and peach 35%.

These results, combined with adult survival data on hosts on which breeding performance was poor in other experiments described in this section, indicate that *S. aurantii* can survive for short periods on a range of hosts on which they do not breed.

Published host lists should distinguish between breeding and feeding populations, and, ideally provide information on the relative suitability as hosts of listed species. Such data, often included in published new host records, often is not captured in host lists.

Table 24: Survival of adult *S. aurantii* after 24 hours on flush leaves of the listed plant species or varieties (13 - 14.5.05, mean of 2 replicates x ~ 10 adult thrips per 30 ml tube).

Latin name	Common name	% survival at 24 hours
Callistemon sp.	Bottlebrush	100
Glycine max	Soybean (cv. Dragon)	95
Musa acuminata	cv. Lady's finger	95
M. acuminata	cv. Williams	95
Acacia sophorae	Coast wattle	94
Schlumbergera truncata	Crab's claw cactus	94
Prunus mumae	Japanese apricot	89
Bryophyllum pinnatum	Green mother of millions	89
Hoya carnosa	Wax flower	89
Mangifera indica	Mango	89
Eucalyptus tereticornis	Forest red gum	88
Cucurbita moschata	Butternut pumpkin	86
E. signata	Scribbly gum	85
Syzygium australe	Lillypilly	83
Aristolochia sp. (pubera?)	Aristolochia	82
Citrus x aurantium	Sweet orange	80
Ficus sp.	Fig	80
Grevillea robusta	Silky oak	80
C. x aurantium	Navelina orange	76
Gardenia augusta	Florida gardenia	72
Callitris columellaris	Bribie Island pine	69
Acacia longifolia	Sydney golden wattle	67
Murraya paniculata	Mock orange	58
C. x paradisi	Red grapefruit	57
Ricinus communis	Castor oil	57
Musa acuminata	cv. GF	54
Prunus persica	Peach	35

Experiment 18

S. aurantii adults (~15 females & 5 males) were confined on 4-6 'leaf' sprigs in each of 3 tubs on *B. pinnatum*, *B. proliferum*, and the traded succulents money or jade plant (*Crassula ovata*) and coral plant or coral jade (*Crassula argentea*) (on 29.7.05). The tubs were held in a constant temperature room at ~ 25°C with an ambient light regime; larvae and surviving adults were counted, adults removed and larvae moved to new tubs at 7 days (on 5.8.05), and all thrips in both sets of tubs were counted by stage at 12 days (on 10.8.05).

Results & Discussion

Survival of adult *S. aurantii* at 7 days on *B. pinnatum* and *B. proliferum* was 83 & 88%; on the two Crassula species 8 & 20% **(Table 25**). *B. pinnatum* had more than twice as many L1 larvae as *B. proliferum*; very few were present on the Crassula. Development on *B. pinnatum* also was more advanced, with second instar larvae and pupae present, but only L1s on the Crassula spp.

B. pinnatum produced a mean of 243 offspring thrips, *B. proliferum* 173 per tub at 12 days (RI_{14} = 21.6 & 15.4), with similar age structures (*B. pinnatum* – 16%, 60% & 24% as L1, L2 & pupae, compared with 13%, 67% & 20% for *B. proliferum*); the two Crassulas produced totals of only 16 and 12 larvae. Those larvae, however, were healthy and apparently developing normally.

After the 5 days from the removal of all thrips at day 7 in the first set of tubs to the final counts at day 12, the populations of thrips on *B. pinnatum* & *B. proliferum* comprised 14 - 21% L1s, 69 - 79% L2s and 7 - 15% pupae (**Table 26**).

Relative performance for the 3 test species compared with the reference host *B. pinnatum* therefore was 71% for *B. proliferum*, and 2 and 1.6% for the *Crassula* spp.

Table 25: *S. aurantii* performance on *B. pinnatum*, *B. proliferum*, *Crassula ovata* & *C. argentea* after 7 days exposure to 20 adult thrips (~15 female & 5 male) in 3 tubs per species.

		Total for 3 replicates:					**Per replicate:**						
							Adults		**% survival**				**RRI**
DAI	**Host**	**L1**	**L2**	**P**	**L&P**	**A's**	**Mean**	**se**	**Mean**	**se**	**RI_{14}**	**se**	**(%)**
7	*B. pinnatum*	116	3	1	12	50	**17**	0.9	**83**	4			
	B. proliferum	47			47	53	**18**	1.2	**88**	6			
	C. ovata	14			14	5	**2**	1.2	**8**	6			
	C. argentea	9			9	12	**4**	0.6	**20**	3			
12	*B. pinnatum*	118	440	51	609	-							
	B. proliferum	69	348	55	472	-							
	C. ovata	0	2	14	16								
	C. argentea	1	2	9	12								
Total	*B. pinnatum*	118	440	167	725	4	**243**	22			**21.6**	2.0	**100**
	B. proliferum	116	348	55	519	0	**173**	14			**15.4**	1.2	**71**
	C. ovata	0	2	14	16	0	**5.3**	0.9			**0.5**	0.1	**2**
	C. argentea	1	2	9	12	0	**4.0**	2.1			**0.4**	0.2	**1.6**

NB: All adult & larval thrips removed to new tubs at 7 DE; the shaded area shows adult survival at 7 days

Table 26: Age distribution of *S. aurantii* offspring on *B. pinnatum* and *B. proliferum* developed in the 5 days from day 7 - when all thrips were removed - to day 12.

Host	Rep (n)	% L1	% L2	% Pupae
B. pinnatum	1 (263)	21	69	10
	2 (191)	18	75	7
	3 (155)	17	75	8
	Total (609)	19	72	8
B. proliferum	1 (140)	14	79	8
	2 (150)	14	71	15
	3 (182)	16	73	12
	Total (472)	15	74	12

Experiment 19

SACT adults reared on *B. pinnatum* (~ 38 female & 12 male per cage) were added to single cages on each of 7 potted citrus trees with small fruit (size & number per cage, as well as the mean number of thrips per fruit, see **Table 27**) – i.e. 3 lime, 3 Kumquat & 1 Hickson (on 16.9.05), and to a single cage on a potted grape plant with actively growing young leaves. Larvae, pupae and adults were counted 13 days after establishment (on 29.9.05).

Results & Discussion

Only two of 77 lime fruit remained attached at the end of this trial; all remained attached on the Kumquats (13 fruit in 4 cages). Only the Kumquat fruit were damaged, and these displayed typical thrips feeding injury (**Plate 6**).

In the single grape trial, F_0 adult survival was 30%; a total of 136 thrips were counted from the cage at 13 days, 105 larvae, 16 pupae and 15 adults. This represents an RI_{14} of 3.6, which equates to a relative performance of 24% of that of the reference host *B. pinnatum* using the mean of 18 trials on that host (i.e. mean *B. pinnatum* RI_{14} 15.3, see **Table 7**).

Thrips population development was comparable with that on other hosts in other trials, including the reference host *B. pinnatum* (eg see **Table 26** above); 13% of offspring thrips were pupate at the conclusion of the experiment at 13 days.

Table 27: *S. aurantii* performance on fruiting lime, Kumquat, Hickson mandarin, and grape leaves.

Test Host	rep	No. Fruit	Thrips /fruit	Size mm L	Size mm W	Thrips L1	Thrips A's	% S	Notes
Lime	1	23	2.2	5-8	3-5		10	20	Leaf hard, fruit dropped
	2	27	1.9				14	28	As above, but **2 *fruit attached***
	3	27	1.9				20	40	Leaf hard, fruit dropped
Kumquat	1	5	10	14-26	9-20	**15**	20	40	Leaf, fruit OK. Larvae on fruit
	2	3	17				25	50	" "
	3	2	25				27	54	" "
Hickson	1	3	17	8-10	9-12		1	2	" "

		L1	L2	Pupa	Live Adults	Total L&P	Total All	% adult survival	RI_{14}	RRI[1] (%)
Grape	1	56	49	16	15	121	**136**	30	**3.6**	**24**
Proportion		**46**	**40**	**13**	**-**	**-**	**100**			

[1] RRI calculated by comparing the RI value with the *B. pinnatum* mean from 18 on- plant trial (i.e. 15.3)

Experiment 20

Three potted lime and three red grapefruit trees with small fruits (0.5 – 1 cm long) were exposed in on-plant cages to 50 adult *S. aurantii* (~ 38 female & 15 male) (on 30.9.05); a further three red grapefruit cages were set up without thrips as controls for caging effects. All fruits were inspected prior to caging and blemishes confusable with thrips damage marked with a felt pen. Thrips were counted and fruit injury assessed at 13 days (on 13.10.05).

Results & Discussion

Adult thrips survival averaged 20%, but was 28 - 38% in three replicates. Most fruit dropped from the plants during the course of the experiment, including in the red grapefruit controls in which there were no thrips; the 3 green fruit that remained attached, in a cage in which there were 19 surviving adult thrips at 13 days, were undamaged.

Table 28: *S. aurantii* performance on potted fruiting citrus after 13 days with 50 adult thrips.

Test host	rep	L&P	Live adults	% adult Survival	Notes
Lime	1	0	15	30	All dropped & black, bar 1 green - no damage
	2	0	3	6	All dropped & black
	3	0	19	38	3 green fruit, all attached - no damage
Red GF	1	0	4	8	All black & dropped
	2	0	14	28	" "
	3	0	6	12	" "
Red GF	1	-	-	-	All black & dropped
Controls	2	-	-	-	" "
	3	-	-	-	" "
	Total	0	61	-	
	Mean	**0**	**10**	**20**	
	se	0	2.7	5.5	

Experiment 21 – Peach & macadamia

Cages were set up on flushing peach, macadamia and *B. pinnatum*. Thirty adult *S. aurantii* (~ 20 female, 10 male) were added to a cage on 3 plants per test host (on 2.12.05); offspring were counted at 14 days (on 16.12.05). The macadamia leaves from the 3 cages were pooled, held in a Ziploc bag and newly hatched thrips counted 4 & 7 days later (18 & 21 days post-establishment).

Results & Discussion

Large numbers of pupae and new adults in the *B. pinnatum* and macadamia cages prevented calculation of F_0 adult survival (**Table 29**). On peach, adult survival averaged 48%.

On *B. pinnatum*, macadamia and peach the means (including offspring & surviving adult thrips) were 477, 621 and 76 per cage. The held-over macadamia leaves produced an additional 866 thrips in the following week. The mean RI values were 22.8, 30.1 and 3.1; performance relative to *B. pinnatum* of macadamia was 132%, and for peach 14%.

Development was comparable on *B. pinnatum* and macadamia, with the latter slightly more advanced (eg 29% compared with 37% of the population as pupae or adults). Development was less advanced on peach.

Table 29: Performance of *S. aurantii* on peach, macadamia and *B. pinnatum*.

Test host	Rep	L1	L2	Pupae	Adults	Total	% adult Survival	RI_{14}	RRI%
B. pinnatum	1	90	180	51	57	378	-	17.9	
	2	190	210	71	91	562	-	27.1	
	3	151	198	67	74	490	-	23.5	
	Total	431	588	189	222	1430	-		
	Mean	**144**	**196**	**63**	**74**	**477**	**-**	**22.8**	**100**
	se	29	9	6	10	54	-	2.7	
	Prop'n	**30**	**41**	**13**	**16**	**100**			
Peach	1	51	40	3	19	113	63	4.7	
	2	23	12	0	8	43	27	1.8	
	3	22	34	0	16	72	53	2.8	
	Total	96	86	3	43	228			
	Mean	**32**	**29**	**1**	**14**	**76**	**48**	**3.1**	**14**
	se	10	9	1	3	20	11	0.9	
	Prop'n	**52**	**46**	**2**	**-**	**100**			
Macadamia	1	154	270	130	99	653	-	31.7	
	2	43	218	82	85	428	-	20.4	
	3	199	301	158	124	782	-	38.1	
	Total	396	789	370	308	1863	-		
	Mean	**132**	**263**	**123**	**103**	**621**	**-**	**30.1**	**132**
	se	46	24	22	11	103	-	5.2	
	Prop'n	**21**	**42**	**20**	**17**	**100**			
Macadamia[1]	(+4 dd)	361	387	21	2	771	-		
	(+3 dd)	81	14	0	0	95	-		
	Total	**442**	**401**	**21**	**2**	**866**	**-**		

[1] Macadamia leaves held in Ziploc bags and thrips counted 4 & 7 days after termination of the experiment

Experiment 22 – *B. proliferum* & macadamia

Cages were set up on flushing terminals of potted macadamia trees, on *B. proliferum* and on *B. pinnatum*. Thirty adult *S. aurantii* (~ 20 female, 10 male) were added to a single cage on each of three plants per test host; offspring were counted by stage at 14 days (on 6.1.06).

Results & Discussion

On *B. pinnatum*, *B. proliferum* and macadamia the means (including offspring & surviving adult thrips) were 312, 332 & 390 per cage. Mean RI_{14} values were 14.6, 15.6 & 18.5; performance relative to *B. pinnatum* of *B. proliferum* was 107%, and for macadamia 127% (**Table 30**).

Development was comparable on *B. proliferum* and macadamia, with *B. pinnatum* slightly more advanced; 22%, 25% & 31% of the respective population were pupae or adults.

These findings suggest that macadamia is a very good host and could be expected to be attacked by *S. aurantii*.

Table 30: Performance of *S. aurantii* on *B. proliferum*, macadamia and *B. pinnatum*.

Test host	Rep	L1	L2	Pupae	Adults	Total	RI_{14}	RRI (%)
B. pinnatum	1	170	100	50	59	379	18.0	
	2	101	61	41	36	239	11.0	
	3	123	89	61	44	317	14.9	
	Total	394	250	152	139	935		
	Mean	**131**	**83**	**51**	**46**	**312**	**14.6**	**100**
	se	20.3	11.6	5.8	6.7	41	2.0	
	Prop'n	**42**	**27**	**16**	**15**	**100**	**-**	
B. proliferum	1	173	85	16	28	302	14.1	
	2	171	153	52	47	423	20.2	
	3	111	89	42	30	272	12.6	
	Total	455	327	110	105	997		
	Mean	**152**	**109**	**37**	**35**	**332**	**15.6**	**107**
	se	20.3	22.0	10.7	6.0	46	2.3	
	Prop'n	**46**	**33**	**11**	**11**	**100**	**-**	
Macadamia	1	224	207	90	55	576	27.8	
	2	90	150	36	43	319	15.0	
	3	136	69	17	53	275	12.8	
	Total	450	426	143	151	1170		
	Mean	**150**	**142**	**48**	**50**	**390**	**18.5**	**127**
	se	39.3	40.0	21.9	3.7	94	4.7	
	Prop'n	**38**	**36**	**12**	**13**	**100**	**-**	

Experiment 23 – dwarf poinciana, coolamon, Poinciana & mock orange

Cages were set up over young growing leaves of dwarf Poinciana (= Pride of Barbados), royal Poinciana, *Syzygium moorei*, *Murraya paniculata* and *B. pinnatum* (on 20.1.06). Thirty adult *S. aurantii* (~ 20 female, 10 male) were added to single cages on 3 plants per test host; offspring were counted by stage at 14 days (on 3.2.06).

Results & Discussion

Survival of F_0 adult thrips was 60% on *B. pinnatum*, which produced a mean per cage (including surviving F_0 adults) of 292 offspring, and a mean RI of 13.7 (**Table 31**). *S. moorei* produced a mean of 75, and *C. pulcherrima* 40 thrips per cage, 25% and 11% as many as *B. pinnatum*; mean per cage adult survival was 22 and 31%. Poinciana and *Murraya* produced maxima of 13 and 6 thrips per cage, less than 1% of the numbers on *B. pinnatum*; adult survival was 18 and 9%.

Table 31: Performance of *S. aurantii* on dwarf poinciana, Poinciana, coolamon and mock orange.

Test host	Rep	L1	L2	Pupae	Adults	Total	% adult survival	RI_{14}	RRI (%)
B. pinnatum	1	41	206	24	17	288	57	13.6	
	2	32	189	47	23	291	77	13.4	
	3	62	149	73	14	298	47	14.2	
	Total	135	544	144	54	877			
	Mean	**45**	**181**	**48**	**18**	**292**	**60**	**13.7**	**100**
	se	9	17	14	3	3	9	0.2	
	Prop'n	**16**	**66**	**17**	**-**	**100**			
C. pulcherrima	1	7	23	0	11	41	37	1.5	
	2	4	9	0	3	16	10	0.7	
	3	16	33	0	14	63	47	2.5	
	Total	27	65	0	28	120			
	Mean	**9**	**22**	**0**	**9**	**40**	**31**	**1.5**	**11**
	se	4	7	0	3	14	11	0.5	
	Prop'n	**29**	**71**	**0**	**-**	**100**			
S. moorei	1	28	64	0	9	101	30	4.6	
	2	10	26	0	0	36	0	1.8	
	3	26	52	0	11	89	37	3.9	
	Total	64	142	0	20	226			
	Mean	**21**	**47**	**0**	**7**	**75**	**22**	**3.4**	**25**
	se	6	11	0	3	20	11	0.8	
	Prop'n	**31**	**69**	**0**	**-**	**100**			
Delonix regia	1	1	2	0	10	13	33	0.2	
	2	0	0	0	6	6	20	0.0	
	3	0	0	0	0	0	0	0.0	
	Total	1	2	0	16	19			
	Mean	**0**	**1**	**0**	**5**	**6**	**18**	**0.1**	**0.4**
	se	0.3	0.7	0	3	4	10	0.1	
M. paniculata	1	1	2	0	3	6	10	0.2	
	2	0	0	0	2	2	7	0.0	
	3	0	0	0	3	3	10	0.0	
	Total	1	2	0	8	11			
	Mean	**0**	**1**	**0**	**3**	**4**	**9**	**0.1**	**0.4**
	se	0.3	0.7	0	0.3	1	1	0.1	

Experiment 24 – Tea

Cages were set up on flushing potted tea *Camellia sinensis* ~ 1 m high (provided by Madura Tea, Murwillumbah, courtesy of Michael Sales) and *B. pinnatum* plants (on 18.8.06). Twenty adult *S. aurantii* (~15 female, 5 male) were added to a cage on each of 3 plants per test host; offspring were counted by stage at 14 days (on 1.9.06).

Results & Discussion

Survival of F_0 adult *S. aurantii* on tea was 25%, on *B. pinnatum* 75% (**Table 32**). Tea produced a mean of 36 thrips and *B. pinnatum* 163 per cage. RI_{14} values were 6.7 - 12.9, with a mean 9.9 for *B. pinnatum*, and 0.3 - 3.5, mean 2.1 for tea. Performance relative to *B. pinnatum* of tea was 21%.

The offspring thrips age distribution was comparable on *B. proliferum* and tea, with 66% of the population as L2 larvae and 33% as L1 for both.

Table 32: Performance of *S. aurantii* on tea and *B. pinnatum*.

Test host	Rep	L1	L2	Pupae	Adults	Total	% adult survival	RI_{14}	RRI (%)
B. pinnatum	1	24	77	0	17	118	85	6.7	
	2	40	110	0	12	162	60	10.0	
	3	87	106	0	16	209	80	12.9	
	Total	151	293	0	45	489		-	
	Mean	**50**	**98**	**0**	**15**	**163**	**75**	**9.9**	**100**
	se	19	10	0	2	26	8	1.8	
	Prop'n	**34**	**66**	**0**	**-**	**100**			
Tea	1	0	5	0	0	5	0	0.3	
	2	19	34	0	10	63	50	3.5	
	3	13	23	0	5	41	25	2.4	
	Total	32	62	0	15	109		-	
	Mean	**11**	**21**	**0**	**5**	**36**	**25**	**2.1**	**21**
	se	6	9	0	3	17	14.4	0.9	
	Prop'n	**34**	**66**	**0**	**-**	**100**			

Experiment 25

S. aurantii adults reared on *B. pinnatum* (~ 20 females & 10 males) were added to a single cage on each of 3 potted *B. pinnatum* plants, and to 16 cages on 2 potted limes, 3 lemons and 1 navelina (on 25.8.06). All 4 cages on the navelina and 3 cages on one lime were over soft flush leaves (1 of the lime cages also contained two 4 mm long fruit); the second lime had 3 cages, the 3 lemons two cages each over fruit and hard leaves (i.e. total of 7 cages over flush, 9 cages over small fruit and hard leaves). Prior to caging, all fruits were inspected and any damage potentially confused with thrips damage marked with a felt pen. Details of fruit number and size by cage are given in **Table 33.** Larvae, pupae and adults were counted after 14 days for *B. pinnatum* (on 8.9.06) and after 17 days for citrus (on 11.9.06).

Results & Discussion

B. pinnatum at 14 days had a mean of 186 thrips per cage (including surviving F_0 adults), representing a mean RI of 8.3; lime and navelina flush combined at 17 days produced a mean of 121 thrips per cage, an adjusted mean RI_{14} of 3.5 (**Table 34**). Survival of F0 adults was estimated at 64% for *B. pinnatum* and 80% for citrus. The two best cages on lime had more than 150 thrips, representing RI_{14} values of 4.7 and 5.0, or relative performance of 57% & 60% of that on the reference host *B. pinnatum*.

The thrips age distribution on citrus was slightly retarded by comparison with *B. pinnatum*; 11% of the population had pupated at 17 days on citrus, 24% at 14 days on *B. pinnatum*.

Most lime and lemon fruit remained on the plants at 17 days, and survival of the F_0 adult thrips was 33 - 60% with a mean of 49%. No thrips damage was apparent on any fruit and only 2 thrips larvae were produced.

This experiment represents the peak performance of *S. aurantii* on citrus (lime and navelina) recorded in our experiments.

Table 33: Cage arrangement on flush & fruit on 1 navelina, 2 lime & 3 potted lemons.

Test host	Plant No.	Cage No.	Cages with: Flush	Cages with: Fruit	No. Fruit	Fruit length
Lime	1	1-3	3	(1)*	2	2 x 4 mm
Navelina	2	4-7	4		-	-
Lime	3	8		1	10	6 x < 5 mm, 4 x 6-9 mm
		9		1	3	6-7 mm
		10		1	4	1 x 4 mm, 3 x 7-8 mm
Lemon	4	11		2	1	40 mm
		12			2	15 & 30 mm
Lemon	5	13		2	2	25 & 32 mm
		14			3	4, 22 & 25 mm
Lemon	6	15		2	5	3 x 15 mm, 2 x 20 mm
		16			2	30 & 55 mm

* 1 of the 3 cages with flush growth had a single 4 mm long fruit

Table 34: *S. aurantii* performance on *B. pinnatum*, citrus flush and fruit.

Test host	rep	L1	L2	Pupae	Adults	Total L & P	Total All	% adult survival	RI_{14}	RRI (%)
B. pinnatum										
14 days	1	19	115	43	23	177	**200**	77	8.9	
	2	17	128	56	20	201	**221**	67	10.1	
	3	8	94	19	15	121	**136**	50	6.1	
	Total	44	337	118	58	499	557			
	Mean	**15**	**112**	**39**	**19**	**166**	**186**	**64**	**8.3**	**100**
	se	3	10	11	2	24	26	8	1.2	
	Proportion 1	**9**	**67**	**24**	**-**	**100**				
	Proportion 2	**8**	**61**	**21**	**10**	**100**				
Flush – 17 days										
Lime	1	0	15	0	18	15	**33**	60	0.5	
	2	19	111	8	24	138	**162**	80	5.0	60
	3	32	79	17	27	128	**155**	90	4.7	57
Navelina	1	31	67	15	27	113	**140**	90	4.1	
	2	33	60	13	25	106	**131**	83	3.9	
	3	27	54	14	26	95	**121**	87	3.5	
	4	26	46	12	22	84	**106**	73	3.1	
	Total - all citrus	168	432	79	169	679	848			
	Mean	**24**	**62**	**11**	**24**	**97**	**121**	**80**	**3.5**	**42**
	se	4	11	2	1	15	16	4	0.6	
	Proportion 1	**25**	**64**	**11**	**-**	**100**				
	Proportion 2	**20**	**51**	**9**	**20**	**100**				
Fruit – 17 days										
Lime	1	0	0	0	18	0	**18**	60	0	
	2	0	0	0	15	0	**15**	50	0	
	3	0	0	0	18	0	**18**	60	0	
Lemon	1	0	0	0	16	0	**16**	53	0	
	2	0	1	0	13	1	**14**	43	0.1	
	3	0	0	0	13	0	**13**	43	0	
	4	0	0	0	13	0	**13**	43	0	
	5	0	1	0	10	1	**11**	33	0.1	
	6	0	0	0	16	0	**16**	53	0	
	Total – all citrus	0	2	0	132	2	134			
	Mean	**0**	**0**	**0**	**15**	**0**	**15**	**49**	**0.01**	**0.1**
	se	0	0.1	0	0.9	0.1	0.8	2.9	0.01	
	Proportion	**0**	**2**	**0**	**98**	**-**	**100**			

Experiment 26

S. aurantii adults (~ 20 female & 10 male per cage) reared in culture on *B. pinnatum* were added to 3 cages on potted *Holarrhena pubescens* (= *Wrightia antidysenterica* Arctic snow), 2 cages on potted lime and 3 on potted lemons; 30 larvae per cage were added to single cages on 3 potted Tahitian limes and 1 Eureka lemon (on 1.11.06).

The five cages into which adult thrips were placed - 2 on lime and 3 on lemon - each had 3-4 small fruit, and the leaves in all were hard except one on lemon which had soft flush leaves. Thrips larvae were added to 3 cages on flushing limes (1 with 2 fruit, 2 without fruit) and 1 on lemon (with 3 fruit and hard leaves). Prior to caging, fruit were inspected and any damage potentially confused with thrips injury marked with a felt pen. The arrangement of cages by fruit and leaf state is shown in **Table 35**.

Larvae, pupae and adults were counted and fruit damage assessed after 14 days (on 15.11.06).

Results & Discussion

B. pinnatum had a mean of 307 thrips per cage including adults, 279 larvae and pupae; the lime and lemon cages with small fruit and hard leaves with adult *S. aurantii* had a mean of 10 including adults, or 3 larvae and pupae, per cage; one cage had 12 larvae on fruit **Table 36**.

Of the 30 larvae placed into one cage with flush and fruit, 37% survived to become adults. Of the 30 placed into each of two cages with flush and no fruit, 57 and 70% became adults; and for the cage with fruit and no flush leaves 27% survived to adults.

No thrips damage was evident on any fruit.

These data, though the numbers of replicates are very low, demonstrate that larval *S. aurantii* reared on *B. pinnatum* can complete development on citrus flush leaves and on small fruit.

Table 35: Arrangement of cages on potted lemons and limes.

Test host	Cage #	Larvae or Adult thrips	Number of fruit	Leaf state
Lime	1	A	3	Hard
	3	A	3	Hard
	4	L	2	Flush
	2	L	-	Flush
	5	L	-	Flush
Lemon	9	L	3	Hard
	6	A	3	Hard
	8	A	3	Hard
	7	A	4	Flush

Table 36: Performance of *S. aurantii* on *B. pinnatum*, potted lemon and lime.

Stage		**No.**	**Leaf**				**Live**	**Total**		**% adult**		**RRI**
Test host	rep	**Fruit**	**state**	**L1**	**L2**	**Pupae**	**adults**	**L&P**	**All**	**Survival**	**RI_{14}**	**(%)**
Adults												
B. pinnatum	1	-	-	71	114	68	27	253	**280**	-	14.0	
	2	-	-	84	133	87	30	304	**334**	-	**16.7**	
	2		Total	155	247	155	57	557	614	-	-	
			Mean	**78**	**124**	**78**	**29**	**279**	**307**	**-**	**15.4**	**100**
			se	7	10	10	2	26	27	-	1.4	
			Prop	**25**	**41**	**25**	**9**	**100**				
Adults												
Lime	1	3	hard	0	0	0	8	0	**8**	27	0	
	2	3	hard	0	0	0	3	0	**3**	10	0	**0**
Lemon	1	3	hard	0	**12**	0	8	12	**20**	27	**0.6**	
	2	3	hard	0	0	0	7	0	**7**	23	0	
	3	4	flush	0	**2**	0	11	2	**13**	37	0.1	**1.5**
	5	16	Total	0	14	0	37	14	51	-		
			Mean	**0**	**3**	**0**	**7**	**3**	**10**	**25**	**0.1**	**0.9**
			se	0	2	0	1.	2	3	4	0.1	
			Prop	**0**	**28**	**0**	**72**	**100**				
Larvae												
Lime	1	2	flush	0	**1**	0	11	1	**12**	37	-	
	2	0	flush	0	0	0	17	0	**17**	57	-	
	3	0	flush	0	0	0	21	0	**21**	70	-	
Lemon	1	3	hard	0	0	0	8	0	**8**	27	-	
	4	5	Total	0	1	0	57	1	58	-	-	
			Mean	**0**	**0**	**0**	**14**	**0**	**15**	**48**	**-**	**-**
			se	0	0.3	0	3	0.3	3	10	-	
			Prop	**0**	**2**	**0**	**98**	**100**				

Experiments 27 – 29: Field experiments

Three experiments were conducted on small trees in the citrus block at MRS Nambour in December 2006 and January 2007, by which time Nambour was well within the known limits of *S. aurantii* distribution. *S. aurantii* reared on *B. pinnatum* were released on 3 occasions into Navel orange trees ~ 2.5m high, with a good fruit load. On 6 and 14 December 2006 and 4 January 2007, 150 adults were released into each of 5 Navel orange trees; 5 tubes of 30 adults on 6 December, 3 tubes of 50 adults on the other two dates. The tubes, into which the thrips had been aspirated onto a small *B. pinnatum* leaf, were attached with U-tac® inside the canopy in a shaded position directly below fruit or flush leaves.

Fruit and flush growth were checked for damage and thrips (20 fruit per tree x 5 = 100 fruit per assessment) on 13 December, 3 January and in mid-February.

Results & Discussion

No thrips were found on navel orange flush or fruit and no thrips damage was apparent in any of the assessments.

4. INSECTICIDE EFFICACY

4.1 INTRODUCTION

Pest thrips such as Western flower thrips are well known for their capacity to rapidly develop resistance to insecticides, making them difficult to manage in commercial horticulture (eg Herron & Gullick 2001, Herron & James 2005). *S. aurantii* in citrus in South Africa also has a history of developing resistance to insecticides, including organophosphates, synthetic pyrethroids and tartar emetic (Grout et al. 1996, Gilbert & Bedford 1998).

'Resistance management' in insects is most commonly practiced in vegetables and cotton, where pest pressure and unit values of losses are high (eg Herron et al. 2005). It is based on sparing use of pesticides from chemical groups affecting the same target sites in the key pests, the aim being to reduce selection pressure and thus maintain pesticide sensitivity in the pest population. A critical element of most resistance management programs is the availability of registered pesticides with different modes of action that can be used in a rotation to further minimise selection of specific target sites for resistance.

The key ecological variable in pesticide resistance management is the proportion of the pest population that is sprayed, and thus subject to selection for increased frequency of resistance genes. Where movement of pest populations between sprayed and unsprayed areas is at high levels, resistance gene frequencies are diluted by the influx of susceptible genes from unsprayed populations. Conversely, where there is little movement between sprayed and unsprayed areas (crop or non-crop), the proportion of the total population sprayed, and thus resistance selection pressure, can be high.

In South African citrus, the first *S. aurantii* generation emerges from within orchards, and feeds and breeds on the spring flush. Mature second instar larvae drop to the ground and pupate in the leaf litter, the flush hardens, and second generation adults colonise small fruit. The resulting larval thrips feed under the calyx where they damage surface cells, which, as they expand with fruit growth, leave scars that make the fruit unmarketable (Gilbert 1990).

Insecticide sprays for *S. aurantii* target the second and subsequent generation that attack small fruit after petal fall. First generation populations on the spring flush, although they are more accessible to sprays than those on the fruit, are usually not sprayed to reduce resistance selection pressure. Also, because the mortality of thrips pupae in the soil is variable and pest pressure on fruit is not always well correlated with numbers on the flush, sprays targeting thrips on flush may result in increased or unnecessary spraying.

Spring in the sub-tropical northern areas of South Africa, where *S. aurantii* pest pressure is highest, is usually very dry, and native plants such as Acacias produce new growth necessary for thrips development only when wet season rains commence in late spring-early summer (November-December). The movement of thrips from these plants - when their new growth hardens and becomes unsuitable for thrips development - into citrus orchards can extend the spray period for 12 weeks or more from petal fall (Samways et al. 1987, Gilbert 1990). Fruit remains susceptible to attack for up to 5 months post-bloom (Gilbert & Bedford 1998).

To test the susceptibility of Australian *S. aurantii* to a range of insecticides used in Queensland citrus IPM, we ran a series of bioassays (Experiments 1-9), and a single experiment of the effects of Biopest spray oil on adult oviposition (Experiment 10).

4.2 MATERIALS & METHODS

Experiments 1 - 9

B. pinnatum leaf in sprigs of 5-6 leaves collected from an uninfested patch or from glasshouse grown plants was sprayed with each test chemical and allowed to air dry. In the first assay, a dry, sprayed leaf was put into each of 5 x 30 ml polystyrene tubes, 20 adult thrips aspirated into each, and the tubes closed by placing a piece of 100 μm nylon gauze over the tube and screwing on the lid into which a 1.5 cm hole had been cut. Mortality was assessed 1 day after treatment (DAT).

In the second and third assays, 10 adult thrips were aspirated into an empty tube, the thrips tapped to the bottom, the leaf with dry insecticide residue added and the tube closed with a lid ventilated with 100 μm mesh.

In subsequent assays (4-9), 25-35 thrips adults were used in each of 4 or 5 replicates per treatment. In experiments 8 & 9, in addition to the untreated Control, a positive control of Endosulfan at 5 ml/100L was employed. Agral (10ml/100L) was used as a surfactant for all treatments other than oils and BYI 8330; for the latter the surfactant Hasten was used at 230ml/100L. For trials 1-4 a single untreated Control with 5 reps was used; for trials 5-9 each treatment had its own untreated Control with the same number of replicates as the treatment (resulting in 10-15 Control replicates), except spirotetramet (formerly BYI 8330) which had 2 treated replicates and untreated Controls. Thrips mortality was assessed 3 DAT.

Experiment 10 – Biopest oil residue trial

This experiment determined the affect of exposure of *S. aurantii* adults to residues of the commonly used paraffinic spray oil, Biopest, on *B. pinnatum* leaves. Aqueous solutions of 0, 0.125, 0.25, 0.5 & 1% oil were sprayed with a 500 ml hand held atomiser onto each of 8 excised *B. pinnatum* leaves, allowed to dry and ~ 15 - 20 adult *S. aurantii* (i.e. ~ 10 females & 5 males) added to each container (on 13.7.06; i.e. 5 treatments x 8 replicates).

Adult thrips were removed after one day, killed in 70% alcohol, counted and sexed to determine the exact numbers used in each replicate. Larvae were counted 8 days after the adults were introduced, i.e. 7 days after the 24 hour oviposition period.

4.3 RESULTS

Experiments 1 - 9

Our assays showed that Australian *S. aurantii* is very susceptible to a range of insecticides (**Table 38**). Abamectin (at 10 ml/100L), chlorpyrifos (at 10 ml), endosulfan (at 2.5 ml) methomyl (at 25 ml) and spinosad (at 5 ml) killed more than 90% of adult thrips; rates substantially lower than those registered for these products in citrus.

Fipronil killed all thrips at the lowest rate tested (5 ml) and imidacloprid (as a foliar spray) was highly efficacious at extremely low rates (< 1 ml/100L). Two formulations containing bluish dogbane also were effective at low rates.

Biopest oil residues did not kill *S. aurantii* adults, and despite promise in one assay, nor did spirotetramet (known during its development as BYI 8330).

Table 38: Efficacy of insecticides against Australian *S. aurantii* in 9 laboratory assays.

Treatment/a.i.	g a.i./L product	ml/100 product	% a.i.	Trial 1	2	3	4	5	6	7	8	9
Treatment reps				5	5	5	5	5	4	4	5	5
Control reps				5	5	5	5	10	12	12	15	10
Control	(i.e. adjusted mortality)			0	0	0	0	0	0	0	0	0
Abamectin	18	50	0.0009000	100								
		25	0.0004500		100	100						
		20	0.0003600						100	100		
		12.5	0.0002250			100	90					
		10	0.0001800						100	90		
		6.25	0.0001125			100	81					
		5	0.0000900						88	61		
		2.5	0.0000450						64	66		
		1.25	0.0000225						36	47		
Biopest Oil	815	1000	0.815000	0								
BYI 8330 = Spirotetramet	240	150	0.036000							5		
		100	0.024000							3		
		50	0.012000						24	0		
		25	0.006000						48			
		12.5	0.003000						91			
Dogbane # 1	5	200	0.001000	94								
		100	0.000500		98	100						
		50	0.000250			100	88					
		25	0.000125			100	83					
Dogbane # 2	5	100	0.000500		100							
		50	0.000250				46					
Chlorpyrifos	500	50	0.025000		100							
		25	0.012500			100						
		10	0.005000			100						
Endosulfan	350	190	0.066500	100								
		80	0.028000					100				
		60	0.021000		100	100						
		40	0.014000					100				
		30	0.010500			100						
		20	0.007000					100	100	100		
		15	0.005250			100						
		10	0.003500					100	100	100		
		5	0.001750					100	100	99	76	56
		2.5	0.000875						90	92		
		1.25	0.000438						92	80		
Fipronil	200	25	0.005	100								
		10	0.002		100							
		5	0.001			100						

Table 38: Efficacy of insecticides against *S. aurantii* (Continued)

Treatment	g a.i./L product	ml/100L product	% a.i.	Trial 1	2	3	4	5	6	7	8	9
Imidacloprid	200	25	0.005000	98				100				
	350	8	0.002800								100	
	200	12.5	0.002500					100				
	200	10	0.002000		100							
	350	4	0.001400								100	
	200	6.25	0.001250					100				
	200	5	0.001000			100						
	350	2	0.000700								100	100
	350	1	0.000350								100	96
	350	0.5	0.000175								100	100
	350	0.25	0.000088									100
	350	0.125	0.000044									87
Methomyl	225	150	0.033750	100								
		50	0.011250		38							
		25	0.005625			100						
Spinosad	120	50	0.00600	100								
		25	0.00300		93	100						
		20	0.00240								100	
		12.5	0.00150			100	95					
		10	0.00120								100	99
		6.25	0.00075			100	90					
		5	0.00060								98	91
		2.5	0.00030								88	96
		1.25	0.00015								84	56
		0.625	0.00008									48

% active ingredient (a.i.) = ml product per 100L/100,000 x g a.i. per L product/1000 x 100

Agral, 10 ml/100L with all products other than Biopest Oil & BYI 8330, the latter with 230 ml/100L Hasten

All actives had 5 reps, except BYI 8330 with 2. All assessments at 3 days except Trial 1 at 1 day

Where Control reps n > 5, each active had its own Control with same number of reps as the treatments

Number of thrips per replicate: Trial 1 = 20, Trials 2 & 3 = 10, Trials 4-9 = 25-40

Data corrected for Control mortality by Abbott's formula

Experiment 10

Mean *S. aurantii* offspring larvae per female seven days after oviposition compared with untreated controls (3.3) was unaffected by Biopest oil residues of 0.125% (2.7) or 0.25% (2.7), but was reduced by 0.5% (0.8) and 1% (1.0) oil (**Table 39**).

The actual number of *S. aurantii* adults per replicate (determined post-assay) was 10 - 15 females and 4 - 8 males (total 429 female, 203 male thrips in 38 replicates; replicate mean 11.3 females, 5.3 males; mean ratio females to males by replicate 2.1 - 2.3.

The replicate mean total larvae at 7 days was 9.6 and 13.0 for 0.5% & 1% oil, 29.8-34.3 for 0.125%, 0.25% oil and the untreated control. A total of 873 larvae resulted from the 24 hour oviposition period of 429 female thrips (2.03 per female). At the conclusion of the trial at 7 days, 61% of larvae were 1st instars (L1's), with a mean of 13.9 L1's & 9.1 L2's per replicate for all treatments; there was significant variation between replicates in the proportions in each of the two instars, but little variation between treatments (range 57 - 63 %).

For the treatments where no oil effect was apparent (Untreated, 0.125 & 0.25% oil; total of 22 replicates) 250 adult female thrips produced 692 larvae giving a mean of 2.8 larvae per female, or 31.5 per rep (13.9 L1's & 12.3 L2's). In the oil affected treatments (16 reps) 181 females produced 11.3 larvae per replicate, a mean of 1.0 per female (6.7 & 4.6 L1's & L2's).

Table 39: The effect of exposure of *S. aurantii* adults to Biopest oil residues on *B. pinnatum* leaves on the number of larvae produced at 7 days.

