Revegetation at property scale - designing the 'right' biodiversity for sustainable vegetable production

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South Australia Research & Development Institute (SARDI)

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South Australian Research and Development Institute
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SARDI
SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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Cover photograph: *Ceranisus* sp. ♂

Statement of purpose of report:
This report details the research and extension undertaken in Project VG06014 on Revegetation at property scale – designing the 'right biodiversity for sustainable vegetable production. Main findings, industry implications and recommendations to industry along with suggested areas of future research are discussed

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Media Summary

On the Northern Adelaide Plains (NAP), pest thrips transmit tomato spotted wilt virus (TSWV) resulting in crop production losses of approximately $25M p.a. Thrips control is heavily reliant on chemical use, which is expensive and biologically unsustainable. Research to determine how beneficial and pest insects interact with native vegetation near crops, will guide native plant selection which can be used to manipulate the horticultural environment to reduce pests, augment natural enemy populations and/or replace current pest management systems

Invertebrates associated with crops and native vegetation were sampled and classified. Their temporal and spatial association with plants and each other were analysed in field and laboratory-based trials to gain an insight into key interactions.

Key findings confirm that judicious placement of select endemic plant species near horticultural facilities has potential for positively impacting on pest management and is likely to be more effective than traditional bare-earth buffers.

A new parasitic wasp (*Ceranisus* sp.) was identified that has been shown to efficiently parasitise western flower thrips (WFT) in culture. This wasp is closely associated with the saltbush *Rhagodia parabolica* and may also use native thrips species as an alternative host. We have also identified a *Telenomus* sp. wasp sampled from native vegetation that parasitises the well known pest *Nysius vinitor*, the Rutherglen bug. These wasps are likely candidates for delivering biological control of both of these wide spread pests. Breeding of a lacewing generalist predator *Micromus tasmaniae* is shown to be associated with a native grass, *Austrodanthonia linkii*, suggesting this will be key species for manipulating *M. tasmaniae* populations at property scale. Indications are that different endemic plant species will become important for different crops to enhance/suppress particular beneficial/pest species. Growers investing in native plant refuges to enhance natural enemy populations should see this as a marketing opportunity rather than simply another expense.

At property scale, select native plants used in the context of best practice Integrated Pest Management systems, can contribute to suppression of western flower thrips and subsequent reduction of TSWV is possible. Feedback from growers on the NAP indicates that the benefits of native vegetation are well understood. Therefore grower acceptance of these principles has increased with time, however large-scale adoption remains the key to positioning the industry to achieve significant benefits. Growers must be willing to be proactive in increasing the level of integration of non chemical controls. Reduced efficacy and tolerance of chemical use for pest control will have long term consequences industry wide. In the current economic climate, integrating new technologies that increase agricultural sustainability by reducing losses generated by pests, disease and pesticide use are urgently required for the industry to move forward.

Technical Summary

The horticultural production area on the Northern Adelaide Plains (NAP) is the largest source of fresh vegetables in South Australia. Here a suite of pest thrips including western flower thrips (WFT; *Frankliniella occidentalis*) transmit tomato spotted wilt virus (TSWV) resulting in crop production losses of approximately $25M p.a. Thrips control is heavily reliant on chemical use, which is expensive and biologically unsustainable. Research was conducted to determine how beneficial and pest insects interact with native vegetation that is planted near crops, and use this knowledge to manipulate their populations to augment and/or replace current pest-management systems. Such an approach would have economic/sustainability benefits and a range of additional benefits such as increasing native biodiversity in degraded landscapes (potentially facilitating involvement of NRM groups in assisting horticulturalists) and improved regional public amenity.

We sampled and classified insects over several years in attempts to understand key relationships and dynamics of movement and breeding. We compared the insects found on the same plant species at the various sites over time and also the relationship between key insect species on these plants. Additionally we attempted to utilise laboratory-based techniques to develop a screening system to predict which plant species have leaves that are of low risk in supporting thrips.

In simple terms, we tried to answer two broad questions:

- (i) can we identify native plant species that will not support thrips reproduction ?
- (ii) can we identify new insects (including *Ceranisus menes,* a thrips parasitoid) with potential for biological control of WFT/crop pests and their association with native vegetation ?

Key findings confirm that judicious placement of select endemic plant species near horticultural facilities has potential for positively impacting on pest management and is likely to be more effective than traditional bare-earth buffers.

Specifically, we have improved on traditional methods for culturing thrips which has allowed development of a laboratory-based screening system that could be adapted for a range of purposes, including predicting plants with foliage that has low risk of supporting pests. Indications are that different endemic plant species will become important for different crops to enhance/suppress particular beneficial/pest species. The thrips screening system showed that leaves were able to support thrips larval emergence and development, and that this varies with plant species and condition.

A new parasitic wasp (*Ceranisus* sp.) was identified that has been shown to efficiently parasitise western flower thips (WFT) in culture. This wasp is closely associated with the saltbush *Rhagodia parabolica* and may also use native thrips species as an alternative host. We have also identified a *Telenomus* sp. wasp sampled from native vegetation that parasitises the well known pest *Nysius vinitor,* the Rutherglen bug. These wasps are likely candidates for delivering biological control of both of these wide spread pests. In addition, breeding of a lacewing generalist predator *Micromus tasmaniae* is shown to be associated with a native grass, *Austrodanthonia linkii* suggesting this will be key species for manipulating *M. tasmaniae* populations at property scale. All knowledge was extended through open days, demonstrations, various media, educational institutions, scientific fora, and internet and we have had our technical publications adopted by primary, secondary and tertiary institutions.

We recently produced two useful guidebooks to extend our findings to growers and scientists, and this received a range of media coverage. Our internet site has been updated with much new information and is being increasingly utilised.

Feedback from growers indicates that the benefits of native vegetation are quite well understood but that only low numbers think that more native vegetation should be planted. This largely reflects the need for grower-independent or grant-supported delivery vehicles (such as NRM bodies, research funders, government rebates), which is a key challenge for policy makers in government and industry. Further research is also needed refine the methodology. Growers must also be willing to increase their level of integration of non-chemical controls as reduced efficacy and acceptance of chemical controls will have long-term consequences industry wide. These consequences can only be mitigated through technologies which delay chemical resistance (through reduced use) and prior integration of multiple pest management approaches. This should be seen by growers as a marketing opportunity rather than simply another expense. We have attracted further funding to address both of these key issues in coming years, by drawing together increased NRM and biosecurity inputs to the research.

