Native vegetation to enhance biodiversity, beneficial insects and pest control in horticulture systems

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VG 05014

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VG 05014

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This is the final report for VG0514 titled 'Native vegetation to enhance biodiversity, beneficial insects and pest control in horticulture systems' which summarised the key findings and outlines plans for future research and industry adoption of integrating native vegetation in horticultural systems. This project was funded for one year, conducted and completed in collaboration with Anna Marcora CSIRO, Mark Wade CSIRO and Maarten Vodde Wageningen University, The Netherlands.

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24 November 2006

Contents

Media Summary (written in conjunction with Jodi Powell)

Revegetation by design could hold the key to combating insect pests, as well as encouraging beneficial insects and reducing the use of chemical sprays a Brisbane-based CSIRO research scientist has found.

Dr Nancy Schellhorn has worked in Queensland for the past year, focussing on the Lockyer Valley, including Gatton and Mulgowie. She and her team have conducted two types of surveys in the area to determine: 1) presence and distribution of key beneficial insects and pests from a range of native vegetation and weeds, and 2) if natural enemies and pests are multi-habitat users, for example, whether they are similarly found in native remnants, horticultural fields and the edges between the remnant and horticultural fields. This project is a follow on from the Revegetation by Design project in South Australia that she developed, where results have demonstrated that several key thrips pests are rarely found on several species of native plants, and that weeds that harbour these pests could replaced with these native plants.

Nancy says some of the key findings include a key jassid pest that vectors wallaby ear was found frequently and in high numbers in the exotic grass along roadsides and fields throughout the region. These jassids were not found on any native herbaceous plant sampled. Beneficial predators and parasitoids were found on a wide range of native vegetation but also on some weeds. More interestingly the team found that the horticulture fields supported a high diversity of hover flies (immature stage feed on aphids), and parasitic hymenoptera, more so than the native remnant. However, several of these species spend a lot of time at the edge of the remnant and field. The same was true for the six parasitoids.

``If we're trying to think about how to encourage hover flies and parasitoids in our fields, understanding how these different species use these different habitats is critical to capturing the pest control service. We don't know why they favour the edge, and hope to investigate this, but the positive aspect is that planting bands or strips of native plants along ditches or fence rows may mimic the edge habitat, hence advantage these beneficial insects. It's a feasible option, unlock planting a remnant!
``Some species are multi-habitat users, so as we design agricultural systems, we need to think about how to change the habitat that favours the pest and replace it with habitat that disadvantages pests, but favours the beneficial insects.'' Several of our key beneficial insects use the edge habitat between remnants and the crop.

The bottom line

- Different species of beneficial insects and pests use a range of habitats. We need to understand this species level information to design our farming systems. We can do this by focusing on our top four pest species.
- Increasing beneficial insects will help keep pests at bay and could allow growers to reduce and target their spraying regimes.
- New research will focus on several key plant species to refine revegetation potential for growers.

Technical Summary

Frequent and large populations of a jassid, *Cicadulina bimaculata*, were found on the exotic grasses, particularly green panic, throughout the Lockyer Valley. This jassid was identified by growers as a key pest that they monitor and spray for because it vectors maize wallaby ear. Therefore, exotic weeds in the region are most likely source populations of jassids colonising sweet corn, beans and other vegetable crops. Management options such as burning, grazing (where possible) or long-term revegetation may change this pest status.

In addition, we found that most species of pests and natural enemies are multi-habitat users, and there appears to be species-specific preference for different habitats. This tells us that pest control strategies need to be considered at the scale of the crop, the farm and the surrounding habitats. Furthermore, key parasitoids of pests and predators (some species of hover flies) are clearly using edge habitat (area between native remnants and the crop) and the native remnants. Whether or not these habitats are essential and result in better capture of the ecosystem service of pest control remains unanswered. Also, the parasitoid, *Diplazon*, attacks hover flies (larvae are predators of aphids) and could reduce aphid suppression because the presence of this parasitoid kills more hover flies, so less are available to kill aphids. These issues and others will be the focus of our currently funded HAL project 'Phase II: Native vegetation to enhance biodiversity, beneficial insects and pest control in horticultural systems' running from October 2006-December 2007.

The work to date both in Australia and overseas certainly suggest that the Revegetation by Design approach is a promising and an important component of pest management, and may create a market advantage. However, several questions need to be answered before the Revegetation by Design concept can be implemented.

Introduction

In horticultural systems numerous species of weeds are known to harbour pests and diseases of crops. Controlling the weeds can often be costly, short-term and cause environmental problems such as erosion, excessive dust, and changes in soil moisture. However, leaving the weeds can result in reservoirs of pests and the diseases.

Revegetation by Design involves the integration of native vegetation with horticultural production systems, with a focus on replacing weeds, ultimately manipulating vegetation to disadvantage pests and disease at a farm scale.

The native plants chosen must meet a range of criteria to be suitable for revegetation and the primary criteria include those plants that: 1) are not the host plants for horticultural pests and diseases (eg. pest and diseases can not develop and populations can not increase on these plants), 2) provide habitat for a range of natural enemies of pests so that they are available for early colonisation into the crop, 3) are workable around farm practices and containment facilities, and 4) native to the region. The secondary criteria is that the native plants provide an additional source of income for the farm such as bush tucker, native cut flowers, and native seed for the revegetation industry. The outcome of Revegetation by Design is long term farm benefit and cost savings for weed, pest and disease control.