Treatment	**Adult thrips**		**Offspring:**			**Mean larvae per:**				
% oil	**Reps**	♀ - ♂	**L1**	**L2**	**Total**	**female**	**Rep**	**se**	♀**/rep**	**se**
Control	7	74 - 37	151	89	240	3.2	34.3	9.3	**3.3**	**1.0**
0.125	8	91 - 41	136	102	238	2.6	29.8	8.1	**2.7**	**0.8**
0.25	7	83 - 37	135	79	214	2.6	30.6	7.7	**2.7**	**0.7**
0.50	8	92 - 44	44	33	77	0.8	9.6	2.4	**0.8**	**0.2**
1.0	8	89 - 44	63	41	104	1.2	13.0	3.8	**1.1**	**0.3**
Total	**38**	**429 - 203**	**529**	**344**	**873**	**2.0**				
Replicate mean		11.3 - 5.3	13.9	9.1	23.0					
Total unaffected	22	**250**	422	270	**692**	**2.8**				
Rep mean		11.4	19.2	12.3	31.5					
Total affected	16	**181**	107	74	**181**	**1.0**				
Rep mean		11.3	6.7	4.6	11.3					

4.4 DISCUSSION

The extreme susceptibility to insecticides shown in our trials suggests that Australian *S. aurantii* originated from a non-citrus source; otherwise it is probable that they would display much higher levels of tolerance to insecticides. They also indicate that if this thrips begins to attack horticultural crops it should – at least initially - be easily controlled with foliar applications of pesticides already commonly employed in citrus IPM, including those currently used for *S. albomaculatus* and *S. dorsalis*.

Imidacloprid was registered in Australian citrus as a soil drench since our data was generated, and has been widely adopted by Queensland growers. Our data for this active ingredient is for foliar sprays, which are not compatible with citrus IPM. Other data we generated but have not presented here indicated that foliar application on *B. pinnatum* resulted in persistent systemic efficacy against S. *aurantii* adults for several months.

In South Africa, despite good efficacy in pre-registration trials (Broeksma et al. 1993), subsequent experience with the registered product was such that this pest was removed from the label and claims for efficacy against SACT on bearing trees are no longer made. It does have a role in young trees, however, and may, by suppressing if not controlling thrips, enable softer management regimes even on bearing trees (Grout & Gilbert pers. comm. 2004).

The lack of efficacy of imidacloprid in protecting fruit at petal fall means foliar sprays of other products are required to achieve acceptable control. Another period when damage can occur if sprays are not applied is late in the thrips season when imidacloprid levels are beginning to fall (Gilbert pers. comm. 2004).

Experience in Queensland citrus orchards with imidacloprid as a soil drench is currently developing; the 2007-8 season is the second in which it has been used. The primary target is red scale, but reduction in other insect pests is claimed, though some are not controlled and may be made worse, eg oriental mite *Eutetranychus orientalis* (Papacek pers. comm. 2007). Because of concern for insects in flowers, imidacloprid is applied after the main flowering has finished, and this will not provide protection of very small fruit at petal fall, though extended thrips suppression by systemic use of imidacloprid may reduce thrips pressure in the longer term. Imidacloprid will not solve thrips problems in lemons, a high value crop susceptible to damage, where the current practice of protecting multiple fruit crops prevents its use because of the long withholding period (20 weeks).

The Biopest oil experiment, in which the numbers of larvae produced by adults allowed a 24 hour oviposition on leaves with oil residues were reduced from 2.8 in unaffected treatments (0-0.25%) to 1.0 per female at 0.5 & 1% – a 64% reduction – suggests that the use of oils for the control of red scale and other pest, may contribute significantly to thrips management.

Any effects of the oil deposits on egg hatch were not determined in our experiment, so treatment effects are a composite of oviposition deterrence and egg mortality. The extensive literature on the effects of oils on oviposition by a range of insects, however, supports the contention that the major effect is probably oviposition deterrence (Liu *et. al.* 2002a, 2002b).

5. PREDATION BY *EUSEIUS VICTORIENSIS*

5.1 INTRODUCTION & METHODS

The native mite *E. victoriensis* is a significant predator in Queensland citrus, most notably of eriophyid and other mites, but also of the smallest stages of scale insects and thrips (Smith & Papacek 1991, Smith et al. 1997). Recent research showed the predator could be mass reared for strategic release into citrus (Freebairn & Smith 2003, 2004, 2007). We assayed predation of *S. aurantii* larvae by *E. victoriensis* using laboratory cultured predators and thrips. Predators were reared on soybean or castor oil plants with field harvested *Typha* pollen dusted onto plants on alternate days as food.

To test for the capacity of *E. victoriensis* to kill, eat and survive on a thrips-only diet, 3 adult predatory mites were confined in 5 replicated 30 ml tubes ventilated with 100 um mesh (on 12.7.06). First instar *S. aurantii* larvae (30 per tube) were added at T_0; a further ~ 20 thrips per tube were added during the course of the experiment (which ran for 19 days) on days 2, 4, 7, 9 & 12 (**Table 40**) to achieve a constant supply of thrips for the predators. As controls, 30 first instar thrips larvae, or 3 predators were placed into each of 5 tubes with *B. pinnatum* leaf; the predators were fed *Typha* pollen on alternate days. Counts of surviving thrips larvae and predators were made at 1-3 day intervals.

5.2 RESULTS

In the thrips predation bioassays, mean survival of thrips in the controls declined in a linear fashion through the first 7 days until all larvae had pupated, averaging 45% (**Figure 6**). Survival was variable between replicates; the best two had 87 & 77% survival, the worst two, 7 & 3% (**Figure 7**).

A mean of 4.5 thrips per day (corrected for control mortality by sample day) (range 2.3-5.9) was eaten by the predators in experimental tubes (**Figure 6**), and the numbers of predators in tubes in which they were fed thrips was similar to those in which they were supplied only with pollen as food (**Figure 8**).

5.3 DISCUSSION

Our results show that adult *E. victoriensis* can survive for at least 19 days on a diet of *S. aurantii* larvae at levels comparable to those fed *Typha* pollen. Adult predators killed a mean of 4.5 first and early second instar thrips larvae per day, and can be expected to make a useful contribution to control of *Scirtothrips* and probably other pest thrips in the field.

Table 40: Number of *S. aurantii* larvae added during the *E. victoriensis* predation assay.

	Days post-initiation					
Replicate	**2**	**4**	**7**	**9**	**12**	**Total**
1	20	15	25	30	20	110
2	20	15	0	0	0	35
3	25	15	15	30	20	105
4	15	20	25	30	20	110
5	25	30	25	30	20	130
Total	**105**	**95**	**90**	**120**	**80**	**490**
Mean	**21**	**19**	**18**	**24**	**16**	**19.6**

6. SURVEILLANCE & PEST RISK ANALYSIS

6.1 INTRODUCTION & GENERAL METHODS

Following the detection of *S. aurantii* on *B. delagoense* at the Queensland Department of Natural Resources & Mines (DNRM, now DNRW) Alan Fletcher Research Station (AFRS) at Sherwood in Brisbane in March 2002, a Consultative Committee on Plant Pests & Diseases (CCEPPD) teleconference in late March 2002 involving state/federal quarantine and industry representatives endorsed an initial response and a follow-up action plan. The station was quarantined, all infested or suspect plant material destroyed, the affected glasshouse emptied and disinfested and a program of ongoing surveillance developed and implemented by QDPI&F and QDNRW staff (Anonymous 2003a). Additional, ad hoc surveys were conducted by APHS &/or AFRS staff in the period 2003-06.

Following the initial survey of the Sunshine Coast area in March 2003 (24 sites around Nambour, Eumundi, Mapleton, Maroochydore, Woombye and Yandina), (Anonymous 2003b), we conducted annual surveys on *Bryophyllum* species in the Nambour area in January-February 2004 and 2005, and in March 2006.

6.2 RESULTS

2002-03 Surveys – Brisbane and the Sunshine Coast

The reports of the surveys conducted by APHS/AFRS in 2002-03 (Anonymous 2003a), and the March 2003 Sunshine Coast survey (Anonymous 2003b) are included as **Appendix 5**. Anonymous 2003a provides extensive detail of activities in Brisbane leading to the discovery that the thrips was widespread on *Bryophyllum*, but it was never detected on hosts other than those in the family Crassulaceae, including potential crop hosts citrus and mango, which are common in suburban backyards, or potential native hosts such as *Acacia* and *Grevillea*.

In the March 2003 Sunshine Coast survey, two sites were positive for thrips and samples were submitted for identification; none was *S. aurantii*. In the 2004, 2005 and 2006 surveys no thrips damage was detected on *Bryophyllum* spp. in the Nambour area.

Additional surveys

S. aurantii was detected in December 2005 by AFRS staff on *B. delagoense* at a number of locations west of Laidley to Toowoomba, and from near Inglewood in the south to Taroom in the north (~ 150 km west of Mundubbera). All 21 samples submitted to John Donaldson, DPI&F Indooroopilly, contained *S. aurantii* (Tree pers. comm. 2006).

These thrips were associated with significant damage to the *Bryophyllum*, including growth stunting and reduced flowering. Follow up surveys in March 2006 failed to detect *S. aurantii* on citrus, macadamia or mango.

S. aurantii was also confirmed present on *B. delagoense* at the Elanda Point car park near Tewantin in March 2006 and on *B. pinnatum* at Caboolture in April 2006. The most recent distribution map for *S. aurantii* in Queensland (as at 30 June 2006) is shown as **Figure 5**.

Pest risk analysis

Included as **Appendix 5**, this analysis also provides a detailed summary of various aspects of the biology ecology and control of *S. aurantii*.

6.3 DISCUSSION

In the surveillance carried out in 2002-03, *S. aurantii* was found to be present in suburban Brisbane over an area exceeding 1700 km^2 on mother of millions, mainly *B. delagoense*, but not other hosts on which it was expected to occur such as citrus, mango, Acacia or Grevillea. It was not detected in surveys in other parts of Australia, including on the Sunshine Coast.

The extent of the area infested, the nature and distribution of the *Bryophyllum* species hosts, the terrain in which it was found (commonly in dense mats under tall grass and very difficult to locate - **Plates 3 & 4**) and the biology of the thrips (pupation in the soil, adults fly readily on bright sunny days if disturbed) were such that the prospects of eradication were agreed by all entomologists present at the CCEPPD meeting in March 2003 to be extremely low.

Successful eradications of thrips are limited to circumstances where the thrips (*T. palmi* in the Netherlands and the UK; *S. dorsalis* in Florida) were not established on favoured hosts over an extensive outdoor area (Cannon et al. 2007a, Anonymous 2007), and as such support rather than contradict the conclusion that eradication of *S. aurantii* in Australia was not feasible.

The hope was that because of its' apparent disinterest in its normal hosts, including citrus, *S. aurantii* in Australia was a biotype, strain or cryptic species that would remain on *Bryophyllum* and never attack crop hosts.

It was also considered, given the normally slow rate of natural dispersal of *Scirtothrips* species, that it would take some years before the thrips reached commercial citrus areas. It was recognised that movement along roads was a likely mode of range expansion, and this has occurred. *S. aurantii* is now known from an extensive area from Laidley west to Toowoomba and from near Inglewood to Taroom, a substantial expansion in range from 2003. Taroom is less than 200 kilometres west of Mundubbera in the Central Burnett where most of Queensland's citrus is grown. *S. aurantii* is also moving northwards in the coastal areas of south-eastern Queensland, with detections at Caboolture and Elanda Point near Tewantin (**Figure 5**).

To date, *S. aurantii* has not been detected or reported on any horticultural crop. It should be noted, however, that since the early surveys in March-December 2002, which sampled all potential thrips hosts but detected breeding populations only on *Bryophyllum,* subsequent surveillance focused on *Bryophyllum*, with only *ad hoc* sampling of relatively small numbers of plants of crop or native species (Anonymous 2003, Rafter et al. 2008).

On this basis, and given the possibility that *S. aurantii* incursion into citrus or other crops may not be noticed because the damage is not recognisably different from that caused by existing *Scirtothrips* species, its' extreme susceptibility to insecticides as shown by our trials, and in the absence of data indicating normal infestation levels on crop host such as citrus and mango distant from commercial citrus in South Africa, conclusions about the potential of this thrips to attack crops or utilise native vegetation must be regarded cautiously.

Firmer conclusions require targeted, quantitative surveys near infested Bryophyllum of potential hosts such as macadamia, mango, citrus, *Acacia* and *Grevillea* in growth states appropriate for thrips development. Ideally, such surveys would sample at variable distances downwind from infested Bryophyllum, to test the possibility that thrips unable to locate their preferred hosts may successfully utilise crop or native species.

7. GENERAL DISCUSSION

7.1 INTRODUCTION

Plant feeding thrips are regarded as preadapted to an invasive lifestyle; they are small and cryptic - hence difficult to detect, opportunistic, have broad host ranges, and oviposit their eggs into plant tissues where they are not killed by insecticides (Morse & Hoddle 2006). The Australian thrips fauna contains more than 60 exotic species, most arriving in the nineteenth century when soils and plants were imported without concern for the risks posed by exotic organisms (Mound 2004), but the problem persists, and international plant movement remains a major route of invasion by exotic species. Recent thrips invaders with serious consequences for horticulture are the now worldwide pests, melon thrips *Thrips palmi* - detected in Northern Territory in 1989 (Anonymous 2005), and Western flower thrips *Frankliniella occidentalis* - detected in Perth in 1993 (Malipatil et al. 1993). Wherever they occur, these two species have destroyed crops, significantly altered cropping practices, increased control costs and restricted market access as a result of quarantines (eg Cannon et al. 2007).

The genus *Scirtothrips* contains over 100 species worldwide (Hoddle & Mound 2004). Of the 21 species known in Australia, 15 are presumed endemic (including *S. albomaculatus*) - 7 associated with Acacias, 8 with diverse plant families (from Casuarinaceae to Zamiaceae); 2 are cosmopolitan species with uncertain origins, including *S. inermis*, a pest of citrus in Spain (Lacasa 1996) known from various locations and hosts in Australia but not citrus (Hoddle et al. 2006); 3 are tropical species whose natural distributions include northern Australia (including S. *dorsalis*), and the recently detected *S. aurantii* is an African species.

Scirtothrips are very small, active thrips that breed on young leaves. They are regarded as poor dispersers, with most pest species restricted geographically, in contrast to many pest thrips (Hoddle & Mound 2004). In recent times, however, three major pest species have expanded their ranges with serious consequences for horticulture. *S. perseae* Nakahara was detected in California avocado groves in 1996 (Hoddle et al. 2003); *S. dorsalis* Hood, was detected and eradicated in Florida in 1991, but was found again in 2005 (Anonymous 2007), and *S. aurantii* was detected in Australia in 2002 (Anonymous 2003).

S. perseae, a central Mexican species, is now a serious pest of avocado in California (Hoddle at al. 2003). *S. dorsalis*, an Asian species and a serious pest of a broad range of crops, was known to be in the Caribbean and was the subject of research and management to reduce the risk of its spread to the USA, but it is now well established in Florida attacking a very broad range of plants including many not previously recorded as hosts (Anonymous 2007).

S. aurantii, an indigenous African species recorded from more than 83 species in 33 plant families, and a pest of mango, banana, tea and grape, is known as the South African citrus thrips (SACT) because it is most damaging in this crop (Gilbert & Bedford 1998). In Australia, however, despite alarm at the potential risk posed to horticulture by this thrips, the extensive initial surveys of all potential thrips host plants detected it only on species of *Bryophyllum,* succulent plants adapted to dry areas and indigenous to Madagascar, five species of which are declared noxious weeds in Queensland responsible for numerous livestock deaths and the displacement of native vegetation (Hannan-Jones & Playford 2002).

Succulents such as Bryophyllum had previously not been considered likely hosts of thrips (Morris & Mound 2004) - their use of Crassulacean acid metabolism, also employed for example by pineapples, was thought to make them unattractive to insects.

7.2 RECENT WORK

As a result of the detection of *S. aurantii* in Australia, extensive surveillance was undertaken to delimit the infestation and inform decisions about eradication or containment, and research was initiated by several groups. As a result of these activities we now know considerably more about Australian *S. aurantii* than we did in 2002-03. Interest also has been stimulated in South Africa, as the unusual behaviour of this thrips in Australia on *Bryophyllum* has encouraged renewed consideration of the possibility that more than one species may be included under the name *S. aurantii*, with potential ramifications for thinking about the natural ecology of the species and its management in citrus. Our *Bryophyllum* leaf rearing method has been recognised as potentially useful for rearing thrips in numbers for mass rearing of predators or parasitoids for strategic releases into citrus (Grout pers. comm. 2007).

Freebairn & Smith (Anonymous 2003b) reported that *S. aurantii* was not found on potted citrus placed amongst infested *B. delagoense* in Brisbane. Morris & Mound's (2004) molecular studies showed that the taxon *S. aurantii* (as sampled) consisted of two distinct but not host restricted groups, each containing thrips from both *Bryophyllum* and citrus. Manners & Dhileepan (2005) reported that in field cage trials on potted plants, including citrus and mango, *S. aurantii* survived only on *B. delagoense*.

In South Africa, Grout (pers comm. 2006) found that potted *B. pinnatum*, *B. delagoense*, *B. proliferum* and *B. daigremontianum* placed about 6m from *C. pulcherrima* infested with *S. aurantii* (the nearest citrus was > 100m away) at Nelspruit were not infested for almost a year, after which they were infested and severely damaged. A colony of *S. aurantii* was established on *B. pinnatum* leaves from thrips on the field infested *B. pinnatum*, but its' performance was poor and the culture failed completely after about 18 months. More recently, in order to rear thrips to enable mass rearing of the parasitoid *Goetheana incerta*, Grout (pers. comm. 2007) confined thousands of *S. aurantii* adults from naturally infested *C. pulcherrima* on *B. pinnatum* leaves in tubs, but not a single thrips larva resulted.

Rafter et al. (2008) found that Australian *S. aurantii* did not infest orange or kumquat plants in flight cages, settled occasionally on mango, but readily settled and established colonies on *B. delagoense*. In no-choice tests thrips reproduced successful only on *B. delagoense*; on mango, nymphs were occasionally produced on young red leaves, but their mortality and that of the few resulting adults was complete and no further eggs were oviposited. They concluded that the '*Bryophyllum* thrips' should not be regarded as a biotype of *S. aurantii*, but as a host-restricted cryptic species that is likely to remain exclusively on *Bryophyllum*, may occur occasionally and sporadically on mango flush leaves, but has no potential to attack citrus.

Other significant recent publications include the following - Hoddle and Mound (2003) reviewed the genus *Scirtothrips* in Australia, Mound (2004) the diversity of Australia thrips and thrips research, Mound (2005) reviewed thrips diversity and interactions with plants, and other organisms including natural enemies, Morse and Hoddle (2006) reviewed the invasion biology of thrips, and Rugman-Jones et al. (2006) developed a molecular identification key for pest Scirtothrips.

7.2 OUR RESEARCH

We addressed the question of the threat posed by *S. aurantii* to Australian horticulture using no-choice testing to establish the capacity of this thrips to utilise as hosts a range of native, crop, ornamental and exotic weed species (**Section 3**). We conducted insecticide efficacy trials (**Section 4**), assessed the potential of the native predatory mite *E. victoriensis* to contribute to the management of this thrips if it attacks citrus (**Section 5**), conducted surveys of *Bryophyllum* species in the Sunshine Coast area to determine the limits of distribution and movement of the pest (**Section 6**), and liaised with the citrus industry (see **Appendices 1 – 3**).

We found that Australian *S. aurantii* has the capacity to develop successfully on a broad range of plant hosts, including crop, native and weed species, but there were marked differences in performance between hosts. Based on the performance of adult thrips confined in cages on growing potted plants, we allocated the 36 plant species tested to one of five categories – Very good, Good, Moderate, Poor or Very poor hosts (**Table 4**).

Performance of *S. aurantii* on tested plants was standardised and expressed as the rate of increase per 14 days, RI_{14}, defined as the number of offspring thrips per female adult added to cages at the start of each trial. The host suitability categories were defined based on maximum mean relative performance in all trials of a test host species. Relative performance was expressed as the relative rate of increase - RRI (%), the RI_{14} for the test host as a percentage of the RI_{14} for a reference host, two or three replicates of which were run in most trials. For trials in which the reference host was not run, performance on test hosts was compared with mean reference host performance from the 18 trials in which it was included (**Table 7**).

B. pinnatum was chosen as the reference host as it has flat phyllodes and an open growing point, making it an easier plant on which to observe and count thrips than the more common and weedy *B. delagoense*, which has appressed tubular phyllodes and a tight terminal. To enable comparisons, *B. delagoense* was included in 5 trials and *B. proliferum* in one trial on potted plants. We also compared thrips performance on excised phyllodes of *B. pinnatum* and *B. proliferum* in tubs to determine their relative suitability as rearing hosts, and the value of folded paper towel in the tubs as a pupation site.

Host utilisation and thrips performance

The *Bryophyllum* species, the traded ornamental *Kalenchoe blossfeldiana* and macadamia were rated as very good hosts, that is, in the best trials they produced 61 - 150% as many offspring thrips per female as the reference host *B. pinnatum* (**Table 4**).

Navelina orange, Tahitian lime and mango were rated as good hosts (31 - 60% of reference host performance). Mango, based on thrips performance in extended trials for periods of up to 6 weeks, and considering the large numbers of thrips produced in cages in which foliage suitable for thrips breeding was available throughout, qualifies as a very good host.

Eureka lemon, red grapefruit, peach, grape, tea and the natives *Acacia sophorae*, *A. longifolia* and *Syzygium moorei* were moderate hosts (21 - 30% of reference host performance).

Caesalpinia pulcherrima was a poor host (relative performance 11 - 20%). Hickson mandarin, sweet orange seedlings, Kumquat fruit, avocado, cotton, soybean, *Eucalyptus tereticornis*, *Grevillea robusta*, *Syzygium australe*, *Crassula ovata* (and *argentea*), *Murraya paniculata*, Poinciana and green bean pods were very poor hosts (relative performance 0 - 10%), although adult thrips survived well over the test period on many, and most produced a few larval thrips

that appeared to be developing normally. No offspring thrips were produced on banana, castor oil, *C. columellaris, K. longiflora, G. lanigera* and *H. pubescens*.

Continuous culture on citrus

Using adult thrips reared on *B. pinnatum*, we successfully reared *S. aurantii* in continuous culture on citrus (mostly lemons & limes, the best performers in prior work) through as many as seven ~14-day cycles in 5 experiments (**Table 23**). We used 100 thrips adults per cage to start each experiment (~70 females) and apportioned equally all thrips from each cycle into cages of the next cycle (i.e. larvae and adults). The overall rate of increase over all experiments combined was 3.0, that is, 20% of mean reference host performance (RI_{14} 15.3); the best performing cages (per experiment) produced RI_{14} values similar to the best cages in our single cycle trials, i.e. 4.0-7.7, representing 26-50% of mean *B. pinnatum* performance (**Table 23**).

Mango as a source of *S. aurantii* attacking citrus

In South Africa, in the sub-tropical areas where thrips pressure is greatest, mango is regarded as a super host of *S. aurantii*, and control is essential on mangoes to prevent increased damage to adjoining citrus. Early in the season huge numbers of *S. aurantii* are found in flowers (in contrast to citrus where this thrips is rare in flowers) and on small fruit. These 'mango thrips' near citrus are sprayed 2 - 3 weeks before the end of citrus petal fall to prevent movement into citrus. Constant checking of the border rows of both crops is necessary, since inadequate control on mango can result in increased damage to adjacent citrus 10 or more rows deep, depending on wind conditions. With good control the 'mango effect' can be limited to 2 - 3 rows, but even in December, when fruit is fairly large in both crops, there are usually more thrips in the first 2 rows of citrus adjacent to mangoes (Gilbert pers. comm. 2005).

The threat to citrus by *S. aurantii* from mango results, therefore, not from any effect of the rearing host on the thrips, but rather from differences in the phenology of the crops and/or from the productivity of mango as a host. We ran a trial comparing performance on several hosts including citrus, of thrips reared on potted mango plants and on *B. pinnatum*. No difference was apparent in performance on citrus; insignificant numbers of offspring thrips were produced regardless of the source of the adults (**Table 12**).

Insecticide efficacy

Australian *S. aurantii* was found to be highly sensitive to a range of insecticides currently used in citrus IPM, with mortalities in bioassays greater than 90% achieved well below the registered rates (**Table 38**). Biopest oil spray residues were found to reduce the numbers of larvae produced by adult female thrips exposed for 24 hours to fresh deposits of 0.5 & 1% sprays, but not to residues of 0.125 or 0.25% sprays (**Table 39**).

This high level of sensitivity to insecticides suggests that the populations of *S. aurantii* in South Africa from which the Australian thrips originated had not recently been exposed to spray regimes of the type commonly employed in commercial citrus orchards in that country. It also indicates that if this thrips ever does attack horticultural crops in Australia it should, at least initially, be easily controlled with currently registered insecticides. In citrus, for example, notwithstanding ecological considerations that may affect pest pressure, it should be more easily managed than the existing pest species *S. albomaculatus* and *S. dorsalis*.

Imidacloprid, a systemic insecticide recently registered as a soil drench and currently widely used by Queensland citrus growers, may over time reduce thrips pest pressure, including from Scirtothrips species, however this remains to be determined.

Imidacloprid also has the potential to disrupt IPM in citrus of pest mites and thrips through hormoligosis, the promotion of greater longevity and fecundity of pests. This is known, for example, in two spotted mite *Tetranychus urticae*, in hops (James & Price 2002), and in citrus thrips *Scirtothrips citri* (Morse & Zareh 1991). It may also disrupt IPM by killing important beneficials such as *E. victoriensis* a predatory mite that extracts material from citrus leaves.

We have preliminary evidence showing that on soybean plants, *E. victoriensis* feeding on Typha pollen were killed by imidacloprid applied to the soil to kill soybean leafminer larvae. It is likely therefore that imidacloprid use in Queensland citrus will detrimentally affect the predator *E. victoriensis*, and thus, may disrupt IPM of the pest species upon which it preys.

Predation by *Euseius victoriensis*

The predatory mite *Euseius victoriensis* occurs naturally in Queensland citrus and makes a major contribution to pest mite control, especially the native *Tegolophus australis*, and to a lesser extent the cosmopolitan *Phyllocoptruta oleivora*. In predation assays, adult mites killed a mean of 4.5 and up to 6 first and early second instar *S. aurantii* larvae per day (**Figure 6**), survived for more than 19 days on a diet of larval thrips at levels comparable to those fed *Typha* pollen (the food used to mass rear this predator) (**Figure 8**), and can be expected to make a useful contribution to the control of *Scirtothrips* spp. in the field.

Another Phytoseiid, *Amblyseius longispinus*, was a common contaminant in our culture tubs, persisted over many generations and significantly suppressed thrips numbers by killing larvae. *A. longispinus* may play a role in thrips suppression in coastal areas, where it is one of several probably better adapted phytoseiid species that apparently displace *E. victoriensis,* but is unlikely to do so in the drier main inland citrus areas of Queensland.

Parasitoids

Small numbers of parasitoid wasps were observed and persisted for several generations in new cultures of *S. aurantii* established with thrips collected from *Bryophyllum pinnatum* and/or *B. delagoense*. No effort was made to sustain these parasitoids or determine their capacity to suppress thrips populations; they may be worthy of further investigation.

Surveillance & Pest Risk Analysis

S. aurantii was initially detected at Sherwood, but following extensive surveillance activity was found by March 2003 to be established over an extensive area in suburban Brisbane, with a single detection to the west at Laidley. A pest risk analysis paper was prepared and informed subsequent discussion about eradication by CCEPPD, which concluded that eradication was logistically infeasible and economically unjustifiable (**Appendix 5**).

The most recent surveillance shows the distribution of *S. aurantii* has expanded significantly; by June 2006 it was confirmed present on *B. delagoense* west and south west of Laidley, and north west to Taroom, less than 200 km west of the Central Burnett citrus town Mundubbera. On the coast it has been detected as far north as Elanda Point, near Tewantin (**Figure 5**).

So far, all detections have been on Bryophyllum, with no records from any crop host.

7.3 POSITIVE USES OF *S. AURANTII* IN AUSTRALIA?

The availability of a highly productive simple rearing method for *S. aurantii* developed in this project may enable the production of natural enemies of *Scirtothrips* spp. (or other pest species) for releases into orchards and should be investigated.

If we can convince ourselves that *S. aurantii* will not attack commercial crops, this method could also be used to mass rear this thrips for dissemination into *Bryophyllum* infestations.

7.4 THE RISK TO HORTICULTURE POSED BY AUSTRALIAN *S. AURANTII*

Macadamia and mango in our experiments rated as very good or good hosts of *S. aurantii*, suggesting that these crops may be attacked by this thrips. The traded ornamental succulent *Kalanchoe blossfeldiana* also may be attacked.

On citrus, the performance of *S. aurantii* in our experiments on Tahitian lime and Navelina orange was comparable or better than on the most weedy mother of millions *B. delagoense*, and sufficiently high relative to the more favoured *B. pinnatum* to be rated as a good host. Lemon and grapefruit were rated as moderate hosts. Peach grape and tea, and the natives, *Acacia sophorae*, *A. longifolia* and *Syzygium moorei* also produced moderate performance relative to the reference host. *Caesalpinia pulcherrima* was rated a poor host. Sweet orange seedlings, Hickson mandarin, and a number of other crop, native and ornamental species were rated as very poor hosts, though many produced some offspring thrips.

Rafter et al. (2008) found citrus to be unattractive to *S. aurantii* compared with *B. delagoense* and mango, and adults confined in pairs in clip cages survived for only 6 days. Adults survived for up to 15 days on mango, but in their choice tests mango was a non-preferred host. Some larvae were produced in both choice and no-choice tests but they did not develop successfully to adults. Based on these results they predicted that Australian *S. aurantii*, which they refer to as the '*Bryophyllum* thrips' should be regarded as a host-restricted species likely to remain exclusively on *Bryophyllum*, that may occur occasionally and sporadically on mango flush leaves, but has no potential to attack citrus.

Our experiments used no-choice methods to assess the capacity of Australian *S. aurantii* collected from and reared on *Bryophyllum* to develop on test hosts. Because this method circumvents host location behaviours potentially critical in determining host utilisation by these insects in nature, the data generated does not support unequivocal predictions about the behaviour of this thrips on those hosts. No-choice methods do, however, provide a robust test of complex behaviours equally critical in determining natural host utilisation patterns. Acceptance of test plants for oviposition by adult female *S. aurantii*, and successful development of eggs and larvae in large numbers and at rates comparable to the reference host on some of them, indicate physiological capacity in this insect to use these hosts.

Choice tests, such as those used by Rafter et al (2008), may provide a better indication of behaviour when the preferred hosts of *S. aurantii* are available, however, they do not enable confident predictions about behaviour in the absence of these hosts, the conventional argument for the retention as the standard test method of no-choice tests in biocontrol agent host range and risk assessment experimentation (eg Marohasy 1996, 1998, van Klinken & Edwards 2002, Briese 2004 for discussion of weed biocontrol testing methods and interpretation of results).

The differences in performance on mango in our no-choice experiments and those of Rafter et al. (2008) could be explained by real differences in the suitability for Australian *S. aurantii* of the plants we each used, or by variation in behaviour between thrips populations; ours were sourced from Indooroopilly, theirs from Brookfield. This may seem unlikely, as it is probably that the number of *S. aurantii* arriving in Australia initially was small. However, it could result if *S. aurantii* on *Bryophyllum* in South Africa was comprised of two or more species, one restricted to *Bryophyllum*, the others capable of utilising hosts such as macadamia and mango, or citrus and natives such as Acacia, as well as *Bryophyllum*.

They could also be attributed to methodological differences. Rafter et al.'s (2008) choice tests involved small numbers of thrips on mango, since most of the 15-25 thrips added as a breeding colony to each of the five flight cages preferred *B. delagoense*. Their no-choice tests used 15 clip cages on leaves, each with a single female and male thrips. In our 8 mango experiments (combined total of 32 cages) we used a total of 960 thrips (approximately 685 of which were female).

Morris and Mound's (2004) molecular data suggests that gene movement does occur between populations of *S. aurantii* on citrus and *Bryophyllum*. Grout's experiments (pers. comm. 2007), however, indicate that gene movement between *Caesalpinia* and *Bryophyllum* is unlikely. It would be interesting to determine if thrips from South African citrus readily utilise *Bryophyllum*, or *Caesalpinia* - which we found to be a poor host of Australian *S. aurantii*.

Predictions about the risks posed to horticulture by Australian *S. aurantii*, therefore, appear likely to remain the subject of debate. Rafter et al (2008) consider this thrips a good example of a useful weed biocontrol agent that would not even be considered because of its reputation as a highly polyphagous species.

It is to be hoped that they are correct, that more than one species will be resolved under the name *S. aurantii*, that we have only one in Australia, that it remains host-restricted, is renamed the *Bryophyllum* thrips, described anew (perhaps as *Scirtothrips bryophyllum*), and never attacks valued crop hosts.

My conclusion, however, is that the capacity demonstrated in our no-choice tests of this thrips to utilise macadamia, mango, citrus, peach, grape, tea and native species including *Acacia* and *Syzygium*, had it been officially host tested prior to release, would have excluded even the *Bryophyllum* form of *S. aurantii* from consideration as a potential weed biocontrol agent.

7.5 IPM OF *SCIRTOTHRIPS* SPECIES IN CITRUS

Five species of thrips are regarded as pests in Australian citrus (Smith et al 1997). Greenhouse thrips *Heliothrips haemorrhoidalis* is a pest in coastal NSW and in Western Australia, Kelly's citrus thrips *Pezothrips kellyanus* is a pest in the Sunraysia and Riverland (estimated to cost industry > $10M p.a.). In Queensland, orchid or rust thrips *Chaetanaphothrips orchidii* is a late season pest causing rusty marks between touching orange fruits, and two species of Scirtothrips are leaf feeders that attack small fruit when soft leaves are unavailable.

The genus *Scirtothrips* in Australia includes 21 species of leaf-feeding thrips. Two species are pests of citrus and other crops such as avocado and mango, *S. albomaculatus* and *S. dorsalis*. *S. albomaculatus*, described initially from New Caledonia, was redescribed by Palmer and Mound (1983) from a few specimens taken widely across New South Wales and South

Australia. It has been found breeding in large numbers only once, on *Dodonaea viscosa* leaves [Family Sapindaceae] at several sites on Lord Howe Island (Mound, 1998). *S. albomaculatus* has been collected rarely from any Acacia species, but it is a member of an Australian species-group in which at least two species are associated with Acacias. *S. dorsalis*, a highly polyphagous and widespread tropical thrips is found from Pakistan to Japan and Taiwan, and south to the Solomon Islands and northern Australia, but has not been collected south of Brisbane. It is recorded as a pest on many crops, including chillies, lotus, tea and strawberry (Hoddle & Mound 2003).

Thrips population fluctuations have long been thought to be driven mainly by weather conditions, and their natural enemies reported to be ineffective. As a result, thrips management has depended largely on insecticides, as has been the case for the invasive melon thrips, *Thrips palmi* (Cannon et al. 2007) and Western flower thrips, *Frankliniella occidentalis* (Broughton & Herron 2007). In recent times, however, *Orius* spp. predatory bugs and *Thripinema* spp. parasitic nematodes have been shown to be important natural enemies that suppress outdoor populations of *Thrips* and *Frankliniella,* even to the point of local extinction (Funderburk 2002).

In South African citrus, the availability of soft flush growth leaves and out of season fruit on which SACT feed and breed are the key drivers of population fluctuations (Gilbert 1990). Natural enemies such as anthocorid bugs, lacewing larvae, coccinellid beetles and predatory thrips are present, but seldom abundant, and levels of parasitism by the wasp *Goetheana incerta* Annecke are generally low. Predatory mites, and to a lesser extent, spiders, are the most abundant natural enemies in trees and in the leaf litter and soil beneath trees where SACT pupates (Grout 2005). A similar suite of natural enemies is known to attack *S. citri* (Grafton-Cardwell and Morse pers. comm. 2004, Anonymous 2005), and the avocado thrips *S. perseae* (see various papers by Hoddle and others, including Hoddle et al, 2002, 2004).

When thrips pressure is high, however, predatory mites are generally accepted to be unable to prevent economic damage. In South Africa, in the temperate southern areas where SACT pressure is lowest, predatory mites are important in maintaining thrips below economic injury levels, but in the sub-tropical northern areas where pest pressure is highest and control most difficult, mild winters allow high levels of thrips survival and continuous breeding through winter if flush growth or out of season fruit is available (Gilbert 1990). As a result of this climatic favourability for SACT, and low predatory mite numbers caused by dry winter conditions, insecticides remain the predominant control method used by commercial growers (Gilbert & Bedford 1998, Grout 2005).

In Queensland citrus, the naturally occurring predatory mite *E. victoriensis* contributes significantly to the management of mites, especially eriophyid or rust mites *Phyllocoptruta oleivora* and *Tegolophus australis* (Smith & Papacek 1991, Smith et al. 1998), and can be reared in numbers suitable for mass releases (Freebairn 2007).

Under typical Queensland IPM practices, however, this predator is incapable of adequately suppressing damaging populations of the two current *Scirtothrips* species, *S. albomaculatus* and *S. dorsalis* (Wallis pers. comm. 2007). Populations of *E. victoriensis* fall to low levels during the cold dry winter, and numbers increase substantially only in late spring-early summer when the onset of wet season rains promotes growth of inter-row Rhodes grass, the pollen of which, an alternative food source of the predators, can sustain the development and

maintenance of high predator levels in the absence of prey (Smith & Papacek 1991, Smith et al. 1998, Freebairn 2007).

Little information is available on the natural ecology or alternative hosts of pest *Scirtothrips* in Queensland citrus – though castor oil, *R. communis,* is known to support populations of at least one of the two species (Freebairn, pers. obs.) - and control decisions are based on monitoring of individual blocks of citrus. This is usually adequate, but control is becoming increasingly difficult, especially in high value varieties like lemons, where multiple crops are protected and withholding periods can restrict insecticide options (Wallis pers. comm. 2007).

Various insecticides registered in citrus will kill thrips, however, broad spectrum organophosphates such as methidathion, chlorpyrifos and dimethoate are hard on beneficial insects and mites. Amongst the softer, newer actives, abamectin is known to be effective against *Scirtothrips* spp., but has been used in citrus as a miticide for some time, Spinosad, which was recently registered in citrus for leafminer, Heliothis and light brown apple moth, has registrations in other crops for thrips. Neither label has rates or use patterns for thrips in citrus. Thiamethoxam has been used under permit as a foliar spray against *Pezothrips kellyanus* in citrus in the Riverland and Sunraysia districts.

Bifenthrin is registered as a soil treatment for banana rust thrips *Chaetanaphothrips signipennis*, and in citrus against citrus leaf eating weevil *Eutinophaea bicristata* (Freebairn & Smith 1996). Fipronil, which has a similar range of activity, is not registered in citrus.

Preliminary work in Queensland citrus with bifenthrin and fipronil applied beneath trees to kill larvae moving into the leaf litter to pupate and/or emerging adults, showed promise for control of rust thrips *Chaetanaphothrips orchidii*, a soil pupating species, but the results were inconsistent between years and have not been followed up (Smith & Papacek pers. comm. 2004). *Scirtothrips* also pupate in the soil and should be susceptible to such treatments.

There is concern, however, that applying persistent insecticides to the soil will disrupt natural enemies of thrips such as predatory mites that contribute to mortality of the soil dwelling stages. If the soil stages of *Scirtothrips* spp. were concentrated beneath the drip line, as they are for Kelly's citrus thrips, *P. kellyanus* (Baker pers. comm.), a pest in the Riverland and Sunraysia districts estimated to cost industry more than $10M p.a., application of such actives to a targeted narrow strip may reduce negative impacts on beneficials. Recent research on *P. kellyanus*, however, suggests that increasing soil organic carbon levels with compost enhances predatory mite densities and reduces thrips damage. It also delivers other benefits such as reduced water use and increased fruit size, and is likely to be a more sustainable solution providing it can be relied upon to produce the desired results (Baker & Crisp 2007).

Research on citrus thrips in Queensland, including *Scirtothrips* spp., is needed to better understand their taxonomy, ecology, insecticide susceptibility and management.

8. CONCLUSIONS

1. Australian populations of *S. aurantii* performed best – in terms of the numbers of offspring thrips produce by adults confined in no-choice trials on plants - on green mother of millions, *B. pinnatum* and on *B. proliferum*. The most common mother of millions, *B. delagoense* was significantly less productive of thrips.

2. Macadamia, mango and the traded ornamental succulent *Kalanchoe blossfeldiana*, which has a value of ~ $6-7 M p.a. were very good hosts of Australian *S. aurantii* and may be attacked at economic levels.

3. Of the citrus varieties tested, Navelina, lime, lemon and grapefruit rated as moderate or good hosts based on thrips performance in the best trials or cages, and must be considered to be at some risk of attack. The generally poor performance of the thrips on citrus in our no-choice trials, and the preference shown by Rafter et al (2008) for *B. delagoense* over citrus and mango suggests this risk is low. Further, targeted surveys of potential hosts are needed before we can say that citrus will not be attacked.

4. Peach, grape and tea may be attacked, but may not support damaging thrips numbers.

5. *Acacia sophorae* and *A. longifolia* supported Australian *S. aurantii* at moderate levels; *Eucalyptus tereticornis* was a very poor host but did support some thrips development. Acacia or Eucalyptus species therefore could potentially act as bridging hosts, enabling thrips movement between *Bryophyllum* infestations and cropping areas.

6. *Euseius victoriensis*, a predatory mite significant in citrus IPM, in bioassays killed up to 6 thrips larvae per day, and was able to persist on a diet of thrips larvae alone. It can be expected to contribute significantly to control of this thrips if it ever attacks citrus.

7. A range of commonly used insecticides killed more than 90% of adult *S. aurantii* in bioassays at rates well below those registered in citrus and other crops. If this thrips does begin to attack citrus or other crops it should not be difficult to control, at least initially, and is likely to develop resistance only if over sprayed.