Project information sessions and technical publications, about how to use native vegetation in a horticultural production context to reduce thrips and increase beneficial insects, have provided the industry with information about ‘additional/complementary IPM strategies’. A target for the end of the project was to position the industry to achieve production efficiencies such as a 15 - 25% reduction of pesticide use, and a similar reduction in crop loss due to Tomato Spotted Wilt Virus.

Growers can potentially achieve these targets at property scale. The key to achieving improved management of western flower thrips will be adoption. However, indications are that grower-funded adoption of select native vegetation to replace weeds and/or bare earth is likely to be a relatively slow process. At this stage many growers express interest but appear reluctant to input their own time and money to plan and invest in this complementary IPM strategy.

Local councils and NRM revegetation providers have also recognised the value of the research and have supported commercial producers by significantly increasing the biodiversity using the native plant species highlighted in the project revegetation recommendations (see Adoption in Ch 10). Indeed, NRM (eg AMLR NRM board) and Biosecurity groups (eg CRC National Plant Biosecurity) have been the greatest supporters of our approach as evidenced by their supply of significant in-kind support (including extensive revegetation) for a new round of revegetation research, funded by HAL. This will address some of the issues associated with slow grower adoption in the region.

In a landscape sense, the use of established native revegetation refuges as an IPM strategy by growers to suppress pests and provide beneficial insects is minimal thus far. However, as the level of plantings by growers, councils and NRM projects increases, we expect there to be a positive effect on regional biodiversity in this seriously degraded area.

1. Introduction

Horticulturalists on the Northern Adelaide Plain (NAP) continue to experience serious crop losses due to Tomato Spotted Wilt Virus (TSWV). A key source of TWSV and the pest thrips including western flower thrips (WFT; *Frankliniella occidentalis*) which transmit the virus are exotic weeds which infest land around horticultural production facilities in the region (Wilding *et al*. 1993, Moerkerk & Barnett 1998). In addition, the NAP has a degraded natural landscape and there is a serious lack of commercial incentives to improve biodiversity in the area. By 1889 exotic weeds had infested parts of the NAP and remaining woodlands in the Angle Vale and Virginia areas were cleared for market gardens after World War I (Kreahenbuehl 1996).

Previous research, including a previous HAL project (HG 02103), has shown that TSWV-vectoring thrips are rare on a range of native broadleaf plants and grasses. In addition, a number of potentially beneficial arthropods were present on native plants established on the NAP (Wood & Schellhorn 2004). Here we build on these findings by examining how key insect species interact with native plants and nearby crops, in attempts to understand how we can manipulate the environment at a property scale, to suppress/enhance specific insect species. As part of this project we established native revegetation plots near several horticultural production facilties on the NAP. The major site was at a commercial lettuce production property (HITECH) with two other sites on properties nearby i.e. Virginia Horticulture Centre Greenhouse Modernisation Project (GMP) and at the property of a commercial tomato producer (THIEN).

Our primary aims and objectives were to:

- replace weeds that harbour pests and diseases by conducting native revegetation plantings of 'best-bet' plants adjacent to horticultural properties on the NAP.
- develop laboratory-based WFT culture and screening system to assess ability of different plant leaves to support pest thrips.
- investigate the presence and abundance of *Ceranisus menes* (thrips parasitoid) associated with native vegetation on the NAP.
- identify any new insects with potential for biological control of WFT/crop pests and their association with native vegetation.
- evaluate insect movement in these revegetated areas and adjacent crops, using Tasman's lacewing (*Micromus tasmaniae*) as a model.
- develop guidelines for use of native revegetation for improved sustainability of pest-management in horticulture on the NAP.
- extend any new knowledge to industry, government and researchers.

We conducted extensive sampling of invertebrates associated with crops and native vegetation using mechanical vacuum, yellow sticky traps and pitfall traps. Invertebrates were classified and their temporal and spatial association with plants and each other were analysed to gain an insight into key interactions.

The ability of plant leaves to support thrips is not well characterised. We applied a novel method using Lebanese cucumbers as a medium to rear insects and to test their development under a range of conditions. These techniques were applied to the development of a thrips screening assay and assessment of insect biology (e.g. parasitoid-host interactions).

The following chapters contain detailed background information, experimental methodology, presentation of data and results, discussion of implications and suggestions for further research. We also summarise technology transfer and list key references.

This report contains the data and findings generated by a project aimed at improving sustainability of intensive horticultural production systems, on the NAP. The report will be of use to growers, industry policy makers, scientists and natural resource managers.

2. A novel screening system to select native plants that are unsuitable for WFT reproduction

Introduction

In Australian cropping systems, using existing mixed suites of endemic plants to promote natural enemies has been the focus of much recent research. However, there is little information describing the associations between individual endemic plant taxa and invertebrate pest guilds. On the Northern Adelaide Plains (NAP), exotic weeds pose a genuine threat to production as they harbour exotic pest thrips and the crop diseases they vector, most importantly, Tomato Spotted Wilt Virus (Wijkamp *et al.* 1995). Currently, creating a bare earth buffer around crops is the standard cultural management strategy for reducing pest thrips incursion into crops. Using perennial, deep-rooted endemic vegetation to replace these ephemeral weeds may provide a more sustainable and long term alternative to this approach. Recent research has indicated that while pest thrips are abundant on weeds on the NAP, they are rare on endemic vegetation (Taverner & Wood 2006, Taverner *et al*. 2006, Wood *et al.* under review).

Previous laboratory studies have demonstrated pest thrips can oviposit into, and pupate on, crop plants such as capsicum (Maris *et al.* 2004). However, thrips ability to survive and reproduce on leaves of plant species indigenous to the NAP, have not been compared. In addition, there is currently no way to predict the suitability of foliage in supporting thrips reproduction, apart from field sampling for thrips larvae and assessing the relatedness of the plant against known thrips hosts.

Therefore, our aim was to develop a lab-based screening approach to select low-risk native plants which could be planted to reduce Western flower thrips (WFT: *Frankliniella occidentalis*) near horticultural crops. In this study, we looked at plants from several endemic genera that are representative of the flora in the area and have physical characteristics that make them suitable to be grown as refuges around horticultural crops on the NAP. If it could be shown in a lab-based test that thrips cannot reproduce on leaves of certain plant species, these species may then be assessed as having low pest thrips risk. Such plants could then potentially be recommended for revegetation to produce plant refuges that inhibit thrips populations. Such a system would be particularly advantageous for assessing plant species for which there are no existing data (especially for plants that may be utilised for an additional income as well as revegetation).