Revegetation by Design has shown great promise on the Northern Adelaide Plains of SA where thrips and the disease that they vector nearly crippled the vegetable industry. The results from the project (previously conceptualized and lead by Dr. Nancy Schellhorn) showed that thrips were rarely present on several species of vegetation native to the region, even when planted adjacent to infested plants (Wood and Schellhorn 2004). The focus of this project, VG05014 was to determine if the same concept could apply more broadly and specifically to the vegetable growing region of the Lockyer Valley in southeast QLD.

We proposed to survey key native plants and weeds in the south east QLD region and to identify the benefits that these plants may provide to horticulture production. Furthermore, this work was designed to link with the Environmental Assurance Guidelines developed by 'Horticulture for Tomorrow.' The vegetable industry is being asked to adopt practices to comply with these guidelines without having information about the benefits for horticulture.

Materials & Methods

Field Component

To identify key beneficial and pest invertebrates of horticultural production associated with native plant species and remnant native vegetation we conducted surveys in the Lockyer Valley QLD in two distinct vegetable growing regions; Gatton and Mulgowie. Gatton can be characterised by intensive agricultural production with sparse native vegetation –a few marginal plants along watercourses or an isolated tree on the road side or dividing properties. Mulgowie can be characterised as a long valley (approximately 20 km) with agricultural production on the valley floor and extensive native remnants (in various condition) on the slopes.

First we identified the plants that are native to the region and that are the focus of revegetation efforts. Second we identified the most abundant weeds in the area. This vegetation assessment was done in concert with groups actively involved in vegetation management, for example, Land Care Groups and SEQ Catchment Authority. Next we used suction sampling monthly for seven months to determine if key beneficial and pests were found on these plants. The sampling dates, number of samples taken and number of locations are as follows for a total of 193 samples:

01/02/06 16 samples taken from 8 locations
15/02/06 31 samples taken from 10 locations
13/03/06 30 samples taken from 10 locations
19/04/06 30 samples taken from 10 locations
25/05/06 28 samples taken from 9 locations
05/07/06 29 samples taken from 10 locations
11/08/06 29 samples taken from 10 locations

Because the morphology among plant species was extremely different (eg. *Casuarina* spp vs. *Lantana* spp.) density estimates would not be comparable. Instead we considered whether a species was present in a sample and calculated the percent of samples with a species. For example if Melaleuca was sampled 28 times and 3 times there were ladybird beetles, never mind how many, then ladybird beetles were found in 10.7% of the samples. In addition, we looked for immature stages of our key insects, which is an indication that plants are growing populations of insects, not just an area where and insect may be resting. The plants sampled are in Table 1.

Table 1. Native vegetation and weeds common to the Gatton and Mulgowie area of the Lockyer Valley. * **Weeds**

Family	**Scientific Name**	**Common Name**
Asclepiadaceae	*Gomphocarpus fruticosus*	Narrowleaf Cotton Bush *
Asteraceae	*Cassinia* sp.	Cough Bush
Casuarinaceae	*Casuarina* sp.	
Euphorbiaceae	*Mallotus philippensis*	Red Kamala
Euphorbiaceae	*Ricinus communis*	Castor Oil Plant *
Fabaceae	*Castanospermum australe*	Black Bean
Mimosaceae	*Acacia concurrens*	Black Wattle
Mimosaceae	*Acacia fimbriata*	Brisbane Wattle
Mimosaceae	*Acacia leiocalyx*	Black Wattle
Mimosaceae	*Acacia macradenia*	Zig-Zag Wattle
Mimosaceae	*Acacia maidenii*	Maidens Wattle
Mimosaceae	*Acacia salicina*	Sally Wattle
Moraceae	*Ficus opposita*	Sandpaper Fig
Moraceae	*Streblus brunonianus*	Whale Bone
Myrtaceae	*Melaleuca bracteata*	Black Tea Tree
Myrtaceae	*Melaleuca linariifolia*	Flax Leaf Paperbark
Myrtaceae	*Eucalyptus* sp.	
Myrtaceae	*Callistemon salignus*	White Bottlebrush
Myrtaceae	*Callistemon viminalis*	Red Bottlebrush
Poaceae	*Panicum maximum*	Green Panic Grass*
Poaceae	*Chloris gayana*	Rhodes Grass*
Proteaceae	*Grevillea robusta*	Silky Oak

Rhamnaceae	*Alphitonia excelsa*	Red Ash
Verbenaceae	*Lantana camara*	Lantana *

Plants were suction sampled for 5 to 30 seconds depending on the density of vegetation, eg. sparse plants for 30 seconds and extremely dense plants like Lantan for 5 seconds. After suction sampling the bags were returned to the laboratory, placed in the freezer to kill insects inside, then sort, curate and enter information into the data base.

Third, due to drought insect numbers were extremely low in the region and we were quite concerned that our suction sampling would not return enough information. Therefore to be able to say something more conclusive we added a question and used Malaise traps to collect the insects. We asked 'are key beneficial insects multi-habitat users?' For example, do some of the beneficial insects that are important for IPM spending time in native remnants and edges between remnants and vegetable crops or do they primarily spend time in the crop?

Also, does the Australian system mimic that of Duelli and Obrist (2003), where species can be characterised in their habitat use (Fig. 1). For example, many species of ladybird beetles are found in all cropping systems, weeds and native remnants. It's quite likely that they are 'ubiquist', therefore on farm habitat management may not be effective, whereas species that are 'ecotone' specialists may require the edge between native remnant and agricultural crop. Identifying the species that are multi-habitat users will allow us to manipulate vegetation on-farm to advantage natural enemies of pests. It should be noted that the purchase of the Malaise traps (ca. $500 / each x 8) and labour to tend traps and sort insects was primarily covered through funds external to VG 05014. Thus, this should be viewed as a coinvestment from CSIRO and Wageningen University, The Netherlands.