8. Foliar sprays of imidacloprid on *B. pinnatum* provided persistent control of the thrips; used as a soil drench it should contribute to control of *Scirtothrips* spp. in citrus, however, South African experience suggests that it may not provide full protection from thrips damage soon after petal fall.

9. Soil applied imidacloprid, in preliminary trials, killed all *E. victoriensis* feeding on Typha pollen on soybean plants, presumably because the predator occasionally extracts material from its host plant. Field use of imidacloprid may reduce numbers of *E. victoriensis*, and increase pest pressure from the species upon which it preys.

9. RECOMMENDATIONS & FURTHER RESEARCH

1. The spread of *Scirtothrips aurantii* on *Bryophyllum* spp. should be monitored and scouts and growers remain alert to its arrival in citrus production areas. It is inadvisable to destroy local infestations of mother of millions, as these may harbour the thrips and thus prevent them from moving into crops. Spraying thrips infested MoM, because adults fly readily away from sprays, may force them onto nearby crops.

2. Further surveillance, targeting potential hosts such as flushing macadamia, mango, citrus and *Acacia* in the vicinity of *S. aurantii* infested *Bryophyllum*, should be done and data recorded. Ideally, the surveyed plants should be downwind of infested Bryophyllum, to test the hypothesis that stranded thrips unable to locate their preferred host may use other hosts, including crop species.

3. The arrival of *S. aurantii* in citrus may not increase fruit damage; the insecticide susceptibility shown by our work, indicate that it should be well controlled by insecticides applied for other insect or mite pests, such as abamectin.

4. If increased fruit damage is not associated with the arrival of *S. aurantii* in Queensland citrus, visual indications apparent to scouts will include the colour of the thrips found on flush and fruit. *S. aurantii* adults are a pale yellow-brown, and the larvae are a pale yellow; the adults of the currently present *Scirtothrips* species are a darker yellow-brown, and the larvae are a conspicuously different yellow-orange.

5. Control options for citrus thrips, including *Scirtothrips* spp., in the short term are restricted to insecticides. Further trials with bifenthrin and fipronil are needed to determine their limits of efficacy. Study of the pupation behaviour of pest thrips may enable reduction in the potential negative effects of soil applied treatments. The efficacy of new thripicides should be tested as they become available.

6. Efficient systems for mass rearing parasitoids such as *Ceranisus menes*, a solitary endoparasitoid of larval thrips of a broad range of genera including *Megalurothrips* and *Frankliniella* have been developed. Efforts to develop biocontrol agents such as *C. menes* for thrips control in Australia, including for citrus thrips may be worthwhile.

7. *Goetheana incerta*, a parasitoid of *S. aurantii* in South Africa, or locally occurring species such as those observed in our thrips cultures, may have potential for releasing into orchards if they can be mass reared. The thrips rearing system (on excised *Bryophyllum pinnatum* phyllodes in tubs) developed in this project has the potential to produce the large numbers of thrips needed for such parasitoid mass rearing systems.

8. *Orius* spp., aggressive bug predators of thrips, also may have potential, as may *Thripinema* nematodes. The latter are obligate thrips parasitoids that tend to be host specific for a given thrips species, develop inside thrips causing sterility of the females and prevent oviposition of viable eggs. So far they have been recorded only from flower thrips, but further investigation may reveal them to occur in other types of thrips, including leaf feeders such as *Scirtothrips*.

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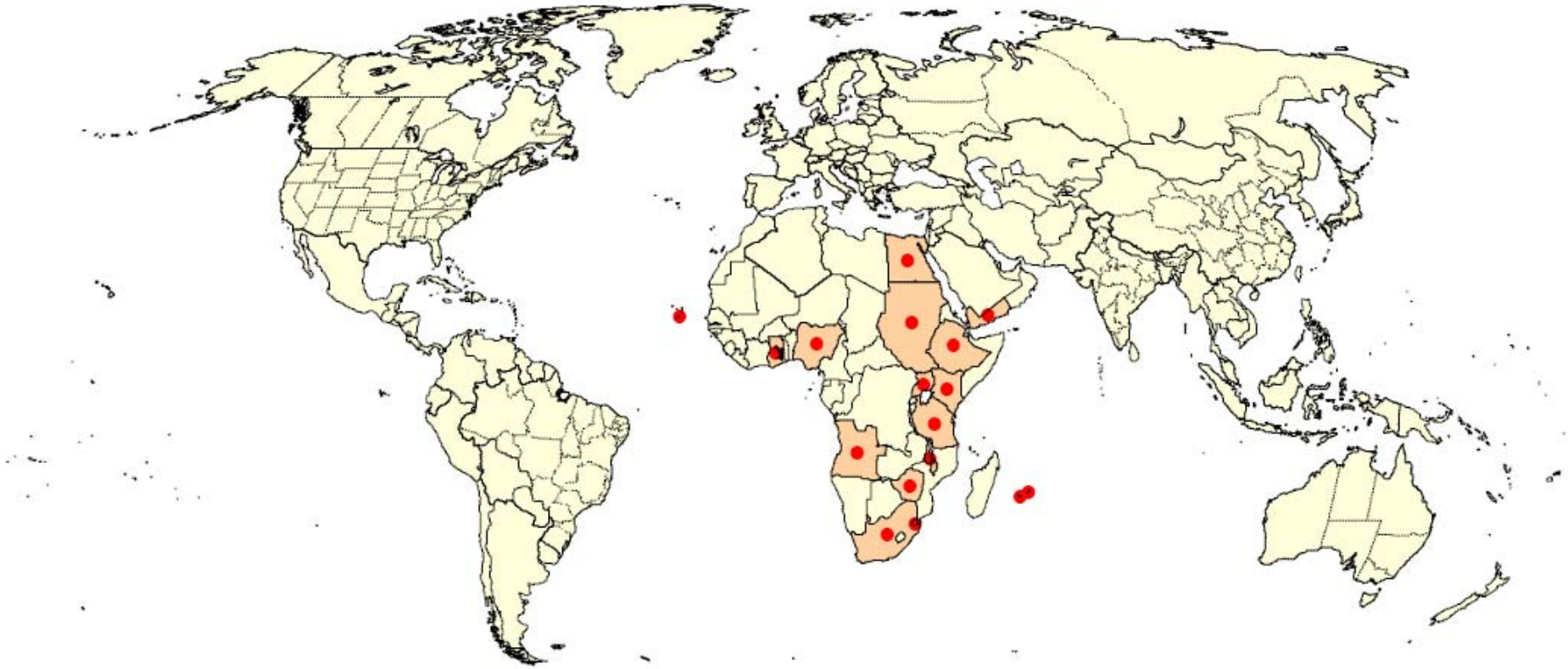
Figure 1: Distribution of *Scirtothrips aurantii* prior to its arrival in Australia in 2002 (with the countries listed below).



ASIA
Yemen

AFRICA
Angola, Cape Verde, Egypt, Ethiopia, Ghana, Kenya, Malawi, Mauritius, Nigeria, Reunion, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zimbabwe

Figure 2: DNRW Map of Mother of Millions distribution, Queensland 2006

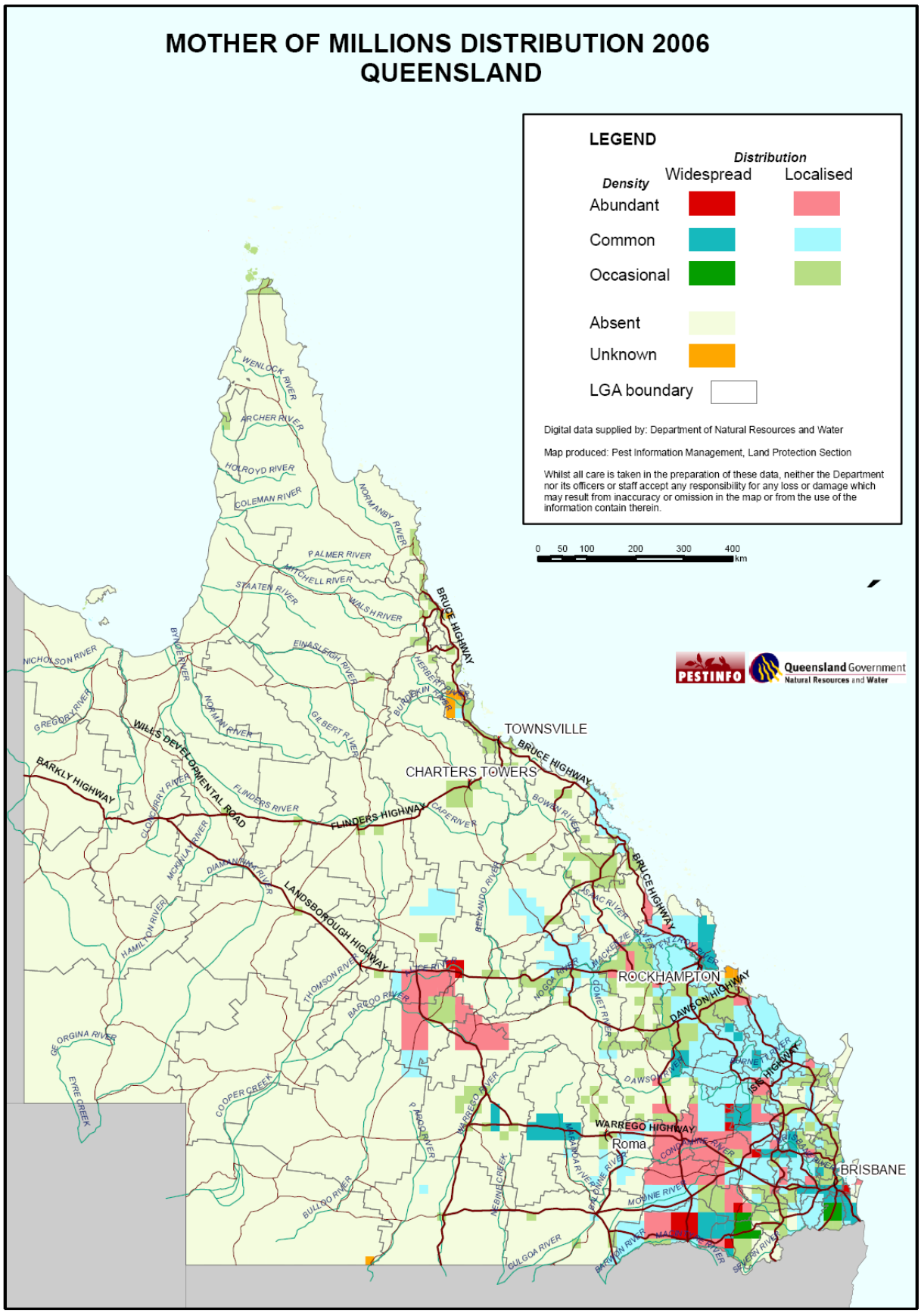


Figure 3: DNRW Map of the potential distribution of *B. delagoense*

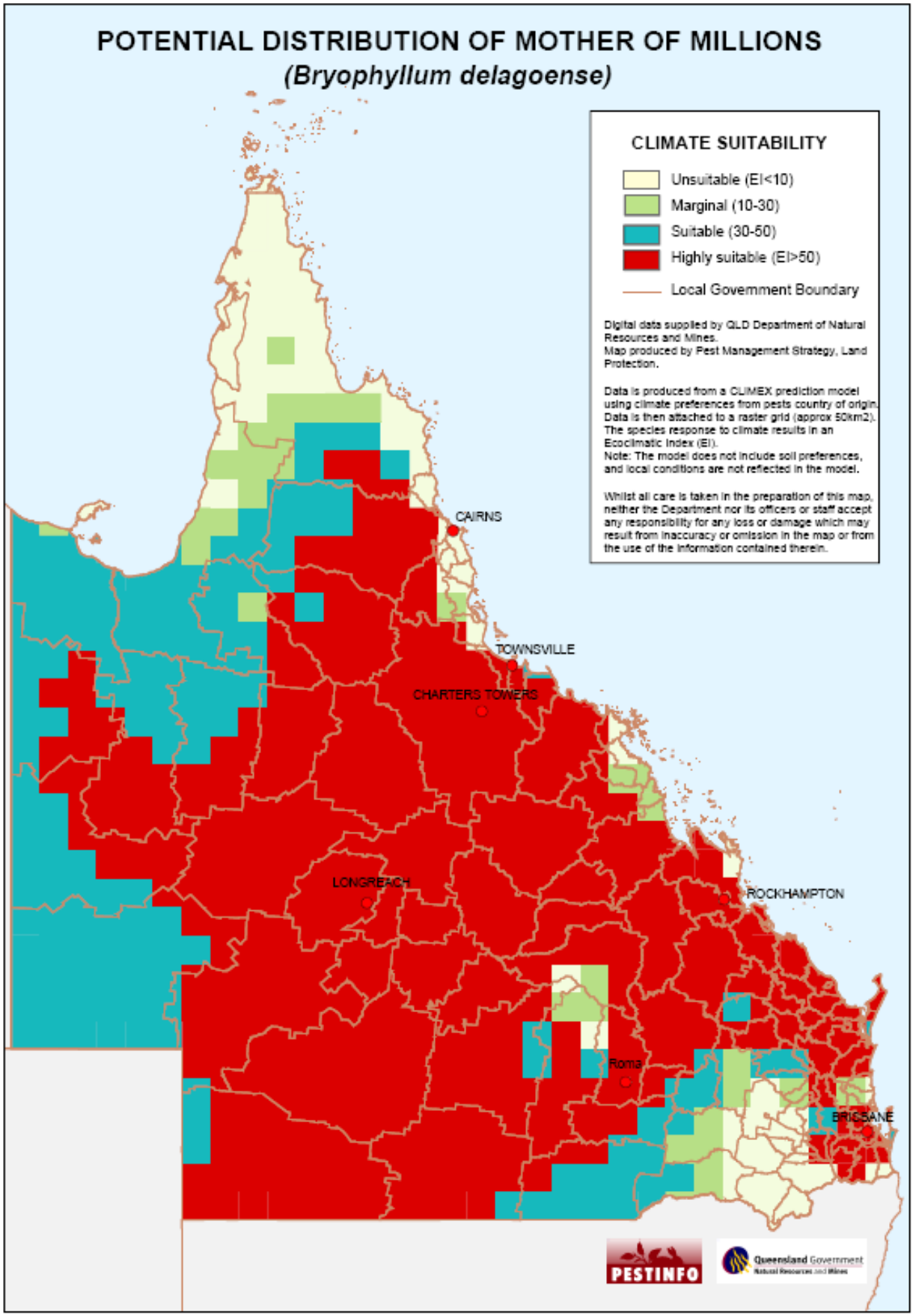


Figure 4: DNRW Map of the potential distribution of *B. pinnatum*

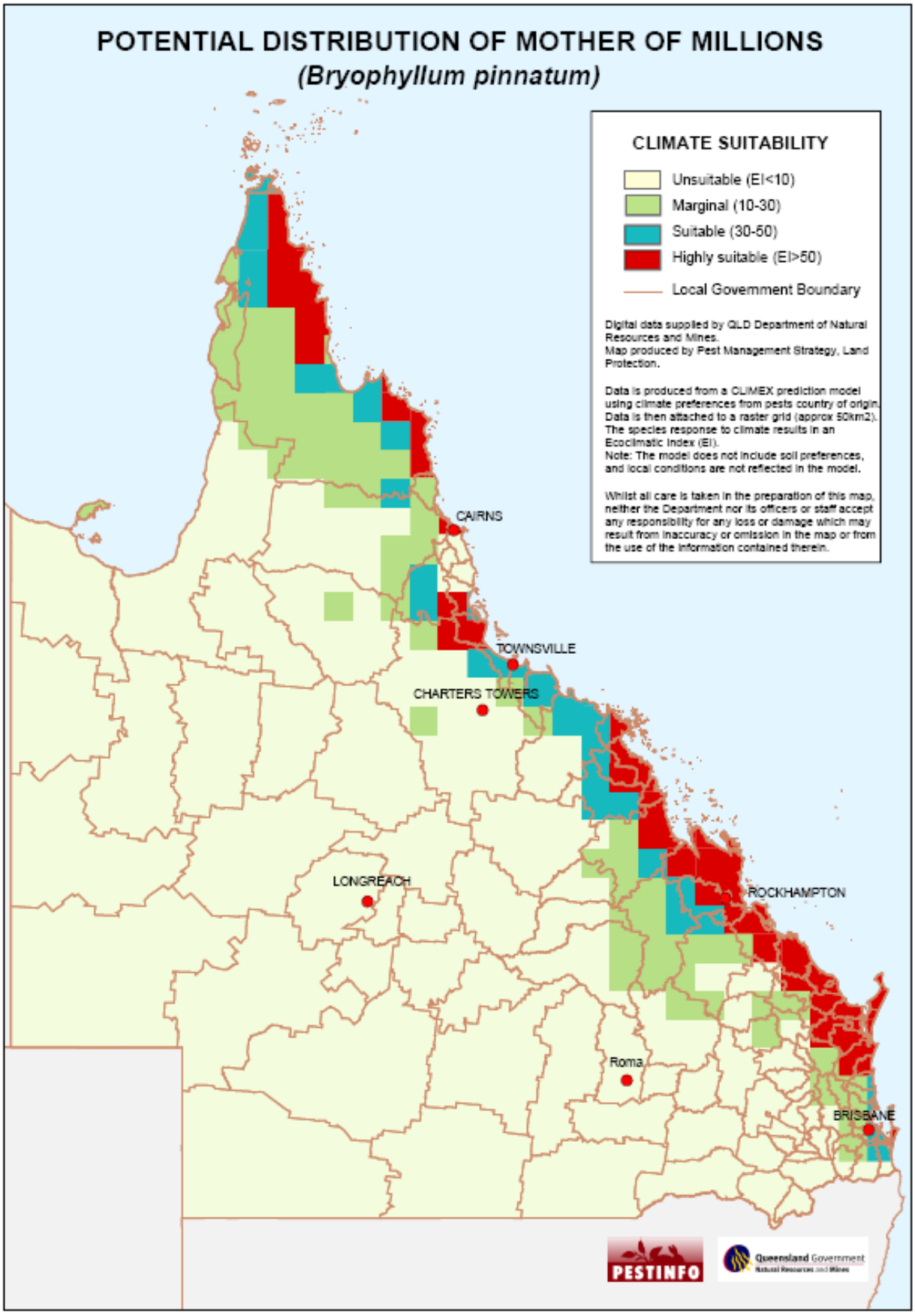


Figure 5: *S. aurantii* distribution in Queensland as at 30 June 2006.

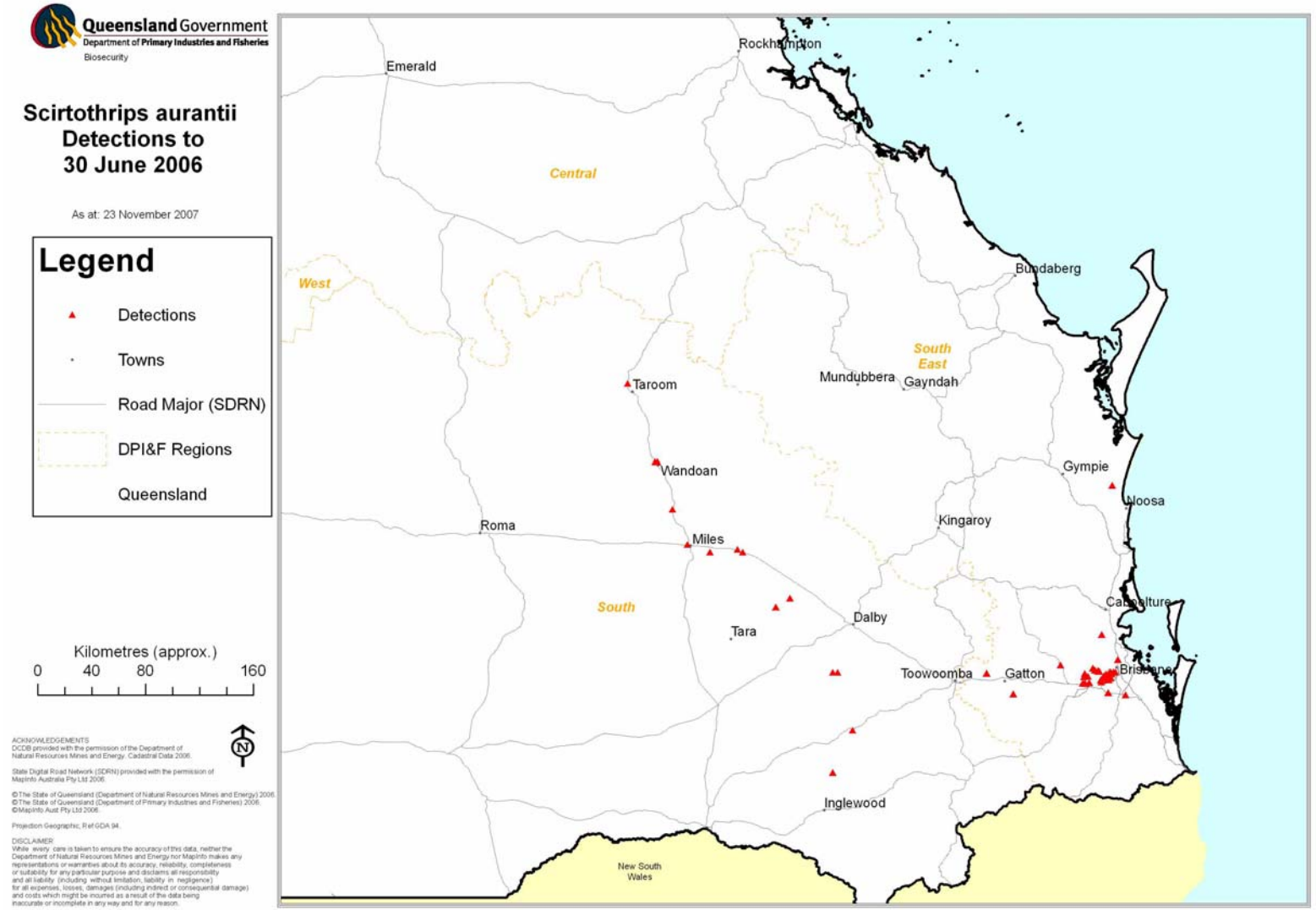


Figure 6: Mean (+se) SACT 'eaten' by Ev, and % survival in Controls over 14 days

(3 Ev +/- 30 thrips at t0; + ~ 20 thrips/rep added on days 2, 4, 7, 9 & 12; data correct for daily control mortality)

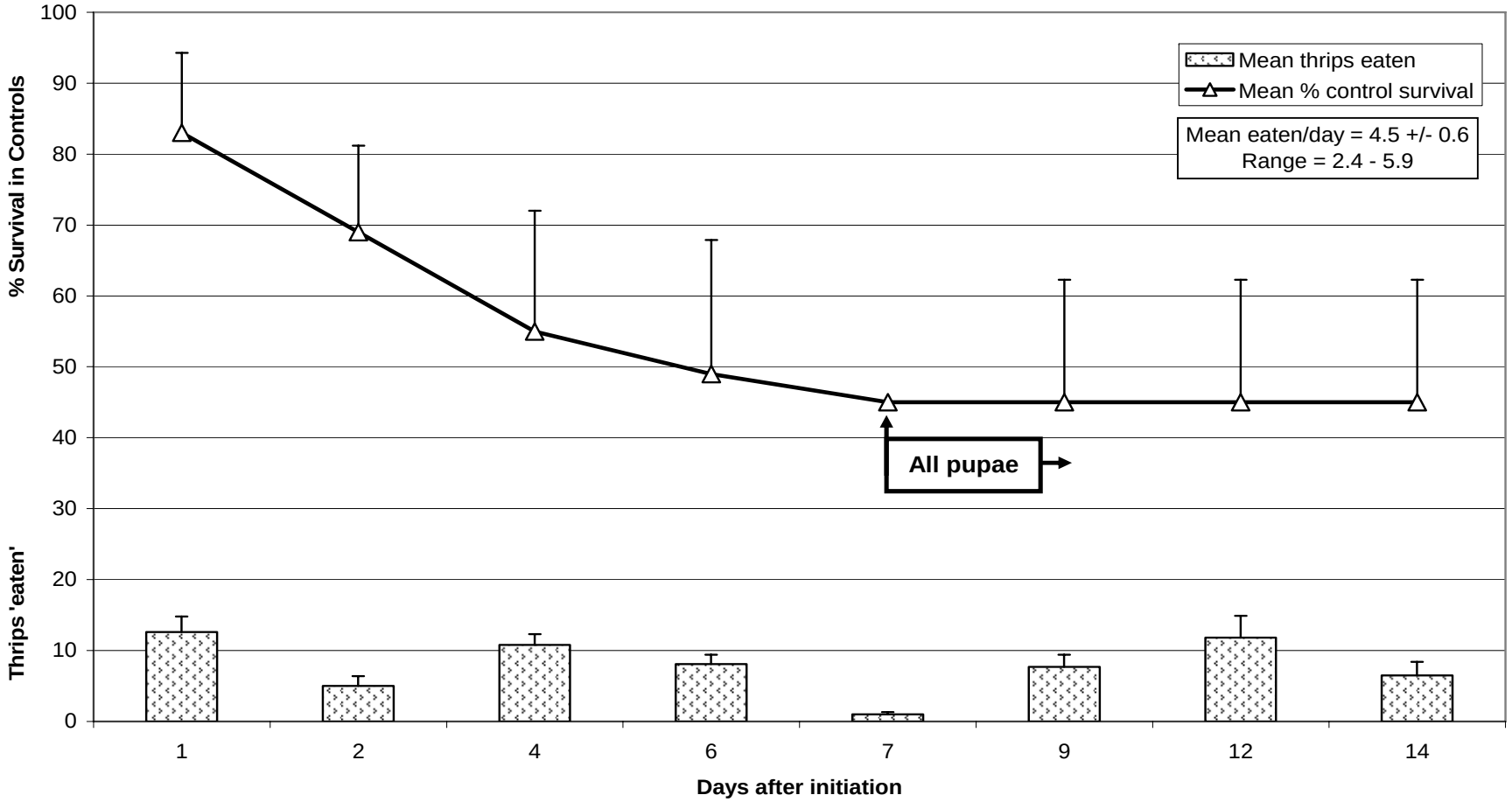


Figure 7: Thrips - % survival in Controls for 5 replicates

(Mean of 5 reps = 45%; best 3 = 72%)

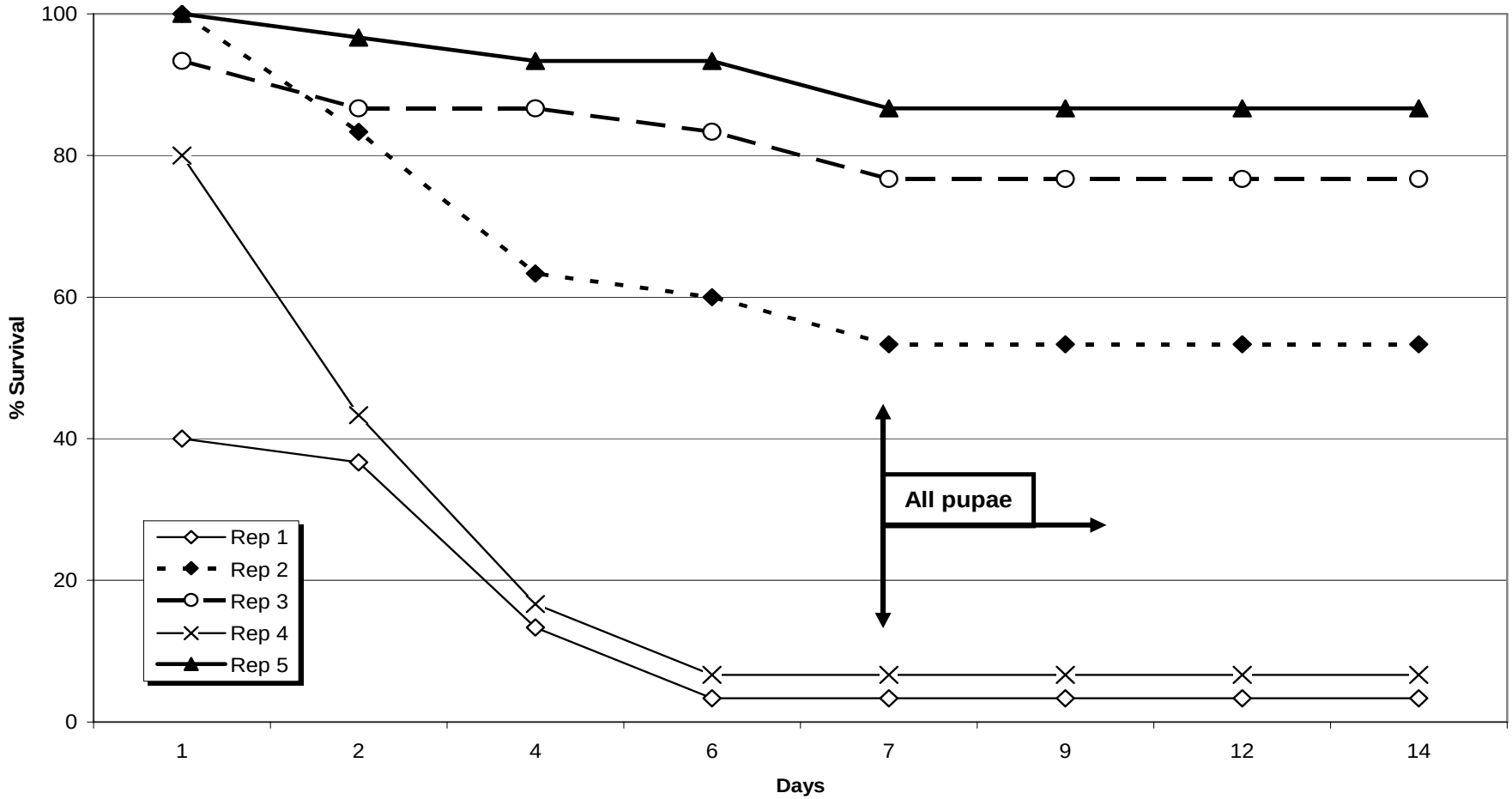


Figure 8: Mean Ev per replicate fed pollen compared with thrips over 19 days

(3 Ev +/- 30 thrips at t0; + ~ 20 thrips per replicate added on days 2, 4, 7, 9 & 12; pollen - fed on alternate days)

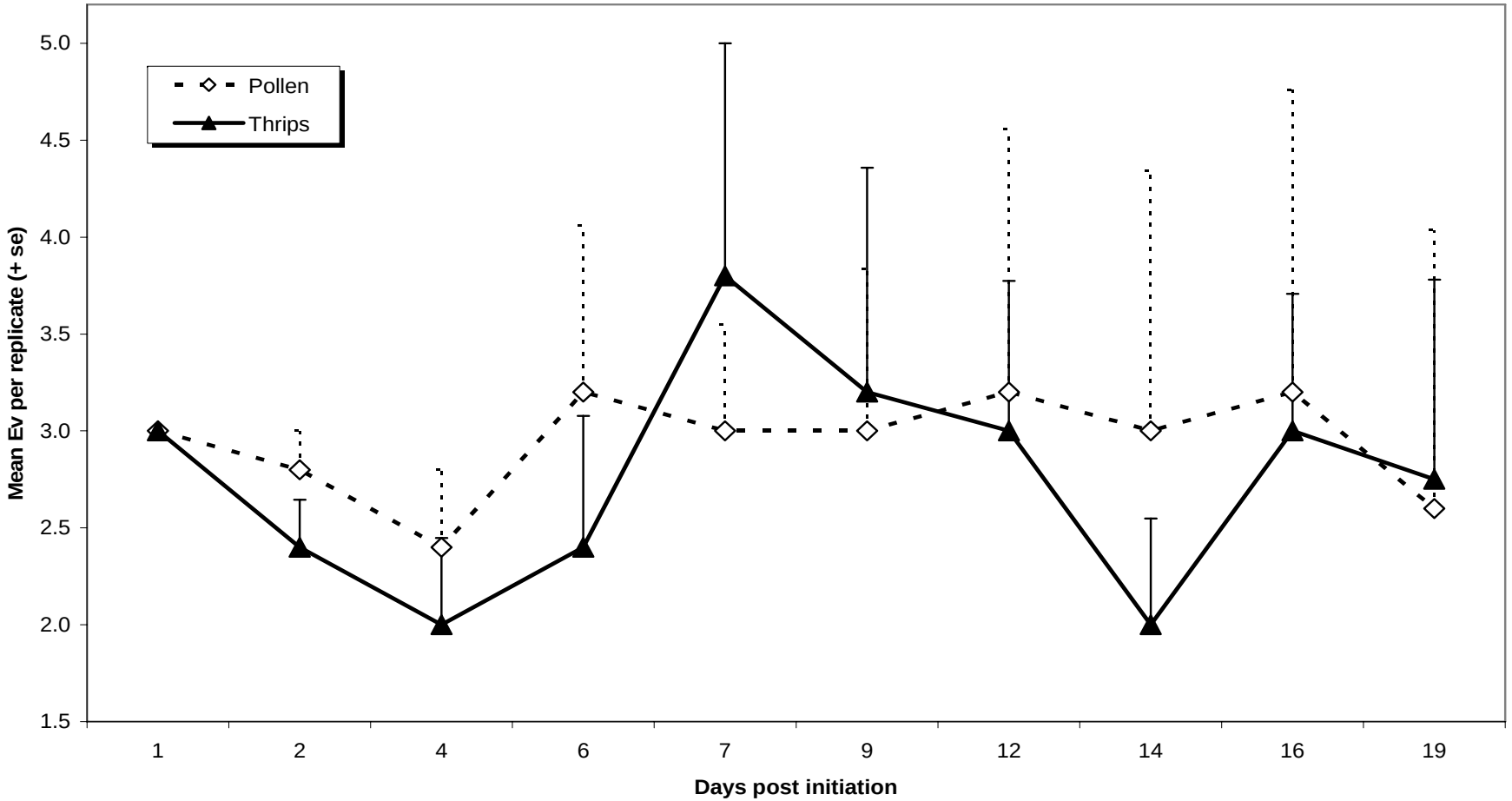


Plate 1: *Scirtothrips aurantii* ex *Bryophyllum* sp., adult female (top L), & male (top R) showing abdominal drepanae and the diagnostic stout row of setae (hairs) on the hind femorae (enlarged – middle); *Scirtothrips* sp. (*albomaculatus* or *dorsalis*) (bottom) a pest of citrus and other crops in Queensland.

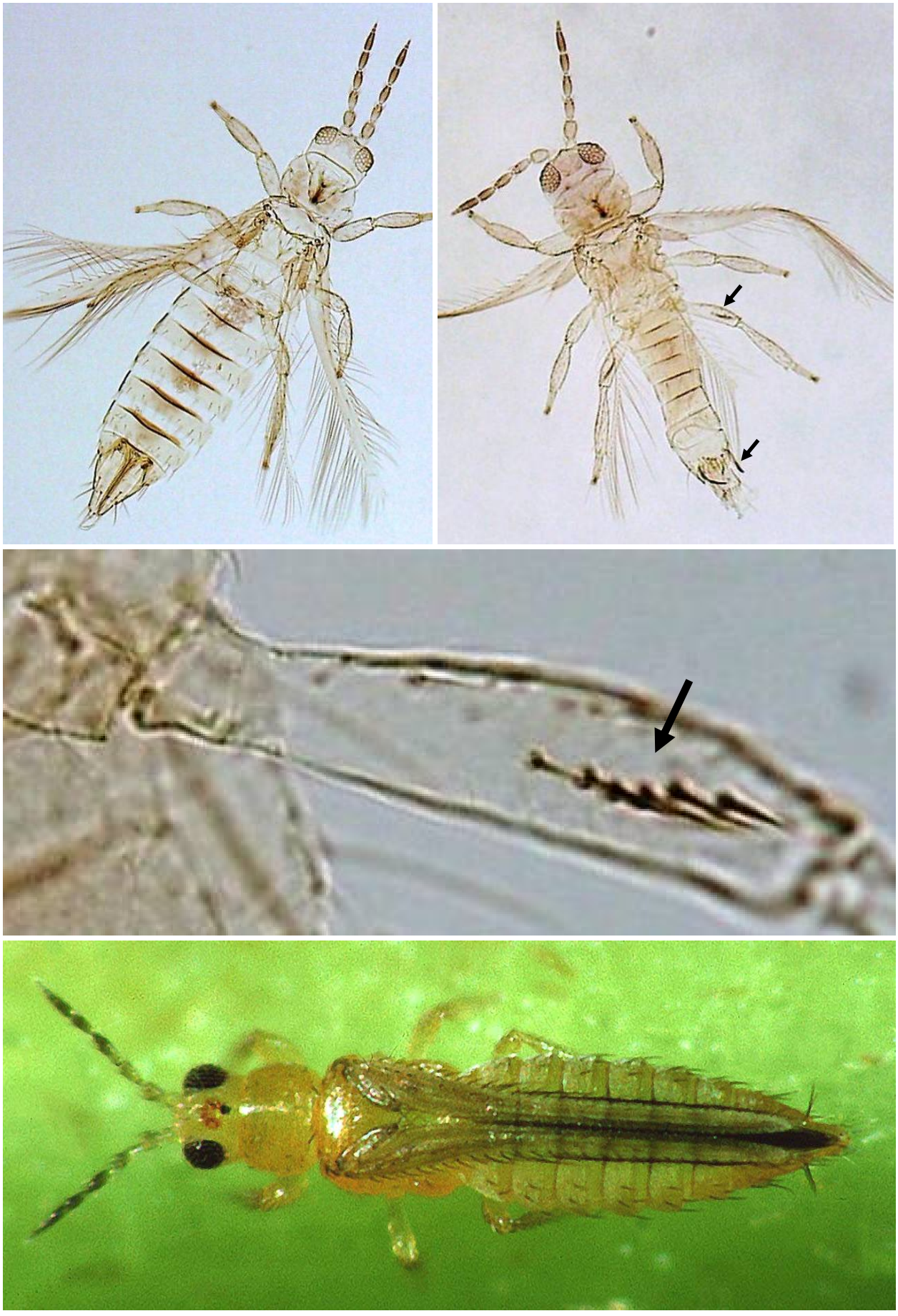


Plate 2: *Scirtothrips aurantii* were reared on *Bryophyllum pinnatum* (Bp) leaves in takeaway food containers with 100 µm nylon mesh ventilated lids (top L). Eggs laid into the leaves hatched in 6-7 days, the 2 larval stages took 3-4 days, the pre-pupal stage 1-2 days & the pupal stage 3-4 days. Late 2nd stage larvae ceased feeding and pupated where the leaf touched the container (middle L – larvae, R - pupae). Heavily damaged leaves turned black (top R), indicating that new leaf was required. Excised Bp leaves, which remain viable for months, readily produce new plantlets from their leaf emarginations. Trays of plants were grown by placing cut leaf segments on top of standard 50: 50 sand: peat potting mix (bottom).

Plate 3: *Bryophyllum delagoense*, the most abundant and widespread species in Queensland, favours dry sites like this Nambour roadside cutting (top L & R), and is often virtually impossible to detect until it flowers in winter, such as at this site on the Brisbane River bank at Indooroopilly (middle L, R). It forms dense mats (lower middle L), reproduces from seed (lower middle R) and from tiny plantlets produced on phyllode ends (bottom L), and forms hybrids (bottom centre) with *B. daigremontianum* (bottom R).

Plate 4: *Bryophyllum pinnatum,* favours moister sites like this one near Nambour. It is easier to detect as it has flat green phyllodes (top middle-L) but can be cryptic unless flowering. *B. proliferum* has thicker phyllodes, an angular stem and different floral structure (bottom middle). *Kalanchoe blossfeldiana K. longiflora*, *Murraya paniculata* & *Caesalpinia pulcherrima* are common ornamentals (bottom).

Plate 5: On-plant cages for host performance testing were made from clear 1L PET bottles cut at each end to form a cylinder; holes were cut into the sides, and a lid was made by cutting a clear plastic cup which when pressed into the bottle provided a tight seal at the top; vent holes and the top were closed with 100 µm nylon mesh; a freezer bag cut across the corner and stuck onto the bottle, when closed over a branch end or stem with 6 mm elastic, provided a thrips proof seal. Contact cement was used as glue.

Plate 6: *S. aurantii* performance was assessed by caging branch ends of plants growing in pots of test hosts (mango - L, potted citrus - R). Cages were taped to supporting sticks, thrips adults aspirated into 30 ml tubes, gently tapped down, the lid removed and the tube stuck facing upwards inside the cage with U-tac®. The cage was closed with 6 mm flat elastic over a freezer bag skirt. Cages were cut from the test hosts after 2 weeks and thrips counted. Fruit injury typical of that reported for *S. aurantii* (eg on citrus in Réunion - top R) occurred only on Kumquat (middle L & R). *S. aurantii* performance on leaves of most citrus varieties was poor, however, significant numbers were occasionally produced on lemon, lime grapefruit and navelina, and on one occasion a scribbling type of injury similar to damage reported from South Africa on orange fruit & *Caesalpinia pulcherrima* leaflets was noted on lime leaves (bottom).