To this end, we developed agar-based ‘arenas’ which contained WFT and plant leaves to be tested. The arenas were designed to allow easy handling/scoring of thrips, whilst maintaining leaf material in a fresh state. Adult female thrips in prime egg laying condition, were exposed to a range of endemic plant leaves (one species of plant per arena) to determine which plants’ leaves inhibited WFT reproduction.

We investigated 16 native plant species from six plant families and attempted to provide answers to the following questions:

1. What is the potential of foliage from our representative range of native plants to support reproduction of WFT?
2. For those native plant species that supported WFT reproduction on their leaves, will the leaves also support thrips development from egg through to viable (reproductive) adults?

3. Does the maturity of the leaves that supported larval emergence, influence the level of WFT larval production?

~~**Materials and Methods**~~

~~*Arena preparation*~~

~~Arenas were prepared using plastic 55mm petri-dishes containing 6ml 1% agar solution (AGAR 800 powder; ACE Chemical Company) in RO water, and allowed to set uncovered in a laminar flow cabinet. Leaves of the plant species to be assayed were sterilised in a 400ppm sodium hypochlorite solution for 3 minutes and then placed on sterile paper towel to dry within the laminar flow cabinet. Leaves were selected primarily for size suitable for the arena and general healthy, undamaged appearance from endemic plants growing in containers or established in-ground (Table 2.1).~~

~~**Table 2.1. Plant family, plant species and source of experimental plants. All plants except capsicums were grown and kept at the Waite Precinct. Experiments were conducted April – August 2007. 'Age at experiment' refers to age at start of experimental period.**~~

~~**Plant Family**~~	~~**Species**~~	~~**Age at experiment**~~	~~**Source**~~
~~Solanaceae~~	~~*Capsicum* sp. var. Raptor~~	~~4 weeks~~	~~Purchased from commercial outlet~~
~~Chenopodiaceae~~	~~*Rhagodia parabolica*~~	~~1 year~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Rhagodia deltaphylla*~~	~~Mature plants (>1year)~~	~~Grown in the ground~~
~~Chenopodiaceae~~	~~*Atriplex semibaccata*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Atriplex cinerea*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Atriplex paludosa*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Atriplex suberecta*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Enchylaena tomentosa*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Einadia nutans*~~	~~< 6 months~~	~~Grown in pots~~
~~Chenopodiaceae~~	~~*Maireana brevifolia*~~	~~< 6 months~~	~~Grown in pots~~
~~Myrtaceae~~	~~*Kunzea pomifera*~~	~~>1 year~~	~~Grown in pots~~
~~Mimosaceae~~	~~*Acacia iteaphylla*~~	~~Young trees (<2 years)~~	~~Grown in the ground~~
~~Mimosaceae~~	~~*Acacia baileyana*~~	~~Mature tree (>6 years)~~	~~Grown in the ground~~
~~Myrtaceae~~	~~*Eucalyptus tetragona*~~	~~Mature trees (>6 years)~~	~~Grown in the ground~~
~~Myoporaceae~~	~~*Myoporum* sp.~~	~~Mature plants (>2 years)~~	~~Grown in the ground~~
~~Rutaceae~~	~~*Correa alba*~~	~~Mature plants (>4 years)~~	~~Grown in the ground~~
~~Leguminoseae~~	~~*Hardenbergia violacae*~~	~~Mature plants (>1 year)~~	~~Grown in the ground~~

~~Once dry, leaves were placed into the arenas with the topside of the leaves pressed lightly into the agar gel (Fig. 2.1a). Leaves were positioned to cover as much of the agar surface as possible without overlapping. The agar ensured that leaves remained turgid for the length of the experiment and also provided high humidity in the arena, for the thrips.~~

4. An evaluation of native plant surveys for thrips parasitoids and pest thrips in the Virginia horticulture area, 2003-2005

Introduction

In recent years there has been a greater focus on natural enemies of thrips as a result of the increased resistance to insecticides and expanded geographic distribution of some key pest species (Parker *et al.* 1995, Loomans 2003). Pest thrips, particularly the key pest western flower thrips (WFT; *Frankliniella occidentalis*) (Pergande) first recorded in Australia by Malipatil *et al*. (1993), are of considerable concern on the Northern Adelaide Plains (NAP). The main concern with exotic pest thrips is their ability to transmit crop viruses such as Tomato Spotted Wilt Virus (TSWV) which devastates infected crops and causes huge production losses. Current management practices rely on the use of in-crop insecticide to kill thrips, and herbicide to remove weeds from around crops (creating a bare-earth buffer), as exotic weeds are known to host thrips and TSWV. This heavy reliance on chemicals means that resistance issues constantly threaten to reduce efficacy and increase costs of treatments, repeated applications (and associated costs) are required and a range of potentially useful insects/plants are removed from the production system; over the long term, such an approach is unsustainable. For these reasons, increasing efforts are being directed towards identifying potential biological control agents that will attack pest thrips. Successful biological controls would provide a degree of ongoing pest control and reduce reliance on chemical controls. These are preferable since they would increase the biological and economic sustainability of the vegetable industry and in addition may have wider environmental benefits in comparison to other methods (Loomans & van Lenteren 1995).

Biocontrol agents such as predatory and parasitic insects are regarded as one of the main factors regulating population dynamics of phytophagous insects in natural systems, and have therefore been investigated as key insects to biological control in primary production systems. Because of their inherent specificity, parasitic wasps have been widely applied to biological control of agricultural pests (LaSalle & Guald 1993). However, most agricultural crops do not have sufficient resources to maintain high levels of beneficial insects (Schellhorn *et al.* 2000). Therefore the establishment and maintenance of more suitable habitat on-farm (or in the surrounding landscape) could potentially enhance the survival of exotic and endemic parasitoid wasps, and thus improve biological control of pest species (Gurr *et al.* 2004). This approach is widely known as conservation biological control. Non-crop vegetation could provide parasitoids with over-wintering sites, refuge from disturbance such as crop harvesting, adult food sources such as nectar, and access to alternative hosts, and can result in the build-up of parasitoid populations over time (Schellhorn *et al.* 2000, Tscharntke 2000). With the right choice of vegetation, it would be possible to elevate levels of key beneficial insects above “natural” levels. This would require remnant vegetation to be preserved and/or specific non-crop plants (both exotic and native) to be grown adjacent to agricultural production.

Given this background, research was undertaken to investigate associations between key parasitic wasps and plants that are endemic to the NAP horticultural region. Endemic plants were the main focus of the investigation since they are adapted to local conditions (reducing potential management requirements once placed into production systems) and are likely to support a wide range of native (potentially beneficial) insects, compared to exotic plant species.