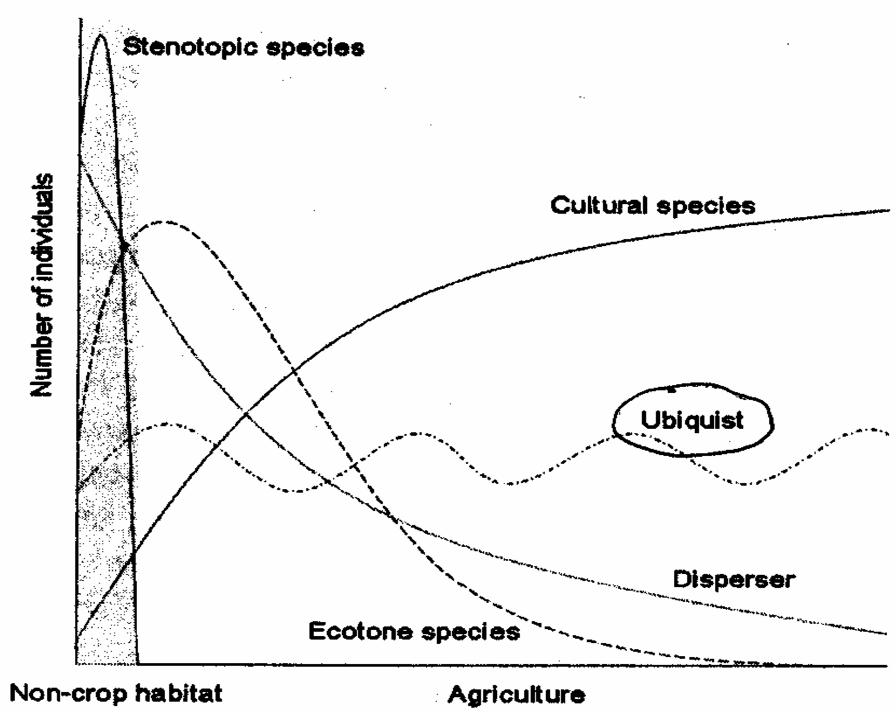

Figure 1. Five types of distribution patterns of insects across the crop-noncrop interface. The noncrop habitat is indicated by the grey area (after Duelli & Obrist 2003). Stenotopic species are restricted to noncrop habitats, cultural species have a preference for crops, dispersers colonize crops from non-crop habitats, ecotone species are typically found at the interface of crop and non-crop habitats and ubiquist species have no preference for crop or noncrop habitats.

Experimental area and design where Malaise traps were placed

Mulgowie Farm (152°22′00"E 27°45′30"S) is situated in the Lockyer Valley enclosed between the Mistake Mountains and the Little Liverpool Range in the Great Dividing Range, Australia, at an altitude of ± 150-160m above sea level. Mulgowie Farm is more than 3200ha (8000 acre) in size and produces several vegetables (sweet corn, green beans, broccoli etc.) throughout the seasons. The experimental site was chosen because of the complex landscape with different habitats located not far from each other. The experiment was set up on (and parallel to) the north and south sides of an 18.2ha (45 acre) broccoli field (see fig. 2.1 and 2.2). Adjacent to the field in the north was a 2m wide grassy strip, a dirt road and power lines and an 9.7ha (24 acre) field with sweet corn. To the east of the field was the Laidley Creek riverbed with trees and shrubs. To the south of the field were a small (1m) dike, then pasture, a car park and Mulgowie Farm. To the south-west was an asphalt road to the farm, a dike and a large water reservoir, and to the south-west-west a smaller water reservoir and eucalyptus-acacia forest. To the west was a ±40m grassy strip with a dirt road, after which the land sloped upward and was covered with forest. The forest consists of native vegetation with Eucalypt-Acacia trees, some red ash and *Callistemon* shrubs, and at ground-level a mix of Rhodes-grass with cottonbush weeds. In order to prevent bushfires, the forest was burnt annually in winter (August). The broccoli and sweet corn fields were sprayed with oil and soft insecticide (Chess®) to control aphids.