Plate 7: *S. aurantii* causes significant injury to *Bryophyllum*, and the thrips has expanded its distribution significantly on *B. delagoense,* the most abundant & widespread species in Queensland (healthy – top L). The thrips are most commonly found in the young terminal growth, even on *B. pinnatum* and *B. proliferum* (on leaves of which they readily develop in the lab.) but as the plant grows damaged tissue fails to expand normally, becoming scarred and distorted. The phyllodes of small plants may become short and stubby (bottom L), plants growing in heavy shade can be killed by *S. aurantii* (bottom R), and there is considerable interest in the prospects of this thrips to contribute to Mother of Millions biocontrol.

Plate 8: *S. aurantii* damaged *Bryophyllum pinnatum* (top L), *B. proliferum* (top R, middle L and bottom L) and *Kalanchoe blossfeldiana* (middle R). Note the extensive scarring and distortion of the phyllodes and reduced internode length. The fungus *Exosporium bryophylli* also damages *B. pinnatum* (bottom R), most severely in winter when dew probably contributes to its spread.

APPENDIX 1

MILESTONE REPORTS

CT03022

MILESTONE 4

Date: 30th June 2004

Description: Host testing & performance studies Australia & South Africa; Specimen collection, DNA testing if required.

Criteria: Data available to allow conclusions on risk posed by *S. aurantii*. Communication of *S. aurantii* pest status to potentially affected industries through peak bodies and/or entomologists.

1. SUMMARY

Culturing & assay development

- A simple but highly productive culturing method utilising *B. pinnatum* leaves has been developed, and has provided the large numbers of thrips required for the host testing & insecticide trials reported here.

Host testing & performance studies

- Extensive surveillance by APHS (to Feb 2003) indicated that SACT was widespread in NW Brisbane, but confined to plants in the Family Crassulaceae, mainly *Bryophyllum* spp. Two preliminary trials lent qualified support to the idea that Australian populations of SACT may be host restricted and not pose a risk to citrus.
- In my recent research I found that SACT performed very well on *B. pinnatum* (10-15 fold increase in numbers at ~ 2 weeks) and poorly on citrus of the 4 varieties tested (sweet orange seedlings, 0-0.07x; small trees of navel orange, Eureka lemon, Tahitian lime, 0-1.5 x).
- Mango (5-11x), macadamia (6x), *Acacia longifolia* (2-5x) and *A. sophorae* (3-5x) were good hosts of SACT; *Eucalyptus tereticornis* (0-1.2x) produced moderate numbers.
- A few larvae were produced on soybean, *Grevillea robusta*, *Syzygium australe*, green bean pods and small banana plants. No offspring were produced on *Ricinus communis*, *Callitris columellaris* or *Grevillea lanigera*.
- For the 'poor hosts', including citrus, at least some larvae developed to pupation.
- These findings are not consistent with the reported host utilisation of this insect in South Africa. The poor performance on citrus suggests that the risk to this crop in Australia is low, however, further trials are required before stronger statements can be made. Of particular concern is the possibility of improved performance over time on citrus, and/or the potential of mango to act as a bridge to citrus, as reported in RSA.
- *Acacia* and *Eucalyptus* species may facilitate movement of the thrips through habitat where *Bryophyllum* spp. are absent, or act as reservoirs for thrips attacking crop hosts.

Biology & Behaviour

- Australian SACT eggs hatched in 6-7 days, the 2 larval stages took 3-4 days, the pre-pupal stage 1-2 days, and the pupal stage 3-4 days, giving a total, at summer room temperatures of 14-19 days. These development times are similar to those reported for SACT in South Africa.

DNA testing & specimen collection

- The molecular data, to be published later this year by Morris & Mound, is consistent with the experimental data. It indicates that there is some separation on the molecular level of SACT populations, but that this is not host plant related. Mound notes (pers. comm.) that there can be no assurance that any current distinctions will be permanent, and that to protect the interests of growers it is essential to proceed with caution.

Monitoring of infestation

- Resurvey of 15 of the 24 sites visited early in 2004 detected no SACT or damage to plants at any site. Small numbers of adults and larvae of a thrips, possibly Scirtothrips sp. but not SACT, were collected on several occasions. No thrips of any species have been detected in regular visits to one *B. pinnatum* site near the research station.
- Limited survey work has been carried out this calendar year by APHS, as staff have been redirected to higher priority issues (fire ant). They report that infestations have persisted in the few key sites revisited and no SACT have been detected on ~ 25 backyard citrus trees inspected in suburbs with known infestations on *Bryophyllum*.

Predators & parasites

- Two species of wasps likely to be thrips parasitoids were observed in SACT cultures where they persisted over several generations. These presumably were brought into the culture with the thrips in the initial colonisation event. They did not persist in the culture, and appeared to be responsible for only low levels of parasitism.
- Predatory mites also were observed to persist in the culture, where little other than thrips was available as food. These have not yet been identified, though they appear to be *Euseius victoriensis*, *Typhlodromips montdorensis* and/or *Neoseiulus wearnei*.

Insecticide trials

- Australian SACT appears to be very susceptible to a broad range of insecticides. In three trials to date, mortality of 94-100% was recorded for all tested products even at very low rates, with the exception of 0.5% oil, which killed only 8% of adults (Table 1). Control mortality was higher in the 2nd trial than the 1st, and at unacceptably high levels in the 3rd, and further trials are needed to confirm these results. They are encouraging, nonetheless.
- This insecticide susceptibility appears to be in contrast to the situation in citrus in SA, but may be consistent with the hypothesis that the introduction to Australia was from an area distant from citrus.

2. NEXT STEPS

It is important to confirm experimentally the finding that citrus is a minor host and to determine the status of some hosts not tested to date. These include grape, tea, cotton & a limited range of traded succulents such as *Kalanchoe longiflora*. In addition to no-choice trials a limited set of choice trials in cages and/or wind tunnel is proposed. Quantification of survival and development of larvae to pupation on various hosts including citrus is proposed, as is testing of performance on citrus of thrips reared on mango. Improvement in performance on citrus over several generations will be test the hypothesis that poor performance on citrus is a reflection of

Taken together these trials will add to the no-choice tests reported here to allow increased confidence in predictions of the risk to citrus.

Further insecticide trials will be done to determine the range of effective chemicals and the lowest effective rates, and on the ability of the predatory mite *Euseius victoriensis* to kill and develop on *S. aurantii*, as per existing milestones

South African work is proceeding in collaboration. Preparations are in progress for further host testing work. This is not at this stage critical, since the critical aspects of work over there become clearer as work proceeds here. New connections are being explored and further discussions will be held with South African entomologists during the International Congress of Entomology in Brisbane in August this year.

DPI&F Animal & Plant Health Service staff have indicated they will have more time for targeted (i.e. mango, macadamia, Acacia, and citrus) surveillance next year, as a result of the decline in banana regulatory workload.

Broader communication of the host testing results is required. A short article has been inserted into a QCG Inc newsletter, and a more detailed correspondence will be prepared for wider distribution within the citrus industry.

Further molecular work is recommended by Morris & Mound. Discussion is required to determine if this will proceed and if so who will do what. Host based collections could be made during the SA trip planned for this project.

3. COMMUNICATION/EXTENSION ACTIVITIES

Progress reports have been made to the Central Burnett Horticultural Committee/Queensland Citrus Growers Inc. on 3rd October 2003 and on February 2004. An e-mail summarising host testing trials data was recently sent to staff at AFRS, The University of Queensland, Laurence Mound (CSIRO), and to 2 South African collaborators. QCG Inc. has been informed of the latest host testing trials data.

DETAIL

Host testing & performance studies

Background

Following the detection of SACT at Sherwood in Brisbane in March 2002, extensive surveys of a broad range of plant species found SACT to occur only on the Family Crassulaceae, specifically the weed species group commonly known as Mother of Millions (MoM), *Bryophyllum delagoense*, *B. pinnatum* the hybrid *B. daigremontianum* x B. *delagoense*, and on *Kalanchoe longiflora.*

A delimiting survey by APHS (DPI&F) in Jan-Feb 2003, combined with extensive trace forward and trace back surveys determined that the thrips was distributed over an area exceeding 1200 sq km, primarily to the North and West of Sherwood. The thrips was declared established and eradication deemed impossible or economically unwarranted. Local surveys by entomologists from several Australian state departments, and MRS, Nambour (24 sites from Nambour, Yandina, Mapleton, Eumundi, Maroochydore & Woombye), found no sign of SACT.

In two host-testing trials in March-April 2003, Australian SACT showed little interest in potted citrus presented in either choice or no-choice tests. AFRS staff found that when 20 adult thrips were placed in a 250 μm gauze cage with test plants of navel orange (*Citrus sinensis*), mango, mock orange (*Murraya paniculata*), *Syzygium* sp. or *B. delagoense* (no-choice test) that thrips were found 6 weeks later only on the latter. In a choice test, DPI&F staff found no indication of colonisation by SACT of citrus (5 varieties/species – lemon, lime, grapefruit, Hickson mandarin & Kumquat) in pots placed within heavily infested *B. delagoense* (exposed over 6 weeks).

These findings indicated that SACT was present in Australia on a very limited sub-set of its reported host range, and provided some support for the contention that the Australian population is a 'biotype' of *S. aurantii*, or a cryptic species closely related to it, restricted to the Crassulaceae. The inference was that SACT in Australia may remain restricted to MoM and not attack citrus or other crop hosts.

Recent research

I developed a simple laboratory rearing system using *B. pinnatum* leaves. This has provided the large numbers of thrips required for host-testing and insecticide trials. I also developed a test cage to enable controlled experimentation with SACT on growing plants (as attempts to use various containers with plant parts, or sprigs in water proved fruitless) and carried out no choice tests on a range of potential host species. Key crop hosts, and others that may support populations in non-crop areas - potentially providing movement bridges or acting as reservoirs affecting pest ecology in crops - were chosen.

Adults SACT (20-50/cage) were confined on soft new growth or small plants of the test species and the number of larvae, pre-pupae, pupae and surviving adults was counted ~ 11-20 days later.

B. pinnatum was clearly the best host, with mango second. Two species of Acacia and *Macadamia integrifolia* also were found to be supportive of oviposition and larval development. *Eucalyptus tereticornis* and citrus of several varieties (sweet orange seedlings, navel orange, Eureka lemon & Tahitian lime) were found to be poor hosts. No offspring were produced on 3 varieties of banana (small plants) or on castor oil. Survival of adults was also much better on *B. pinnatum* than other hosts (most reps 60-80 % on Bp, *maximum* of 45% on macadamia, 25% on Acacia, 50% on Grevillea, 28% on banana & 25% on citrus).

On green bean pods, on which some thrips species are reared, SACT adults survived reasonably well but produced only a few larvae. In a test to determine acute host effects on SACT, ~ 10 adults were confined in each of 2 x 30 ml containers with a few leaves of each of 27 plant species. Survival at 24 hrs was above 50% for most species tested.

In a single small South African trial, Grout found that SACT adults and larvae collected from Pride of Barbados (dwarf Poinciana), *Caesalpinia pulcherrima*, survived & developed on *B. delagoense* and produced some F1 larvae.

Biology & Behaviour

General aspects of the biology of Australian SACT have been determined in the course of culturing the insect. Eggs hatched in 6-7 days, the 2 larval stages took 3-4, the pre-pupal stage 1-2, and the pupal stage 3-4 days, giving a total, at summer room temperatures of 14-19 days. These development times are similar to those reported for SACT in South Africa.

Mating is readily observed. Males attempt to mate with nearby females, also occasionally with other males and with pupae or even squashed remains, though they are not too persistent with the latter. It seems that the female does the 'deciding', and if unresponsive will flick up her abdomen, run about or otherwise attempt to dislodge the male. He may be carried around for a short time on her back but usually soon gives up. In successful matings the male tucks his abdominal tip under the female and inserts his aedeagus then stands over her for several minutes as sperm is transferred with conspicuous pumping movement of the abdomen. The ovipositor of the female is exserted throughout, and presumably needs to be so for the male to insert his aedeagus. The drepanae do not appear to be involved in copulation. These observations were made in containers on *B. pinnatum* on which there were quite a few thrips. It was noticeable that when thrips were aspirated into a small container from the culture (where they have more space), that mating events were frequently observed, presumably because of the closer proximity of individuals.

Adults live for about 1 month on *B. pinnatum* in culture and can survive for several days on a broad range of hosts, (including 25+% survival over 11 days on bean pods on which no damage and only minimal egg hatch (3 x L1 larvae produced from 150-200 adults) was observed. Unmated females on *B. pinnatum* produced numbers of larvae similar to mated females (9 females produced 148 larvae in a 10-13 day hatching period, giving an oviposition rate of 1.3-1.6 eggs per female per day). All adults produced from unmated females were males, as expected since thrips are haplo-diploid (i.e. females are produced from fertilised eggs, males from unfertilised eggs).

DNA testing & specimen collection

The molecular work (by Morris, recently conveyed to me by Mound) has produced results consistent with my host-testing results. Mound regards this data (to be published in Aust. J. Entomology (4) 2004) as ‘equivocal’. He comments “there is an indication that some gene exchange has occurred between populations on MoM and citrus - but in the absence of any base-line data on what variation exists in SACT between different host plants and sites in Africa it is not possible to conclude anything more than is possible from your own data. That is - populations on MoM and citrus are *currently more or less distinct* (italics by CGF) but there can be no assurance that this distinction will be permanent. He suggests that to protect the interests of farmers it is essential to err on the side of caution.

Monitoring of infestations

APHS, Brisbane suburbs – limited survey work has been carried out this calendar year as staff have been redirected to higher priority issues. Infestations have persisted in the few key sites revisited and no SACT have been detected on 12 backyard citrus trees inspected in suburbs with known infestations on Bryophyllum species.

Nambour – Resurvey of 15 of the 24 sites visited early in 2004 detected no thrips or damage to plants at any site. Regular visits were made to one *B. pinnatum* site (to collect leaf for culturing and insecticide assays) but again no thrips or damage was observed.

Predators & parasites

Two species of wasps likely to be thrips parasitoids were observed in SACT cultures where they persisted over several generations. These presumably were brought into the culture with the thrips in the initial colonisation event. Unfortunately they did not persist in the culture, and appeared to be responsible for only low levels of parasitism.

Predatory mites also were observed to persist in the culture, where little other than thrips was available as food. These have not yet been identified, though they appear to be *Euseius victoriensis*, *Typhlodromips montdorensis* and/or *Neoseiulus wearnei*.

Culturing & assay development

Culture established from Bd & Bp material ex Indooroopilly, different visits

B. delagoense plants infested with thrips were held in sealed clip lock bags in which they survived for more than a week. Using these thrips preliminary observations were made on survival in various small containers.

These showed that Munger cells were inappropriate, as larvae readily wandered off the leaf (citrus) and were often found in the tiniest of cavities in the cell's structure. Other small containers, designed to confine the thrips close to the host, and to enable ready microscopic observation, were also made and tested, but thrips mortality in these was high on hosts including *B. delagoense*, mango & citrus.

It became apparent in these tests that *B delagoense* was not a particularly suitable host for laboratory observations in small containers. The plant sections readily rolled around in the container, killing the thrips, and the closeness of the phyllodes at the growing point made observations difficult.

Observation of thrips on *B. pinnatum* (Bp) in the field suggested that this species may be a better laboratory & experimental host because it has large flat leaves and an open growth habit. Infested material was collected from Indooroopilly, where a relatively small area of *B. pinnatum* is surrounded by a large area of *B. delagoense*. This material had apparently been sprayed recently, as plants showed symptoms of heavy infestation, but very few thrips were present. Good numbers of first instar larvae (L1) subsequently hatched from these leaves developed successfully and became the founding population of the laboratory colony.

With Bp as the host, successful rearing and observation was found to be achievable in containers of almost any size or shape. 30 ml polystyrene tubes with a 1.5 - 2 cm hole in the lid ventilated with 100 μm nylon mesh proved adequate for many observations and were used

in 3 insecticide assays. As numbers increased 120 ml polystyrene tubes were used and eventually take-away food or storage containers (700 ml).

Bp leaves are very durable, even when cut into sections. Whole leaves, if not damaged by thrips or fungi, remain in good condition for weeks in containers or on a laboratory bench, sprouting new plantlets within a week or so. These continued to grow or remained green and viable for months. However, when damaged by thrips, water loss increased rapidly and dehydration was hastened.

Bp plants are readily transplanted from the field into pots, where they strike and grow readily. Bp can also be readily propagated from stem sections or leaf pieces, which put out tiny new plants (plantlets) from each leaf emargination. Success using the latter was achieved with both soil and saw-dust, however establishment rate in sawdust was much lower as the new rootlets often failed to make contact with the growing medium.

Cultures can be maintained using either or both of 2 methods. Adults can be put into containers with new Bp leaves and left to oviposit for 2 or 3 days then removed. This produces a relatively synchronous cohort of larvae, which pupate and produce new adults within a few days of one another, and is useful if thrips of known age are required for experiments. It also makes removal of thrips from the culture simpler and easier; for example, in a container where most individuals are larvae or pupae, these can be extracted without concern for escaping adults.

In a less intensive method, adults can be left with the Bp leaves and allowed to oviposit continuously. Over time this produces a mixed age population, consisting of old adults new adults L1 & L2 larvae, pre-pupae & pupae.

Three key aspects of the rearing system are important. The Bp leaves used for culturing must be free of contaminating thrips, either SACT or other species. This has not proved to be an issue in our cultures, since uninfested plants are readily available in the Nambour area. No other thrips species have been noted in our collections from the infested Brisbane area, though several species were collected in the extensive surveys of APHS & AFRS staff, the most common of which was *Thrips tabaci*. Similarly, no contaminating thrips species have been noted on Bp plants grown in our glasshouse at MRS, Nambour.

Ventilation must be good and the number of thrips per leaf must not be too high. If ventilation is poor, fungal growth and rotting of leaves can result. If too many adults are used, or allowed to remain for too long on the leaf, heavy damage results and the leaves deteriorate before all the eggs have hatched, resulting in egg wastage. As few as 20 adults can almost completely damage a 6 x 3 cm leaf or leaf section within a week.

Provided that the oviposition leaf is not too heavily attacked large numbers of larvae can be reared on individual leaves. If new leaves are added to containers when the old ones are starting to deteriorate adults and larvae transfer readily to the new leaf, with the exception of very small new larvae on deteriorating old leaves.

Mature L2 larvae wander off the leaf and settle under or between leaves in confined spaces where they moult to the pre-pupa, and then to the pupal stage. New adults remain motionless for a day or so, while their cuticle hardens, before moving to the leaf. Mating has been observed on many occasions, especially when numerous adults are aspirated into smaller containers (e.g. 30 ml).

Insecticide trials

Introduction

The production in culture on Bp of large numbers of SACT enabled insecticides trials, three of which have been done so far. A range of products, most of which are potentially suitable for integration into our citrus IPM have been tested.

Methods

Bp leaf in sprigs of 5-6 leaves collected from an uninfested patch or from the glasshouse grown plants was sprayed with each test chemical, and allowed to air dry. In the first assay, a dry, sprayed leaf was put into each of 5 x 30 ml PS tubes, 20 adult thrips aspirated into each, and the tubes closed by placing a piece of 100 µm nylon gauze over the tube and screwing on the lid into which a 1.5 cm hole had been cut. In the second and third trials, 10 adult thrips were aspirated into an empty tube, which was closed as above. When treated leaf was dry thrips were tapped to the bottom of the tube the cap removed, leaf added and the cap replaced.

Mortality was assessed 1 and 3 days after treatment.

Results & Discussion

Control mortality was higher in the second trial than the first, and at unacceptably high levels in the third trial (**Table 1** first 3 trials), and further trials are needed to confirm these results. They are encouraging, nonetheless.

MILESTONE 5

Date: 31 December 2004

Description: Chemical controls tested; or
Ongoing monitoring of SACT for transfer to crop hosts

Criteria: Effective IPM compatible chemical known; or
Transfer to crop hosts detected/not detected

1. SUMMARY

Insecticide trials

- Earlier trials pertinent to this milestone were reported under Milestone 4 (though according to the contract should have been MS 3). This data is also shown in Table 1, as Trials 1-3.
- Further insecticide trials have been carried out using our SACT laboratory culture on *Bryophyllum pinnatum*. High control mortalities, requiring testing of thrips transfer methods and repeated assays, have retarded progress to some degree. These problems have been partially resolved; some assays now have low control mortalities, whilst in others it is occasionally high. Nonetheless, we have now tested 11 active ingredients.
- The recent trials confirm the earlier reported findings that Australian SACT appears to be very susceptible to a range of insecticides. The most notable results were in 2 most recent multi-dose assays (with low control mortality) - almost 100% mortality resulted with Endosulfan at 5 ml/100L (Table 1, Trial 7) and 90% with Abamectin at 10 ml/100L, both very low rates for this level of efficacy.

Host testing & Performance

- Experimental work is underway to test the hypothesis that performance on citrus will improve with repeated rearing on this host. Adult thrips are confined on flush growth in secure on-plant cages on potted lemon & lime trees, the best hosts in my earlier work. These will be reared continuously on these citrus hosts and their performance on citrus & *B. pinnatum* compared every 5 generations with *B. pinnatum*-reared thrips.

3. COMMUNICATION/EXTENSION ACTIVITIES

- A progress report was made to the Queensland Citrus Growers Inc. meeting, Gayndah, in October 2004. Regular communication is maintained with local citrus scouts.

2. NEXT STEPS

- Performance testing on citrus and on additional hosts, surveillance on citrus, mango and *Acacia* species and further insecticide trials will be done as time permits.
- The ability of the predatory mite *Euseius victoriensis* to kill and develop on *Scirtothrips aurantii* will be determined for milestone 7.

MILESTONE 7

Date: 30th June 2005

Description: *Euseius victoriensis* tested; or Citrus thrips identity, ecology & IPM studies

Criteria: Potential significance of Ev in IPM of SACT known; or improved knowledge of citrus thrips identity, ecology & IPM

1. SUMMARY

Work since the last MS report has been in 3 areas – 1) performance of SACT on citrus and other hosts, - 2) trials on persistence of foliar applied imidacloprid and - 3) predation of SACT by the predatory mite *Euseius victoriensis* (Ev).

Performance trials

The performance of SACT has been tested on several new hosts, with one, an as yet unidentified succulent (possibly a *Bryophyllum* or related species) proving a very good host. This plant was cultivated as a potential host of scale insects, and now supports a thriving colony of the cosmopolitan pest species white peach scale, *Pseudaulacaspis pentagona*, which may be used in host testing of the mango scale parasitoid *Aphytis chionaspis* from Thailand via South Africa.

Following the relatively poor performance of SACT on citrus in our prior experiments we have attempted to culture the thrips on citrus through several generations to determine if improved performance resulted. Continuous culture was maintained on flush growth of lemon and lime (the best performing citrus varieties in prior trials) using on-plant cages, cycled at ~ 2 weeks, over a period on several months, with occasional replicates producing reasonable numbers of SACT, however we were not able to maintain the culture beyond the 5th generation.

Plant factors may have contributed to this inability to rear SACT on citrus for longer, however the major limiting factor is its relatively poor performance on citrus.

This is an interesting finding, though some caution is required in extrapolating too confidently from it. In South Africa, SACT collected from dwarf poinciana, *Caesalpinia pulcherrima,* and from mango, both regarded as good field hosts of the pest, were unable to be cultured on flushing citrus seedlings (Tim Grout, pers. comm. 2005). Dr Grout also found that *Bryophyllum delagoense* in pots placed in the field including some in contact with infested *C. pulcherrima* remained uninfested over a period of 6 months.

These results are suggestive of genetic differences between SACT populations.

Imidacloprid persistence

Imidacloprid has been shown in a series of trials to persist in killing SACT for several months on growing *B. pinnatum*, and to be absorbed by sprayed older leaves and translocated to new leaves. This is interesting in terms of the potential of a single application to control the thrips for an extended period, but worrying in that it may indicate that this host is highly absorptive of insecticides in general. If this is the case, the high susceptibility to insecticides noted in our prior assays may be unrepresentative for other plant species. Further assays on other hosts such as citrus & mango are advisable to check the validity of the prior insecticide susceptibility results.

E. victoriensis predation & survival on SACT

Several assays of Ev with SACT larvae have been conducted but results to date are equivocal and our assay system needs to be further developed. Adult Ev have been observed to feed on 1st but not 2nd instar SACT larvae. When adult Ev were placed in tubs with *B. pinnatum* on which 1st instar larvae were available over an extended period survival was poor, few eggs were observed and the predators failed to persist for more than 7-10 days.

Direct observations with broad mite and two spotted mite also suggest Ev adults are unlikely to kill SACT other than 1st instar larvae. Adults are timid, and retreat rapidly when confronted with mites greater than 50% their size, and even smaller individuals moving rapidly, showing none of the signs characteristic of prey recognition. While they show interest in broad mite males (but not the larger faster females) they are unable to kill them. Broad mite males caught by Ev adults pull their legs in against the body and remain motionless until the predator fails to penetrate the body with its stylets and gives up. In our Ev-soybean culture Ev seems to be repelled by two-spotted mite (tsm), and production seems to be adversely affected by tsm once populations of the pest species are above very low levels. Smaller Ev are less likely to kill large prey.

Restriction of predation by Ev to 1st instars is likely to mean that this species will not exert significant field control of SACT.

2. NEXT STEPS

We propose to continue with -

1. preference & performance tests on potential hosts, including field transfer experiments with citrus and other hosts, and collaboration with Dr Grout on same
2. assessment of capacity of Ev to develop on SACT larvae
3. field surveys for SACT on hosts other than MoM, i.e. citrus, mango, Acacia
4. insecticide trials, including testing the possibility that plant host factors may contribute to susceptibility of SACT to insecticides

3. COMMUNICATION/EXTENSION ACTIVITIES

A report of general research activities was given to the National Citrus RD&E Liaison meeting at Bargara, 10th March. Growers & QCG Inc. have been informed of results throughout the project.

MILESTONE **8 (CT04001 Predatory mite mass rearing & release systems – years 3 & 4)**

Date: 30th June 2006

Description: *Euseius victoriensis* predation of SACT tested

Criteria: Potential significance of Ev in IPM of SACT known

SUMMARY

Prior assays indicated that *E. victoriensis* (Ev) adults could kill first instar (L1) SACT larvae *aurantii*, but perhaps not second instars (L2's). In 2 current trials, we have found that L1's and small but not larger L2' thrips larvae are killed in good numbers by Ev adults; 13 Ev killed or consumed 208 larvae over 9 days (1.78 thrips/Ev/day) and produced 9 or more eggs in the first, and 25 Ev killed or consumed 147 SACT larvae in 3 days (1.96 thrips/Ev/day) and produced 6 eggs in the second. These results are quite encouraging and suggest that the predator may make a significant contribution to control of this thrips if and when it arrives in Queensland's citrus.

APPENDIX 2

CITRUS INSIGHT REPORT – 2004/05

SOUTH AFRICAN CITRUS THRIPS – TO BE OR NOT TO BE (A PEST OF AUSTRALIAN CITRUS)?

Major South African citrus pest ignores Aussie citrus

South African citrus thrips (SACT), *S. aurantii*, is one of the most important citrus pests in the world, requiring the use of chemicals disruptive of IPM for up to 12 weeks after petal fall. SACT was detected in Brisbane in March 2002, and despite attempts to eradicate the apparently limited infestation, further detections were made from December 2002 to February 2003 over an area of ~ 1700 sq km in suburban Brisbane and west to Laidley near Gatton, and eradication was regarded as no longer feasible.

In Brisbane *S. aurantii* appears to be restricted to succulents in the genus *Bryophyllum*, predominantly *B. delagoense* and *B. pinnatum*, exotic weeds commonly known as Mother of Millions, and has not been found on other hosts, including citrus and mango. This is unusual for SACT, which has a very broad host range, and suggests that the incursion may represent a host-restricted biotype or cryptic species.

Research goals

Our research set out to determine for SACT - 1) performance on various hosts including citrus, 2) biology & ecology under Australian conditions, 3) effective natural & chemical controls and 4) integrate the above into a management plan.

Results

Biology

A simple but highly productive culture method utilising excised *B. pinnatum* leaves has been developed, and provides large numbers of thrips for host testing & insecticide trials. A simple on plant cage has also been developed and used extensively for host performance work.

Australian SACT eggs hatch in 6-7 days, the 2 larval stages take 3-4, the pre-pupal stage 1-2, and the pupal stage 3-4 days, giving a total, at summer room temps of 14-19 days. These development times are similar to those reported for SACT in South Africa.

Host testing

In no-choice tests, SACT performed very well on *B. pinnatum* (10-15 fold increase in numbers from 30 adults at ~ 2 weeks) and poorly on citrus of 4 varieties tested (sweet orange seedlings, 0-0.07x; small trees of navel orange, Eureka lemon, Tahitian lime, 0-1.5 x). Mango (5-11 x), macadamia (6 x), *Acacia longifolia* (2-5 x) and *A. sophorae* (3-5 x) were reasonable hosts & *Eucalyptus tereticornis* (0-1.2 x) produced low numbers. Very few larvae were produced on soybean, *Grevillea robusta*, *Syzygium australe*, green bean pods and small banana plants. No offspring were produced on *Ricinus communis*, *Callitris columellaris* or *Grevillea lanigera*.

For the 'poor hosts', at least some larvae developed to pupation, and in the odd replicate, performance on lemon and lime was close to that on *B. delagoense* (not as productive a host as *B. pinnatum)*, the most common infested species, with rates of increase of 3-4 x. Limes occasionally demonstrated an unusual 'scribbling' symptom not dissimilar to that

occasionally seen in South Africa on the outer surface of fruit and on the dorsal surface of the flat leaflets of seedlings of dwarf Poinciana, *Caesalpinia pulcherrima*.

Insecticide assays & E. victoriensis

Australian SACT adults are highly susceptible in laboratory assays to a broad range of insecticides including abamectin, spinosad, endosulfan, chlorpyrifos, imidacloprid, fipronil & methomyl, with > 90% mortality at rates as low as 2.5 ml/100 L for spinosad, 10 ml for abamectin, 5 ml for endosulfan and 0.25 ml for imidacloprid.

E. victoriensis work has only recently begun, but adult Ev have been observed to kill first instars, but not 2nd instar larvae or SACT adults.

DNA study

Molecular testing for differences between South African & Australian populations on citrus and Bryophyllum, carried out by Morris & Mound (ANU & CSIRO Canberra), did not detect location or host-based differences. In their words, 'These preliminary data suggest that the Australian population is not a distinct species or subspecies from the populations of S. aurantii on either citrus or Bryophyllum in South Africa (D.C. Morris & L.A. Mound 2004 – Molecular relationships between populations of South African citrus thrips (Scirtothrips aurantii Faure) in South Africa and Queensland, Australia. Aust. J. Entomol. 43: 353-358).

Conclusions & next steps

Our host performance findings are not consistent with the reported host utilisation of this insect in South Africa, and appear to contradict the molecular data. However they do suggest that this thrips is polyphagous, and is not likely to remain restricted to Mother of Millions in the field.

The relatively poor performance on citrus suggests that the risk to this crop in Australia may be low, however, further trials are required before stronger statements can be made. Of particular concern is the possibility of improved performance of the thrips over time on citrus, and/or the potential of mango to act as a bridge to citrus, as reported in South Africa. In Australia *Acacia* and *Eucalyptus* species may facilitate movement of the thrips through habitat where *Bryophyllum* is absent, or act as reservoirs for thrips attacking crop hosts.

It is prudent therefore to proceed with caution, and unlikely that a name change to 'South African Mother of Millions thrips' could be supported.

Our current research focus is on testing *E. victoriensis* against SACT, and on determining if continuous culturing of SACT on citrus improves performance. Further host performance testing and insecticide assays will also be done as time permits.

A THRIPS TO WATCH CLOSELY

Research by Queensland's Department of Primary Industries and Fisheries (QDPI&F) is seeking ways to protect Queensland's citrus from another threatening pest, the South African Citrus Thrips (SACT). In South Africa, SACT is one of the two most important pests of citrus. It is also associated with damage to bananas, grapes, macadamia and mangos and occurs on a broad range of non-crop hosts.

While SACT is not as big a threat as the disease citrus canker, QDPI&F Entomologist Mr Chris Freebairn warned that insecticide sprays to control the thrips for up to 12 weeks after petal fall could significantly increase the costs of fruit production and disrupt our long established citrus IPM systems.

While the thrips has not yet been detected on citrus in the field, Mr Freebairn, who heads the research project, said the aim was to determine if SACT posed a real threat to Australia's citrus industry, and if it does, which control methods and strategies are most effective. The $250,000 project 'South African citrus thrips in Australia – identity, pest and control', funded by HAL through citrus industry levies started in October 2003 and will finish in September 2006.

The discovery

SACT, *Scirtothrips aurantii* Faure, was first detected in Australia on 'mother of millions' (*Bryophyllum delagoense* - Family: Crassulaceae) plants in the quarantine house at Alan Fletcher Research Station (AFRS) at Sherwood in Brisbane. AQIS immediately quarantined the station and a local survey revealed a second small infestation within 500 m of the station. All infested plants were destroyed and glasshouses emptied and disinfested.

Surveillance in the winter-spring months of at risk areas suggested that the infestation was confined to the station and its immediate environs.

Mr Freebairn said the initial attempts to eradicate the thrips using insecticides and destruction of infested plants appeared to be successful, however, the following summer surveys found well established SACT populations on *Bryophyllum* species 20 kilometres north and west of Sherwood over an area of more than 400 square kilometres. Local surveys by other state departments did not find SACT anywhere else in Australia, nor was it found on the Sunshine Coast. Apparently the thrips infestation was confined to Brisbane, but because this encompassed such a large area eradication was determined not to be feasible.

The research

The extensive surveillance carried out by QDPI&F and AFRS of a very broad range of potential hosts found SACT was confined to *Bryophyllum* species. This was unusual behaviour for SACT, but since it had only recently been recorded for the first time on this host in South Africa the relevance of this finding was difficult to determine.

"Given the pest status of this thrips in South Africa it was vital that research proceeded to determine the risk to Australian citrus posed by this new thrips, and to develop control options consistent with our IPM systems in preparedness for its arrival in citrus", said Mr Freebairn.

"We all hoped that in Australia SACT would remain confined to these strange, succulent plants and not attack citrus or other crop hosts such as mango. Then we could rename it the South African mother of millions thrips."

Early research by AFRS suggested that Australian SACT did not develop on potted navel orange, mango, *Syzygium australe* or mock orange in cages. In a DPI&F trial, SACT failed to transfer to potted citrus of various varieties placed amongst infested mother of millions plants.

Similarly, in early laboratory experiments, SACT adults confined in small cages on Navelina orange seedlings produced very few offspring.

"These findings appeared to be inconsistent with the major pest status of this thrips in South Africa, and suggested that it may not pose a major threat to Australian citrus."

Further host testing experiments, however, revealed that Australian SACT, when confined in cages on plants, is in fact able to develop successfully on a broad range of hosts including Acacia, Eucalyptus, Grevillea, Syzygium, Poinciana, mango, macadamia, peach, grape, cotton, soybean, *Kalanchoe blossfeldiana*, *Bryophyllum pinnatum*, *B. proliferum, B. delagoense* and citrus.

There are, however, substantial differences between hosts in the performance of SACT, as measured by the number of offspring produced by 20 adult thrips confined in a cage on each plant. The best hosts are the *Bryophyllum* species, followed by mango and macadamia. Coast wattle (*Acacia sophorae*), Sydney golden wattle (*A. longifolia*), grape and peach were good hosts, while forest red gum (*Eucalyptus tereticornis*) was a moderate host. Avocado, banana, cotton, soybean, *Kalanchoe longiflora*, *Syzygium*, castor oil, Poinciana, coral plant, money plant and mock orange were poor hosts.

Most varieties of citrus were found to be poor hosts, but both lemon and lime occasionally produced good numbers of SACT offspring. Small Kumquat fruit exposed in on-plant cages to 50 adult thrips produced a few larvae and showed typical thrips scurfing damage.

"The hypothesis put forward by South African entomologists that SACT that develop on mango may perform better on citrus has been tested, but our experiments did not support this theory" Mr Freebairn said. "We also have not been able to show improved performance of the thrips on flush growth of lemon or lime over 5 generations of continuous culture."

Mr Freebairn said "While these data suggest that while SACT may not appear to pose a high risk to Australian citrus there is sufficient cause for continued concern about the risks posed by this pest to citrus, mango and macadamia".

Finding a control

Trials over the past year have confirmed that Australian SACT is very susceptible to a range of insecticides.

Mr Freebairn said the most notable results were in two most recent multi-dose assays, in which almost 100% mortality was achieved with Endosulfan at 5ml/100L, and 90% with Abamectin at 10ml/100L, very low rates for this level of efficacy. From the standpoint of local eradication efforts, imidacloprid has been shown to be highly effective and persisted for several months in killing SACT on mother of millions (*B. pinnatum*).

Preliminary trials have shown that the predatory mite *Euseius victoriensis,* which is common in Australian citrus orchards, is capable of killing first instar SACT larvae, but further work is required to determine how effective this predator may be in controlling thrips populations.

The biology of SACT

SACT is regarded as one of the most threatening pests to the Australian citrus industry. In South Africa, populations which over-winter in orchards go through their first generation on the soft spring growth flush. As this hardens off they attack the young fruit, and continue to feed and breed on these for up to 12 weeks after petal fall. Further attack by SACT moving into orchards occurs after summer rains promote flush growth on bush hosts like *Acacia karroo*.

SACT feeding injures rind cells of the young fruit, mostly under the calyx and between touching fruit, and results in unsightly blemishes as the fruit enlarges. A high proportion of fruit can be damaged if control is not effective.

SOUTH AFRICAN CITRUS THRIPS IN AUSTRALIA – IDENTITY, PEST STATUS & CONTROL

Introduction

South African citrus thrips (SACT) is one of the most important pests of citrus in the Republic of South Africa (RSA). It also attacks banana, grape, macadamia and mango and occurs on a broad range of non-crop hosts.

SACT is a lesser threat to Australian citrus than the diseases citrus canker or greening, but insecticide sprays to control it for up to 12 weeks after petal fall could significantly increase the costs of fruit production and disrupt our long established citrus IPM system.

While SACT has not yet been detected on citrus or any other crop host in Australia, the aim of our research was to determine the risk it posed to the citrus industry, and to develop effective control options.

Methods

Host testing was done by confining adult thrips in small cages on potted plants of the tested species. Surviving adults and any larvae produced were counted two weeks later. Insecticide trials were done on fresh spray residues on leaves held with adult thrips in small ventilated tubes. Predatory mite trials were conducted by providing adult mites with a constant supply of first and second instar thrips larvae and comparing surviving thrips numbers in control tubes without predatory mites.

Results

Australian SACT developed successfully on flush growth of a range of crop and non-crop hosts. Whilst performance was best on the succulent *Bryophyllum pinnatum*, it also was very good on mango and macadamia. Other crop hosts that supported SACT development were peach, tea and grape, and the traded succulent *Kalenchoe blossfeldiana*. Several species of the natives *Acacia* and *Eucalyptus* that could act as bridging hosts to assist movement across hostile terrain into crops also supported the development of SACT.

Most citrus varieties, including navel orange – the variety most affected in RSA, were very poor hosts; lemon and lime flush leaves, however, occasionally supported performance equivalent to that of *B. delagoense*, the main field host of this thrips in Australia. In fruit trials, Kumquat was damaged but lemon and lime were not, even though the adult thrips survived on the latter for several weeks; very few larvae were produced on fruit.

Australian populations of SACT were highly susceptible to a range of commonly used insecticides at very low rates – almost 100% mortality was achieved with endosulfan at 5ml, and 90% with abamectin at 10ml/100L. Such susceptibility to insecticides suggests strongly that Australian populations of SACT have non-citrus origins.

Adults of the native predatory mite *E. victoriensis* were shown to kill 2-3 first or second instar SACT per day, indicating potential to contribute to citrus pest thrips control. However, egg production was poor, indicating and the predators may need additional food sources such as pollen or pest mites to sustain population growth.

SACT distribution in Australia

From its first detection in Australia in March 2002 until November 2005, SACT was known only from the suburbs of Brisbane on succulents – the most common of which was *Bryophyllum delagoense*. In November 2005 it was detected by Alan Fletcher Research Station and DPI&F staff in numerous locations along the highway from Millmerran to Wandoan, the latter only a few hundred kilometres west of Mundubbera. The surveys included citrus, mango and macadamia but SACT was detected only on *B. delagoense*. SACT also has been detected on this host at Caboolture and at Elanda Point north of Tewantin.

Key outcomes

This research indicates that the risk posed to Australian citrus by SACT can be considered to be low. There is a need, however, for continuous vigilance to detect as early as possible the arrival of this thrips in citrus and other crops such as mango, macadamia, peach, grape and tea, as well as traded succulents such as *Kalenchoe blossfeldiana* - especially since SACT has now moved well beyond its former Brisbane suburban confines.

Our demonstration of the efficacy of a range of insecticides at very low rates, and of the extended persistence of efficacy of imidacloprid in *B. pinnatum*, suggests that there should be little difficulty controlling this pest in crop hosts in the short term. SACT however has a noted history of developing resistance to pesticides and it should not be taken for granted that this will always be the case.

Captions for photographs

SACT pupae in culture on the succulent *Bryophyllum pinnatum* (**Plate 2**)
On-plant cages were used to determine performance of SACT on a range of plant hosts (**Plates 5 & 6**)
SACT larvae on lime leaves (**Plate 6**)
Kumquat fruit damaged by SACT in on-plant cage trials (**Plate 6**)

APPENDIX 3

AUSTRALIAN CITRUS NEWS - 2005/06

South African citrus thrips – a pest of Australian citrus?