Thrips parasitoids and biocontrol

In the field, beneficial insects such as parasitoid wasps that attack thrips eggs (e.g., *Megaphragma* spp.; Mymaridae) and larvae (e.g. *Ceranisus* spp.; Eulophidae) generally inflict low levels of mortality (Morse & Hoddle 2006). These parasitoids tend to be specific at the subfamily level, but can be specific to genus or species (Loomans & van Lenteren 1995).

Currently, there are no parasitoid wasps commercially utilised to control pest thrips. Rather, augmentative releases are made against pest thrips using predatory mites (*Amblyseius* spp.), pirate bugs (*Orius* spp.) and occasionally the nematode *Steinernema* sp. (van Lenteren *et al.* 1997). Biological control of thrips pests using parasitoid wasps has been tried but without great success, the exceptions being *Thripobius similuteus* (Eulophidae) for control of greenhouse thrips (*Heliothrips haemorrhoidalis*) in New Zealand and California (McMurtry & Badii 1991, Froud *et al.* 1996), and *Ceranisus femoratus* for the control of cowpea thrips (*Megalurothrips sjostedti*) (Neuenschwander & Markham 2001). *T. similuteus* does occur in Australia but is less common than *Ceranisus menes* (Steiner & Goodwin 1998, Loomans *et al.* 2006), a known parasitoid of WFT. Releases of laboratory raised parasitoids (*C. menes* and/or *C. americensis*) in commercial and experimental greenhouses in Europe were disappointing and provided minimal control under the tested conditions (Loomans *et al.* 2006).

Known hymenopteran parasitoids of thrips all belong to the superfamily, Chalcidoidea (see Boucek, 1988; Naumann, 1991). Most are solitary endoparasitoids of eggs (e.g. Trichogrammatidae, Mymaridae) or larvae (e.g. Eulophidae) (Gibson 1993; Loomans 2003). Egg parasitoids are only known from thrips laying their eggs inside the plant tissue. The most common thrips egg parasitoids, *Megaphragma* spp., are among the smallest known insects, most of them measuring between 0.2-0.3 mm (Loomans 2003). Their minute size (and that of their hosts) has greatly hampered collection and research of this group; many species await discovery and host records are poor. So far, *Megaphragma* species are only known from tropical and subtropical regions (see references in Loomans 2003). Field parasitism rates for *Megaphragma mymaripenne* in California can exceed 50% (Hessein & McMurtry 1988).

All known thrips larval and pupal parasitoids occur in the family Eulophidae. Except for several species in the subfamily Tetrastichinae (*Thripastichus* spp.), all others can be found in five closely related genera currently placed within the subfamily Entedontinae, i.e. *Ceranisus*, *Goetheana*, *Thripobius, Pediobius* and *Entedonastichus* (Loomans & van Lenteren 1995). They are all minute (0.5 to 1.1mm), solitary endoparasitoids of thrips larvae, prepupae and/or pupae. In 2003, 27 species had been described (Loomans 2003).

The most common thrips parasitoid: *Ceranisus menes*

Recently the genus *Ceranisus* has been revised and currently contains 14 species, of which three are found in Australia (Triapitsyn 2005). In contrast to most thrips parasitoids, *C. menes* is cosmopolitan, appears to have a wide host range and has been recorded from over 20 thrips in two subfamilies (Thripinae and Pancheothripinae). Its hosts include key pests such as *Frankliniella* spp. and *Thrips* spp. and therefore, *C. menes* has been previously investigated as a potential biological control agent.

Explorations in various regions in the world have shown that *C. menes* is the predominant parasitoid attacking pest thrips (Tamo 1991, Hirose *et al.* 1993, Loomans *et al*. 2006). Occasionally, natural parasitism levels by *C. menes* are quite high on vegetative plant structures in the field. In Japan, on onions infested by *Thrips tabaci*, parasitism levels by *C.*

menes reached as high as 79% and showed a clear positive density dependent response (Loomans & van Lenteren 1995). A high level of natural parasitism (40-60%) by *C. menes* of *Thrips palmi*, infesting leaves of eggplant, was mesured in Thailand and Japan (Loomans & van Lenteren 1995). Explorations in Australia on WFT and related thrips hosts also showed that *C. menes* was the most common parasitoid attacking pest thrips (Steiner & Goodwin 1998). However, knowledge of the biology of *C. menes* in Australia, including level of parasitism, is poor.

Adult female *C. menes* can lay 20-30 eggs per day, but may lay less eggs depending on temperature and host species (Murai & Loomans 1995). Longevity at 20-25°C is 10-20 days (Murai & Loomans 1995).

C. menes in Europe, North and South America has populations composed entirely of females. In several Asian countries and Australia (British Museum of Natural History collection) sexual populations predominate in field collected material, but non-sexual populations are present as well (Loomans *et al*. 2006). *C. menes* can also kill thrips by host feeding (Loomans 2003); after insertion of the ovipositor, adult wasps may feed on the exuding host fluids.

This chapter relates to data from two surveys of potential biocontrol agents occurring in the highly modified agricultural landscape of the Virginia horticultural area (NAP), that were previously conducted by our group in order to identify potential thrips parasitoids. Study A was conducted over spring 2003-summer 2004 (Stephens *et al* 2006), and Study B on three dates in mid spring-early summer 2005 (Taverner & Wood 2006). During these surveys, a thrips larval parasitoid, *Ceranisus* sp., has been repeatedly found in invertebrate samples collected from plants by mechanical vacuum. The wasp was subsequently identified as *C. menes* by Dr John LaSalle, ANIC, CSIRO Entomology), the most commonly recorded parasitoid of pest thrips in Australia.

Data from Study A were analysed to determine when *Ceranisus* sp. amongst other potential biocontrol parasitoids were present and their plant/thrips host associations. The rationale for this was to understand the role of non-crop vegetation in affecting the abundance and distribution of *Ceranisus* sp. and potential thrips hosts, on the NAP. We also analysed samples from Study B at a site in Virginia (Taverner & Wood, 2006) to further confirm the previous plant-host associations and evaluate associations between the *Ceranisus* sp. wasp and each of the four individual pest thrips on the NAP: WFT, *F. schultzei* (tomato thrips), *Thrips tabaci* (onion thrips) and *T. imaginis* (native plague thrips).