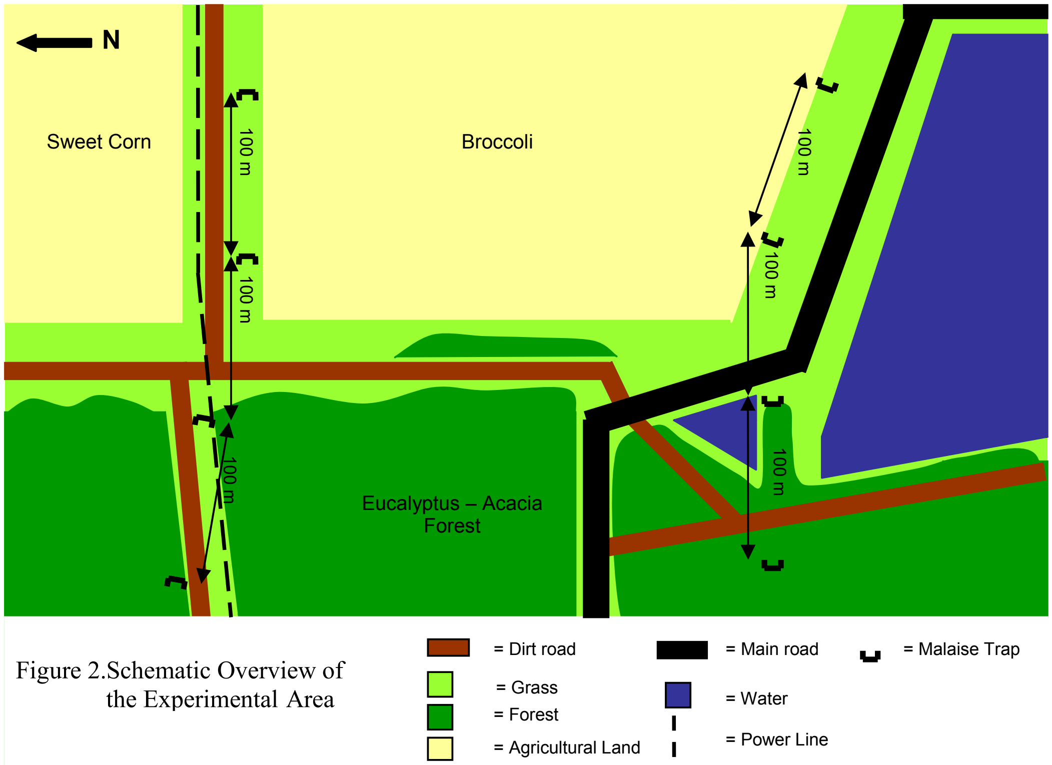

Figure 2.Schematic Overview of the Experimental Area

On both sides of the broccoli field, two transects were laid out parallel to the field edge (Fig. 2). On each transect, four Malaise traps were situated. The first trap was located in the forest 100m from the forest edge, the second trap at the forest edge, the third 100m and the fourth 200m from the forest edge next to the field. To minimize variation, all Malaise traps were placed on grass.

Eight Malaise traps (Fig. 2 and 3) were used to trap the insects. The Malaise traps used in this study have been purchased at BioQuip and consist of green polyester with a vertically attached dry-catch collecting bottle. The collecting bottle consists of a 1000 ml plastic outer jar with an inverted funnel attached at the base. Attached to the inside of the lid of the outer jar is a 150 ml inner jar, which is provided with holes to allow the release of insecticide into the outer jar. In order to kill the insects, 25 grams of Fresh Guard (997g/kg paradichlorobenzene) was used in the first two weeks (March 22^{nd}-April 5^{th}). This was replaced with 27.5 grams of BinKill (80g/kg dichlorvos and 800g/kg napathalene) on April 6th. In order to study the direction of movement of the beneficial insects (from the forest into the field or the opposite direction), one of the two opening sides of the Malaise traps was closed. The traps of one transect were all opened in the same direction, while the traps in the other transects were all opened to the other direction. The opening sides of the traps were switched weekly.

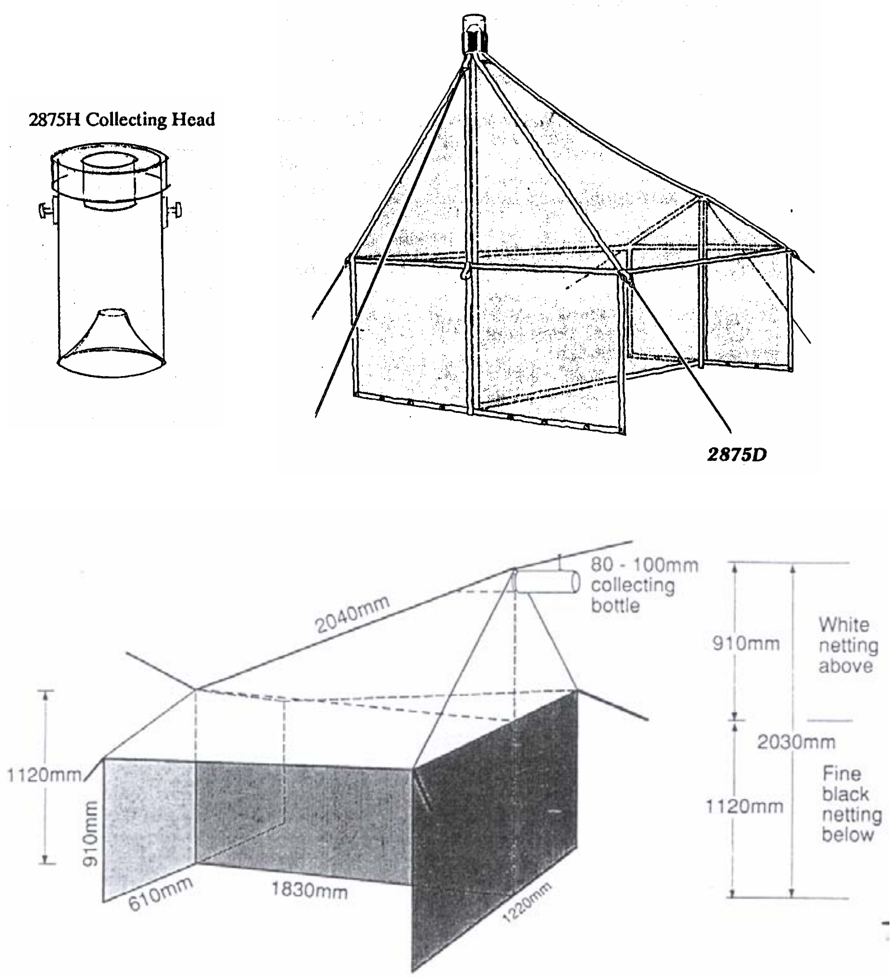

Figure 3. The Malaise Trap is designed as a passive trap intended to survey insects flying in a given area at a given time. It consists of an open-fronted tent with a roof that slopes upward to the innermost corner at which there is an aperture leading to a collecting bottle. It halts the insects in flight and directs them to the collecting bottle, utilizing the natural behaviour of most insects to crawl upward and to move towards the light penetrating the trapping bottle.