Project number: CT03022

Aim: Determine the potential threat posed by South African citrus thrips to Australian citrus and ascertain Integrated Pest Management options to manage it.

Funding source: R&D levy

Project duration: October 2003 – September 2006

In South Africa, South African citrus thrips (SACT, *Scirtothrips aurantii* Faure) is one of the two most important pests of citrus. It also damages banana, grape, macadamia and mango and occurs on a broad range of non-crop hosts.

SACT is not as big a threat to Australian citrus as the disease citrus canker, but insecticide sprays to control it for up to 12 weeks after petal fall could significantly increase the costs of fruit production and disrupt long established citrus IPM systems.

While the thrips has not yet been detected on citrus in the field, the aim of this research project is to determine if SACT poses a real threat to Australia's citrus industry, and if it does, which control methods and strategies are most effective.

Host performance experiments

Our host testing experiments revealed that Australian SACT, when confined in cages on plants, is able to develop successfully on a broad range of hosts including *Acacia*, *Eucalyptus*, *Grevillea*, *Syzygium*, Poinciana, mango, macadamia, peach, grape, cotton, soybean, *Kalenchoe blossfeldiana*, *Bryophyllum pinnatum*, *B. proliferum, B. delagoense* and citrus.

However, there are substantial differences between hosts in the performance of SACT, as measured by the number of offspring produced by 20 adult thrips confined for two weeks in a cage on each plant.

The best hosts were the *Bryophyllum* species, followed by mango and macadamia. Coast wattle (*Acacia sophorae*) and Sydney golden wattle (*A. longifolia*), grape and peach were good hosts, while forest red gum (*Eucalyptus tereticornis*) was a moderate host. Avocado, banana, cotton, soybean, *Kalenchoe longiflora*, *Syzygium*, castor oil, Poinciana, coral plant, money plant and mock orange were poor hosts.

Most varieties of citrus were found to be poor hosts, but both lemon and lime occasionally produced good numbers of SACT offspring. Small Kumquat fruit exposed in on-plant cages to 50 adult thrips produced a few larvae and showed typical thrips scurfing damage.

The risk

While these data suggest that SACT may not appear to pose a high risk to Australian citrus there is sufficient cause for continued concern about the risk it poses to citrus, mango, macadamia, peach and grape.

In experiments to determine if continuous culture on citrus improved performance on this host, SACT was maintained in on-plant cages on flush growth of lemon and lime over a

period of several months. Occasional replicates produced reasonable numbers of offspring, however the culture was not able to be maintained beyond the fifth generation.

Finding a control for Australian citrus

Trials over the past year have confirmed that Australian SACT is very susceptible to a range of insecticides.

The most notable results were in two recent assays, in which almost 100% mortality was achieved with Endosulfan at 5 millilitres/100 litres, and 90% mortality with Abamectin at 10ml/100L, very low rates for this level of efficacy.

From the standpoint of local eradication efforts, imidacloprid has been shown to be highly effective and persisted for several months in killing SACT on mother of millions (*B. pinnatum*).

Preliminary IPM trials have shown that the predatory mite *Euseius victoriensis,* which is common in Australian citrus orchards*,* is capable of killing first instar SACT larvae, but further work is required to determine how effective this predator may be in controlling thrips populations.

APPENDIX 4

Exposure of potted citrus to *Scirtothrips aurantii* on Mother of Millions, *Bryophyllum delagoense,* at Indooroopilly, Brisbane.

CG Freebairn & D Smith

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SUMMARY

A trial to determine if potted citrus trees placed within a heavily infested patch of the known Australian host *Bryophyllum delagoense* (mother of millions, MoM) would be infested by and support development of the exotic pest thrips *Scirtothrips aurantii* (SACT) was conducted in a patch of heavily infested MoM on the Queensland Department of Primary Industries site at Indooroopilly from March to April 2003.

Three species of thrips were found on the potted citrus plants - citrus rust thrips, *Chaetanaphothrips orchidii, Asprothrips seminigricornis* and *Dendrothrips* sp. No leaf or fruit damage attributable to thrips was apparent. Suburban backyard citrus trees near heavily infested MoM hosted *C. orchidii, A. seminigricornis* and *S. dorsalis*, a species related to SACT that is known to be present in Australian citrus. No *S. aurantii* was found on either potted or backyard citrus.

These results lend support to the contention that the Australian *S. aurantii* may be a host-restricted form of SACT. Determination of the risk posed to citrus and other important crop species by this potentially very serious pest requires further research.

INTRODUCTION

The exotic pest thrips, *Scirtothrips aurantii*, commonly known as South African citrus thrips (SACT), was detected on mother of millions plants (MoM, *Bryophyllum* spp.) at the Queensland Department of Natural Resources and Mines (DNRM) Alan Fletcher Research Station (AFRS), at Sherwood in suburban Brisbane in March 2002. This was the first detection of this serious citrus pest in Australia (Telford & Planck 2003).

Initial detections were followed by a survey out to 500 m from AFRS, which detected several additional positive sites. Eradication procedures were initiated and no further detections made until follow up surveys in December 2002, when further positive sites were found.

A delimiting survey in January-February 2003, combined with extensive trace forward and trace back surveys determined that the thrips was distributed over an area exceeding 1200 sq km, primarily to the North and West of Sherwood. The thrips was declared established in Australia and eradication deemed impossible and/or economically unviable.

The early surveys targeted all plant species that may have harboured thrips. Only *Bryophyllum* spp. and *Kalanchoe* sp. were found to be infested. No SACT was detected on other hosts, including citrus and mango, which are common in suburban Brisbane backyards. Subsequent surveys targeted MoM, which, apart from being the only known host, is also a good indicator host because it supports large SACT infestations which cause conspicuous damage, and because the local distribution of this exotic weed was well known as a result of the AFRS exotic weeds biocontrol program.

SACT is native to South Africa and, although it has been intercepted on fruit in several European countries, and in US ports, it has not established anywhere else in the world. In South Africa, it is a major pest of citrus, requiring the use of disruptive insecticides for up to 12 weeks after petal fall. It is also a pest of mango where these are near infested citrus. In Yemen, SACT attacks banana, and in Reunion it is a pest of grapes.

SACT has a very broad host range, including more than 50 crop and non-crop species, however it was not detected on *Bryophyllum* in Madagascar, the plant's supposed country of origin, in surveys of 79 sites (in southern Madagascar) over a 2-year period from August 1999. The weevil *Osphilia tenuipes* was imported into quarantine at AFRS Sherwood (from S. Africa) as a promising biocontrol agent for MoM in May & July 2000. The wasp *Eurytoma* sp. was imported from South Africa in 2001-02. The first detection of SACT on *Bryophyllum* in South Africa was reported in 2001-2002 (AFRS Weed Research Projects, 2002).

The Australian citrus industry, which accounts for about 20% of the total value of Australian horticultural production, with annual production of about 650,000 tonnes of fruit worth approximately $450M, is regarded as potentially at risk from SACT. Damage to fruit leading to downgrading, and disruption of the well-developed IPM system by heavy insecticides are the main potential impacts. Adverse impact on exports may also occur, as most of the 180,000 tonnes exported, worth $190M, are oranges, the variety most susceptible to SACT damage.

The contingent annual loss (with control) to citrus was estimated at $24.3M by Whittle (Situation Assessment & Pest Risk Analysis, 2003).

The likely pest status of SACT in Australia on mango, banana and grapes is difficult to determine. Other crops may also be at risk if the behaviour of other recently arrived exotic thrips is any indication. For example, western flower thrips, *Frankliniella occidentalis*, attacks stone fruit (mainly nectarines, but also peaches and plums) in Australia, but does not do so elsewhere in the world. It also attacks strawberries in other parts of the world, and does this in southern Australian states, but does not attack them in Queensland.

Given this scenario it was deemed important to gather further information on the potential host range of SACT in Australia, especially with respect to the key crop hosts citrus and mango. To this end two small trials were established in suburban Brisbane in which potted plants of a range of host species were exposed to infestation by SACT from *B. delagoense*. One was conducted by staff of AFRS, and has been reported separately (Manners and Dhileepan, 2003). This paper reports on the second trial, conducted within the grounds of the Queensland Department of Primary Industries at Indooroopilly, Brisbane.

MATERIALS & METHODS

Citrus trees ~ 1.2 m high purchased from a nursery at Nambour were re-potted into large pots. The navel oranges were utilised in the AFRS trial, the remaining varieties – lemon (*Citrus limon* - 5 potted plants), Tahitian lime (*C. x latifolia* - 4 plants), Kumquat (*F. margarita* - 3 plants, 2 with small fruit), Hickson mandarin (*C. reticulata* - 1 plant) & red grapefruit (*C. paradisi* -1 plant) - were used in this trial at Indooroopilly.

The plants were transported from Nambour to Indooroopilly and held in a glasshouse for several weeks prior to being placed randomly within a large patch of *B. delagoense* heavily infested with SACT on 13th March 2003.

To allow the thrips free access over time the citrus trees were not caged. The trial was, therefore, an uncontrolled choice test.

Approximately 6 weeks later, on 29th April 2003, all leaves and fruit considered likely to harbour thrips or show symptoms of their presence were cut from the plants into zip lock bags and washed with 60% ethyl alcohol. Two samples of MoM plants were taken to determine SACT infestation level, one about 1 month prior to the start of the experiment (2 heavily infested plants), the second on the day of its conclusion (3 samples each of 10 plants in the patch in which potted citrus were placed). A fourth sample of MoM was taken from Fig Tree Pocket on the trial assessment day. Plants were cut off at ground level, placed into a zip lock bag, washed with alcohol and sealed.

On the day the trial was concluded at Indooroopilly, backyard citrus trees of several varieties was sampled on three properties in Fig Tree Pocket – a mandarin (probably a Hickson) at the Pylara St nursery, three trees (a lime, a navel and a mandarin) from 30 Fern Pde and three trees (a lemon a navel and a mandarin) at 40 Fern Pde. The latter two properties were adjacent to a public park heavily infested with both *B. delagoense* and SACT. A 10-plant sample was taken from *B. delagoense*. The Pylara St nursery and nearby areas contained infested MoM.

All thrips, both larvae and adults, were extracted into a 120 ml container from the plant material in bags with several washes of 60% alcohol, transferred to a Petri dish for examination under a dissecting microscope (by CGF), and then put into small tubes and despatched for identification. Samples were pooled by variety for potted citrus and by location or host for other specimens.

RESULTS

Mother of Millions

SACT was detected on MoM on all sampling occasions. Infestation levels at the conclusion of the trial at Indooroopilly were 1.0-2.3 SACT/plant. The Fig Tree Pocket sample of 10 plants had a similar number of 1.9/plant, considerably lower than the earlier two plant sample on 14th February 2003, which had a mean of 39 SACT/plant (total of 58 larvae and 20 adults). No other thrips, and very few other insects, were found on the MoM.

Citrus

Three species of thrips were collected from backyard citrus, including 2 known pest species – citrus rust thrips, *Chaetanaphothrips orchidii,* the chilli thrips, *Scirtothrips dorsalis*, and *Asprothrips seminigricornis* (Table 1). No fruit or leaf damage was observed.

Thrips larvae or adults were found on all four varieties of potted citrus amongst MoM (Table 1). All five lemon trees had some thrips, as did three of the four limes, one of the three Kumquats, and the single red grapefruit. No thrips were present on the single Hickson mandarin.

No thrips damage to leaves was observed, nor were the Kumquat fruit damaged (fruit length at assessment was 10-30 mm).

Identifications were made only for the adult thrips, which were from lemons and limes (no keys to immature *Scirtothrips* species are available). None was *S. aurantii*.

DISCUSSION

Four species of thrips were identified from the potted and backyard citrus trees in this trial. These included two known citrus pest species, the chilli thrips, *S. dorsalis*, and the citrus rust thrips, *C. orchidii*. No leaf or fruit damage of the type expected from SACT was found. *S. aurantii* was collected only from MoM, *B. delagoense*.

This result may be due to factors including the low incidence of suitable soft tissue or fruit on the test citrus plants at the time the results were assessed in late April 2003, the declining level of infestation of SACT on the MoM, and the choice available to the thrips of MoM.

At the start of the trial all citrus plants had soft new growth suitable for SACT, however, at assessment little soft tissue was present on either the potted citrus or the backyard trees. This may have resulted in few or no thrips remaining on the plants at assessment (SACT is known to disperse readily as leaf tissue hardens, Grout, pers. comm.). On the other hand, signs of damage would have been apparent had the flush growth available earlier been significantly utilised by the thrips. Larval and adult thrips of several other species were found, and the backyard trees, with similarly little suitable tissue, supported *S. dorsalis,* which is known to have similar feeding behaviour to SACT. The Kumquat fruit, although it was of appropriate size, had a very small, open calyx, possibly not attractive to *S. aurantii*.

The SACT infestation level on the MoM was quite low when the results were assessed, with a maximum of 2.3 SACT/plant. At the start of the trial, when ample soft tissue was available, large numbers of SACT were present on the MoM (mid-February sample - 39/plant).

Nothing is known of the relative preferences of SACT for MoM and citrus, however, given the availability of suitable leaf tissue and large numbers of thrips on the MoM, it is reasonable to expect that significant utilisation of the citrus leaf would have occurred unless the Australian *S. aurantii* has a marked preference for MoM.

This result is comparable with that gained from the AFRS experiment at Fig Tree Pocket (Manners and Dhileepan 2003) using, amongst other plant hosts, navel oranges, the most susceptible to damage of the citrus varieties. Manners and Dhileepan exposed navel orange (*Citrus sinensis*), mango (*Mangifera indica*), mock orange (*Murraya paniculata*) and Syzygium sp. to adult thrips collected from MoM in individual sleeve-cages. Only MoM supported F1 populations of *S. aurantii*.

The failure of SACT to develop on citrus in the no-choice AFRS trial suggests that Australian *S. aurantii* may be incapable of developing on citrus, whereas the DPI trial suggests a strong preference for MoM. This is supported by the failure to detect SACT on citrus in surveillance reported by Telford and Planck (2003).

Had this trial shown that SACT was present in significant numbers on the potted citrus, this would have provided immediately useful information. This was a preliminary experiment that was always going to be subject to asymmetric interpretation; a positive result - thrips development on the citrus - would have been very informative; a negative one unlikely to be definitive. Further research based on controlled host testing, including choice and performance trials would be vital early components of this project that should allow more definite conclusions to be drawn.

In the course of deliberations of the Consultative Committee on Exotic Plant Pests & Diseases in early 2003, it was argued that this trial was of little value, and potentially dangerous in promoting a host shift from MoM to citrus. Our view is that as SACT is present over a large area in which thousands of citrus, and other potential crop hosts occur, this small trial would contribute infinitesimally to this probability.

REFERENCES

Manners AG & K Dhileepan (2003) - Australian *Scirtothrips aurantii Faure* (Thysanoptera: Thripidae) does not survive on citrus or mango plants. Unpublished report, Queensland Department of Natural Resources and Mines.

Telford G & JB Planck (2003) - Pest Survey Report for South African Citrus thrips in Queensland. Unpublished report, Queensland Department of Primary Industries.

Whittle PJL (2003) - Situation Assessment and Pest Risk Analysis March 2003. *Scirtothrips aurantii* Faure Detection in Brisbane, Queensland, March 2002. Unpublished report, Queensland Department of Primary Industries.

Table 1: Thrips from *Bryophyllum delagoense*, backyard citrus (29.4.03) and potted citrus (exposed 13.3 – 29.4.03).

Accession No.	Host	Location	Thrips collected (CGF comments)	Identifications (J. Donaldson)
N5649	*Bryophyllum delagoense*	Indooroopilly - Fig Tree Pocket -	17 L*, 4/2 A#; 3 L, 7/3 A; 7/3 A – all males SACT 4 L, 7/8 A – all males SACT.	*Scirtothrips aurantii* Faure
N5650	Backyard citrus	Fig Tree Pocket	1 L, 3/0 A - not SACT, 1/0 A - *Scirtothrips* sp.? 7 red L - not SACT.	*Scirtothrips dorsalis* Hood *Asprothrips seminigricornis* (Girault) *Chaetanaphothrips orchidii* (Moulton)
N5651	Lemon	Indooroopilly	4 L, 5/0 A – not SACT.	*Asprothrips seminigricornis*
N5652	Lime	Indooroopilly	3 L - ?; 1 L - *Scirtothrips* sp.?, 2/0 A - 1 ea. of 2 species – not SACT.	*Chaetanaphothrips orchidii* *Dendrothrips* sp.
N5653	Kumquat	Indooroopilly	1 larva	Unidentifiable
N5654	Red Grapefruit	Indooroopilly	2 larvae	Unidentifiable

* L = larva, # A = adults, x/y = females/males (males of SACT have characters that allow identification in alcohol at stereomicroscope magnifications).

APPENDIX 5

PEST RISK ANALYSIS & SURVEILLANCE REPORTS

SITUATION ASSESSMENT and PEST RISK ANALYSIS
MARCH 2003
Scirtothrips aurantii Faure
Detection in Brisbane, Queensland, March 2002

Animal and Plant Health Service
Queensland Department of Primary Industries

Peter JL Whittle

1 Executive summary

The exotic thrips species *Scirtothrips aurantii* Faure was found in Brisbane in March 2002, and is established in an area of between 400 and 1,200 km^2 to the south-west of the city. This insect appears to be limited in its host range to the declared weeds *Bryophyllum* spp., to which it is causing significant damage. In southern Africa, *S. aurantii* is a significant pest of citrus and there is a possibility that this insect will host-adapt to citrus and a number of other plant species here at some time in the future. If the *S. aurantii* currently in Brisbane did broaden its host range, it would be expected to spread into all citrus-growing areas of Australia. Otherwise, it would remain limited to the summer-dominant rainfall areas, as is *Bryophyllum*.

A pest risk analysis was conducted for the citrus production areas in the winter- and summer-dominant rainfall regions of Australia. The analysis took into account the likelihood of the insect being introduced, establishing and spreading in the regions, and the economic consequences. The unrestricted risk estimates were *negligible* and *very low* respectively for the two regions. Both of these estimates were below the appropriate level of protection threshold, so containment or eradication was unjustified. The likelihood of containment is negligible. A preliminary cost estimate for eradication was at least $113.6 million, possibly far greater, with low likelihood of success.

An economic estimate indicated that the cost of control and residual losses, if *S. aurantii* became a pest on citrus, would be about 5.4 percent and 16.2 percent in the winter- and summer-dominant rainfall areas respectively, or 5.4 percent overall. The net present value of accumulated, indefinitely continuing control costs and residual losses was estimated at $13 million using a conservative discount rate that takes into account the uncertainty of if and when pest status on citrus would eventuate.

Some benefit may be obtained by monitoring the spread and host range of *S. aurantii* for the next few years. The Department of Natural Resources and Mines (DNRM) conducts a control program on *Bryophyllum* spp. In the course of this work, DNRM may be able to monitor the spread of *S. aurantii* and report this information to plant health authorities and plant industries.

In order to prepare industries, particularly citrus, for the possibility that *S. aurantii* will become a pest, awareness materials on *S. aurantii* should be prepared and distributed amongst citrus (and other horticultural) entomology specialists, to facilitate surveillance for the possible development of citrus-attacking preference in this species. Also, integrated pest management (IPM) workers should give consideration to whether and how IPM systems in citrus could help to ameliorate potential damage from *S. aurantii*.

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2 Introduction

S. aurantii was detected on mother-of-millions (MOM) plants (*Bryophyllum delagoense*) at the Department of Natural Resources and Mines' (DNRM) Alan Fletcher Research Station (AFRS) at Sherwood in Brisbane, in March 2002. The thrips species was identified by Dr Laurence Mound, a thrips specialist of CSIRO Entomology. In southern Africa, its common name is South African citrus thrips (SACT).

After consideration by the national Consultative Committee on Exotic Plant Pests and Diseases (CCEPPD), known infested plants were destroyed, the detection area was quarantined and further surveillance was undertaken (Anonymous 2003c). More detections were made in January 2003 up to 1 km from AFRS and then at sites up to 17 km away. This was discussed in a CCEPPD teleconference on 23 January 2003, and it was agreed to carry out wider delimiting surveillance. This surveillance has demonstrated that *S. aurantii* is widespread and well-established in south-west Brisbane over a range of at least 400 km^2 and possibly much more, with dense infestations at some locations, but not elsewhere in the city (Telford 2003). Surveillance beyond the known range has been limited to trace back sites in coastal Queensland from the New South Wales border north to Rockhampton.

CCEPPD requested a technical paper discussing the feasibility of eradicating this incursion. This followed debate among CCEPPD members of the notion that eradication is not possible, based on failure of previous attempts anywhere in the world to eradicate thrips. CCEPPD policy is that implementation of any nationally cost-shared eradication program will only be recommended if there is a reasonable chance of eradication success and a cost/benefit analysis of eradication is significantly positive.

The Queensland Department of Primary Industries (DPI) is the lead agency for the response. The delimiting survey of the greater Brisbane area conducted by DPI has developed a more accurate picture of the distribution of *S. aurantii*, so that the geographic scope of any eradication program may be determined. DPI has also prepared this pest risk analysis (PRA) to contribute towards assessment of the technical feasibility of eradicating *S. aurantii*.

3 Risk analysis

A PRA may be initiated by identification of a pest, or a pathway by which the pest may enter the pest risk area. The detection of *S. aurantii* in Brisbane provides cause for conducting a PRA, in order to consider the risk posed by this insect, and what response measures are appropriate. The framework used for the PRA is based on the process described by Kumar *et al.* (2002) for Western Australia's risk estimation on black Sigatoka on fruit from Queensland, and also refers to that proposed by Plant Health Australia (McLeod 2002) and the appropriate international standard, the International Standard for Phytosanitary Measures (ISPM) No. 11 (Anonymous 2001b). The WA model provides substantial detail, is readily applied, and is consistent with the approach adopted by Biosecurity Australia for import risk analysis (Anonymous 1998a).

3.1 Risk assessment

3.1.1 Pest categorisation

The definition of a quarantine pest is:

> *"A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled"* (Anonymous 2001b).

The background information provided for *S. aurantii* (see Section 0) indicates that it is potentially important economically. *S. aurantii* was prescribed as a pest in Queensland after its detection[1]. It is present but not widely distributed. Although local eradication in the vicinity of AFRS was attempted initially, no quarantine has been implemented beyond a formal undertaking by DNRM (the owner of AFRS) and whether official control will be established is still under consideration.

A component of pest categorisation is the identity of the pest. While the species, *S. aurantii,* has been identified authoritatively, *S. aurantii* in Brisbane seems to be limited to *Bryophyllum* spp. and the existence of host-preferring biotypes is readily conceivable (see Section 0). This incursion cannot, for the moment, be concluded to be a citrus-attacking biotype of *S. aurantii* and the organism in Brisbane should not be referred to as SACT. There is a chance, undetermined in scale, that the detected form of *S. aurantii* will at some time in the future change its host preference to attack citrus.

3.1.2 Pest data sheet for Scirtothrips aurantii

Following is a summary of detailed pest data provided in the Crop Protection Compendium (Anonymous 2002a).

3.1.2.1 Scientific name

Scirtothrips aurantii Faure
Synonym: *Scirtothrips acaciae* Moulton

3.1.2.2 Common name

South African citrus thrips (SACT)

3.1.2.3 Host plants

Primary hosts: citrus, lemon, navel orange
Secondary hosts: groundnut, asparagus, cotton, plantain, castor bean, grapevine, tea, silky oak, mango, banana
Wild hosts: Acacia, Combretum.

3.1.2.4 Plant stages and parts affected; symptoms

Vegetative growing stage, flowering stage and fruiting stage
Fruits/pods, growing points and leaves

Citrus: Silvering of leaf surface, linear thickening of leaf lamina, brown frass markings on leaves and fruit, grey to black markings on fruit forming a ring around the apex, then fruit distortion and early leaf senescence.

Mango: lesions on fruit, leaf malformation, stunting of new growth.
Banana: fruit spotting (Yemen).

3.1.2.5 Geographic distribution

Valid records are available from numerous African countries and Yemen.

S. aurantii has been reported 17 times at US ports, from Ghana, Israel, Kenya, Netherlands, South Africa and Zimbabwe (source: USDA PIN 309 database).

3.1.2.6 Pest status

S. aurantii is a major citrus pest in southern Africa, where it gained its common name SACT. Larvae and adults feed on young fruits and cause rind damage that does not affect eating quality but, if substantial, makes the fruit unexportable, with culls of up to 75 percent of fruit in some orchards (Wentzel *et al.* 1978). Sometimes serious damage may be done to new

[1] *Plant Protection Amendment (No. 1) 2003*

shoots, especially in new plantings, causing leaf discolouration and distortion. While it attacks several crops (Gilbert and Bedford 1998), it was stated to be a major pest on citrus only (Gilbert 1990). It can cause severe scarring on young mango fruit (*Mangifera indica*) (Grove *et al.* 2000), but this may heal as the fruit matures (Grout personal communication). It has been reported as a pest of tea (*Camellia sinensis*) and plantain (*Musa paradisiaca*) (Anonymous 2002a).

S. aurantii is found in many African countries from South Africa to Egypt, covering latitudes from about 32ºS to 30ºN. Its pest status within South Africa varies considerably, being severe in north-eastern areas where 60 per cent of citrus is grown (eg Mpumalanga Lowveld, Northern Province, eastern Transvaal), but of less significance in the Eastern and Western Cape Province (Gilbert and Bedford 1998; Wentzel *et al.* 1978), south of latitude 29ºS.

3.1.2.7 Biology

S. aurantii feeds on epidermal or palisade cells of young leaves and on the apex of young fruit often concealed under the calyx, and do not feed on mature leaves. Two nymphal (feeding) stages are followed by two pupal (non-feeding) stages. *S. aurantii* lays its eggs in leaves in the first growth flush and later in the rind of young fruit. Pupation is usually on the ground amongst leaf litter and rarely under the calyx of fruits. Reproduction is continuous, taking about 30 days although slowed in winter.

Thrips fly weakly, but may be dispersed in substantial numbers over longer distances with wind assistance (Lewis 1997). The period of thrips survival in flight is generally limited to a few hours, due to desiccation. Such a mode is not likely to occur over a long distance, nor does the limit of range of *S. aurantii* to Africa (Mound 1997) support the postulation of rapid long-distance spread, independent of host plants, for this species.

In the subtropical areas of South Africa where *S. aurantii* damage is severe, dry winters result in low frequencies of natural enemies. Summer rains cause growth flushes in the bush surrounding orchards, leading to thrips movement into the orchards over an extended period after petal-fall (Grout 2003 personal communication). In temperate areas south of 29ºS, which have harsher winter conditions and also winter rains, higher numbers of predatory phytoseiid mites contribute to lower thrips populations immediately after petal-fall when fruit is most susceptible, and with dry summers the period of attack is shorter.

3.1.2.8 Control

Numerous insecticides are registered for *S. aurantii* control in South Africa and detailed information on their use in IPM programs is available from Dr Tim Grout[2]. The most popular options for IPM programs are abamectin, and tartar emetic with white sugar, which is used to protect young leaves and to reduce over-wintering by thrips. While organophosphates have given reliable control with some compatibility with IPM, their use is hampered by restrictions on pesticide residues, consequently, growers have resorted to pyrethroids, resulting in damage to IPM programs. Trunk-spraying with Confidor is claimed to give long-term protection and to be compatible with IPM (Anonymous 2003a), but for unknown reasons it has not become prominent in South Africa. In Australia, numerous compounds and products are registered for thrips control, including organophosphates and pyrethroids, but Confidor and tartar emetic are not (Anonymous 2003b).

The period of thrips control that is required varies depending on conduciveness of the environment to *S. aurantii* and the market tolerance of blemish. In the cooler areas of South

[2] Dr TG Grout, Research & Technical Manager, Citrus Research International Group, PO Box 28, Nelspruit, 1200 South Africa, ph. +27 13 759 8000, email tg@cri.co.za

Africa, citrus normally requires a single spray four to six weeks after petal-fall, whereas in conducive areas several sprays are required to give control for up to 12 weeks after petal-fall.

Treatment is timed using sticky card traps. Grove et al. (2000) found yellow sticky traps and counts on fruit to be effective monitoring methods, although traps needed to be counted using a stereo microscope, to see *S. aurantii* and to discriminate it from several other thrips species. In South Africa, a threshold population level for 1 per cent damage on citrus fruit by *S. aurantii* is taken at nine or 20 thrips per three traps (fluorescent sticky yellow) in 5,000 trees, depending on the time of the season (Parker and Skinner 1997).

Several natural enemies of *S. aurantii* have been reported, including two predatory phytoseiid mites. While these are significant in IPM in South Africa, their rearing and release has not been reported. Baker *et al.* (2001) in the Murray River areas have focused the search for natural enemies of Kelly's citrus thrips, *Pezothrips kellyanus,* on the soil and the pupae, having found no potential agents in the canopy, and this may be relevant to *S. aurantii*.

3.1.2.9 Phytosanitary risk

The species is notable amongst thrips for not having dispersed more widely (Mound 1997). Many pest thrips species have increased their range through transport of infested plant material (Lewis 1997). *Scirtothrips* spp. require soft, green tissues for feeding, so only seedlings or cuttings are likely to carry the pests. It is easily removed from fruit with normal packing processes (Anonymous 1998b), which generally include washing, pesticide treatments, waxing and drying, and is not known to present an import barrier from South Africa, which is the third largest citrus exporter in the world (Anonymous 2002b), with major sales of fresh fruit into North America, Europe and Asia (Mabiletsa 2002). Although thrips may be carried by humans on their clothing, equipment or transport, no examples were cited by Lewis (1997).

S. aurantii is a declared quarantine pest for the following Regional Plant Protection Organisations: Asia and Pacific Plant Protection Commission (APPPC), European and Mediterranean Plant Protection Organization (EPPO), Organismo internacional regional de sanidad agropecuaria (OIRSA) (Central America), Pacific Plant Protection Organization (PPPO).

3.1.3 Assessment of the probability of introduction, establishment and spread

A PRA may be conducted for regions, if warranted (Kumar *et al.* 2002). For *S. aurantii*, South African experience indicates that Australian citrus production regions may be discriminated as follows:

- Summer-dominant rainfall (Central Burnett *Queensland*, coastal northern New South Wales, NT)
- Winter-dominant rainfall (Riverland SA, Sunraysia VIC, Riverina and other inland New South Wales)

3.1.3.1 Probability of introduction

The likelihood of introduction of a pest to the defined citrus regions is dependent on the pathway(s) from its expected origin and the frequency of the pest associated with it/them. Pest *introduction* is comprised of *entry* (to the PRA area) and *distribution* in a viable state to a point where it may establish. The pathways proposed for *S. aurantii* are by human-assisted movement or by natural dispersal.

S. aurantii has already entered and established in the summer-dominant rainfall area, by an unknown pathway. However, the uncertainty over the likelihood of the insect to attack citrus reduces the estimate of its probability of introduction to MODERATE[3].

The likelihood of *S. aurantii* entering the winter-dominant rainfall area by natural dispersal from its present known distribution near Brisbane is negligible (see Section 0). It would need to have spread across the range of *Bryophyllum* spp. before this likelihood increased greatly (see Section 0). The likelihood of *S. aurantii* entering this region on citrus fruit is negligible (see Section 0). Thrips can also be carried on plants. The hosts, *Bryophyllum* spp., while ornamental species, are declared weeds and are not likely to be carried around in great numbers by human activity. S. *aurantii* may be carried on plants moved from production or retail nurseries, or on cut flowers, with significant frequency if the plant is of a host species, or with very low frequency otherwise. *Kalanchoe longiflora,* on which a single thrips was found and may be a host, is a popular nursery plant, as are other *Kalanchoe* spp. (see Section 0). Hence, the overall likelihood of entry to the region is proposed as VERY LOW (Kumar *et al.* 2002 p. 28)[4]. As the expected mode of entry to the region would be on a host plant, the likelihood of distribution in the region to a place where it might establish would be HIGH, since the plant would still be available. The total probability of introduction to the winter-dominant rainfall area is proposed as VERY LOW.

3.1.3.2 Probability of establishment

Establishment of *S. aurantii* will depend on factors including:

- Environmental suitability of the region for the insect
- Availability of host plants at densities able to support the insect through its lifecycle
- Potential for the insect to adapt to different environments.

S. aurantii is already well-established in the summer-dominant rainfall area (Brisbane), with some dense infestations. Its host plant is widely available. Brisbane is well within the range of climates preferred by *S. aurantii* in Africa and indeed is climatically similar to parts of South Africa where it has the highest pest status. In South Africa, *S. aurantii* is reported to have a wide range of horticultural and wild hosts, but this is not the case for the Brisbane insect. The host plant in the Sherwood detection was *B. delagoense*. To date, all subsequent findings were on this, *B. pinnatum* and *B. daigremontianum x B. delagoense*, except for a single thrips found on the closely related succulent *K. longiflora*; it was not found on species including citrus, that were adjacent to dense infestations of *S. aurantii* (Anonymous 2003c). In South Africa, where *S. aurantii* is native, it has a wide host range, including citrus and numerous wild plant species that are used in windbreaks around orchards, or that grow in surrounding bush. These populations are considered to be important sources for *S. aurantii* to migrate into orchards. For the Brisbane population of *S. aurantii* to adapt to such a wide host range may take a considerable period, if it happens at all. This substantially reduces the likelihood of its establishment. Thus, the probability of establishment in this region is LOW.

The winter-dominant rainfall areas fall within the climatic range of *S. aurantii* in South Africa. However, host-adaptation would be required for *S. aurantii* to establish in that region. *Bryophyllum* spp. are confined to the summer-rainfall dominant region; while their potential ranges are extensive, CLIMEX modelling did not indicate them to include the citrus-growing areas of the Murray-Darling basin (Hannan-Jones and Playford 2002). *S. aurantii* has been reported to attack *B. delagoense* in South Africa (Hannan-Jones and Playford 2002). *S. aurantii* is known to be polyphagous (Gilbert and Bedford 1998), but the insect found in Brisbane appears to exhibit a marked host preference for this distinct botanical taxon, which

[3] Moderate = the event would occur with an even probability
[4] Very low = the event would be very unlikely to occur

are succulents that have Crassulacean Acid Metabolism. The leaves have high tannin content, which deters insect-feeding (Hannan-Jones and Playford 2002). Possibly the insect in its natural range exists as a mixed population of different biotypes. Some thrips species are known to make 'host shifts', to become pests on plants other than their natural hosts, but it is speculative to propose future pests from current ecology and behaviour (Mound 1997). DNRM and DPI staff have begun a trial in which potted citrus plants have been placed amongst *S. aurantii* infestations to determine whether the pest will feed on them. However, this trial may not be conclusive, particularly in the case that the citrus plants did not become infested. It is also proposed to carry out DNA comparisons of the Brisbane insects with *S. aurantii* from South Africa, which may reveal the extent of molecular similarity. In summary, because its establishment in the winter-dominant rainfall region would depend on host-adaptation, its likelihood of establishment there is proposed as VERY LOW[5].

3.1.3.3 Spread potential

The potential for spread of a pest may be deduced from comparison of its known range with the PRA area. Factors to consider include:

- Suitability of the environment for natural spread
- Potential for movement with commodities
- Potential natural enemies.

S. aurantii has spread over a known range of about 400 km^2 in the Brisbane area, and possibly many times this area to the west given a single detection at Laidley, since the unknown date of its original introduction. Thrips may spread readily by flying with the aid of wind; some species have spread globally with great rapidity, although *S. aurantii* is not one of these. *S. aurantii* may be expected with certainty to spread naturally through the range of *Bryophyllum* spp. (the summer-dominant rainfall area) (i.e. its likelihood of spread is EXTREME), over a period of, say, 10 years in *Queensland* and coastal northern New South Wales and longer to NT.

Unless *S. aurantii* was shown to attack citrus, it cannot be assumed that it will spread into the citrus production areas of the Murray-Darling basin beyond the range of *Bryophyllum* spp. Even if it did so, the large distances and the range of environments would dictate very slow natural spread (several decades at least). This corresponds with a likelihood of VERY LOW.

3.1.3.4 Overall likelihood

The overall likelihood of introduction, establishment and spread is the product of the respective probabilities (Kumar *et al.* 2002). For the summer-dominant rainfall region, it is LOW (product of moderate, low and extreme). For the winter-dominant rainfall region, it is VERY LOW.

3.1.4 Assessment of consequences

3.1.4.1 Economic impact

3.1.4.1.1 Method for evaluating economic impact

The potential economic impact of a pest can be assessed by comparison of knowledge of the pest in its known range, with features of the PRA area. Consideration may be given to factors affecting its severity, to comparable pests in the PRA area, and to expert judgement. Consequences may be:

- *Direct* – e.g. crop losses (yield and grade), control and surveillance measures, environmental effects*;* or

[5] Very low = the event would be very unlikely to occur

- *Indirect* – e.g. effects on markets, phytosanitary measures, changes to costs of production, changes to consumer demand, feasibility and cost of eradication or containment, costs of research and advice, etc.

The economic impact is considered at different levels, for example producer, geographic region, state or national, and a qualitative rating is given (Kumar *et al.* 2002).

A cost estimate can also be made by identifying cost differentials between states of presence and absence of the pest and discounting them to net present value (NPV)[6]. There may be regional differences in pest significance and associated costs. The time at which the costs commence may differ between regions. It may be assumed that the costs will be ongoing, in which case the appropriate financial technique is to find the NPV of a perpetuity[7] for each region. An appropriate discount rate is the expected interest rate, which reflects the risk inherent in the particular use of funds (Frick 2002). Given the uncertainty surrounding the time frame for spread and host-adaptation, the risk premium is considerable and 20 percent has been used for ventures that are probably less risky (Strayhorn 2002).

3.1.4.1.2 Implications for Australian plant industries

The citrus industry comprises about 20 percent of the total value of Australian horticultural production and was worth $431 million in 1999/2000, a sum which varies considerably by year (Anonymous 2001a). Regional contributions also vary considerably, but approximately 80 percent of production is located in the Murray-Darling basin, with SA 30 percent, New South Wales 32 percent, Victoria 20 percent and Central Burnett region of *Queensland* 18 percent, with small industries in Western Australia, Northern Territory and coastal northern New South Wales. The crop is grown by 3,000 growers on 32,000 ha, with most holdings growing other fruit also. Citrus production is concentrated between April and October, but some fruit is produced at all times. Citrus contributed $157 million to export earnings in 1999/2000, or 36 per cent of total value, with the major destinations being Asian countries and USA and less than 0.5 percent was sent to Europe (Anonymous 2001a). For citrus in South Africa, direct damage by *S. aurantii* is experienced primarily as downgrading fruit from export (first) grade to second grade and the actual production loss is low. The unit cost of potential *S. aurantii* damage in Australia is estimated at 40 per cent, being the price difference between first and second grades of fruit[8].

Although the Brisbane population of *S. aurantii* has not, to date, been found to be infesting species other than *Bryophyllum* spp., there is a low chance that it would be carried on nursery plants or cut flowers. These industries also may have control costs, loss of markets or compliance costs. As an example, present controls on melon thrips, *Thrips palmi,* consist of 100 km restricted zones for movement of host plants to another state, with pest freedom inspections required.

Given that *S. aurantii* is reported in Africa as pest of mango and banana (see Section 0), this may eventuate in Australia, but this is not supported by present observations and the notion is speculative (Mound 1997) and does not warrant further consideration here.

Bryophyllum spp. and *Kalanchoe* spp. have botanical and ornamental interest (Hannan-Jones and Playford 2002) and *Kalanchoe* spp. nursery trade value is up to $5 million per annum. This trade may experience significant costs from pest control and movement controls.

[6] Net present value is the value today of a sum promised at a specified future time, given a rate of interest or 'discount' rate.
[7] A perpetuity is an infinite series of equal payments at equal intervals of time.
[8] Example, Ellendale mandarin, first grade $24/box, second grade $14/box. Graham McCosker, Gayndah Packing Cooperative, personal communication.

As a likely benefit from *S. aurantii*, *Bryophyllum* spp. are poisonous to stock, with over 1,000 cattle deaths recorded (Hannan-Jones and Playford 2002) and more reported from the present drought. As a result of their toxicity and invasiveness, *Bryophyllum* spp. are declared pests in *Queensland* and New South Wales costing over $500,000 per year (Hannan-Jones and Playford 2002). A substantial quantity of the losses and control costs may be saved.

3.1.4.1.3 Factors affecting *S. aurantii* severity

The following discussion applies to a *S. aurantii* population with a wide host range including citrus, apparently unlike the Brisbane population of *S. aurantii*.