~~Materials and Methods~~

~~Study area~~

~~*Study A (2003-4)*~~

~~A survey by Stephens *et al.* (2006) in 2003-4 examined invertebrate populations on a range of native plants and exotic weeds from several sites on the NAP. Here we examine data from two sites that were situated in the Virginia horticulture area and evaluated during this study. The area surrounding these sites supports diverse horticultural production as open or covered crops (eg. potatoes, carrots, cauliflower, onions, celery, tomatoes, capsicums, lettuce, asian bunch-line crops, lemongrass, cucumbers, olives and grapes). The first site contained native plants that were established adjacent to greenhouses of the Virginia Horticulture Centre Greenhouse Modernisation Project (GMP; Fig. 4.1). The second site, the Playford Seed~~

5. Survey of endemic native saltbush refuges for native parasitoids of exotic pest thrips on the Northern Adelaide Plains

Introduction

Western flower thrips, *Frankliniella occidentalis* (WFT), were first identified in Australia in 1993 (Malipatil *et al.* 1993) and are now well established in the Virginia horticulture region of South Australia. Here they transmit the Tomato Spotted Wilt Virus (TSWV) which causes regional crop losses in the vicinity of $20 million p.a. Current management strategies involve the use of pesticides within crops and/or a bare earth buffer surrounding crops (as weeds are known to harbour TSWV and WFT). Insecticide resistance and regionally high densities of problem weeds means that significant region-wide control of WFT/TSWV remains elusive. Therefore, both of the current control measures require significant ongoing time and money and have limited effectiveness.

An Australia-wide survey to identify native natural enemies of WFT produced an inventory of invertebrates with potential for biocontrol that included the common thrips parasitoid wasp, *Ceranisus menes* (Hymenoptera: Eulophidae) (Goodwin & Steiner 1996). *C. menes* was subsequently collected in Queensland and a small laboratory colony was reared on *Frankliniella schultzei* (Tomato thrips) as a host (Steiner & Goodwin 1998). In the northern hemisphere, the potential for *Ceranisus* spp. as biocontrol agents of WFT has also been investigated. Loomans *et al.* (2006) evaluated two *Ceranisus* species that were released into closed ornamental horticulture crops. These experiments were unsuccessful in showing significant thrips control, largely because parasitoids were unable to maintain sufficient populations under the conditions tested.

For parasitoid wasps to persist in the environment, the host population needs to be of consistent and sufficient density, and reasonably stable over time. In addition to host availability, a pesticide-free habitat, providing shelter and food resources, is an important requirement.

Shaw (2006) suggested that plant species composition influences the presence of specialist parasitoids of oligophagous herbivorous hosts and of less specialised wasps that use a range of hosts. Adult parasitoid wasps do not require large amounts of protein in their diet; sugars are their major nutrient source. Refugia that can provide sugar through sources such as nectar, honeydew and/or host haemolymph (blood), can mean a longer and more productive life for individual parasitoids, and higher fecundity at the population level. The architecture of plants within the habitat may also be important, for providing optimal shelter in terms of protection and environmental conditions (e.g. sufficient humidity is important for preventing the dessication of small parasitoids in hot/dry environments).

The presence of *C. menes* in the study site (Virginia horticulture region of the NAP) was investigated by Stephens *et al*. (2006), who sampled remnant native vegetation and found the parasitoid on isolated saltbush plants (or small plots of single saltbush species) in an area with minimal remaining biodiversity. It is intuitive that increasing the size of associated endemic vegetation patches may provide increased and sustained resources for *C. menes*. This could in turn increase the regional parasitoid populations and increase the level of “free” thrips control provided the wasp. Here we examine the potential of several saltbush species endemic to the

NAP for their potential to host *C. menes* and provide biological control of pest thrips, such as WFT, tomato and onion thrips (all vectors of TSWV).

~~Materials and Methods~~

~~Survey/Collection~~

~~Parasitic wasps and soil/litter samples, were collected from experimental endemic plant refuges in the horticulture area of Virginia (34°40.074'S 138°33.545'E), NAP, South Australia (Table 5.1). Sampling was conducted at two sites:~~

1) ~~Playford seed orchard (PSO), Womma Road~~
2) ~~Hi Tech Hydroponic Lettuce (HITECH), Old Port Wakefield Road~~

~~Table 5.1. Collection of thrips parasitoids, *Ceranisus* sp. (Hymenoptera: Eulophidae) at two localities from saltbushes, *Rhagodia parabolica*, *Atriplex semibaccata* and *Enchylaena tomentosa* between December 2007 and March 2008~~

~~Date~~	~~Location~~	~~No. samples~~	~~Females~~	~~Males~~	~~Total Parasitoids~~	~~Parasitoids/ sample~~
~~11/12/2007~~	~~PSO~~	~~11~~	~~6~~	~~7~~	~~13~~	~~1.2~~
~~14/12/2007~~	~~PSO~~	~~10~~	~~30~~	~~0~~	~~30~~	~~3.0~~
~~14/12/2007~~	~~HITECH~~	~~6~~	~~170~~	~~14~~	~~184~~	~~30.7~~
~~7/01/2008~~	~~HITECH~~	~~12~~	~~53~~	~~25~~	~~78~~	~~6.5~~
~~22/01/2008~~	~~HITECH~~	~~10~~	~~200~~	~~200~~	~~400~~	~~40.0~~
~~27/02/2008~~	~~HITECH~~	~~12~~	~~28~~	~~32~~	~~60~~	~~5.0~~
~~25/03/2008~~	~~HITECH~~	~~10~~	~~7~~	~~1~~	~~8~~	~~0.8~~
~~28/03/2008~~	~~HITECH~~	~~5~~	~~1~~	~~0~~	~~1~~	~~0.2~~
~~Totals~~		**~~76~~**	**~~495~~**	**~~279~~**	**~~774~~**	~~Mean 10.2~~

~~In this area, mean maximum summer temperature is 29.2°C and mean minimum winter temperature is 6.4°C. The area has a winter-dominated rainfall pattern with a mean annual rainfall of 428 mm (Bureau of Meteorology, SA, Edinburgh RAF Base: 34°71'S 138°62'E, years 1972-2008).~~

~~Samples were taken from three saltbush species (*Rhagodia parabolica*, *Atriplex semibaccata* and *Enchylaena tomentosa*) between December 2007 and March 2008. Invertebrates were collected into a purpose designed voile sleeve using a petrol-powered mechanical vacuum device (Makita RBL 250; see Fig. 5.1a). All vacuum samples were taken for 30 seconds. While in the field, samples were emptied into fine gauge voile sleeves that permitted only thrips and "micro wasps" to exit, and placed into emergence boxes (Décor® Tellfresh Superstorer 8.5L) sealed with clingwrap (Fig. 5.1b). Emergence boxes were provisioned with water and honey (applied to the silk windows of the box), and chilled to maximise survival during the travel back to the laboratory. In the laboratory, wasps were collected individually from within emergence boxes.~~

6. Association of pest thrips and a thrips parasitoid (*Ceranisus* nr *menes*) with native revegetation sites in the Virginia horticultural region in 2007-2008.