Malaise traps are considered to be unbiased to capture strong flying insects like larger Hymenoptera and some Diptera. However, Juillet (1963, in: Southwood, 1978) found that the traps were unsatisfactory for trapping Coleoptera and Hemiptera. The traps were initially set on March 22nd and were collected weekly from 1 April till 20 July. The caught insects were taken back to the lab and stored in vials of variable size (12, 15 and 18 ml) with 98% ethanol. In the lab, the beneficial insects were selected and sorted into morphospecies. Ten morphospecies were selected from the beneficials on basis of 1) highest density in the first weeks, or 2) importance in biological control. These morphospecies were identified as far as possible, using two identification keys (Gauld, 1984, CSIRO, 1991), and sent to expert taxonomists to be identified to species in July.

Results

Survey of pests and natural enemies

There were very samples with pests or natural enemies on native vegetation. This was probably in part due to the drought and in part the type of vegetation sampled. The Lockyer Valley has been in a drought for nearly 3 years which has stressed the vegetation, in turn insects that depend on the vegetation. Irrigated agricultural systems are most likely providing an attractive resource during this time.

Insect herbivores that feed on plants and can be pests of vegetables were rarely found on the most abundant and prevalent native species in the region (Table 2). Green mirids were found a few times. Although flea beetles were in several samples all were thought to be fairly specialized and not pests of vegetables. The most interesting result and one that is also supported in the Malaise trap collections (see below) is the high percentage of samples from exotic grasses that had the jassid, *Cicadulina bimaculata*, which is monitored and controlled in vegetable crops (beans and corn) because it vectors Maize Wallaby ear (Table 3). Further, this was the only insect that had huge densities, as seen in detail for the Malaise trap data.

Again there were some Chrysomelids in the grasses, but none of the species were associated with pests of vegetables. However, we are still waiting taxonomic confirmation (Table 3). Green veggie bugs, *Nezara viridula* was also seen on Lantana and exotic weeds, while it was not present on any of the native vegetation sampled. The lygid found on all sampling occasions on the narrow-leaf cotton bush was a specialist on Asclepiadaceae and was only found on those plants.
Natural enemies were rarely found in samples (Table 4 and 5). Minute pirate bug, a predator of thrips and small larvae, was the most frequently sampled enemy and found most often in the exotic grasses. Otherwise, natural enemies of horticultural pests were far and few between and was one of the main impetus for redesigning the question and methods of collecting.

Table 2. Percent of suction samples from native vegetation with insect herbivores, some of which are pests of horticulture. Empty boxes mean that a species was never present in a sample.

	Brokenbacked bug: *Taylorilygus pallidulus*	Brown mirid: *Creontiades pacificus*	Green mirid: *Creontiades dilutus*	Flea beetles: Family Chrysomelidae	Lygaeidae: *Nysius vinitor* or *Nysius clevelandensis* Rutherglen bug	Lygaeidae: Other species of seed bugs within that family	Lace bugs: Family Tingidae	Weevil (brown): Family Curculionidae	Jassid: Tribe Macrostelin *Cicadulina bimaculata*
Sandpaper Fig *Ficus opposite* (7)			28.6%			14.3%			
Acacia spp. (28)				17.7%		3.6%	21.4%	3.6%	
Black bean *Castanospermum australe* (7)									7%
Whale bone *Streblus brunonianus* (7)				28.6%			57%		
Red Ash *Alphitonia excelsa* (13)			23%	7.7%					
Melaleuca spp. (28)				28%	11%	3.6%	3.6%		
Casuarina spp. (13)	7.7%	15.3%		6.2%					3.6%
Red Kamala *Mallotus philippensis* (7)				28.6%	14.3%				
Eucalyptus spp. (12)				**66.6%**					
Silky oak *Grevillea robusta* (6)				33.3%					
Callistemon spp. (6)									

Table 3. Percent of d-vac sample from weeds with insect herbivores, some of which are pests of horticulture. Empty boxes mean that a species was not present in any sample.

Insect species / Plant species (number of locations)	Brokenbacked bug: *Taylorilygus pallidulus*	Brown mirid: *Creontiades pacificus*	Green mirid: *Creontiades dilutus*	Flea beetles: Family Chrysomelidae	Lygaeidae: *Nysius vinitor* or *Nysius clevelandensis* Rutherglen bug	Lygaeidae: Other species of seed bugs within that family	Lace bugs: Family Tingidae	Green veggie bug *Nezara viridula*	Jassid: Tribe Macrostelin *Cicadulina bimaculata*
Lantana *Lantana spp.*(20)	14.3%		20%					15%	20%
Green panic (grass) *Panicum maximum* (6)		14.3%		**66%**				15%	**50%**
Mixed grasses (Green panic and Rhodes) (32)			3%	**44%**	6.3%		3%	6.3%	**50%**
Castor Oil *Ricinus communis* (4)				25%					
Narrowleaf cotton bush *Gomphocarpus fruticosus* (5)			20%			**100%**			20%

Table 4. Percent of d-vac sample from native vegetation with natural enemies. Empty boxes mean that a species was not present in any sample.