The latitudes of citrus production areas in South Africa (latitudes 34-23ºS) encompass those in Australia (latitudes 38-25ºS). There is insufficient published detail on the environmental preferences of *S. aurantii* to carry out modelling (e.g. CLIMEX) on the similarities of South African and Australian citrus-growing regions, but some approximations may be attempted. The Murray-Darling basin of Australia has (at Echuca) total rainfall of about 430 mm spread evenly through the year, supplemented by irrigation, with mean monthly temperature ranges from 22.6ºC to 8.5ºC (Anonymous 1999). The Western Cape area of South Africa, where *S. aurantii* is of minor significance, has (at Riversdale) similar rainfall to Echuca, and a temperature profile which is slightly lower in summer (21.6ºC) and slightly higher in winter (12.1ºC). In the areas of South Africa where *S. aurantii* damage is severe, mean monthly temperatures are similar to those of Echuca, but rainfall is summer-dominant. When the irrigation of the Murray-Darling basin is taken into account, water provided to the citrus crop may be similar, although humidity during warm weather in the South African areas would be greater than in the Riverland. The features of the Western Cape asserted to result in lower *S. aurantii* significance are winter rainfall promoting natural enemies and the lack of summer rains causing low *S. aurantii* populations in the surrounding bush. In the Murray River area, the significance of natural enemies is unknown, while the surrounding vegetation is often sparse and arid would be unlikely to host high thrips numbers. Thus, the respective regions may be broadly comparable.

The Queensland citrus-growing region in the Central Burnett has a subtropical wet climatic profile (Anonymous 1999), more similar to the Natal province of South Africa (Durban), where *S. aurantii* is important on citrus. The climate of Brisbane, where *S. aurantii* is flourishing, has a similar rainfall pattern to the Central Burnett, but more moderate summer and winter temperatures. The features asserted to give rise to the significance of *S. aurantii* in such areas are low frequencies of natural enemies at the most vulnerable time, due to the dry winter, and invasions of large numbers of thrips from surrounding bush flourishing from summer rainfall. The situation with natural enemies of *S. aurantii* in the Australian summer-dominant rainfall area is unknown. The insect would only be common in surrounding bush if *Bryophyllum* spp. were present, or if further host adaptation had occurred.

An analogy may be provided by *P. kellyanus*, which is present in the Riverland, Sunraysia and Riverina citrus-growing areas on the Murray River. It is an important pest in the Riverland, but is less significant in the Sunraysia and of little importance in the Riverina, however, the reasons for this are unclear (Baker *et al.* 2001).

3.1.4.1.4 Control options for *S. aurantii*

In summer-dominant rainfall areas of Australia, the main citrus pests are red scale and mites, requiring up to three sprays for each from November, as well as baiting for fruit fly from January (Dan Papacek, personal communication). In winter-dominant rainfall areas, there is a lower pest load except for Kelly's citrus thrips in the Riverland and Sunraysia areas (Baker *et al.* 2001). Control measures for this pest may also be efficacious for *S. aurantii*; spraying begins shortly after petal-fall and continues for about two months. Baker *et al.* (2001) are

investigating the application of insecticides to the soil, to kill pupae, and this also may be applicable to *S. aurantii*. IPM programs are of significance in all areas, varying by farm, locality and season. In either region, if *S. aurantii* was introduced and the environment proved favourable for it, the control cost would consist of any extra treatments that were required for *S. aurantii*, and further chemical or IPM input (e.g. re-introduction of biological control agents) resulting from disruption of IPM programs. Approximations of costs, for the purpose of cost/benefit estimation, are $1000 per hectare for current programs incorporating IPM, and $3000 per hectare where *S. aurantii* was serious and full chemical control measures were required (Dan Smith, personal communication), suggesting an additional cost of $2000 per hectare for a full control program for *S. aurantii*.

As discussed above (see Sections 0 and 0), the role of natural enemies is thought to contribute substantially to the relative significance of *S. aurantii* in different regions of South Africa. Significant mite predators in southern Africa include *Amblyseius tutsi*, *Euseius addoensis, E. citri, E. orygmus* and *Typhlodromus* spp. (Anonymous 2002a). The existence of natural enemies of *S. aurantii* in Australia has not been assessed in this analysis and would be considered by the industry as part of its risk management.

3.1.4.1.5 Cost estimate

Assuming that the Brisbane population of *S. aurantii* had the capacity and preference to attack citrus, a cost estimate can be made (Table 1). *S. aurantii* may be predicted to be a minor pest requiring no control measures in, say, 40 percent of orchards (half of the Murray-Darling basin), some control measures in, say, another 40 percent of orchards (the other half of the Murray-Darling basin) and substantial control measures in the remaining 20 percent of orchards. It is assumed that there would be no market access effects, either interstate or export. Even with control measures, some residual downgrading of fruit would be expected in the area of high damage.

The contingent (on pest status developing) annual loss with control ($24.3 million) remains a high proportion of the contingent annual loss in the absence of control ($25.2 million), due to the disruption to IPM and the expectation of incomplete control and residual loss. The total loss is 5.4 percent of the annual crop value. Tempering this, the NPV of the total loss with control over an infinite period is $13 million, using the discount rate of 20 percent, which conservatively takes into account the uncertainty surrounding if and when citrus pest status is developed by *S. aurantii*.

Economic consequences of infestation by *S. aurantii* must also be considered for industries under direct threat of damage to production, and to those which would bear costs of movement controls. It has been suggested that equivalent controls are those imposed for melon thrips, for which the restricted area is 100 km radius. Within that area (which would include parts of northern New South Wales), nurseries shipping product interstate might be required to have local freedom from infestations of *S. aurantii* and *Bryophyllum* spp. There might be prohibitions on the intra- and interstate movement of *Bryophyllum* and the related *Kalanchoe* and *Kitchingia*. As a nursery owner might be unable to procure eradication of hosts on nearby properties, this might prevent some nurseries from trading. In such a case, a suitable systemic spray within a certain period of dispatch would provide reasonable confidence of phytosanitation. A cost estimate for these situations has not been made here.

Table 1. Estimated annual losses from a citrus-attacking form of *S. aurantii* in Australia. The first comparison is of annual losses in the situation with no control and the situation with control. The net present value (NPV) of the least costly option is then calculated, using the discount rates 15 percent and 20 percent.

	Extent of damage to citrus crop			
	Nil	**Low**	**High**	**TOTAL**
Proportion of crop	40%	40%	20%	
Area of crop (ha)	12800	12800	6400	32,000
Domestic value	$126,000,000	$126,000,000	$63,000,000	$315,000,000
Export value	$54,000,000	$54,000,000	$27,000,000	$135,000,000
Total value	**$180,000,000**	**$180,000,000**	**$90,000,000**	**$450,000,000**
Situation with no control:				
Loss of production	0	2%	10%	
Value of lost production	$0	$3,600,000	$9,000,000	$12,600,000
Mean % fruit culled 1st to 2nd grade	0	5%	25%	
Lost value of cull (40% of price)	$0	$3,600,000	$9,000,000	$12,600,000
Annual loss with no control	**$0**	**$7,200,000**	**$18,000,000**	**$25,200,000**
Situation with control:				
Extra cost of control ($/ha)	$0	$700	$2,000	
Total cost of control	$0	$8,960,000	$12,800,000	$21,760,000
Mean residual loss (% of fruit culled)	0	1%	5%	
Residual loss	$0	$720,000	$1,800,000	$2,520,000
Annual loss with control	**$0**	**$9,680,000**	**$14,600,000**	**$24,280,000**
% of annual value	**0.0**	**5.4**	**16.2**	**5.4**
NPV of estimated future losses with control (infinite period from commencement)				
Commencement (years)	n/a	20	10	
Discount rate 15%				15%
Perpetuity value at commencement*	$0	$64,533,333	$97,333,333	$161,866,667
NPV factor 15% (from tables)		0.0611	0.2472	
NPV of future losses (15%)	**$0**	**$3,942,987**	**$24,060,800**	**$28,003,787**
Discount rate 20%				20%
Perpetuity value at commencement*	$0	$48,400,000	$73,000,000	$121,400,000
NPV factor 20% (from tables)		0.0261	0.1615	
NPV of future losses (20%)	**$0**	**$1,263,240**	**$11,789,500**	**$13,052,740**
*assumed no cost before this time				

3.1.4.1.6 Qualitative estimate of economic significance

The estimated loss in the summer-dominant rainfall region is 16.2 percent of crop value, and in the Murray-Darling basin is 5.4 percent of crop value, with a total loss of 5.4 percent (Table 1). From Kumar (2002), the economic consequence is proposed as LOW[9] in the winter-dominant rainfall region and MODERATE[10] in the summer-dominant rainfall region.

3.1.4.2 Environmental impact

With the present knowledge of the restricted host range, environmental impact of *S. aurantii* may be considered positive, through the negative effect on its weedy host, and through any further control measures that are established against *Bryophyllum* spp.

[9] Low = the impact is likely to be recognised within an affected geographic region and significant to directly affected parties. It is not likely that the impact will be recognised at the State level (Kumar *et al.* 2002).

[10] Moderate = The impact is likely to be recognised at a State level, and significant within affected geographic regions. The impact is likely to be highly significant to directly affected parties (Kumar *et al.* 2002).

3.1.4.3 Social impact

There is no significant potential for social impact.

3.1.5 Combined risk

The risk estimate is an integration of the above-mentioned likelihoods and consequences, *viz.*:

Unrestricted risk = (expected loss)
Potential for introduction, establishment and spread
x
Economic consequence of introduction, establishment and spread

Region	Potential for introduction, establishment and spread	Economic consequence	Unrestricted risk
Winter-dominant rainfall	VERY LOW	LOW	**NEGLIGIBLE**
Summer-dominant rainfall	LOW	MODERATE	**VERY LOW**

Using this risk estimation system, Western Australia has adopted the level of 'very low' as its 'appropriate level of protection' (ALOP). If the unrestricted risk for a pest is above the ALOP, then the pest will proceed to the stage of considering whether risk management measures are warranted. Otherwise, the risk analysis proceeds no further (Kumar *et al.* 2002). On this basis, the risk analysis would terminate for *S. aurantii*. The model of Plant Health Australia (McLeod 2002) recommends specific action against the pest in the case of extreme risk, or in the case of high risk, it recommends interim generic action, followed by specific action. By this model, *S. aurantii* would qualify as a low or moderate risk in the summer-dominant rainfall area.

3.2 Risk management - Response options

Although no risk management measures are recommended from the risk analysis (see Section 0), possible actions are discussed below.

3.2.1 Feasibility of containment

The spread of *S. aurantii* on citrus fruit appears to be negligible from Africa and no movement controls are required there for export, nor should they be in Queensland or Australia.

The risk of spread on plants would be managed by treatment of known host plants with a systemic insecticide registered for thrips, within a specified period prior to the movement. Given the limited known host range of the Brisbane population of *S. aurantii*, this control would not be a significant imposition on the public, nor would the absence of such control add greatly to the risk of spread, but achieving compliance would be very difficult. Requirements similar to those for melon thrips (see Section 0) may be considered.

3.2.2 Feasibility of eradication

To eradicate a limited infestation of *S. aurantii*, a combination of repeated systemic insecticide, fogged insecticide, and soil drench could be used, as well as eradication of the host. This range of insecticide application modes is required to deal with feeding insects, those that fly onto other hosts when disturbed, and pupae in the soil. Eradication of the host is required to deal with escaping insects. The program would involve an exhaustive search of the area for *Bryophyllum* spp. and eradication where it was found, and submission of samples of thrips from these areas, followed by insecticide treatment where *S. aurantii* was present.

The known infestation area was about 400 km^2 prior to the detection at Laidley, some 45 km west. Hence, an area of about 1700 km^2 is involved.

Telford (personal communication) estimated surveillance costs for an area of 5 km radius (78.5 km^2) around AFRS to be $425 000, hence the cost for the known infestation area of over 1,700 km^2 would be $9.2 million.

In germination tests, seeds of *B. delagoense* showed 57 per cent germination after 38 days, which reduced to four per cent after 5 months. Herbicidal eradication of *Bryophyllum* spp. is feasible, with a single application and follow-up costing about $180 per hectare in 1999 (Hannan-Jones and Playford 2002). This would total $30.6 million.

Assuming that *S. aurantii* was found in 20 percent of the sites and treatment costs are $500 per site (hand application of systemic, fog and soil drench insecticides), the treatment cost total would be $17 million.

As demonstrated in recent eradication programs for black Sigatoka and fire ants, support requirements include vehicles and equipment, public awareness, geographic information systems, buildings and administration staff. A cursory estimate is for a doubling of the in-field costs. Hence, the total cost estimate for eradication is $113.6 million.

There would be significant questions over whether eradication attempts would be successful, because of the risk of missing an infestation, or incomplete eradication at any site. Hence, ongoing surveillance and treatment would be required for a further 2 years. This would multiply if any outlying infestations were identified in the meantime, and the recent detection at Laidley indicates that this is highly likely.

No reports of eradication of *S. aurantii* were found in the literature examined in this study. This is consistent with widespread entomological experience showing that thrips are difficult to control and almost impossible to eradicate. Factors such as their small size, ease of dispersal, wide host ranges, high fecundity, ability to develop insecticide resistance and pupation in the soil mitigate against eradication success. Previous experience suggests that such widespread use of chemicals would be politically and socially unacceptable in residential areas. It would also be labour intensive and costly.

4 Conclusions

The insect *S. aurantii* is established in a significant area in the greater Brisbane region. This insect, which is a significant pest of citrus in southern Africa, appears to be limited in its host range to the declared weeds *Bryophyllum* spp., to which it is causing significant damage. There is some chance, as yet undetermined, that it will host-adapt to citrus at some time in the future. If its host range did broaden, it would be expected to spread into all citrus-growing areas of Australia. Otherwise, it would remain limited to the summer-dominant rainfall areas, as is *Bryophyllum*.

A pest risk analysis was conducted for the citrus production areas in the winter- and summer-dominant rainfall regions of Australia. The analysis took into account the likelihood of the insect being introduced, establishing and spreading in the regions, and the economic consequences. The unrestricted risk estimates were *negligible* and *very low* respectively for the two regions. Both of these are below the appropriate level of protection threshold, so further responses of containment or eradication should not be considered; neither is likely to be feasible and the cost of eradication would be at least $113.6 million, possibly far greater.

An economic estimate indicated that the cost of control and residual losses, IF *S. aurantii* became a pest on citrus, would be about 5.4 percent and 16.2 percent in the two regions, or 5.4 percent overall. The net present value of accumulated, indefinitely continuing control costs and residual losses was estimated at $13 million using a conservative discount rate that takes into account the uncertainty of if and when pest status on citrus would eventuate.

The Department of Natural Resources and Mines (DNRM) conducts a control program on *Bryophyllum* spp. In the course of this work, DNRM may be able to monitor the spread of *S. aurantii* and report this information to plant health authorities and plant industries.

In order to prepare industries, particularly citrus, for the possibility that *S. aurantii* will become a pest, awareness materials on *S. aurantii* should be prepared and distributed amongst citrus (and other horticultural) entomology specialists, to facilitate surveillance for the possible development of citrus-attacking preference in this species. Also, IPM workers should give consideration to whether and how IPM systems in citrus could help to ameliorate potential damage from *S. aurantii*.

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TABLE OF CONTENTS

SOUTH AFRICAN CITRUS THRIPS SURVEY FOR QUEENSLAND FOR PERIOD MARCH 2002- FEBRUARY 2003.

Pest Survey Report for:	South African Citrus Thrips- *Scirtothrips aurantii* (Faure)	
Commodity:	All susceptible plants.	
Survey area:	City of-	Brisbane and surrounding districts
	Intensive survey of-	Alan Fletcher Research Station
		500-metre radius
		At-risk locations
Survey date:	March 2002 **-** February 2003	
Survey conducted by:	Grant Telford	- Senior Inspector (APHS South East)
	Jan De Vries	- District Inspector (APHS South East)
	John Steele	- Inspector (APHS South East)
	Leonie Youdale	- Inspector (APHS South East)
	David Borland	- Field staff (APHS South East)
	Andrew Manners	- Research assistant (UQ)
	Martin Hannan-Jones	- Chemist (AFRS)
	Allan Tomley	- Senior Plant Pathologist (AFRS)
Identification services:	John Donaldson	- Entomologist (DPI Indooroopilly)
Mapping:	John Arrowsmith	- Corporate support (APHS)
Report compiled by:	Grant Telford	- State Coordinator (Plant Health Surveillance)
	James Planck	- Project Leader (Plant Health Surveillance)

ABBREVIATIONS AND DEFINITIONS

DPI - Queensland Department of Primary Industries
APHS - Animal and Plant Health Service (Queensland Department of Primary Industries)
DNRM - Department of Natural Resources and Mines
AFRS - Alan Fletcher Research Station (Department of Natural Resources and Mines)
AQIS - Australian Quarantine Inspection Service
CCEPP - Consultative Committee on Exotic Plant Pests

Mother of Millions - *Bryophyllum delagoense (syn Bryophyllum tubiflorum) and Bryophyllum daigremontianum X Bryophyllum tubiflorum.*
Hybrid Mother of Millions - *Bryophyllum daigremontianum X Bryophyllum tubiflorum*.
Investigating Officer **-** The officer responsible for carrying out the survey or leading the survey team on that particular property.
Pest sample **-** Sample of plant material containing live insects or isolated insect specimens.
Property Contact Person **-** The person from the property who is the contact person for the survey.
Survey Coordinator **-** The DPI officer responsible for coordinating the survey.
Survey District **-** The geographic area in which the survey is being carried out.

1 INTRODUCTION

This report details surveillance activities conducted by the Queensland Department of Primary Industries (DPI) for the exotic insect, South African citrus thrips, *Scirtothrips aurantii* Faure.

S. aurantii was detected at Sherwood in Brisbane in March 2002. This was the first record of this insect in Australia. Overseas, this thrips feeds on a wide variety of ornamental and fruit crops, but is particularly damaging to citrus. It is widespread in Africa and has also been detected in Yemen, Mauritius, Reunion and Cape Verde. In Australia, *S. aurantii* has not been found on citrus or any other fruiting crops, and has been detected only on succulents in the family Crassulaceae, such as mother of millions.

Entomologists speculate that the Australian biotype of *S. aurantii* may have a preference for succulent weeds of this family. This hypothesis is currently being investigated.

Overseas, *S. aurantii* feeds on fruit and young leaves causing leaf drop and fruit distortion. Because it blemishes fruit overseas, it has been known to reduce marketable yield, particularly in citrus. It is important pest of that crop in low altitude dry parts of South Africa and Zimbabwe. Significant parts of Queensland and interstate would most likely contain suitable habitats for its establishment.

2 SUMMARY FINDINGS

Surveillance activities have detected *S. aurantii* at thirty-five (35) sites (TABLE 14 Section 0) within the Cities of Brisbane, Logan and Ipswich and the Shire of Laidley:

Barellan Point	**Fig Tree Pocket**	**Karana Downs**	**Sherwood**
Berrinba	**Greenbank**	**Kenmore**	**Sumner**
Brookfield	**Indooroopilly**	**Laidley**	**St Lucia**
Chapel Hill	**Jindalee**	**Mt Crosby**	**Upper Brookfield**
Corinda	**Karalee**	**Oxley**	**Westlake**

This thrips appears to be well established in the southwest Brisbane area (ATTACHMENT 1). The level of infestation indicates that *S. aurantii* may have been present for several years.

S. aurantii has been found only on plants of the family Crassulaceae and was most frequently found on mother of millions *Bryophyllum delagoense (syn Bryophyllum tubiflorum)* and *Bryophyllum daigremontianum X Bryophyllum tubiflorum.* At several of the infested sites, *S. aurantii* could not be found on adjacent potential hosts, including citrus and mango.

3 BACKGROUND

S. aurantii was detected during March 2002 on 'mother of millions' plants AFRS at Sherwood in Brisbane. This was the first detection in Australia of this economic pest of citrus and other plants.

AQIS immediately quarantined the station. A survey of the AFRS and its surrounds was implemented and no further detections of *S. aurantii* were made. Mother of millions plants and other material suspected of being infested were destroyed and affected quarantine glasshouses were emptied and disinfested. *S. aurantii* was declared a pest under Queensland legislation (*Plant Protection Act 1989*) and the DPI assumed management of the outbreak. Quarantines restrict movement of plants, soil and potting media, or an appliance, matter or thing potentially infested with *S. aurantii*, without an inspector's approval.

CCEPP met to review the response to the outbreak during April 2002 and recommended that intensive surveillance be maintained in areas within close proximity of AFRS for a further six months to determine if the initial eradication attempt was successful. This surveillance program included the inspection of sentinel mother of millions plants and the completion of traceback and traceforward investigations, as well as an intensive December survey of high-risk sites.

Sentinel mother of millions plants were established on 33 high-risk sites (three plants per site) on and off AFRS. These plants underwent monthly inspections for the presence of thrips. Wet traps are also maintained in quarantine facilities on AFRS, which are regularly inspected for thrips.

From March 2002 to January 2003, DPI conducted over 650 property inspections for *S. aurantii* at locations that posed a risk of thrips transfer from AFRS. No *S. aurantii* was found during the winter period, but the pest was detected during the intensive December survey at Sherwood and subsequently was located in other suburbs in southwest Brisbane.

Following these detections, the CCEPP reconvened in January 2003 and recommended that a delimiting survey be conducted for *S. aurantii* in southeast Queensland and other States. This was to include the inspection of at least 50 sites in the greater Brisbane area. This survey found *S. aurantii* at an additional twenty-eight (28) of the seventy-six (76) sites inspected.

4 ACTIONS

4.1 Survey Schedule

Task	Action by	Expected completion date
1. Traceforward inspections. These are sites that AFRS has moved plants to and are considered to be medium-high risk, due to the potential for movement on hosts or other plants.	DNRM / APHS	March-September 2002
2. Traceback inspections. These are sites that AFRS has received plants from in Australia.	DNRM	November 2002–February 2003
3. 60 sentinel mother of millions plants to be inspected for *S. aurantii* absence and placed in individual pots ready for field placement (3 plants per station)	DNRM	24 May 2002
4. Sentinel plants placed in field (15 sites on station, 6 within 500 metres of station and 12 on other high-risk sites). Total of 33 sites - each site has three plants.	DNRM / APHS	June 2002
5. Sentinel plants inspected and sampled for thrips presence each month. Monthly results report to be provided to the General Manager, Plant Health.	1. On station: DNRM 2. Within 500 metres of station: APHS 3.Other sites: DNRM	June 2002–February 2003
6. All thrips samples identified to determine if *S. aurantii* present.	QDPI	As supplied
7. Resurvey of AFRS and high-risk sites. High-risk sites include properties within 500metres of AFRS, and locations that have received host plants from the station and staff properties.	APHS/DNRM staff	December 2002
8. Survey 50 sites throughout the Greater Brisbane Area	APHS/DNRM staff	January 2003-February 2003
9. Final surveillance report to be provided to the General Manager, Plant Health	APHS	February 2003

4.2 Initial Response Delimiting survey (March 2002)

AQIS, DPI and AFRS staff conducted intensive surveys of AFRS and areas within 500m of the station, during March 2002.

DPI established an 'incident response' on 21 March 2002, with a Local Incident Control Centre (LICC) at the Animal Research Institute at Yeerongpilly.

Main areas of operations were Surveillance, Tracing and Destruction of infected material.

S. aurantii was confirmed by the reference entomologist at one location in close proximity to AFRS, bringing the total number of detections to two (2). This location was also in Magazine Street, Sherwood.

The LICC ceased operations on Friday 5 April 2002. The continuing response to SACT then became part of the APHS Plant Health Surveillance Project.

Results for Initial Response surveys are captured in TABLE 1, Section 0 RESULTS.

4.3 Traceforward Survey (March 2002–September 2002)

In order to ascertain the true extent and distribution of *S. aurantii*, APHS initiated investigation into locations that may have become infested as a result of inadvertent dispersal of *S. aurantii* from AFRS.

These investigations have been termed 'traceforward surveys' as these are used to determine potential forward dispersal of the pest.

Potential avenues of dispersal were determined to be-

1. Human assisted dispersal through the movement of plants off site.
   - Plant movements associated with the Lantana rust program.
   - Plant movements associated with the Groundsel rust program.
   - Plant movements associated with the Parthenium rust program.
2. Human assisted dispersal through the movement of display plants.
   - 'Weedbusters' promotions.
3. Human assisted dispersal on the clothing of staff members.
   - Inspection of staff homes.

Data pertaining to plant movements occurring over the past 12 months was supplied by AFRS staff to APHS staff, who compiled an investigation spreadsheet. APHS staff investigated each movement, and movements considered to be medium to high risk led to physical inspection of properties by staff of APHS and AFRS.

A total of one hundred and three (103) properties were investigated as potential avenues for dispersal of *S. aurantii*. Of these properties, ninety-one (91) properties were determined to be of medium to high risk and were inspected. On twenty-seven (27) properties, thrips were collected for identification.

S. aurantii has not been detected on lantana, groundsel bush or parthenium weed populations propagated and stored on site at AFRS. Plants are monitored for pests on a regular basis.

All samples taken during the course of this investigation were negative for *S. aurantii*. Results for Traceforward surveys are captured in TABLES 2-6, Section 0 RESULTS.

4.4 Traceback Survey (November 2002–February 2003)

In order to ascertain the true extent and distribution of the pest, APHS initiated investigation into locations that may have been the source of infestation of AFRS.

These investigations have been termed 'traceback surveys' as they are used to look back into potential sources of the pest.

Potential avenues of introduction from local sources were determined to be-

1. Human assisted introduction through sourcing of host plants off site.
   - Mother of Millions plant introductions associated with the weevil (*Osphilia tenuipes)* host specificity trial program.
2. Inadvertent introduction of the pest by staff members from collection or inspection sites.

Data pertaining to *Bryophyllum* plant introductions or inspections occurring over the last 12 months was supplied by AFRS staff to APHS staff, who compiled an investigation spreadsheet. APHS staff investigated each source location, and movements considered to be medium to high risk led to physical inspection of *Bryophyllum* sites by AFRS staff.

A total of sixty-three (63) sites were investigated as potential avenues for introduction of the pest. Of these sites, forty-five (45) sites were determined to be of medium to high risk and were inspected (a number of sites listed that were included as part of the original data were never visited by AFRS staff and were reclassified as low risk). At thirty (30) sites, thrips were collected for identification.

S. aurantii was detected at three (3) sites where AFRS staff had collected plants for use in host specificity trials. These sites were at Brookfield, Upper Brookfield and Laidley. These detections led to the discovery of additional infested sites within two of the localities through opportunistic sampling.

A request was also made to the Department of Primary Industries in Victoria to investigate the following succulent plants sourced from the Melbourne botanic gardens during August 2000.

Crassula monstrosa "Giant Form"
Graptopetalum paraguayense spp bernalense
Sedum nussbaumerian
Crassula arborescens

Officers from AFRS had noticed, and taken photographs of, plants displaying damage consistent with the presence of thrips while visiting the gardens.

Results of sampling for thrips at the Botanic Gardens in South Yarra on the 4th Dec. 2002 are that no South African Citrus Thrips were identified from the samples taken. Thrips found were Plague, Onion and Tomato thrips. The thrips were identified by Dr Mali Malipatil, reference entomologist at Knoxfield.

Results for Traceback surveys are captured in TABLE 7, Section 0 RESULTS.

4.5 Sentinel Plant Survey (June 2002–February 2003)

On 31 May 2002, APHS was granted permission by DNRM (Land Protection Branch) to establish mother of millions sentinel plants, to monitor for the presence of *S. aurantii*, as is required to satisfy the requirements of the Queensland *Rural Lands Protection Act 1985*.

Mother of Millions plants were selected for use as biological attractants as-

- The plants were determined to be favoured hosts based on observations made during the initial response phase.
- The plants require little field maintenance and are extremely hardy.

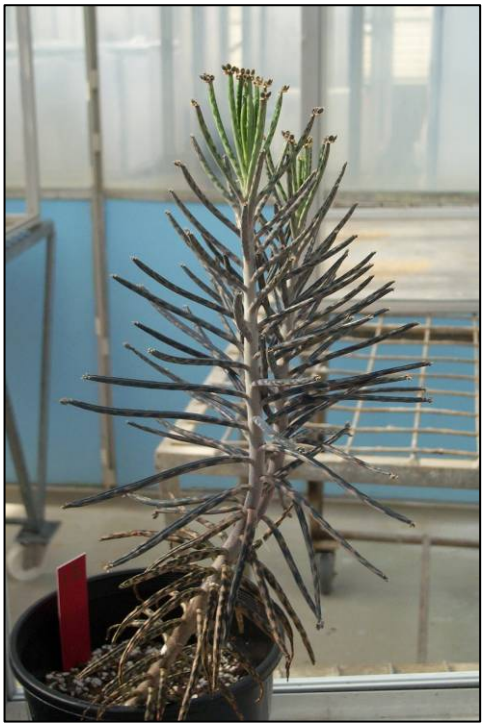
The following sentinel plant sites (three plants per site) have been established-

AFRS (ATTACHMENTS 2&3)	- 15 sites.
Sites within 500m of AFRS	- 5 sites.
Other high-risk sites	- 13 sites.

Sites are inspected on a monthly basis. Eight (8) samples were taken from sentinel plants during this timeframe. One sample taken from a plant station within 500m of ARFS during December 2002 was subsequently identified as *S. aurantii*. An additional site was established in Sherwood in January 2003 and located on a newly infested site. After a short time, *S. aurantii* was detected on sentinel plants established at this location bringing the total number of detections on sentinel plants to two (2).

Inspection of sentinel plant sites also led to the discovery of additional sites at Jindalee and Mt Crosby through opportunistic sampling of plants that were in close proximity to these sites.

Figure 1 (Below left)- Bryophyllum sentinel plant-trapping station for field use.
Figure 2 (Below right)- Bryophyllum sentinel plant-trapping station for quarantine facility.



Results for Sentinel plant surveys are captured in TABLE 8, Section 0 RESULTS.

4.6 Wet Trap Survey (June 2002–February 2003)

In South Africa, sticky yellow traps are utilized to sample flying adults of *S. aurantii*. This technique is used to supplement assessment of *S. aurantii* populations in citrus orchards by counting the percentage of fruit or flush points infested with the pest (Gilbert & Bedford, 1998).

A modification of this principle is the 'wet trap'. A wet trap is a yellow tray filled with a thin layer of water. As opposed to the sticky trap, the wet trap may be inspected and the contents removed without physical damage to the thrips. Within a closed environment the trap remains clear of other organic/inorganic environmental debris.

'Wet Traps' have been installed within each room of the Quarantine facility located at the Alan Fletcher Research Station (ATTACHMENT 3). Traps are monitored on a continual basis. All samples taken from wet traps have been reported as negative for *S. aurantii*.

Figure 3- Wet trap installed within the AFRS quarantine facility within close proximity to a Bryophyllum sentinel plant trapping station.

Results for Wet trap surveys are captured in TABLE 9, Section 0 RESULTS.

4.7 Intensive survey (December 2002)

During December 2002, APHS and AFRS staff conducted an intensive survey of the AFRS and properties within 500m of the initial detection. No further detections of *Scirtothrips aurantii* (Faure) had been recorded subsequent to the initial detections in March 2002. It is estimated that over 80% of the total area within the 500m zone was inspected. Two (2) samples taken during the survey were identified as positive for *S. aurantii*. Both samples were taken from plants of the genus *Bryophyllum*. One sample was taken from a sentinel plant station.

Results for the Intensive survey (December 2002) are captured in TABLE 10, Section 0 RESULTS.

4.8 Greater Brisbane Survey (January-February 2003)

On 23 January 2003, CCEPP endorsed a proposal for additional surveillance for *S. aurantii* throughout the greater Brisbane area and other States to determine if the pest had established outside of known infested suburbs.

CCEPP agreed to a proposal to survey at least 50 sites in the greater Brisbane area, aiming to ascertain the distribution of *S. aurantii* in the area. APHS and AFRS staff compiled a list of sites where populations of target host plants were known to occur. Survey sites were selected to ensure a representative distribution of sites throughout the survey area.

In Africa, *S. aurantii* feeds on a wide range of plants, but is particularly known as a pest of citrus. In Brisbane it has only been detected on succulent plants in the family Crassulaceae, including *Kalanchoe longiflora, Bryophyllum pinnatum, Bryophyllum delagoense (syn Bryophyllum tubiflorum)* and *Bryophyllum daigremontianum X Bryophyllum tubiflorum.* It is possible that the biotype of *S. aurantii* in Australia is slightly different to the one occurring in Africa and that it has a preference for feeding on these succulents.

For the purpose of this survey, plants of the genera *Bryophyllum* and *Kalanchoe* were targeted.

Results for the Greater Brisbane survey are captured in TABLE 11, Section 0 RESULTS.

4.9 Collection of thrips for DNA study (February 2003)

On 10 February 2003, specimens of *S. aurantii* were collected for DNA analysis and shipped to CSIRO in Canberra. Samples are awaiting comparative analysis with specimens to be collected from Bryophyllum and citrus in South Africa.

Sample details are as follows-

Site-	Roadside. Upper Brookfield Rd, Brookfield. QLD
GPS-	-27.49255 152.90135. dd WGS 84.
Host-	Bryophyllum (hybrid Mother of Millions- *B daigremontianum* x *B tubiflorum*).
Collection date-	10/2/2003.
Collector-	G Telford. QDPI. Ph (07)3362 9539.
Collection medium-	90% alcohol
Site confirmed +ve	John Donaldson on 30/1/2003. Scirtothrips aurantii Faure.
Estimated number	200

4.10 Passive surveillance

The following passive surveillance tools were used-

Education of local residents during the survey
As part of the intensive survey procedure, survey teams fully explained the reason for the survey to property owners and property contacts throughout the survey area. This may have included distribution of the DPI note, description of typical symptoms thrips infestations and a brief description of *S aurantii* to encourage reporting of the insect or suspicious damage to plants. In order to minimise false reports, a preserved sample was often displayed. This ensured that householders held an accurate perspective of the size and colour of the pest.

DPI Note (ATTACHMENT 4)
A DPI note was produced as a result of the initial detection of *S aurantii* at Sherwood. This includes information on distribution, appearance, method of spread, response actions and DPI contact details. Information is updated as required and a revised note issued.

Web site
Information pertaining to *S aurantii* is available on the DPI Web site, including the DPI Note and current DPI media releases. The DPI website can be accessed at www.dpi.qld.gov.au. Search link- "South African Citrus Thrips".

Local garden group meeting
Departmental officers included a South African citrus thrips presentation during a local plant group meeting on 10 July 2002 at Corinda. Copies of the DPI Note were also distributed to members.

Newspaper articles
SOUTH-WEST NEWS- Wednesday 19 February 'Thrips take hold despite kill plans'.

Local and regional QDPI offices
DPI staff based at regional offices throughout the State associated with the Plant Health Surveillance project have been briefed on *S. aurantii* and are able to service local enquiries if required.

A detection of *S aurantii* at Upper Brookfield during January 2003 was a result of information flow through the Departmental communications network.

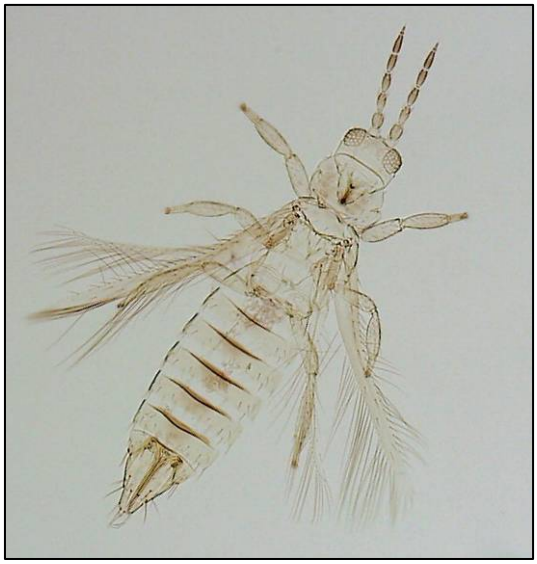
5 METHOD

Pest details and host damage

Description

S. aurantii is a small (1.0 mm long as adults) cigar-shaped insect that can barely be seen with the naked eye and are cream to pale green to yellow or orange in colour. *See Figures 4,5,6,7 (not to scale- thrips prepared on slides for identification).*

Figure 4 (Below left)- *S. aurantii* female
Figure 5 (Below right)- *S. aurantii* male



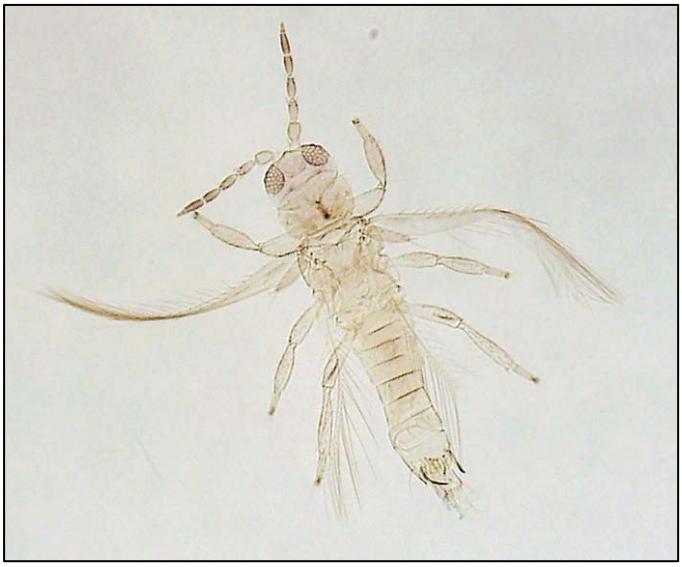


Figure 6 (Below left)-Setal comb on hind femur of male.

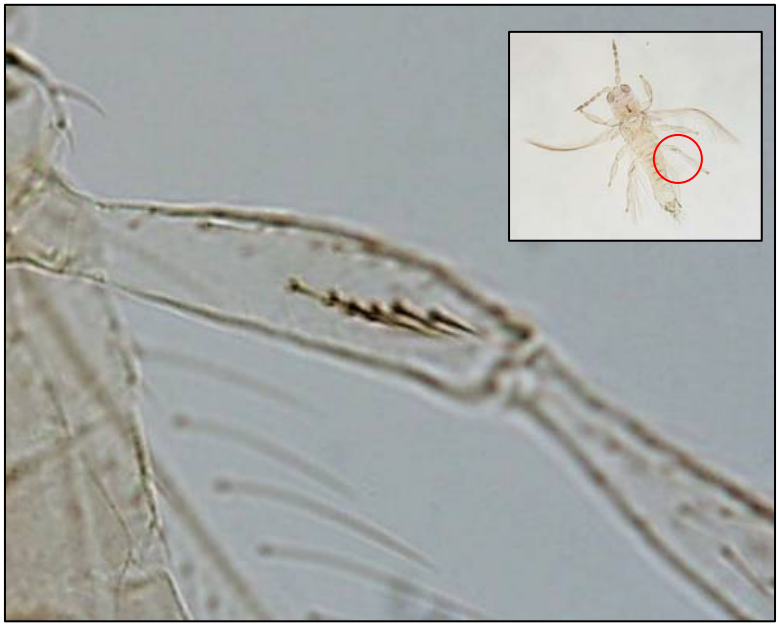
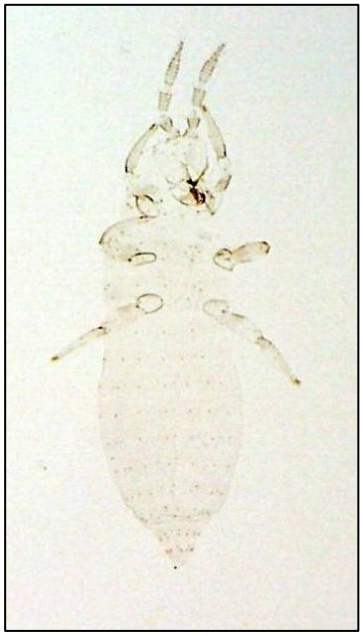


Figure 7 (Below right)- Immature thrips



5.1.2 Damage

Thrips damage plants by killing surface cells of leaves or young fruit with their rasping mouthparts. Once established and present in large numbers, they produce silvering, yellowing and bronzing of affected areas and generally unsightly brown blemishes on fruit.

If thrips are abundant on tender young shoots, their feeding causes the young stems and leaves to become thickened and distorted. Apical shoots may turn black and fall off. Less severe damage, at least on citrus, is characterised by two thickened parallel streaks on either side of the mid-rib.

The overall effect is a loss of plant vigour and a possible reduction in marketability of fruit in citrus.

Brown scarring on the surface of fruit, leaves or stems could indicate their presence. The tips of injured leaves often curl or roll inward around the midrib like a rat's tail, forming a groove in which the thrips feed. Heavily infested leaves may be stunted in growth and deformed. Very young shoots may turn black and fall off plants and damage on citrus fruit is characterised by a ring of brown scarring on the stem end.

S. aurantii can build up to damaging levels during prolonged periods of hot, dry conditions, but is normally less of a problem after periods of heavy rainfall and/or cool weather.

Brisbane survey observations

Damage observed on Crassulaceae during the Brisbane survey was limited to brown scarring of leaves and stems, with stunting of the growth tip on heavily infested plants (*Figure 8*). At some locations, loss of vigour and death was observed amongst plants growing in heavily shaded areas.

In suburbs where scattered infestations were detected, on occasion, large numbers of thrips were sometimes collected from infested plants that displayed little or no obvious damage.

Damage to plants infested with *S. aurantii* was severe in comparison to plants infested with *Thrips tabaci* Lindemann (onion thrips- which was also frequently detected on *Bryophyllum*).

Figure 8 -

Damage observed on Bryophyllum sp. Brown scarring can be easily observed along the midrib of leaves. This plant also displays stunting of the growth tip.

5.1.3 Detection

The symptoms described are the result of a heavy population of thrips. A light infestation may show no visible damage. *S. aurantii* was easily detected after 'beating' infested plants into a dark coloured beating tray where their light colour contrasted well against the dark surface.