Introduction

We previously discussed the confirmation of the presence of a parasitoid wasp (*Ceranisus* nr *menes*) of western flower thrips (WFT) in the horticultural region of the Northern Adelaide Plains (NAP) and developed a method for culturing the wasp (see Chapter 5). We also found that there were several biological differences between our study wasp and the known WFT parasitoid (*C. menes*) and that these differences were reflected in the DNA sequences of the wasps.

Here we present data derived from mechanical vacuum sampling, comparing the abundance and distribution of our study wasp over time, on two saltbushes and a grass. We performed the sampling at three experimental native revegetation plots in the region, allowing for site comparisons. We also compare the dynamics of wasp populations with that of the four regional pest thrips species.

~~Materials and Methods~~

~~Sampling~~

~~To determine whether trends in abundance and diversity of pest thrips and the *Ceranisus* sp. parasitoid are consistent on a given plant species, we have evaluated two native saltbushes (*Rhagodia parabolica* and *Enchylaena tomentosa*) and a native grass (*Austrodanthonia linkii*). Sampling was undertaken at commercial properties at Virginia (34°40.074'S 138°33.545'E) on the NAP between March 2007 and April 2008. The properties were all greater than a kilometre apart and located within the horticulture production area. Three properties with well established native plants were sampled: HITECH (hydroponic lettuce in semi-enclosed netting), GMP (greenhouse tomatoes plus field root crops) and THIEN (greenhouse tomatoes). At the THIEN site, *A. linkii* was overtaken by exotic grasses in late spring and therefore only sampled for part of the year when it was dominant (monthly from April to September). Three transects per native plant species were sampled monthly. Transects were 2m long and insects were collected into a purpose designed voile sleeve using a petrol vacuum suction device (Makita RBL 250). Each sample comprised 20 seconds of suction.~~

~~Samples were placed directly into plastic containers and returned to the laboratory where they were placed in frozen storage until sorting. Each sample was sorted and the thrips parasitoid *Ceranisus* nr *menes* and four pest thrips were recorded, i.e. WFT (*Frankliniella occidentalis*), tomato thrips (*F. schultzei*), onion thrips (*Thrips tabaci*), which all vector Tomato Spotted Wilt Virus, and the native plague thrips (*T. imaginis*).~~

~~Statistical analyses~~

~~Statistical analyses were conducted to detect significant associations between populations of individual thrips species (and total thrips numbers) and their associated location and/or plant taxon. As these associated data did not meet the conditions for stringent factorial ANOVA comparing three factors (*plant species, location* and *season*) data were analysed with three, two-factorial Kruskal Wallis Tests with 'Scheirer-Ray-Extension' using SPSS (Version 15.0,~~

7. Preliminary results on parasitism of the Rutherglen bug (*Nysius vinitor*: Lygaeidae) by a native parasitoid wasp (*Telenomus* sp: Telenominae) on the Northern Adelaide Plains.

Introduction

The native Rutherglen bug (*Nysius vinitor)* has been recognised as a pest of a range of crops such as sunflower, potatoes, tomatoes, grapes and peaches since early in the last century (French 1918). The species is now also considered a major problem in Australian canola crops (Gu *et al*. 2007) where they can reach plague proportions, damaging stems of young plants and compromising seed production through feeding. *N. vinitor* are not known to vector viral plant diseases and are not considered to be a key insect pest in the Northern Adelaide Plains (NAP) horticultural region. However, they are abundant during the major cropping periods of the region and cause significant problems in terms of vegetable damage and contamination especially to the lettuce industry. In addition, their wide distribution, potentially high abundance and the range of crops they attack, means they are a multi-industry pest across sub-tropical and temperate regions of Australia.

Cultural strategies such as removing weeds from around crops may provide some protection as *N. vinitor* will utilise weeds as a food source or refuge, they can disperse rapidly by flying, and all stages of the bugs will move between weeds and crops (Ramesh 1984) especially when weeds senesce. Chemical management of *N. vinitor* tends to be relatively ineffective because incursions of adults are difficult to predict and eggs that have been deposited in seed crops (such as sunflower) are not usually treated until adults begin to appear. In addition, chemical control generally has deleterious side-effects on predatory insects and/or specific biological control agents of other pests, and induction of resistance in target pests.

Prior to this study, there were no candidate insects being investigated for biological control of *N. vinitor*. The only previous literature related to parasitism of *N. vinitor* that we are aware of, reported on rates of parasitism by a tachinid fly (*Alophora lepidofera*) on exotic plants in NSW (Attia 1973). Interestingly, the parasitism level of field-collected male bugs was only 2%, while that of females was 48%. This fly has apparently never been investigated as a biological control agent or was apparently inefficient as we can find no other record of it in relation to the bug. Indeed, the same author subsequently only published work on effectiveness of pesticides against the bug (Attia 1974).

Data from our previous surveys on the NAP (Stephens *et al.* 2006) suggested that there were a number of wasps with potential as parasitoids of crop pests. On further investigation in the current study, we discovered that an abundant wasp (*Telenomus* sp: Telenominae) on the NAP, parasitises eggs of *N. vinitor* and probably other Hemiptera. Here we present the evidence for this interaction, which was first identified in experimental native revegetation plots adjacent to enclosed lettuce production facilities.

~~Materials and methods~~

~~Field sampling of Rutherglen bug~~

~~*Nysius vinitor* adults were sampled from native saltbushes, *Rhagodia parabolica, Enchylaena tomentosa* and *Atriplex semibaccata* (Chenopodiaceae) at sites in Virginia (34°40.074'S~~

8. Temporal and spatial association of the brown lacewing, *Micromus tasmaniae,* with endemic saltbush plantings

Introduction

The brown lacewings (*Micromus tasmaniae,* Tasman's lacewing; Fig. 8.1) (Neuroptera: Hemerobiidae) are generally regarded as being beneficial in cropping systems due to the predatory habits of the adults and larvae, which are thought to primarily target aphids (Duelli 2001). Over the previous decade, several studies have begun to assess the potential of *M. tasmaniae* (and a few other native lacewings) as biological control agents in southern Australia (New 2002; Horne *et al.* 2001). Our previous research on the Northern Adelaide Plains (NAP) showed that (apart from supporting only low pest thrips numbers) endemic saltbush species could potentially offer additional support for integrated pest management programs by providing refuge for endemic predatory insects such as *M. tasmaniae* (Taverner & Wood 2006).

a)

c)

b)

Fig. 8.1. Life stages of the Tasman's lacewing (*Micromus tasmaniae*). (a) larva on *E. tomentosa* (b) pupa within silk cocoon on *R. parabolica* (c) adult.