	Coccinella transversalis (transverse ladybeetle)	*Coelophora inaequalis* (variable ladybeetle)	*Micraspis frenata* (striped ladybeetle)	*Harmonia conformis* (common spotted ladybeetle)	Coccinellid larvae	Mantidae	Brown lacewing: *Micromus tasmaniae*	Green lacewing: *Mallada spp.*	Assassin bug: Family Reduviidae	Pirate bug: *Orius spp.*
Sandpaper Fig *Ficus opposite* (7)		14%								
Acacia spp. (28)		7%	3.6%			3.6%		3.6%	3.6%	
Black bean *Castanospermum australe* (7)										
Whale bone *Streblus brunonianus* (7)			14%							
Red Ash *Alphitonia excelsa* (13)										
Melaleuca spp. (28)	3.6%			3.6%		3.6%				
Casuarina spp. (13)										
Red Kamala *Mallotus philippensis* (7)										
Eucalyptus spp. (12)							8.3%			
Silky oak *Grevillea robusta* (6)										16%
Callistemon spp. (6)					16%					

Table 5. Percent of d-vac sample from weeds with natural enemies. Empty boxes mean that a species was not present in any sample.

Insect species Plant species (number of locations)	*Coccinella transversalis* (transverse ladybeetle)	*Coelophora inaequalis* (variable ladybeetle)	*Micraspis frenata* (striped ladybeetle)	*Diomis Notescens* (two-spot ladybeetle)	Coccinellid larvae	Mantidae	Green lacewing: *Mallada spp.*	Lacewing larvae	Assassin bug: Family Reduviidae	Pirate bug: *Orius* spp.
Lantana *Lantana spp.*(20)	5%		20%		15%	10%			5%	5%
Green panic (grass) *Panicum maximum* (6)	16.6%	16.6%		16.6%						**50%**
Mixed grasses (Green panic and Rhodes) (32)		3%	18.8%		6.3%	15.6%	3%			6.3%
Castor Oil *Ricinus communis* (4)										
Narrowleaf cotton bush *Gomphocarpus fruticosus* (5)		4%						16%		

Malaise traps and 'are key beneficial insects multi-habitat users?'

Approximately 66 species were collected from our Malaise traps and primarily from the Hymenoptera (66%), Diptera (20%), a few Coleoptera (7%), plus 2 species of Lepidoptera and the single species of Heteroptera the jassid *Cicadulina bimaculata*. For the purpose of this report we have focued on six species of parasitic hymenoptera, two species of ladybird beetles (Table 6), and 14 species of hover flies (Fig 7). As we complete more detailed taxonomy we will complete a manuscript with the 66 species, some of which will be morpho-species.

Based on our 66 species, 24 (100 m) and 18 (200m) were found in the agricultural crops, 18 on the edge and only six in the native remnant.

Most of the parasitoids included in Table 6 are natural enemies of horticultural pests except for *Diplazon* spp., which is a parasitoid of hover flies. This species was included because it was relatively abundant and common and will cause mortality to hover flies; the natural enemy of aphids.

Table 6. Six species of parasitic hymenoptera and two species of aphidophagous coccinellids focused on in this study.

(Super) Family / (Sub) Family	**Genus / Species**	**Diet**
Chalcidoidea / Chalcinidae	? (waiting on confermation)	Grubs Larvae of lepidopteran
Ichneumonidae / Banchinae	*Leptobatopsis* spp.	Grubs Larvae of lepidopteran
Ichneumonidae / Pimplinae	*Lissopimpla* excelsa (Costa)	Grubs *Helicoverpa spp.* Native bud worm
Ichneumonidae / Diplazontinae	*Diplazon spp.*	Hover Flies
Ichneumonidae / Campopleginae	*Xanthocampoplex* spp.	Grubs
Ichneumonidae / Tryphoninae	*Netelia producta* (Brullé) Orange Caterpillar Parasite	Grubs *Helicoverpa spp.* Native bud worm
Coccinellidae	*Coelophora inaequalis* Variable Ladybeetle	Aphids, lepidopteran eggs, small larvae
Coccinellidae	*Harmonia octomaculata* Three-banded / maculate ladybeetle	Aphids, lepidopteran eggs, small larvae