Bryophyllum plants that were heavily scarred and sampled during the survey were almost always infested with *S. aurantii*. It was also noted that *S. aurantii* was more likely to be found on plants growing in shaded or semi shaded areas.

5.2 Sampling Procedure

5.2.1 Survey and collection materials

Equipment required	Purpose
Pest Survey form	To record survey details
Pest Sample Identification Request form	To record pest sample details
Photographs of the pest (or preserved sample)	Reference tool
Hand lens (X10 magnification)	Inspection
Collection vials with preservation solution- 5ml vial is sufficient.	(Prefered-60% alcohol/glycine/acetic acid in the ratio 10:1:1)
Plastic bags	Vial storage
Camelhair brush	Collection equipment
Beating tray (any flat black tray will be suitable)	Collection equipment- Deep tray is preferred
Adhesive labels to label collecting vials	To mark collection vials and sample bags
Soft lead pencil, eg 2B	To mark collection vials. Will not be affected by spilt preservation fluid.
Permanent marker.	To mark plastic bags
Secateurs or suitable knife.	To remove foliage for beating
Disposable overalls and gloves.	Hygiene measure
Note book/pen.	To record additional information
Hand broom.	Hygiene measure
Copy of this procedure.	Reference tool

Figure 9 –

Beating tray, brush, hand lens, secateurs, collection vial and pencil suitable for use to collect and sample thrips.

5.2.2 Arriving at the survey property

Upon arriving at the property, an explanation was given to the property contact person or resident outlining the reason for the survey and permission was sought to carry out a survey on their property. This procedure was not used at public access sites.

Disposable overalls and gloves were utilised as risk minimisation measures to avoid potential inadvertent human assisted dispersal of *S. aurantii*.

5.2.3 Conducting the survey

Target hosts

S. aurantii can seriously blemish the fruit of citrus, mango, and macadamia. On occasion severe attack on young foliage can damage seedlings and young plants of these crops.

The thrips has a wide host range although it is possible that a species complex is involved. Known hosts include:

Acacia nilotica
Citrus and deciduous fruit trees
Mango
Macadamia
Grevillea
Mother of millions, Bryophyllum and other Crassulaceae
Poinciana
Jacaranda
Bauhinia
Legumes such as beans and peas
(ATTACHMENT 5)

Intensive surveys of Sherwood between March 2002 and December 2002 were not limited to recorded hosts of *S. aurantii* as it was uncertain how the pest would react in a foreign environment. A wide and diverse selection of plants, trees and shrubs were inspected for the presence of thrips during this period. Survey and sampling techniques were validated with the collection and identification of an extensive number and type of thrips during this phase (TABLE 12 Section 0). Citrus, the primary host of *S. aurantii* in South Africa was closely scrutinised during surveys and although thrips of other types were collected from citrus, no *S. aurantii* was identified (TABLE 13 Section 0).

It has been established through survey and investigation that the preferred hosts of the biotype of the thrips that exist in Brisbane are plants of the family Crassulaceae, in particular the genus *Bryophyllum*. *S. aurantii* has only, to date, been identified on *Bryophyllum delagoense (syn Bryophyllum tubiflorum), Bryophyllum pinnatum, Bryophyllum daigremontianum x Bryophyllum tubiflorum and Kalanchoe longiflora.*

It is for this reason that Crassulaceae, in particular *Bryophyllum*, were specifically targeted during the Greater Brisbane survey conducted in February 2003.

Site inspection

During surveys conducted from March 2002 to December 2003 a thorough inspection was conducted on all plants at each survey site.

Survey teams moved through sites and inspected plants. Inspectors looked for the presence of thrips and evidence of thrips damage. A description of *S.aurantii* is given in section 0, while damage is described in section 0.

Young leaves, growing tips and other plant parts were inspected for both thrips and damage. A hand lens was used for closer inspection.

Note- On occasion, thrips were present even when damage or the insect was not seen during inspection. The following beating procedure was used as part of the inspection procedure as an additional measure to confirm the absence of thrips.

Taking a pest sample
Young foliage of the plant was sampled by shaking above the beating tray (this can be quite vigorous). Any thrips present were dislodged onto the beating tray where they could be clearly seen.

Note- The beating tray was not exposed to direct sunlight for an extended period. A warm or hot surface will encourage thrips to escape from the beating tray.

If thrips were present, a sample was taken for identification. The thrips were collected with a camelhair brush that had been saturated in the preservation solution, and transferred to the collection vial.

Note- Thrips are very small and will adhere quite strongly to the fibres on the brush. Using a fine brush and picking up thrips using a gentle sideways sweeping motion achieved the best results. This technique prevented thrips from becoming entangled amongst the bristles and minimised physical damage to the specimen.

Vials were marked with a pest sample number. Adhesive labels and a soft lead pencil were used to mark the sample. The number included a code for the survey type, and the number of the sample in sequence for that pest collected by that inspector. The vials were then placed into a plastic bag and the bag was labelled with the same data as the vial.

Sampling rate
Host plants were inspected at the following rate.

Number of plants on site	Number inspected
0 to 30	All plants
31 to 300	30 plants
> 300	30 plus 5% of those above 300

5.2.4 Recording details of the pest sample
Pest sample details were recorded on a Pest Sample Identification Request form. Each sample was assigned a separate form (ATTACHMENT 6). The pest sample number was recorded on the Pest Survey Form.

5.2.5 Recording details of the survey
Details of the property were recorded on a Pest Survey form (ATTACHMENT 7). If no sample was taken then ‘nil’ was recorded under ‘Pest Sample Number’ on the Pest Survey Form.

5.2.6 Before leaving the survey property
The property contact person was thanked if applicable. Disposable overalls were brushed down and if a sample had been taken for identification the disposable overalls were removed and sealed in a plastic bag. Survey teams ensured that all sampling equipment was disinfested and was clear of thrips and other matter before departure.

Note- Like other thrips, S. aurantii can easily spread to other locations on wind currents, infested plant material and on almost any surface they come into contact with, including clothing. Due to the risk of being transferred through human assisted movement, all standard hygiene measures were fully implemented.

5.2.7 Dispatching the pest sample

The Investigating Officer maintained copies of the Pest Sample Identification Request prior to dispatch of the pest sample. The sample with the original Pest Sample Identification Request form was delivered to the address shown on the form. The Senior Entomologist (Insect Identification) 07 3896 9419 was advised that the sample was being sent.

5.2.8 Identifying the pest sample

The entomologist carried out the identification and identification details were entered on the Pest Sample Identification Request form. The Senior Entomologist at Indooroopilly confirmed the identification by signing the form.

5.2.9 Reporting and notification

The Senior Entomologist at Indooroopilly sent copies of the Pest Sample Identification Request form to the Survey Coordinator and the Investigating Officer and retained the original on file.

The Senior Entomologist at Indooroopilly advised the Survey Coordinator of the identification result as soon as was practicable after identification.

In the case of *S. aurantii* being detected, the Survey Coordinator was advised in the first instance. The Survey Coordinator then advised the Senior Plant Health Officer at Primary Industries Building that *S. aurantii* had been detected

The property contact person was advised of this result after the Investigating Officer had consulted with the Survey Coordinator.

At the conclusion of the survey and following completion of the Pest Survey Form, the Investigating Officer retained a copy of the Pest Survey form and forwarded the original to the Survey Coordinator.

The Survey Coordinator checked the details of the Pest Survey Form and crosschecked the Sample Numbers against corresponding Pest Sample Identification Request forms to ensure that all samples had been identified.

5.2.10 Record keeping

The Survey Coordinator maintains a record of copies of Pest Sample Identification Request forms and originals of Pest Survey forms.

The Senior Entomologist (Insect Identification) at Indooroopilly maintains a record of original Pest Sample Identification Request forms.

5.2.11 GPS set up

All GPS coordinates were recorded using the following specifications-

POSITION:	hddd.ddddd^{o}
DATUM:	Austrl Geod ‘84’ (WGS ‘84’)
CDI SCALE:	± 0.25
UNITS:	Metric
HEADING:	Auto Mag E010

6 RISK MANAGEMENT

Movement restrictions- On the 3rd of April 2002, Terrance Philip Hogan, on behalf of the Department of Natural Resources and Mines, signed an Undertaking given under section 11(4) of the *Plant Protection Act 1989.* The Undertaking prohibits movement of restricted items from the land described as Lot 443 Registered Plan SL9124 Par Oxley to any other parcel of land in the State of Queensland, or in any other State or Territory without an Inspector's Approval (ATTACHMENT 8).

To date, nine Inspector's Approvals have been issued for the removal, treatment and inspection of restricted items (ATTACHMENT 9).

7 IDENTIFICATION

All samples were delivered to the DPI identification entomologist at the following location-

John Donaldson
Senior Entomologist
Entomology Building
Queensland Department of Primary Industries
80 Meiers Road,
Indooroopilly, QLD 4068
Australia

The confirmatory entomologist for the initial response detections was-

Dr Lawrence Mound
CSIRO Entomology
GPO Box 1700
Canberra, A.C.T. 2601
Australia

8 REPORTING AND NOTIFICATION

At the end of the survey program the state surveillance coordinator is to provide a written report on findings to the State Project Leader and General Manager for distribution to industry and other stakeholders, including interstate quarantine authorities.

9 DATA COLLECTION AND STORAGE

All data collected in hardcopy form, as part of this survey will be stored at-

Animal Research Institute.
Queensland Department of Primary Industries
665 Fairfield Road,
YEERONGPILLY QLD 4105

All data will be stored electronically in Microsoft Access 2000 format as part of the SOUTH AFRICAN CITRUS THRIPS survey database. At the completion of the survey, read-only copies of the database will be distributed on compact disc to staff at the following locations-

HEAD OFFICE

Project Leader (Surveillance)
Queensland Department of Primary Industries
Primary Industries Building
80 Ann Street
BRISBANE QLD 4000

Project Leader (Interstate Plant Quarantine)
Queensland Department of Primary Industries
Primary Industries Building
80 Ann Street
BRISBANE QLD 4000

SOUTH EAST REGION

Animal Research Institute.

Queensland Department of Primary Industries
665 Fairfield Road,
YEERONGPILLY QLD 4105

Information pertaining directly to persons and businesses contained within this database should be considered as confidential. Access is available to officers of the Queensland Department of Primary Industries only.

10 RESULTS

10.1 Initial Response Delimiting survey (March 2002)

Departmental officers conducted surveys of a total of one hundred and thirty one (131) properties within a 500-metre radius of the initial detection. Surveys were conducted within the suburbs of Sherwood, Figtree Pocket and Chelmer.

A total of fifty-seven (57) samples were submitted for identification. The reference entomologist reported that **one (1) sample was identified as *S. aurantii***. Including the detection at AFRS, this brought the total number of infested properties to two (2). The detection occurred on the footpath of a residential property in very close proximity to AFRS. A report for the initial response delimiting survey is summarised in TABLE 1.

TABLE 1- Initial Response Delimiting Survey

Category	Location	Suburb	Date	Properties surveyed	Samples taken	SACT present
SURVEY	Jordan Street	Sherwood	3/04/2002	7	0	No
SURVEY	Honour Avenue	Sherwood	3/04/2002	3	0	No
SURVEY	Marlborough Street	Sherwood	3/04/2002	5	0	No
SURVEY	Berry Street	Sherwood	3/04/2002	15	11	No
SURVEY	Prospect Street	Sherwood	3/04/2002	10	0	No
SURVEY	Magazine Street	Sherwood	3/04/2002	9	2	On one property
SURVEY	Sherwood Road	Sherwood	4/04/2002	2	0	No
SURVEY	Lilly Street	Sherwood	4/04/2002	3	2	No
SURVEY	Sherwood Arboretum	Sherwood	14/03/2002	1	1	No
SURVEY	Ferry Street	Sherwood	2/04/2002	7	2	No
SURVEY	Kinkead Street	Sherwood	4/04/2002	5	0	No
SURVEY	Joseph Street	Sherwood	4/04/2002	3	1	No
SURVEY	Dudley Street	Sherwood	4/04/2002	15	2	No
SURVEY	Dewar Street	Sherwood	5/04/2002	1	1	No
SURVEY	Dunella Street	Sherwood	5/04/2002	4	2	No
SURVEY	Hazelmere Parade	Sherwood	3/04/2002	10	5	No
SURVEY	Woodbury Street	Sherwood	3/04/2002	4	2	No
SURVEY	Barchester Street	Sherwood	4/04/2002	8	6	No
SURVEY	Bentinck Street	Sherwood	5/04/2002	6	8	No
SURVEY	Weinholt Street	Sherwood	5/04/2002	1	2	No
SURVEY	Park Terrace	Sherwood	14/03/2002	1	1	No
SURVEY	Kitchner Street	Sherwood	14/03/2002	1	1	No
SURVEY	Jesmond Road	Fig tree pkt	14/03/2002	3	3	No
SURVEY	Gunnin Street	Sherwood	14/03/2002	1	1	No
SURVEY	Molonga Terrace	Sherwood	14/03/2002	1	1	No
SURVEY	Frazer Street	Sherwood	14/03/2002	1	1	No
SURVEY	Long Street West,	Chelmer	14/03/2002	4	3	No
Total number of properties inspected		**131**	**Total samples**		**57**	**Number positive** **1**

10.2 Traceforward surveys

10.2.1 Plant movements associated with distribution of Lantana Rust

Departmental officers from AFRS conducted twenty-one (21) traceforward investigations of properties that had received materials associated with the distribution of lantana rust spores from AFRS. Of these, ten (10) locations were classified as high risk and required inspection and seven (7) samples were submitted for identification. Inspections were conducted during the months of May and June 2002.

The reference entomologist reported that **no samples contained *S. aurantii***. A report for this investigation is summarised in TABLE 2.

TABLE 2- Traceforward Investigations – Plant movements and Lantana rust distribution

Ref No.	Location	Taxon	Location	Date	Sample	Present
SACT TF001*	Tamborine	*Lantana camara*	Sandy Creek Tamborine	4/06/2002	1	No
SACT TF002	Tamborine	*Lantana camara*	Sandy Creek Tamborine	4/06/2002	0	No
SACT TF003*	Mt Warning	*Lantana camara*	Mt Warning National Park	25/05/2002	1	No
SACT TF004*	Mt Warning	*Lantana camara*	Mt Warning National Park	24/05/2002	1	No
SACT TF005	Nth NSW	*Lantana camara*	Toonumbar	24/05/2002	1	No
SACT TF006*	Tamborine	*Lantana camara*	Sandy Creek Tamborine (3)	4/06/2002	0	No
SACT TF007*	Tamborine	*Lantana camara*	Haselers Tamborine (4) SEQ	4/06/2002	0	No
SACT TF008	Mid NSW	*Lantana camara*	Creek, Show Kendall	25/5/2002	1	No
SACT TF009	Port Macquarie	*Lantana camara*	Creek, Timbe Port Macquarie	25/5/2002	1	No
SACT TF010*	NSW	*Lantana camara*	Boat harbour South West	N/A	N/A	N/A
SACT TF011	Bellingen	*Lantana camara*	Waterfall Way Billengen	22/05/2002	1	No
SACT TF012*	Sydney	*Lantana camara*	Laguna Ave Copacabana	N/A	N/A	N/A
SACT TF013*	Sydney	*Lantana camara*	Fern Valley Lane Cove	N/A	N/A	N/A
SACT TF014*	Mt Lindsay	*Lantana camara*	Roadside Border Range	N/A	N/A	N/A
SACT TF015*	Maleny	*Lantana camara*	Property Malaney SEQ	N/A	N/A	N/A
SACT TF016*	Dimbula North	*Lantana camara*	Creekbank Dimbula NQ	N/A	N/A	N/A
SACT TF017*	Johnstone	*Lantana camara*	Riverbank Johnstone	N/A	N/A	N/A
SACT TF018*	Sydney area	*Lantana camara*	Hawkesbury river area	N/A	N/A	N/A
SACT TF019*	Sydney area	*Lantana camara*	Hawkesbury river area	N/A	N/A	N/A
SACT TF020*	Mt Tamborine	*Lantana camara*	Mtn Top Mt Tamborine	N/A	N/A	N/A
SACT TF021*	Redlands	*Lantana camara*	Swamp Redland Shire	N/A	N/A	N/A

Total properties investigated	**21**	**Total properties inspected**	**10**	**Total samples**	**7**	**Number positive**	**None**

**Lantana rust release site. No plants taken to this location. Spores only! Spores were freeze dried prior to leaving site.*

10.2.2 Plant movements associated with distribution of Groundsel Bush material

Departmental of Natural Resource officers conducted two (2) traceforward investigations of properties that had received materials associated with the distribution of Groundsel Bush material from AFRS. Of these, two (2) locations required inspection and two (2) samples were submitted for identification. Inspections were conducted during the month of June 2002.

The reference entomologist reported that **no samples contained *S. aurantii***. A report for this investigation is summarised in TABLE 3.

TABLE 3- Traceforward Investigations – Plant movements associated with Groundsel Bush material

Ref No.	Location	Taxon	Location	Date	Sample	Present
SACT TF104	Fraser Island	Groundsel Bush	Site1	6/06/2002	1	No
SACT TF105	Fraser Island	Groundsel Bush	Site2	6/06/2002	1	No

Total properties investigated	**2**	**Total properties inspected**	**2**	**Total samples**	**2**	**Number positive**	**None**

10.2.3 Plant movements associated with distribution of Parthenium Weed rust spores

AFRS staff conducted eight (8) traceforward investigations of three (3) properties that had received materials associated with the distribution of Parthenium weed material from AFRS. Three samples including two (2) composite samples were submitted for identification. Inspections were conducted during the months of May and June 2002.

The reference entomologist reported that **no samples contained *S. aurantii***. A report for this investigation is summarised in TABLE 4.

TABLE 4- Traceforward Investigations – Plant movements associated with Parthenium Weed materials

Ref No.	Location	Taxon	Location	Date	Sample	Present
SACT TF106	Bauhinia	Parthenium Weed	Delargum property	1/05/2002	1	No
SACT TF107	Bauhinia	Parthenium Weed	Delargum property	1/05/2002	1	No
SACT TF108	Bauhinia	Parthenium Weed	Delargum property	1/05/2002	1	No
SACT TF109	Injune	Parthenium Weed	Injune Parthenium	22/05/2002	1	No
SACT TF110	Injune	Parthenium Weed	Injune Parthenium	22/05/2002	1	No
SACT TF111	Injune	Parthenium Weed	Injune Parthenium	22/05/2002	1	No
SACT TF112	Injune	Parthenium Weed	Injune Parthenium	22/05/2002	1	No
SACT TF113	Emerald	Parthenium Weed	Emerald DPI Complex	27/06/2002	1	No

Total properties investigated	**3**	**Total sites inspected**	**8**	**Total samples**	**3** (2 composite)	**Number positive**	**None**

10.2.4 Thrips transfer through possible human assisted movement

AFRS staff conducted forty (40) traceforward investigations and inspections of AFRS staff properties. Eleven (11) samples were submitted for identification. Inspections were conducted during the months of March and April 2002. Sentinel plant stations were installed post survey on eleven (11) properties for further monitoring purposes.

The reference entomologist reported that **no samples contained *S. aurantii***. A report for this investigation is summarised in TABLE 5.

TABLE 5- Traceforward Investigations – Human assisted movements and AFRS staff

Ref No.	Taxon	Location	Date	Sample	Present
SACT TF022	All susceptible plants	Sangate Rd Clayfield	1/04/2002	0	No
SACT TF023	All susceptible plants	Castor Rd Wavell Heights	1/04/2002	0	No
SACT TF024	All susceptible plants	Hayden St Nudgee	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 122.					
SACT TF025	All susceptible plants	Beaconsfield St Gordon Park	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 123.					
SACT TF026	All susceptible plants	Minore St Chermside	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 124.					
SACT TF027	All susceptible plants	Drapers Rd Eatons Hill	1/04/2002	0	No
SACT TF028	All susceptible plants	Montpelier St The Grange	1/04/2002	0	No
SACT TF029	All susceptible plants	Heysen St Everton Park	1/04/2002	0	No
SACT TF030	All susceptible plants	Allambic St The Gap	1/04/2002	0	No
SACT TF040	All susceptible plants	Mitre St Lucia	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 121.					
SACT TF041	All susceptible plants	Twickenham St Chelmer	1/04/2002	0	No
SACT TF042	All susceptible plants	Almeida St Indooroopilly	1/04/2002	0	No
SACT TF043	All susceptible plants	Dobell St Indooroopilly	25/03/2002	3	No
SACT TF044	All susceptible plants	Ninth Avenue St Lucia	1/04/2002	0	No
SACT TF045	All susceptible plants	Alexandra Avenue Taringa	25/03/2002	1	No
Ongoing surveillance- See SENTINEL 120.					
SACT TF046	All susceptible plants	Ada Street Taringa	1/04/2002	0	No
SACT TF047	All susceptible plants	Equinox Street Taringa	25/03/2002	2	No
SACT TF048	All susceptible plants	Dornie Place Fig Tree Pocket	1/04/2002	0	No
SACT TF049	All susceptible plants	Norman St Fig TreePocket	25/03/2002	3	No
SACT TF050	All susceptible plants	Dougy Place Bellbourie	1/04/2002	0	No
SACT TF051	All susceptible plants	Molesworth St 17 Mile Rocks	1/04/2002	0	No
SACT TF052	All susceptible plants	Canowie Rd Jindalee	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 129.					
SACT TF053	All susceptible plants	Bilkurra St Middle Park	27/03/2002	1	No
SACT TF054	All susceptible plants	Cliveden St Corinda	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 125.					
SACT TF055	All susceptible plants	Magazine St Sherwood	25/03/2002	1	No
SACT TF056	All susceptible plants	Magazine St Sherwood	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 126					
SACT TF057	All susceptible plants	Bute St Sherwood	1/04/2002	0	No
SACT TF058	All susceptible plants	Adelaide St West End	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 127.					
SACT TF059	All susceptible plants	Alkira St Sunnybank Hills	1/04/2002	0	No
SACT TF060	All susceptible plants	Gaynesford St Mt Gravatt	1/04/2002	0	No
SACT TF061	All susceptible plants	New Beith Rd Greenbank	1/04/2002	0	No
SACT TF062	All susceptible plants	Ford Rd Burbank	1/04/2002	0	No
SACT TF063	All susceptible plants	Kindred St Alexandra Hills	1/04/2002	0	No
SACT TF064	All susceptible plants	Ingham Street Capalaba	1/04/2002	0	No
SACT TF066	All susceptible plants	Pinkwood Street Cedar Vale	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 128.					
SACT TF067	All susceptible plants	Flaggy Ck Rd Mt Crosby	1/04/2002	0	No
SACT TF068	All susceptible plants	Lake Manchester MtCrosby	1/04/2002	0	No
Ongoing surveillance- See SENTINEL 130.					
SACT TF070	All susceptible plants	left Sept 2001.	1/04/2002	0	No
SACT TF071	All susceptible plants	only briefly at AFRS	1/04/2002	0	No
SACT TF072	All susceptible plants	University of Queensland	1/04/2002	0	No

Total properties investigated	40	Total properties inspected	40	Total samples	11	Number positive	None

10.2.5 Thrips transfer through movement of display plants

APHS staff conducted thirty-two (32) traceforward investigations and thirty-one (31) inspections of properties that had hosted 'display plants' sourced from AFRS. Four (4) samples were submitted for identification. Inspections were conducted during the months of August and September 2002.

The reference entomologist reported that **no samples contained *S. aurantii***. A report for this investigation is summarised in TABLE 6.

TABLE 6- Traceforward Investigations – Movement of display plants

Ref No.	Taxon	Location	Date	Samples taken	Present
SACT TF073	All susceptible plants	Kilcoy Flower Show.	9/08/2002	0	No
SACT TF074	All susceptible plants	Woodford Cattle Sale	9/08/2002	0	No
SACT TF075	All susceptible plants	Eumundi	17/09/2002	0	No
SACT TF076	All susceptible plants	Beenleigh Marketplace	2/08/2002	0	No
SACT TF077	All susceptible plants	Palmwoods	9/08/2002	0	No
SACT TF078	All susceptible plants	Monto	30/08/2002	0	No
SACT TF079	All susceptible plants	Palmwoods	9/08/2002	0	No
SACT TF080	All susceptible plants	Yowie Park. Kilcoy	9/08/2002	0	No
SACT TF081	All susceptible plants	Woodford cattleyards	9/08/2002	0	No
SACT TF082	All susceptible plants	CHOGM Convention Centre South			N/A
All plants used in the Convention Centre display Bank Brisbane SEQ were in secure display unit & there was no risk of SACT spread. No Inspection was carried out.					
SACT TF083	All susceptible plants	Roma St Parklands	5/09/2002	4	No
SACT TF084	All susceptible plants	Blue Gum Rsv Karalee	13/08/2002	0	No
SACT TF085	All susceptible plants	Moreton Saleyards, Purga	21/08/2002	0	No
SACT TF085	All susceptible plants	Moreton Saleyards, Purga	21/08/2002	0	No
SACT TF086	All susceptible plants	Perrin Park Josling St Toowong	30/08/2002	0	No
SACT TF087	All susceptible plants	Kingaroy Shire Council	9/08/2002	0	No
SACT TF088	All susceptible plants	Bunya Mountains	9/08/2002	0	No
SACT TF089	All susceptible plants	Toowoomba	1/08/2002	0	No
SACT TF090	All susceptible plants	Ingleside State School,	1/08/2002	0	No
SACT TF091	All susceptible plants	Shelter Rd Coombabah. Gold C	1/08/2002	0	No
SACT TF092	All susceptible plants	Beenleigh Shopping Centre	1/08/2002	0	No
SACT TF093	All susceptible plants	Robina Shopping Centre	1/08/2002	0	No
SACT TF094	All susceptible plants	The Pines Shopping Cntre Elanora	1/08/2002	0	No
SACT TF095	All susceptible plants	Indooroopilly State School	3/09/2002	0	No
SACT TF096	All susceptible plants	Queensland Herbarium	13/09/2002	0	No
SACT TF097	All susceptible plants	Caboolture	9/08/2002	0	No
SACT TF098	All susceptible plants	Toowoomba DNRM office	1/08/2002	0	No
SACT TF099	All susceptible plants	Roma Street Parklands	5/09/2002	4	No
SACT TF100	All susceptible plants	BCC Perrin park Toowong	0/08/2002	0	No
SACT TF101	All susceptible plants	Murgon. Private	9/08/2002	0	No
SACT TF102	All susceptible plants	Caboolture	9/08/2002	0	No
SACT TF103	All susceptible plants	Caboolture	9/08/2002	0	No

Total properties investigated	**32**	**Total properties inspected**	**31**	**Total samples**	**4**	**Number positive**	**None**

10.3 Traceback Survey

APHS staff conducted sixty-three (63) traceback investigations and forty-five (45) inspections of sites from which AFRS staff had sourced *Bryophyllum* plants for use in host specificity trials. Thirty-two (32) samples were submitted for identification. Inspections were conducted during the months of August 2002 and February 2003.

The reference entomologist reported that **three (3) samples were identified as *S. aurantii***. A report for this investigation is summarised in TABLE 7.

TABLE 7- Traceback survey

Ref	Taxon	Location	Date	Samples	Detected
TB001	*Bryophyllum delagoense*	Gracemere - Gavial	3/12/2002	1	No
TB002	*Bryophyllum delagoense*	Mt Morgan Cnr Coles Rd	6/12/2002	1	No
TB003	*Bryophyllum delagoense*	Leichardt Hwy	6/12/2002	1	No
TB004	*Bryophyllum delagoense*	Leichardt Hwy	6/12/2002	0	No
TB005	*Bryophyllum delagoense*	Leichardt Hwy Taroom	6/12/2002	1	No
TB006	*Bryophyllum delagoense*	Leichardt Hwy	6/12/2002	1	No
TB007	*Bryophyllum delagoense*	Warrego Hwy- Miles	6/12/2002	1	No
TB008	*Bryophyllum delagoense*	Nudley State Forest Jandowe	6/12/2002	1	No
TB009	*Bryophyllum delagoense*	Jandowe - Durog South Rd	6/12/2002	1	No
TB010	*Bryophyllum delagoense*	Bell on Dalby Road	6/12/2002	1	No
TB011	*Bryophyllum delagoense*	Hattonvale	6/12/2002	0	No
TB016	*Bryophyllum delagoense*	Upper Kedron- Cedar creek rd.	16/01/2003	1	No
TB017	*Bryophyllum delagoense*	South Deebing Ck Rd Yamanto	18/11/2002	0	No
TB018	*Bryophyllum daigremontianum*	South Deebing Ck Rd Yamanto	18/11/2002	0	No
TB019	*Bryophyllum daigremontianum*	Somerset Road -Kedron	15/12/2002	0	No
TB023	*Bryophyllum delagoense*	Bruce Hwy before Marmor Roadhouse	3/12/2002	1	No
TB024	*Bryophyllum delagoense*	Ebenezer	10/02/2003	1	No
TB028	*Bryophyllum delagoense*	Cnr. Daisy Hill Rd and Springwood Rd, Daisy Hill	17/01/2003	1	No
TB029	*A.Berger x B.delagoense*	Cnr. Daisy Hill Rd and Springwood Rd, Daisy Hill	17/01/2003	1	No
TB030	*Bryophyllum pinnatum*	Bardon, Stuart Holme -Birdwood Terrace	17/01/2003	1	No
TB031	*Bryophyllum daigremontianum*	Bardon, Stuart Holme -Birdwood Terrace	17/01/2003	1	No
TB032	*Bryophyllum delagoense*	Bardon, Stuart Holme- Birdwood Terrace	17/01/2003	1	No
TB036	*Bryophyllum delagoense*	Mungle Creek Reserve "Yalbindi"	20/11/2002	1	No
TB037	*Bryophyllum delagoense*	Bundamba TAFE	10/02/2003	0	No
TB038	*Bryophyllum pinnatum*	Bundamba TAFE	10/02/2003	0	No
TB039	*Bryophyllum delagoense*	Legume	19/11/2002	1	No
TB040	*Bryophyllum delagoense*	Legume	19/11/2002	1	No
TB041	*Bryophyllum daigremontianum*	Upper Brookfield Rd, Upper Brookfield	17/01/2003	1	Yes
TB042	*Bryophyllum delagoense*	Moggill Rd, Pinjarra Hills	17/01/2003	1	No
TB043	*Bryophyllum delagoense*	Cunningham HWY- Yelarbon	19/11/2002	1	No
TB044	*Bryophyllum delagoense*	Upper Brookfield Rd, cnr Carbine St	17/01/2003	1	Yes
TB045	*Bryophyllum delagoense*	Laidley	7/02/2003	1	Yes
TB046	*Bryophyllum delagoense*	Chinchilla	06/2002	0	No
TB047	*Bryophyllum delagoense*	Childers- Hebbards Rd	3/12/2002	1	No
TB048	*Bryophyllum delagoense*	Childers- Hebbards Rd	3/12/2002	0	No
TB049	*Bryophyllum daigremontianum*	Tindall Road Gracemere	3/12/2002	1	No
TB050	*Bryophyllum daigremontianum*	Tindall Road Gracemere	3/12/2002	0	No
TB051	*Bryophyllum delagoense*	Howard	3/12/2002	1	No
TB052	*Bryophyllum delagoense*	Millmerran	3/12/2002	1	No
TB053	*Bryophyllum delagoense*	Millmeran on Inglewood-Milleran Road	18/11/2002	1	No
TB054	*Bryophyllum delagoense*	Taunton National Park	4/12/2002	1	No
TB057	*Bryophyllum delagoense*	Mt Larcom -Gladstone	3/12/2002	0	No
TB060	*Bryophyllum delagoense*	Goodiwindii	21/11/2002	1	No
TB061	*Bryophyllum daigremontianum*	Goodiwindii	21/11/2002	0	No
TB062	*Bryophyllum daigremontianum*	Bunya Mts Kaimkillenbun road	27/02/2002	0	No

Total properties investigated	**63**	**Total inspected**	**45**	**Samples**	**32**	**Positive**	**3**

10.4 Sentinel Plant Survey

APHS and AFRS staff conducted two hundred and fifty-four (254) inspections of sentinel plant stations located throughout Brisbane between June 2002 and February 2003. Eight (8) samples were submitted for identification.

The reference entomologist reported that **two (2) samples were identified as *S. aurantii***. A report for this investigation is summarised in TABLE 8.

TABLE 8- Sentinel plant survey

Ref No.	Site	Taxon	Location	Inspections	Detected
SENTINEL 146	Sherwood- 500m radius	*Bryophyllum tubiflorium*	Magazine Street.	13	No
SENTINEL 114	Sherwood- 500m radius	*Bryophyllum tubiflorium*	Dudley Street	8	No
SENTINEL 115	Sherwood- 500m radius	*Bryophyllum tubiflorium*	Dunella Street	8	Yes
SENTINEL 116	Graceville- 500m radius	*Bryophyllum tubiflorium*	Wylie Street	8	No
SENTINEL 117	Graceville- 500m radius	*Bryophyllum tubiflorium*	Bank Road	8	No
SENTINEL 118	Sherwood- 500m radius	*Bryophyllum tubiflorium*	Berry Street	8	No
SENTINEL 119	Rocklea	*Bryophyllum tubiflorium*	Sherwood Road Rail Overpass	8	No
SENTINEL 121	St Lucia- AFRS staff	*Bryophyllum tubiflorium*	Mitre Street	7	No
SENTINEL 122	Nudgee- AFRS staff	*Bryophyllum tubiflorium*	Hayden Street	7	No
SENTINEL 123	Gordon Park-AFRS staff	*Bryophyllum tubiflorium*	Beaconsfield Street	7	No
SENTINEL 124	Chermside- AFRS staff	*Bryophyllum tubiflorium*	Minore Street	7	No
SENTINEL 120	Taringa- AFRS Staff	*Bryophyllum tubiflorium*	Alexandra Avenue	7	No
SENTINEL 125	Corinda- AFRS staff	*Bryophyllum tubiflorium*	Cliveden Street	7	No
SENTINEL 126	Sherwood- AFRS staff	*Bryophyllum tubiflorium*	Magazine Street	7	No
SENTINEL 127	West End- AFRS staff	*Bryophyllum tubiflorium*	Adelaide Street	7	No
SENTINEL 128	Cedar Vale- AFRS staff	*Bryophyllum tubiflorium*	Pinkwood Street	7	No
SENTINEL 129	Jindalee- AFRS staff	*Bryophyllum tubiflorium*	Canowie Road	7	No
SENTINEL 130	Mt Crosby- AFRS staff	*Bryophyllum tubiflorium*	Lake Manchester Road	7	No
SENTINEL 131	Sherwood	*Bryophyllum tubiflorium*	AFRS site 1. SEE SITE MAP.	8	No
SENTINEL 132	Sherwood	*Bryophyllum tubiflorium*	AFRS site 2. SEE SITE MAP.	8	No
SENTINEL 133	Sherwood	*Bryophyllum tubiflorium*	AFRS site 3. SEE SITE MAP.	8	No
SENTINEL 134	Sherwood	*Bryophyllum tubiflorium*	AFRS site 4. SEE SITE MAP.	8	No
SENTINEL 135	Sherwood	*Bryophyllum tubiflorium*	AFRS site 5. SEE SITE MAP.	8	No
SENTINEL 136	Sherwood	*Bryophyllum tubiflorium*	AFRS site 6. SEE SITE MAP.	8	No
SENTINEL 137	Sherwood	*Bryophyllum tubiflorium*	AFRS site 7. SEE SITE MAP.	8	No
SENTINEL 138	Sherwood	*Bryophyllum tubiflorium*	AFRS site 8. SEE SITE MAP.	8	No
SENTINEL 139	Sherwood	*Bryophyllum tubiflorium*	AFRS site 9. SEE SITE MAP.	8	No
SENTINEL 140	Sherwood	*Bryophyllum tubiflorium*	AFRS site 10. SEE SITE MAP. Quarantine room 2	8	No
SENTINEL 141	Sherwood	*Bryophyllum tubiflorium*	AFRS site 11. SEE SITE MAP. Quarantine room 1.	8	No
SENTINEL 142	Sherwood	*Bryophyllum tubiflorium*	AFRS site 12. SEE SITE MAP. Quarantine room 3.	8	No
SENTINEL 143	Sherwood	*Bryophyllum tubiflorium*	AFRS site 13. SEE SITE MAP. Quarantine room 4.	8	No
SENTINEL 144	Sherwood	*Bryophyllum tubiflorium*	AFRS site 14. SEE SITE MAP. Quarantine facility.	4	No
SENTINEL 145	Sherwood	*Bryophyllum tubiflorium*	AFRS site 15. SEE SITE MAP. Quarantine facility.	3	No
SENTINEL 147	Sherwood- survey site	*Bryophyllum tubiflorium*	Bentinck St, Sherwood	5	Yes

Total number of stations	34	Total inspections	254	Total samples	8	Number positive	2

10.5 Wet Trap Surveys

TABLE 9- Wet Trap survey						
Ref No.	**Site**	**Location**			**Inspections**	**Samples**	**Detected**
SENTINEL 140	Sherwood	AFRS site 10. SEE SITE MAP. Quarantine room 2			Continuous	1	No
SENTINEL 141	Sherwood	AFRS site 11. SEE SITE MAP. Quarantine room 1.			Continuous	0	No
SENTINEL 142	Sherwood	AFRS site 12. SEE SITE MAP. Quarantine room 3.			Continuous	0	No
SENTINEL 143	Sherwood	AFRS site 13. SEE SITE MAP. Quarantine room 4.			Continuous	0	No
SENTINEL 144	Sherwood	AFRS site 14. SEE SITE MAP. Quarantine facility.			Continuous	1	No
SENTINEL 145	Sherwood	AFRS site 15. SEE SITE MAP. Quarantine facility.			Continuous	0	No
Total number of stations	**6**	**Total samples**	**2**	**Number positive**	**0**		

10.6 Intensive survey (December 2002)

APHS staff officers conducted surveys of a total of one hundred and twenty (120) properties within a 500-metre radius of the initial detection at Sherwood. Surveys were conducted within the suburbs of Sherwood, Figtree Pocket, Graceville, Corinda and Chelmer.

A total of seventy (70) samples were submitted for identification. The reference entomologist reported that **two (2) samples were identified as *S. aurantii***. A report for the Intensive survey conducted during December 2002 is summarised in TABLE 10.

TABLE 10- Intensive Survey (December 2002)						
Category	**Location**	**Suburb**	**Date**	**Properties surveyed**	**Sample taken**	**SACT present**
SURVEY	Jordan Street	Sherwood	5/12/2002	7	5	No
SURVEY	Honour Avenue	Sherwood	13&23/12/2002	5	3	No
SURVEY	Marlborough St	Sherwood	5/12/2002	5	4	No
SURVEY	Berry Street	Sherwood	3/12/2002	11	6	No
SURVEY	Prospect Street	Sherwood	5/12/2002	7	3	No
SURVEY	Magazine Street	Sherwood	2/12/2002	6	3	No
SURVEY	Lilly Street	Sherwood	23/12/2002	1	0	No
SURVEY	Sherwood Arboretum	Sherwood	2/12/2002	1	0	No
SURVEY	Cubberla Street	Fig Tree Pkt	4/12/2002	3	2	No
SURVEY	Ferry Street	Sherwood	2/12/2002	8	0	No
SURVEY	Kinkead Street	Sherwood	4/12/2002	4	2	No
SURVEY	Joseph Street	Sherwood	2/12/2002	2	2	No
SURVEY	Dudley Street	Sherwood	4/12/2002	7	3	No
SURVEY	Dewar Street	Corinda	23/12/2002	3	0	No
SURVEY	Dunella Street	Sherwood	4/12/2002	4	4	Yes
SURVEY	Hazelmere Pde	Sherwood	3/12/2002	9	9	No
SURVEY	Woodbury Street	Sherwood	3/04/2002	1	0	No
SURVEY	Barchester St	Sherwood	5/12/2002	6	3	No
SURVEY	Bentinck Street	Sherwood	6 & 23/12/2002	9	10	Yes
SURVEY	Weinholt Street	Sherwood	6/12/2002	9	5	No
SURVEY	Skew Street	Sherwood	23/12/2002	2	0	No
SURVEY	Long St West,	Chelmer	3&6/12/2002	7	4	No
SURVEY	Bank Street	Graceville	23/12/2002	1	0	No
SURVEY	Wylie Street	Graceville	23/12/2002	2	0	No
Total number of properties inspected	**120**	**Total samples**	**70**	**Number positive**		**2**

10.7 Greater Brisbane Survey

APHS and AFRS staff conducted surveys of a total of seventy-six (76) properties within the cities of Brisbane, Ipswich and Logan and the shires of Redland and Pine Rivers during January and February 2002. Surveys targeted plants of the family Crassulaceae.

A total of thirty-six (36) samples were submitted for identification. The reference entomologist reported that **twenty-eight (28) samples were identified as *S. aurantii***. A report for the Greater Brisbane delimiting survey is summarised in TABLE 11.