While there is some data relating to the movement of *M. tasmaniae* in crops, particularly grains, it is unclear to what extent *M. tasmaniae* will survive and reproduce on the prey (and other resources) associated with native plants. Additionally, while it is known that predatory insects (including *M. tasmaniae*) will actively search for patches of prey, there is little information about associations between *M. tasmaniae*, endemic insects utilised as prey, and individual native plant species. A better understanding of whether lacewings are associating with particular endemic plants over others (and whether this is prey-related) will enable informed decisions to be made regarding plant selection for refuges adjacent to crops.

In this study, we further examined the temporal and spatial association of *M. tasmaniae* with two saltbush species, in an experimental revegetation site adjacent to hydroponic lettuce production facilities on the NAP. We attempted to assess *M. tasmaniae* numbers across the same transects (occurring in bare earth, saltbushes and crops), over two consecutive years. We applied three different sampling methods to ascertain when the lacewing population peak occurs and if this peak is driven through on-site breeding or migration. As part of this study, we also attempted to examine the effect of reducing the saltbush-associated invertebrates (through insecticide application) on subsequent lacewing numbers.

~~Materials and Methods~~

~~Study site and sampling period~~

~~Sampling was conducted on a well established, experimental native plant refuge growing adjacent to a commercial lettuce enterprise partially enclosed by shade cloth at Virginia (34°40.074'S 138°33.545'E) on the NAP, in South Australia. The refuge consisted of a row of *Rhagodia parabolica* and two parallel rows of *Enchylaena tomentosa* with foliage that completely covered an area of 700m^2. Sampling was conducted fortnightly in spring/summer in two consecutive years (2007-08), from the beginning of September to the end of December using three different methods (see below). Invertebrates from all three sampling methods were identified to the highest level possible given available expertise and literature.~~

~~Vacuum sampling~~

~~A mechanical vacuum sampler (Dvac) was used to capture a 'snapshot' of both flying and sedentary (juvenile and/or wingless) invertebrates on each of the two saltbush species. Six 2m-long sections were vacuum sampled for 20s along the length of the row of each plant (and/or treatment), on each sampling date.~~

~~Sticky traps~~

~~Yellow sticky traps were placed equally along a grid consisting of four 100m long parallel transects. Transects occurred within the lettuce crop, outside of the shade-house against a row of *R. parabolica*, down the centre of two rows of *E. tomentosa*, and 15m away on the other side of a bitumen road in a bare earth buffer (Fig. 8.2). Six traps were placed along each transect. The traps were exposed for 2-3 days fortnightly over spring and summer, and monthly in autumn. The rate of arrival of pest and beneficial insects (including *M. tasmaniae*) was calculated as the number of individuals arriving on a given trap, per day exposure.~~

~~Within both years' sampling periods (2007-08), preliminary sampling was conducted on two dates in September prior to spraying one half of the experimental site with insecticide. On 2nd October 2007 and 10th October 2008, the western 50m half of each native plant transect was sprayed with a natural pyrethroid-based insecticide (13g/L Pyrethrins; 50g/L Piperonil Butoxide; Kendon Chemical & Manufacturing Co. Pty Ltd Australia) with a 24 hour withholding period, to non-specifically remove invertebrates (Fig. 8.3). To evaluate pre-insecticide invertebrate abundance and diversity, sticky traps were placed in the 4 transects for three days and then removed immediately prior to early morning (9.00am) spraying. At dusk on the spray date, a new set of sticky traps was presented.~~

9. Seasonal variation of native lacewings on select native plants growing adjacent to horticulture on the Northern Adelaide Plains

Introduction

It is thought that reservoirs of lacewing populations adjacent to crops may provide additional pest management options for horticulturalists, as they are potentially predatory on a range of crop pests. However there is very little information about their native host-plant associations, particularly in relation to seasonal variation adjacent to horticulture. The brown lacewing *Micromus tasmaniae* (Tasman's lacewing) (Neuroptera: Hemerobiidae) is considered indigenous in New Zealand and long established in Australia (Wise 1995) where it is abundant and widely distributed, occurring in all states including Tasmania (New 1997 & 2002). The green lacewing, *Mallada signata* (Neuroptera: Chrysopidae) is common, though not abundant, across eastern and southern Australia (Horne *et al.* 2001, New 2002).

A previous survey of invertebrates on endemic plants on the Northern Adelaide Plains (NAP) identified a number of potentially beneficial arthropods during spring and early summer, including *M. tasmaniae* and to a lesser extent, green lacewings (Taverner & Wood 2006; Table 9.1). To better understand the seasonal relationship of lacewings to native plants in vegetation refuges at various sites on the NAP, we selected those plant species that had supported the highest *M. tasmaniae* numbers in 2005, for further investigation. These species, two saltbushes (*Rhagodia parabolica* and *Enchylaena tomentosa*) and a grass (*Austrodanthonia linkii*), were used to establish property scale refuges adjacent to vegetable crops on commercial properties, at three different sites on the NAP.

Table 9.1. Average number of larval and adult *M. tasmaniae* on five native plant species sampled by mechanical vacuum, at the Greenhouse Modernisation Project in spring 2005 (From Taverner & Wood 2006).

Plant species	Mean # *M. tasmaniae* per sample
Austrodanthonia linkii	14.7
Enneapogon nigricans	7.7
Themeda triandra	6.3
Chloris truncata	2.7
Rhagodia parabolica	2.7

These native plant refuges were then surveyed to determine how the following parameters varied over time, between plant species and site:

1) relative abundance of *M. tasmaniae* and green lacewings over time.
2) relationship of thrips and other potential prey, to lacewing density.

~~Materials and Methods~~

~~Sampling and Classification~~

~~Sampling was undertaken at three commercial properties at Virginia (34°40.074'S 138°33.545'E) on the NAP, between March 2007 and April 2008. The properties were all located within the main horticultural production area and were separated from each other by~~

10. Technology transfer

Information days held in the Virginia horticulture area

Information transfer was directed towards growers, industry workers, educators and students (including apprentices in the horticulture industry through to secondary/tertiary students). Workshops and open days were well attended and contained practical information about pest management and using native vegetation to improve the resilience of cropping systems.