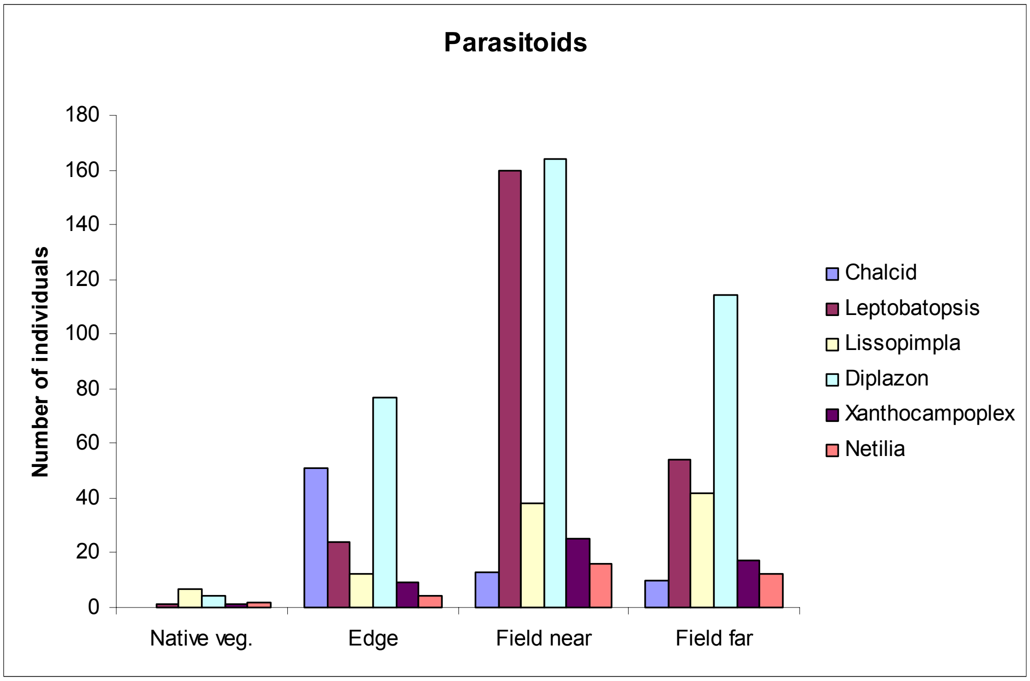

Figure 4. Number of parasitoids captured in each habitat between April and July 2006.

The chalcid was primarily found in the edge habitat and moved into the field (Fig 4). *Leptobatopsis* spp, *Diplazon* spp, and *Lissopimpla* spp were primarily found in the agricultural fields (Fig 4). *Lissopimpla* spp has a gradual decline from the field, to the edge, to the native vegetation. Of our six focal species the chalcid was the only one not found in native vegetation, all others were present in all four habitats (Figure 4).

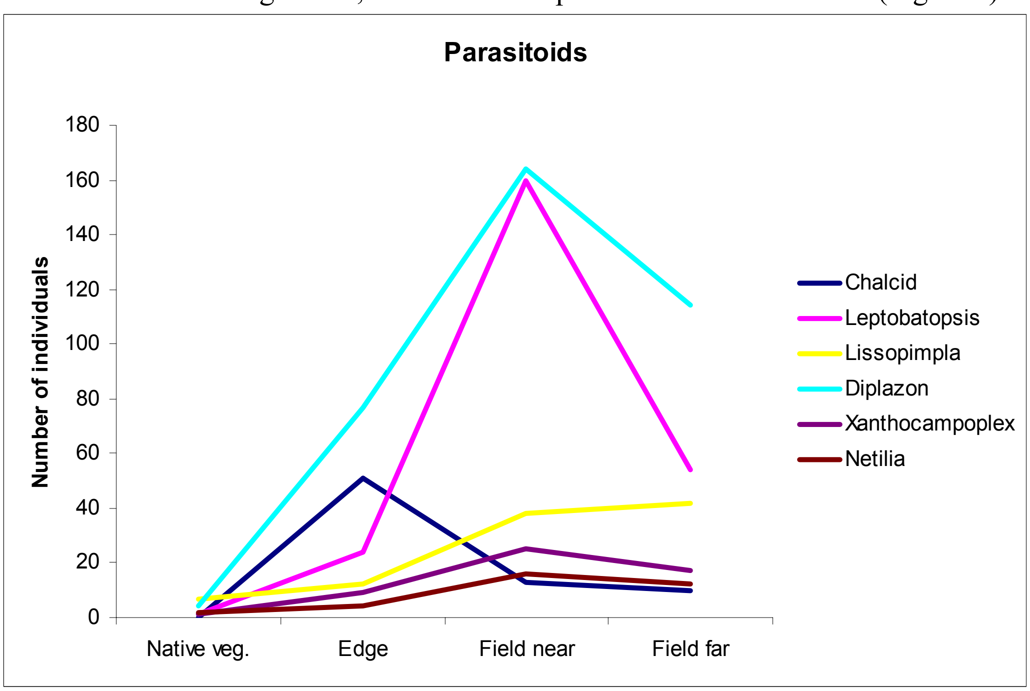

Figure 5. Number of parasitoids captured in each habitat between April and July 2006 and represented as Duelli & Obrist 2003 'five-types of distribution patters.

Lissopimpla, *Xanthocampoplex*, and *Netilia* would all be classified as 'cultural species,' while the chalcid would be a 'ecotone species.' Although *Leptobatopsis* and *Diplazon* are also 'cultural species' they are slightly different in that they are not as abundant in the middle of the agricultural fields, hence they may be a type of 'ecotone species' but on the agricultural field side instead of the native remnant side.

Hoverflies

Although it is thought that *Melangyna* spp and *Sphaerophoria macrogaster* and *Simsyrphus grandicornis* have larval stages that are beneficial and prey on aphids, some species of hoverflies are pests of fruit or detritivores. Some species of Eurerus can be injurious to plant bulbs and some can live in rotting vegetation.

Most of the hover flies in our study were collected from Malaise traps in the agricultural fields 100m from the edge (210 individuals) and 200m from the edge (200 individuals). The two most abundant hover flies were *Sphaerophoria macrogaster* (154 individuals) and *Melangyna (Austrosyrphus) sp.* (151 individuals) (Fig. 7).