TABLE 11- Greater Brisbane Delimiting Survey

Location	Date	Host	Samples taken	SACT present
Barellan Point	12/02/2003	*Bryophyllum delagoense*	1	Yes
Belmont	13/02/2003	*Bryophyllum delagoense*	0	No
Berrinba	12/02/2003	*Bryophyllum delagoense*	1	Yes
Brookfield	24/01/2003	*Bryophyllum delagoense*	1	Yes
Brookfield	24/01/2003	*Bryophyllum delagoense*	1	Yes
Burbank	13/02/2003	*Bryophyllum delagoense*	0	No
Calamvale	13/02/2003	*Bryophyllum delagoense and B hybrid*	0	No
Camp Hill	12/02/2003	*Bryophyllum delagoense*	0	No
Capalaba West	13/02/2003	*Bryophyllum delagoense*	0	No
Chandler	13/02/2003	*Bryophyllum delagoense*	0	No
Chapel Hill	13/02/2003	*Bryophyllum delagoense*	1	Yes
Chelmer	12/02/2003	*Kalanchoe sp.*	0	No
Coorparoo	12/02/2003	*Bryophyllum delagoense*	0	No
Coorparoo	12/02/2003	*Bryophyllum delagoense and B pinnatum*	0	No
Corinda	15/01/2003	*Bryophyllum delagoense*	1	No
Corinda	15/01/2003	*Bryophyllum delagoense*	1	Yes
Everton Park	14/02/2003	*Bryophyllum delagoense*	0	No
Fig Tree Pocket	13/02/2003	*Bryophyllum delagoense*	1	Yes
Fig Tree Pocket	13/02/2003	*Bryophyllum delagoense*	1	Yes
Greenbank	13/02/2003	*Bryophyllum delagoense*	1	Yes
Greenwood	12/02/2003	*Bryophyllum delagoense*	1	No
Holland Park	12/02/2003	*Bryophyllum delagoense & Crassulaceous plant*	0	No
Holland Park West	12/02/2003	*Bryophyllum delagoense*	0	No
Indooroopilly	31/01/2003	*Bryophyllum pinnatum*	1	Yes
Indooroopilly	12/02/2003	*Bryophyllum delagoense*	1	Yes
Indooroopilly	12/02/2003	*Bryophyllum delagoense, B pinnatum and Hybrid*	0	No
Jindalee	17/01/2003	*Bryophyllum delagoense*	1	Yes
Jindalee	13/02/2003	*Bryophyllum delagoense*	0	No
Joyner	14/02/2003	*Bryophyllum delagoense*	0	No
Joyner	14/02/2003	*Bryophyllum delagoense*	0	No
Karalee	12/02/2003	*Bryophyllum delagoense*	1	Yes
Karalee	12/02/2003	*Bryophyllum delagoense*	1	Yes
Karalee	12/02/2003	*Bryophyllum delagoense*	1	Yes
Karana Downs	12/02/2003	*Bryophyllum delagoense*	1	Yes
Kenmore	13/02/2003	*Bryophyllum delagoense*	1	Yes
Keperra	14/02/2003	*Bryophyllum delagoense*	0	No
Larapinta	12/02/2003	*Bryophyllum delagoense*	0	No
Mackenzie	13/02/2003	*Bryophyllum delagoense*	0	No
Moorooka	12/02/2003	*Bryophyllum delagoense*	0	No
Mount Cotton	13/02/2003	*Bryophyllum delagoense*	0	No
Mt Cootha	13/02/2003	*Bryophyllum delagoense*	0	No
Mt Cootha	13/02/2003	*Bryophyllum delagoense*	0	No
Mt Cootha	13/02/2003	*Bryophyllum delagoense*	0	No
Mt Crosby	22/01/2003	*Bryophyllum delagoense*	1	Yes
Mt Crosby	12/02/2003	*Bryophyllum delagoense*	1	Yes
Mt Gravatt	12/02/2003	*Bryophyllum delagoense*	0	No

TABLE 11- Greater Brisbane Delimiting Survey cont.

Location	Date	Host	Samples taken	SACT present
Mt Gravatt	12/02/2003	*Bryophyllum delagoense*	0	No
Mt Gravatt	12/02/2003	*Bryophyllum delagoense*	0	No
Nathan Heights	12/02/2003	*Bryophyllum delagoense*	0	No
Oxley	12/02/2003	*Bryophyllum delagoense*	1	Yes
Oxley	12/02/2003	*Bryophyllum delagoense*	1	Yes
Oxley	12/02/2003	*Bryophyllum delagoense*	1	Yes
Pallara	13/02/2003	*Bryophyllum delagoense*	0	No
Pallara	13/02/2003	*Bryophyllum delagoense*	0	No
Pallara	13/02/2003	*Bryophyllum delagoense*	0	No
Salisbury	12/02/2003	*Bryophyllum delagoense*	0	No
Salisbury	12/02/2003	*Bryophyllum delagoense and B pinnatum*	0	No
Salisbury	12/02/2003	*Bryophyllum delagoense*	0	No
Sheldon	13/02/2003	*Bryophyllum delagoense and B hybrid*	0	No
Sherwood	14/01/2003	*Bryophyllum delagoense*	1	Yes
Sherwood	15/01/2003	*Bryophyllum pinnatum*	1	Yes
Sherwood	15/01/2003	*Bryophyllum delagoense*	1	No
St Lucia	14/02/2003	*Bryophyllum delagoense*	1	Yes
St Lucia	14/02/2003	*Bryophyllum delagoense*	1	Yes
Sumner	13/02/2003	*Bryophyllum delagoense*	1	Yes
Tarragindi	12/02/2003	*Kalanchoe sp.*	0	No
Tarragindi	12/02/2003	*Bryophyllum delagoense and B hybrid*	0	No
The Gap	14/02/2003	*Bryophyllum delagoense*	1	No
Thornlands	13/02/2003	*Bryophyllum delagoense*	1	No
Upper Brookfield	17/01/2003	*Bryophyllum delagoense*	1	No
Upper Mt Gravatt	12/02/2003	*Bryophyllum delagoense*	0	No
Victoria Point	13/02/2003	*Bryophyllum delagoense*	1	No
Wacol	13/02/2003	*Bryophyllum delagoense and B pinnatum*	1	No
Westlake	13/02/2003	*Bryophyllum delagoense*	1	Yes
Yeerongpilly	12/02/2003	*Kalanchoe sp.*	0	No

Total number of sites inspected	**76**	**Total samples**	**36**	**Number positive**	**28**

10.8 Collection and survey summary

The following table details a summary of thrips species sampled from all plants and surveys conducted between March 2002 and February 2003. The reference entomologist reported that **thirty-five (35) samples were identified as *S. aurantii*)**.

TABLE 12- Collection summary	**Positive sites for type per survey type**							
Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**
Andrewarthaia kellyana Bagnall					2			**2**
Anothrips sp.		2		3				**5**
Asprothrips seminigricornis Girault	3	2						**5**
Australothrips bicolor Bagnall			1					**1**
Caliothrips sticatopterus Kobus	1		1	5				**7**
Chaetanaphothrips orchidii Moulton	1							**1**
Dendrothripoides innoxius Karny	1							**1**
Dolichothrips sp.	1							**1**
Emprosthiothrips brimblecombei Mound				2				**2**
Frankliniella occidentalis Pergande					1		1	**2**
Frankliniella schultzei Trybom	33	36	1	2	4			**76**
Halothrips bituberculatus Girault	1							**1**
Halothrips froggatti Hood		1		1				**2**
Halothrips gowdeyi Franklin		5		1				**6**
Heliothrips haemorrhoidalis Bouche	1							**1**
Hydatothrips argenticinctus Girault				1				**1**
Idolothripinae sp.			1					**1**
Microcephalothrips abdominalis Crawford		2			4			**6**
Mycterothrips sp.	1							**1**
Neohydatothrips haydni Girault				1				**1**
Pezothrips kellyanus Bagnall	2	8			2			**12**
PHAEOTHRIPIDAE					4			**4**
Pseudanaphothrips achaetus Bagnall	1	11			4			**16**
Rhamphothrips sp.	4							**4**
Salpingothrips sp.	1							**1**
Scirtothrips albomaculatus Bianchi	7		1					**8**
***Scirtothrips aurantii* Faure**	**2**	**2**	**28**	**3**		**(2)**		**35**
Scirtothrips casuarinae Palmer&Mound	1							**1**
Scirtothrips dorsalis Hood	11							**11**
Scirtothrips helenae Palmer&Mound	1							**1**
Scirtothrips sexmaculatus Pergande			1					**1**
Scirtothrips sp. (not *aurantii*)				1				**1**
Scolothrips sp.	3			1				**4**
Tenothrips fricii Uzel		2	1	1				**4**
Thrips florum Schmultz	1	19						**20**
Thrips hawaiiensis Morgan		17			3			**20**
Thrips imaginis Bagnall		1		3				**4**
Thrips nigropilosus Uzel	2							**2**
Thrips parvispinus Karny	3							**3**
Thrips setipennis Bagnall		3						**3**
Thrips simplex Morison					1			**1**
Thrips sp.		2		1	2		1	**6**
Thrips tabaci Lindemann	1	5	7	7	5	3		**28**

1- Initial Response
2- Intensive Survey (December 2002)
3- Greater Brisbane Survey (Jan/Feb 2003)
4- Traceback Survey
5- Traceforward Survey
6- Sentinel Plant Survey

10.9 Thrips collected and identified from *Citrus sp*.

The following table details a summary of thrips species sampled from citrus between March 2002 and February 2003. **No samples collected from citrus during the survey period contained *S. aurantii***.

TABLE 13-Thrips collected and identified from citrus sp

Type	Location	Date	Survey type	Properties
Pezothrips kellyanus Bagnall	Sherwood	December 2002	Intensive survey	1
Pseudanaphothrips achaetus Bagnall	Sherwood	December 2002	Intensive survey	1
Thrips florum Schmultz	Sherwood	December 2002	Intensive survey	3
Thrips hawaiiensis Morgan	Sherwood	December 2002	Intensive survey	3
Thrips imaginis Bagnall	Sherwood	December 2002	Intensive survey	1
Thrips setipennis Bagnall	Sherwood	December 2002	Intensive survey	1

10.10 South African Citrus Thrips detection summary

The following table details date, location, survey strategy and host data pertaining to detections of *S. aurantii* during the survey period between March 2002 and February 2003.

TABLE 14-Detection timeline

Date	Location	Survey type	Host	Comments
March 2002	AFRS Sherwood	N/A	*B. delagoense*	Detected by DNRM staff
March 2002	Sherwood	Initial response	*K. longiflora*	In close proximity to AFRS
4/12/2002	Dunella St, Sherwood	Intensive survey	*B. delagoense*	Detected on sentinel plant station
5/12/2002	Bentinck St, Sherwood	Intensive survey	*B. Pinnatum*	And on sentinel plant 7/2/2003
14/01/2003	Jolimont St, Sherwood	GBA survey	*B. delagoense*	Targeted survey on Crassulaceae
15/01/2003	Dunella St, Sherwood	GBA survey	*B. pinnatum*	Targeted survey on Crassulaceae
15/01/2003	Augustus St, Corinda	GBA survey	*B. hybrid*	Targeted survey on Crassulaceae
17/01/2003	Jindalee	GBA survey	*B. delagoense*	Sampled during sentinel plant monitoring
17/01/2003	Brookfield	Traceback	*B. delagoense*	Plant collection site. AFRS
17/01.2003	Brookfield	Traceback	*B. delagoense*	Plant collection site. AFRS
17& 23/01/2003	Mt Crosby	GBA survey	*B. delagoense*	Sampled during sentinel plant monitoring
24/01/2003	Upper Brookfield	GBA survey	*B. hybrid*	Community report
24/01/2003	Brookfield	GBA survey	*B. hybrid*	Opportunistic sampling
24/01/2003	Brookfield	GBA survey	*B. delagoense*	Opportunistic sampling
31/01/2003	Indooroopilly	GBA survey	*B. pinnatum*	Opportunistic sampling. AFRS
7/2/2003	Laidley	Traceback	*B. delagoense*	Plant collection site. AFRS
12/02/2003	Indooroopilly	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Mt Crosby	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Karana Downs	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Barellan Point	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Oxley	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Karalee	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Oxley	GBA survey	*B. delagoense*	Structured survey
12/02/2003	Karalee	GBA survey	*B. delagoense* & hybrid	Structured survey
12/02/2003	Karalee	GBA survey	*B. hybrid*	Structured survey
12/02/2003	Greenbank	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Berrinba	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Kenmore	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Sumner	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Chapel Hill	GBA survey	*B. delagoense*	Structured survey
13/02/2003	West Lake	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Fig Tree Pocket	GBA survey	*B. delagoense*	Structured survey
13/02/2003	Fig Tree Pocket	GBA survey	*B. delagoense*	Structured survey
14/02/2003	St Lucia	GBA survey	*B. delagoense* &*B. pinnatum*	Structured survey
14/02/2003	St Lucia	GBA survey	*B. delagoense*	Structured survey

11 CONCLUSION

In excess of 700 site inspections for *S. aurantii* were conducted from March 2002 to February 2003. Surveys were conducted in two stages, with the first stage to December 2002 charged with determining if the initial eradication attempt at AFRS had been successful. No detections of *S. aurantii* occurred during the winter and spring months, however it was found in December 2002 near the AFRS facility in Sherwood.

This provided the impetus to conduct a second survey stage in January and February 2003 to delimit the extent of the infestation.

As shown in the attached map (ATTACHMENT 1), 35 infested sites have been located within the City of Brisbane, the City of Logan, the City of Ipswich and the Shire of Laidley. Affected suburbs include **Barellan Point, Berrinba, Brookfield, Chapel Hill, Corinda, Fig Tree Pocket, Greenbank, Indooroopilly, Jindalee, Karalee, Karana Downs, Kenmore, Laidley, Mt Crosby, Oxley, Sherwood, Sumner, St Lucia, Upper Brookfield and Westlake.**

All detections were on plants in the family Crassulaceae, including mother of millions *Bryophyllum delagoense* (syn *B. tubiflorum*), *B. pinnatum*, *B. daigremontianum* x *B. tubiflorum* and *Kalanchoe longiflora*. Mother of millions was the most commonly infested.

S. aurantii appears to be well established in the southwest Brisbane area, with some suburbs extensively and heavily infested, suggesting that this thrips may have been present in the area for several years.

12 REFERENCES

Gilbert, MJ & Bedford, ECG. 1998. *Citrus Thrips Scirtothrips aurantii Faure*. In Bedford, ECG; Van der Berg, MA & de Villiers, EA. *Citrus Pests in the Republic of South Africa.* (2nd Edition). Institute for Tropical and Subtropical crops.

13 SUPPLEMENTARY DOCUMENTS

SURVEY PROCEDURE FOR INSPECTION AND SAMPLING OF PLANTS OF THE FAMILY CRASSULACEAE FOR SOUTH AFRICAN CITRUS THRIPS- *Scirtothrips aurantii* Faure. Queensland Department of Primary Industries. Issue 2. January 2003.

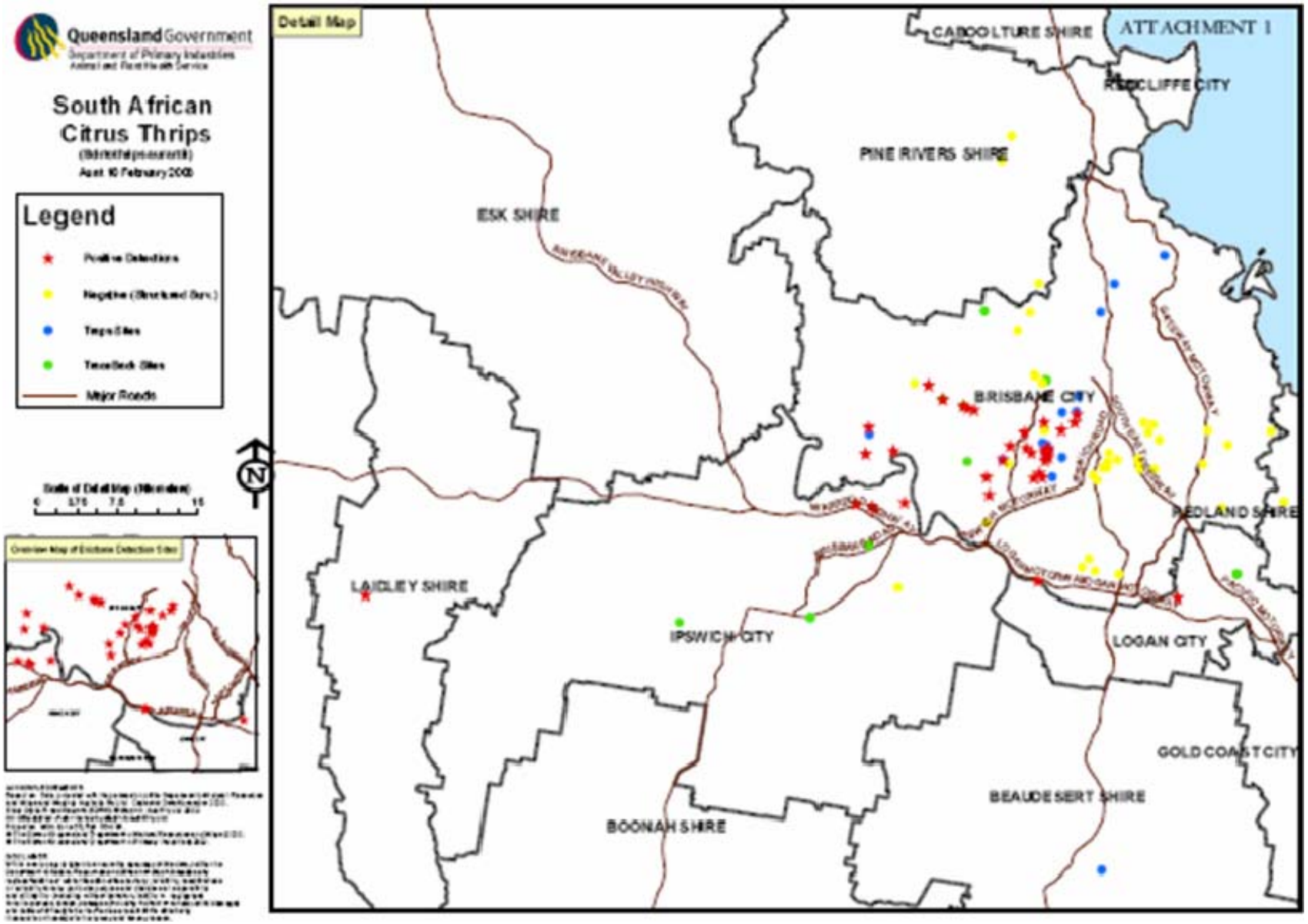
14 ACKNOWLEDGEMENTS

The assistance of collaborators in AFRS and CSIRO is acknowledged.

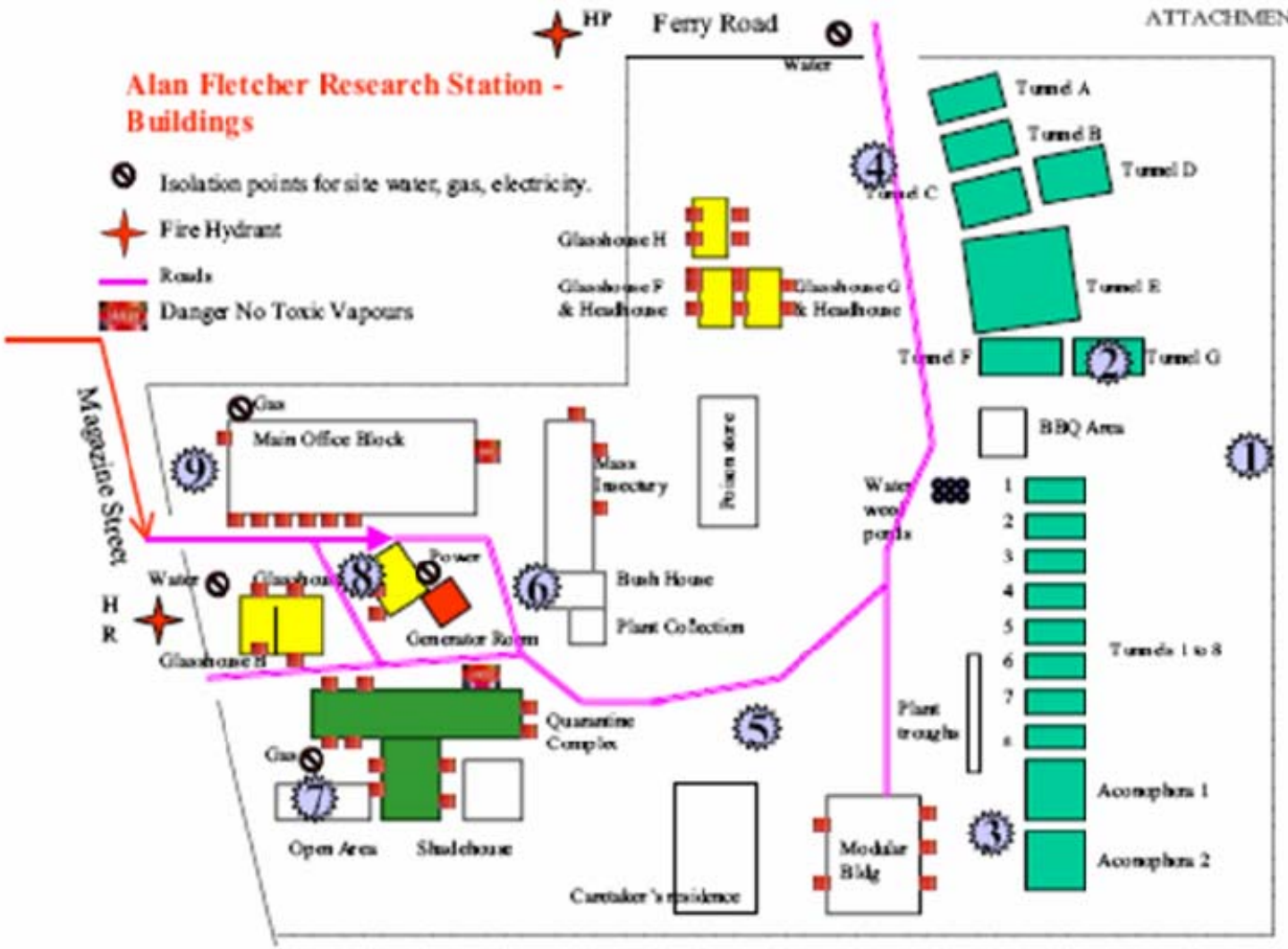
15 ATTACHMENTS

ATTACHMENT 1 - South African citrus thrips survey and detection map
ATTACHMENT 2 - AFRS Site map
ATTACHMENT 3 - AFRS quarantine facility
ATTACHMENT 4 - DPI Note

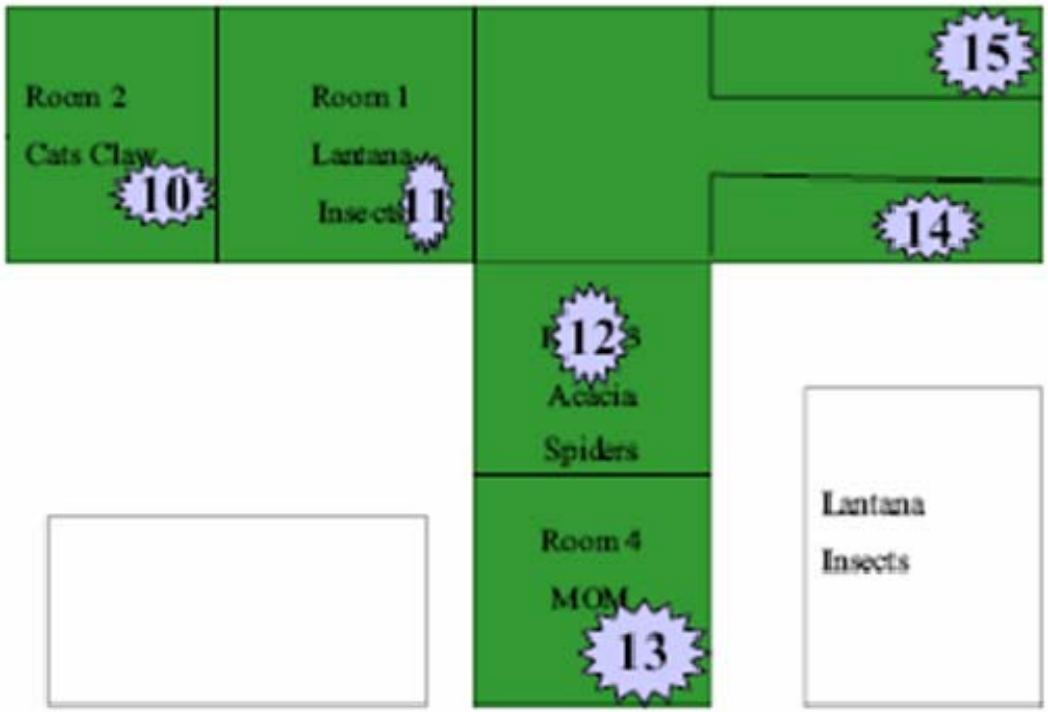
NB: ATTACHMENTS 5-9 not included in this report


Queensland Government
Department of Primary Industries
Animal and Plant Health Service
South African
Citrus Thrips
(Scirtothrips aurantii)
Alert 10 February 2003
Legend
Positive Detections
Negative (Structured Surv.)
Target Sites
Trace Back Sites
Major Roads
Detail Map
CABOOLTURE SHIRE
ATTACHMENT 1
REDCLIFFE CITY
PINE RIVERS SHIRE
ESK SHIRE
BRISBANE CITY
REDLAND SHIRE
LAIDLEY SHIRE
IPSWICH CITY
LOGAN CITY
GOLD COAST CITY
BEAUDESERT SHIRE
BOONAH SHIRE
N

ATTACHMENT 2



Quarantine Area



Agdex 622

Queensland Government
Department of Primary Industries

DPI Notes

South African citrus thrips

Animal and Plant Health Service, Brisbane

What is it?

Fig 1 Magnified larvae and single adult of South African citrus thrips

Fig 2 Mother of millions plant, a common host of South African citrus thrips

Ackrowledgment: figure 1 courtesy of Citrus Research International, South Africa.

South African citrus thrips (*Scirtothrips aurantii* Faure) (SACT) was detected at Sherwood in Brisbane in March 2002, feeding on mother of millions, a succulent weed belonging to the family Crassulaceae. This was the first record of this thrips in Australia.

To date, SACT has only been found on these weeds and has not been recorded on fruiting crops such as citrus. There is some speculation that the biotype of SACT that occurs in Australia is slightly different from the overseas pest biotype and that it could have a preference for feeding on Crassulaceae weeds. Researchers are investigating this possibility and will compare DNA analyses of SACT from Brisbane and South Africa.

Since the first detection of SACT, an intensive surveillance program has found it over a relatively wide area of southwest Brisbane, indicating that the pest is well established.

Overseas information shows that SACT feeds on a wide variety of ornamental and fruit crops, but is known to be particularly damaging to citrus. On citrus, SACT feeds on fruit and young leaves causing leaf drop and fruit distortion, leading to a reduction in marketable yield. It is widespread in Africa and has also been detected in Yemen, Mauritius, Reunion and Cape Verde. It is an important pest in low altitude dry parts of South Africa and Zimbabwe. Significant parts of Queensland and interstate would most likely contain suitable habitats for its establishment.

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What does it look like?

South African citrus thrips adults are tiny (less than 1mm) pale yellow-orange insects (see Figure 1). On citrus they prefer to feed in young growing tips and on young fruit. Brown scarring on the surface of fruit, leaves or stems could indicate their presence. The tips of injured leaves often curl or roll inward around the midrib like a rat's tail, forming a groove in which the insect feeds. Heavily infested leaves may be stunted in growth and deformed. Damage on citrus fruit is characterised by a ring of brown scarring on the stem end. Young shoots may turn black and fall off.

SACT can build up to damaging levels during prolonged periods of hot, dry conditions, but will become scarce after periods of heavy rainfall and/or cool weather.

How does it spread?

Like other thrips, SACT can easily spread to other locations on wind currents, infested plant material and on almost any surface they come into contact with, including clothing. As SACT requires access to soft green tissues; nymphs and adults are normally found only on seedlings or cuttings with young growing leaf buds. Similarly mature harvested fruits are unlikely to carry SACT, because it only attacks immature fruit.

What has been done about it so far?

After SACT was detected on mother of millions and related plants in the vicinity of the Queensland Department of Natural Resources and Mines' (NR&M), Alan Fletcher Research Station at Sherwood in Brisbane, the area was quarantined and infested plants were destroyed. An initial survey in and around the station as well as on other at-risk properties did not find any more evidence of SACT, raising the possibility that the population had been eradicated.

Further surveillance over the winter months found no more evidence of SACT, however surveys conducted in late 2002 and early 2003 detected SACT on more properties in Brisbane.

What will happen now?

DPI in cooperation with NR&M will attempt to further delimit the outbreak by conducting surveillance for SACT in Brisbane and other parts of Queensland. Other states and territories will also conduct surveys to determine if the pest is present. Surveillance will target the succulent weed hosts in the Crassulaceae family, such as mother of millions. Further action will depend on the outcome of the surveys.

Further information

If you would like further information or think that you may have seen South African citrus thrips, contact your nearest DPI plant health inspector or the **DPI Call Centre** on **13 25 23** (free call for Queensland residents; 8 a.m. to 6 p.m. weekdays) for advice on what to do next. Non-Queensland residents: phone 07 3404 6999. E-mail the DPI Call Centre: callweb@dpi.qld.gov.au. DPI Internet site: www.dpi.qld.gov.au. ■

SOUTH AFRICAN CITRUS THRIPS SURVEY FOR QUEENSLAND SUNSHINE COAST SURVEY SUPPLEMENT 1A - MARCH 2003.

Pest Survey Report for: South African Citrus Thrips- *Scirtothrips aurantii* (Faure)

Commodity: Plants of the family Crassulaceae.

Survey area:

Eumundi	**Maroochydore**
Nambour	**Woombye**
Mapleton	**Yandina**

Survey date: March 2003

Survey conducted by: Chris Freebairn - Entomologist (QHI)
Dan Smith - Senior Principal Entomologist (QHI)

Mapping services: John Arrowsmith - Corporate support (APHS)

Compiled by: Chris Freebairn - Entomologist (QHI)
Grant Telford - State Coordinator (Plant Health Surveillance)

ABBREVIATIONS AND DEFINITIONS

DPI - Queensland Department of Primary Industries
APHS - Animal and Plant Health Service (Queensland Department of Primary Industries)
QHI - Queensland Horticulture Institute (Queensland Department of Primary Industries)
AFRS - Alan Fletcher Research Station (Department of Natural Resources and Mines)
CCEPP - Consultative Committee on Exotic Plant Pests

1 INTRODUCTION

This report details additional surveillance activities in the Sunshine Coast district conducted by Queensland Horticulture Institute staff of the Queensland Department of Primary Industries (DPI) for the exotic insect, South African citrus thrips, *Scirtothrips aurantii* Faure during March 2003.

S. aurantii was detected at Sherwood in Brisbane in March 2002. This was the first record of this insect in Australia. Overseas, this thrips feeds on a wide variety of ornamental and fruit crops, but is particularly damaging to citrus. It is widespread in Africa and has also been detected in Yemen, Mauritius, Reunion and Cape Verde. In Australia, *S. aurantii* has not been found on citrus or any other fruiting crops, and has been detected only on succulents in the family Crassulaceae, such as mother of millions.

Entomologists speculate that the Australian biotype of *S. aurantii* may have a preference for succulent weeds of this family. This hypothesis is currently being investigated.

2 SUMMARY FINDINGS

Surveys of twenty-four (24) sites (TABLE 1 Section 0) within the Sunshine Coast district were conducted by QHI staff during March 2003.

Thrips were detected in samples from two sites within the survey district. **Both samples were negative for *Scirtothrips aurantii* Faure.**

Host plants surveyed were *Bryophyllum delagoense, B. pinnatum and the hybrid, B daigremontianum X B tubiflorum.*

3 BACKGROUND

S. aurantii was detected during March 2002 on 'mother of millions' plants AFRS at Sherwood in Brisbane. This was the first detection in Australia of this economic pest of citrus and other plants.

CCEPP met to review the response to the outbreak during April 2002 and recommended that intensive surveillance be maintained in areas within close proximity of AFRS for a further six months to determine if the initial eradication attempt was successful. This surveillance program included the inspection of sentinel mother of millions plants and the completion of traceback and traceforward investigations, as well as an intensive December survey of high-risk sites.

From March 2002 to January 2003, DPI conducted over 650 property inspections for *S. aurantii* at locations that posed a risk of thrips transfer from AFRS. No *S. aurantii* was found during the winter period, but the pest was detected during the intensive December survey at Sherwood and subsequently was located in other suburbs in southwest Brisbane.

Following these detections, the CCEPP reconvened in January 2003 and recommended that a delimiting survey be conducted for *S. aurantii* in southeast Queensland and other States. This was to include the inspection of at least 50 sites in the greater Brisbane area. This survey found *S. aurantii* at an additional twenty-eight (28) of the seventy-six (76) sites inspected.

Staff from the Queensland Horticulture Institute based at the Maroochy Research Station also agreed to perform a survey of sites within the Sunshine Coast District. The survey was completed during March 2003. This report outlines findings of the Sunshine Coast survey.

4 VARIATION TO METHOD

Sampling technique

Survey staff used an alternative sampling procedure during the Sunshine Coast survey. Due to wet conditions the 'beating technique' was replaced by the following procedure.

Heads were removed from approximately six plants per site. Vegetative material was placed into a baking dish then sprayed liberally with alcohol. The liquid was then poured into a collecting tube in preparation for further examination.

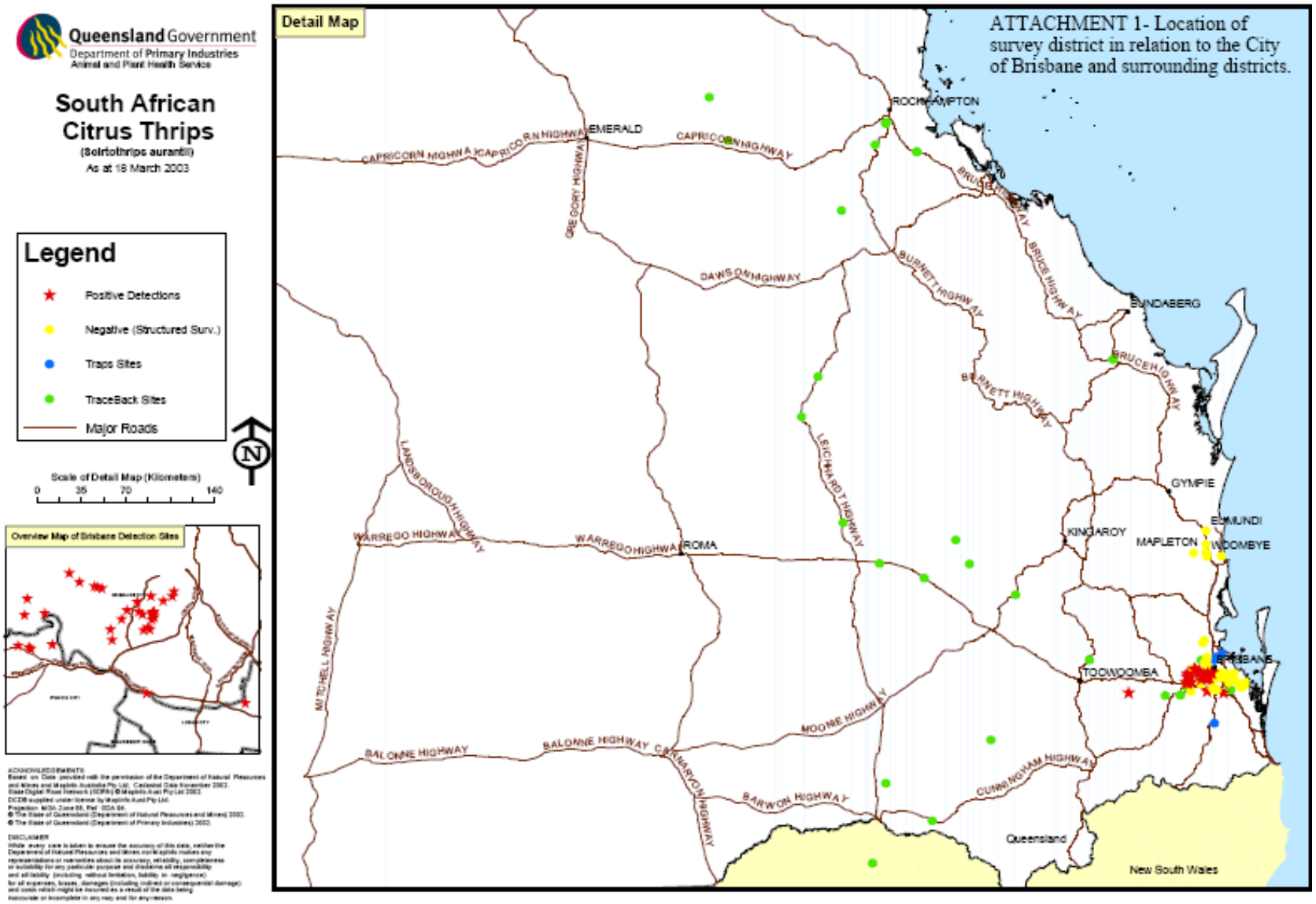
5 RESULTS

QHI staff based at the Maroochy Research Station in Nambour conducted surveys of a total of twenty-four (24) properties within the Sunshine Coast district during March 2003. Surveys targeted plants of the family Crassulaceae.

A total of two (2) samples containing thrips were identified. **The reference entomologist reported that nil (0) thrips were identified as *S. aurantii***. A report for the Sunshine Coast survey is summarised in TABLE 1. A map identifying the location of the survey district is included as ATTACHMENT 1.

TABLE 1- SUNSHINE COAST SURVEY RESULTS MARCH 2003

Site	Date	Location	Plant species	Thrips	*S. aurantii*
1	7.3.03	Cnr Mayer's & Burnside Rds, Nambour	*Bryophyllum pinnatum*	Yes	No
2	7.3.03	Cnr Glenys St & Perwillowen Rd, Nambour	*Bryophyllum delagoense*	Yes	No
3	7.3.03	Top of Carter Rd, Nambour	*B. delagoense*	None	No
4	7.3.03	Cnr Ghost Gum Ave/Jones Rd, Maroochydore	*B. pinnatum*	None	No
5	7.3.03	Jones Rd, Maroochydore (100m nth of site 4)	*B. delagoense*	None	No
6	7.3.03	Cooloolabin Rd, west of Yandina.	*B. daigremontianum* x *B. tubiflorum*	None	No
7	7.3.03	Mapleton Rd, Mapleton	*B. pinnatum*	None	No
8	7.3.03	Mapleton Rd, Mapleton	*B. delagoense*	None	No
9	7.3.03	Blackall Range Rd, Woombye	*B. delagoense*	None	No
10	7.3.03	Cnr Blackall Range & McKenzie Rds, Nambour	*B. daigremontianum* x *B. tubiflorum*	None	No
11	7.3.03	Panorama Drv, Nambour	*B. delagoense*	None	No
12	7.3.03	Petrie Ck Rd, Nambour	*B daigremontianum* x *B. tubiflorum*	None	No
13	7.3.03	Coronation Ave, Nambour (Opposite badminton hall)	*B. delagoense*	None	No
14	7.3.03	Netherton St, Nambour	*B. delagoense*	None	No
15	7.3.03	Hospital Rd, Nambour	*B. pinnatum*	None	No
16	8.3.03	Eumundi-Kenilworth Rd	*B. delagoense*	None	No
17	8.3.03	Baloo St, Nambour	*B. pinnatum*	None	No
18	8.3.03	Cnr Bushbird Ct & Didillibah Rd, Nambour	*B. daigremontianum* x *B. tubiflorum*	None	No
19	8.3.03	Blackall Range Rd, Nambour	*B. delagoense*	None	No
20	8.3.03	Cobb's Rd, Nambour	*B. delagoense*	None	No
21	8.3.03	Diddillibah Rd, Nambour	*B. delagoense*	None	No
22	9.3.03	Erbacher Rd, Nambour	*B. delagoense*	None	No
23	9.3.03	Perwillowen Rd, Nambour	*B. delagoense*	None	No
24	9.3.03	Perwillowen Rd, Nambour	*B. delagoense*	None	No


Queensland Government
Department of Primary Industries
Animal and Plant Health Service
South African Citrus Thrips
(Soirtothrips aurantii)
As at 18 March 2003
Legend
Positive Detections
Negative (Structured Surv.)
Trap Sites
TraceBack Sites
Major Roads
Scale of Detail Map (Kilometers)
0 35 70 140
Overview Map of Brisbane Detection Sites
Detail Map
ATTACHMENT 1- Location of survey district in relation to the City of Brisbane and surrounding districts.
ROCKHAMPTON
EMERALD
CAPRICORN HIGHWAY
GREGORY HIGHWAY
DAWSON HIGHWAY
BURNETT HIGHWAY
BRUCE HIGHWAY
BUNDABERG
GYMPIE
LEICHHARDT HIGHWAY
LANDSBOROUGH HIGHWAY
WARREGO HIGHWAY
ROMA
KINGAROY
MAPLETON
NOOMBYE
TOOWOOMBA
BRISBANE
MITCHELL HIGHWAY
MOONIE HIGHWAY
BALONNE HIGHWAY
CARNARVON HIGHWAY
BARWON HIGHWAY
CUNNINGHAM HIGHWAY
Queensland
New South Wales