National lettuce IPM Meeting April 2008.
A presentation of research findings was delivered at the Revegetation by Design research and education site situated at Hi-Tech Hydroponics on Old Port Wakefield Road (Fig. 10.1). The presentation was attended by Dr Sandra MacDougal (PIRSA Rural Solutions), growers, communicators and Horticulture Industry consultants/providers. Growers had the opportunity to discuss their needs and gained first hand information on 'best bet' native plants on site, with personalised advice for growing their own native vegetation refuges.

Research Round-Up Field Day November 2008.
Research outcomes were presented to growers, researchers and industry stakeholders in a presentation titled 'Revegetation for Pest Management'. The field day was co-ordinated by Craig Feutrill (Vegetable Industry Development Officer) and included demonstration of revegetation concepts, irrigation and soil management to a broad group of growers.

Fig. 10.1. 'Revegetation for Pest Management' was the theme for the November 2008 Research Round-Up Field Day at the Hi-Tech lettuce production property owned by Dino Mussolino.

Field day and book launch April 2009

The final field day and book launch was held at the Greenhouse Modernisation Project site in conjunction with the Adelaide & Mt. Lofty Ranges Natural Resources Management Board, PIRSA Rural Solutions and other SARDI researchers. The event showcased research findings using several types of interactive display. Visitors were able to see pest and natural enemy insects under a microscope and observe several different methods of collecting insects. In a ministerial brief, the state Minister for Agriculture, Food and Fisheries, Paul Caica, recognised the project as an ‘important step forward’ and the event was well covered by local and state media, including Channel 7 Adelaide evening news. The SARDI research plant trial plots were also on display which allowed growers to observe the native plants that have been evaluated in this project and discuss their options for revegetation on their own properties (Fig. 10.2).

Fig. 10.2. SARDI book launch field day on 24 April 2009; Greenhouse Modernisation Demonstration Site, Virginia. Clockwise from top left: Glenys Wood (Principal Investigator) discusses plant selection with collaborator and grower, Dino Mussolino; and showing the insect guide to local grower Doc Thach; Dr Richard Glatz (Project Leader) launching the SARDI guides at the field day; and Helen DeGraaf (Horticultural Entomologist) discussing insect pests and natural enemies with grower Vince Ruggiero.

Two SARDI technical publications were launched. The *SARDI Entomology Guide to using native plants on the Northern Adelaide Plains to benefit horticulture* (see Fig. 10.3) was produced in response to the most frequently asked questions by growers about how to plant their own native plant refuges.

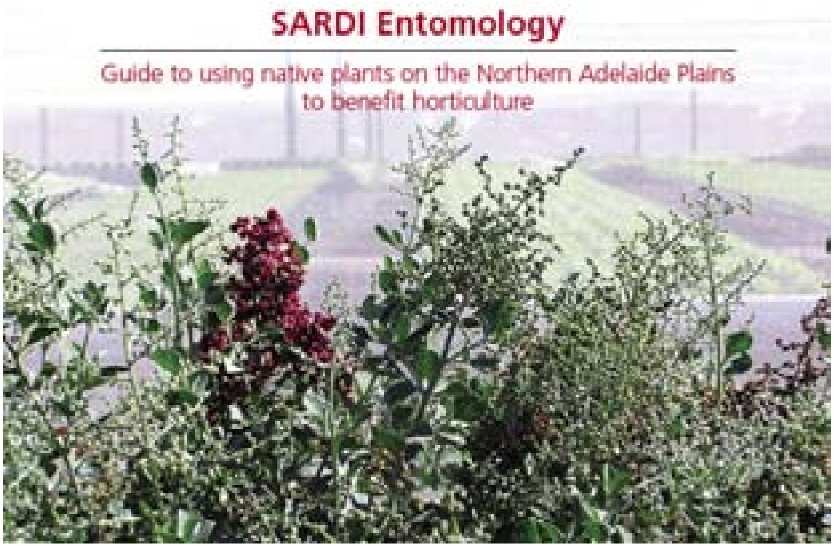

Fig. 10.3. The 'SARDI Entomology Guide to using native plants on the Northern Adelaide Plains to benefit horticulture' is a practical step-wise guide for selection and planting of native plant refuges.

Fig. 10.4. The 'SARDI Entomology Guide to the insects on the Northern Adelaide Plains' is a visual guide to insects found on vegetation native to the Northern Adelaide Plains.

The *SARDI Entomology Guide to the insects on the Northern Adelaide Plains* (Fig. 10.4) is a visual guide to insects that were frequently found on the regional native vegetation and contained information about identifying the insects and about how they impact on horticultural production systems. This publication is designed as a starting point for scientists, growers and natural resources managers who wish to identify and understand the biology of insects they find on their native plants. This unique guide has been disseminated to a range of groups performing research on sustainable systems, including Dept of Environment and Heritage (DEH), Dept. Water, Land and Biodiversity Conservation (DWLBC) and Dept. Primary Industries and Resources SA (PIRSA). The guide is primarily aimed at the NAP horticulture region but has much broader application.

Information days held at the Waite Precinct

Several groups participated in workshops/tours at the Waite Campus research facility that demonstrated analysis and interpretation of field samples and an overview of the science behind the research findings.

SARDI celebrates science November 2006.
More than 5,500 people attended the inaugural Waite Festival, taking advantage of the invitation to meet SARDI and Adelaide University researchers to better understand how scientific research influences the taste and quality of the foods we eat every day. The Revegetation at the Property Scale project was featured, with large posters showing native re-vegetation near horticulture at Virginia. The display was very popular, especially the microscopes where the public could look at examples of crop pests and beneficial insects found on native plants. Collaborators supporting the event include the South Australian Research & Development Institute, The University of Adelaide, Department of Further Education, Employment Science and Technology, CSIRO, Australian Centre for Plant Functional Genomics and the Australian Wine Research Institute.

Information session GREENCORPS October 2006.
A demonstration and tour of the facilities involved with this project was conducted at the SARDI Entomology Unit as part of our participation in training the group in native plant conservation on the Northern Adelaide Plains.

Information session December 2006.
Mayor of the City of Playford, Martin Lindsell, Maria Yfantides (Grower representative for the Northern Adelaide Plains) and Craig Feutrill (Vegetable IDO) visited the Entomology Unit of SARDI (Fig. 10.5). These visitors had a keen interest in the laboratory research and indicated that they felt much more informed about the research as a result of the visit.