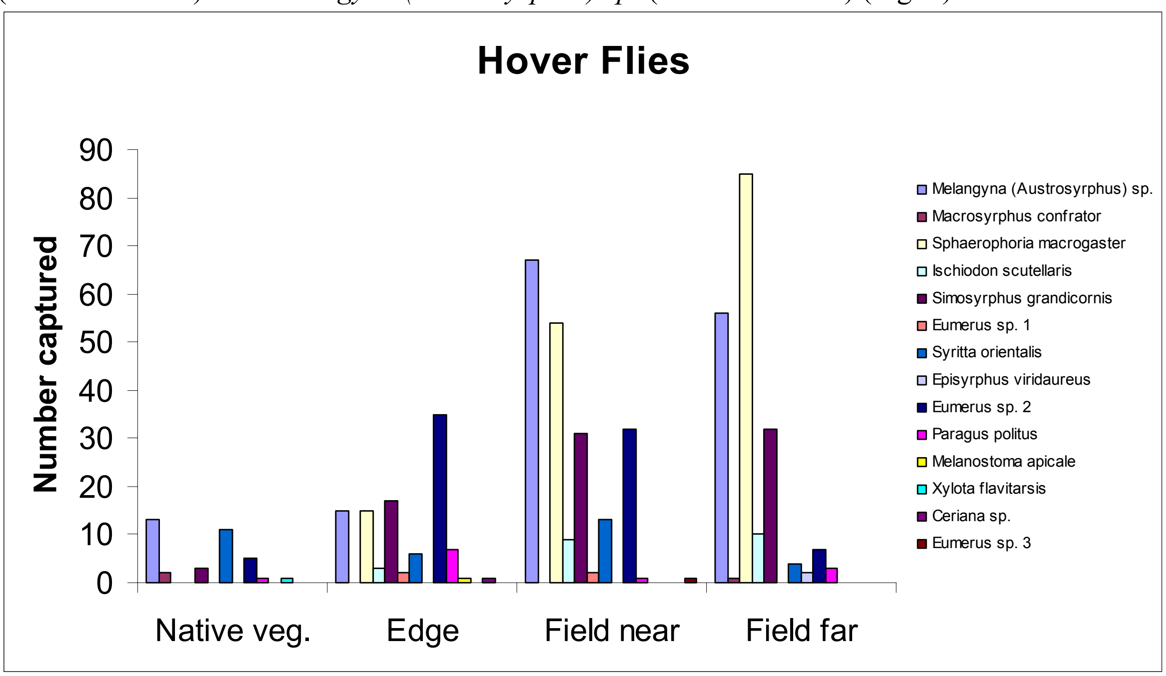

Figure 7. Number of hover flies captured in malaise traps in each habitat from 12 April 2006 to 19 July 2006.

Some species were only found in a single habitat – 5 species total (Fig. 8). *Xylota flavitarsis* was only in found in the native vegetation, *Melanostoma apicale* and *Ceriana sp.* were only found in the edge habitat, and *Eumerus sp. 3* in the crop 100m from the edge and *Episyrphus viridaureus* in the crop 200m from the edge – the middle of the field.

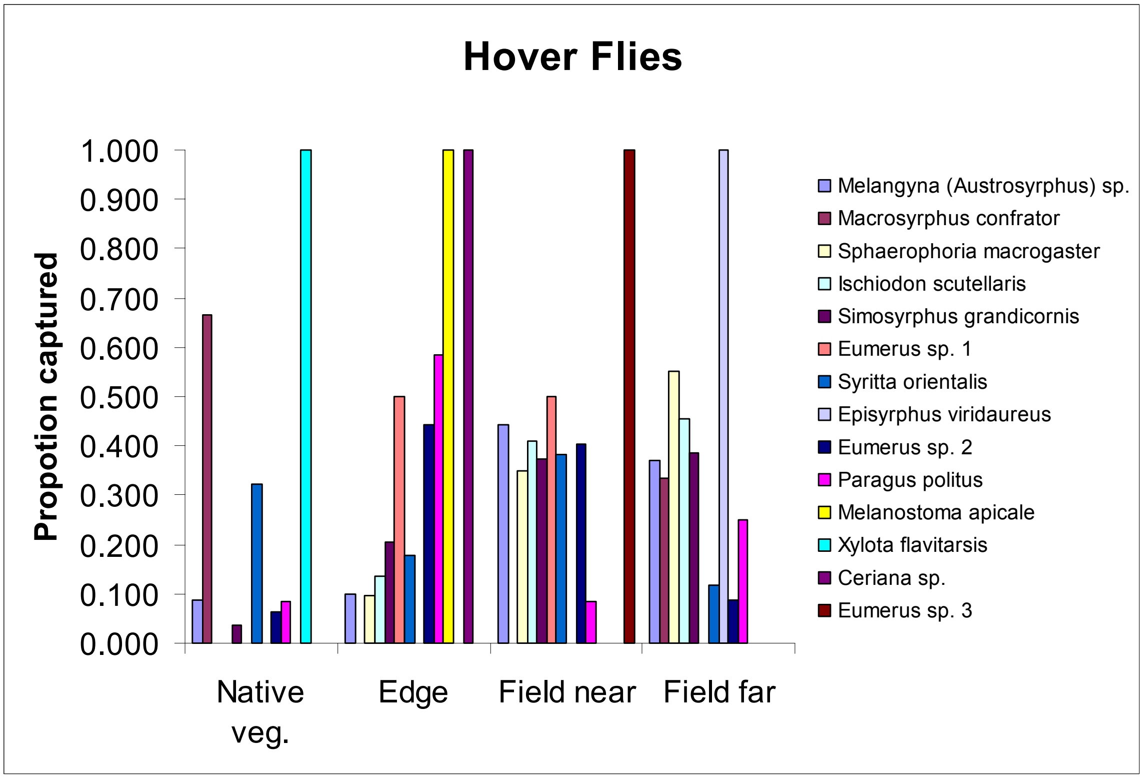

Figure 8. Proportion of hover flies captured in malaise traps in each habitat from 12 April 2006 to 19 July 2006.

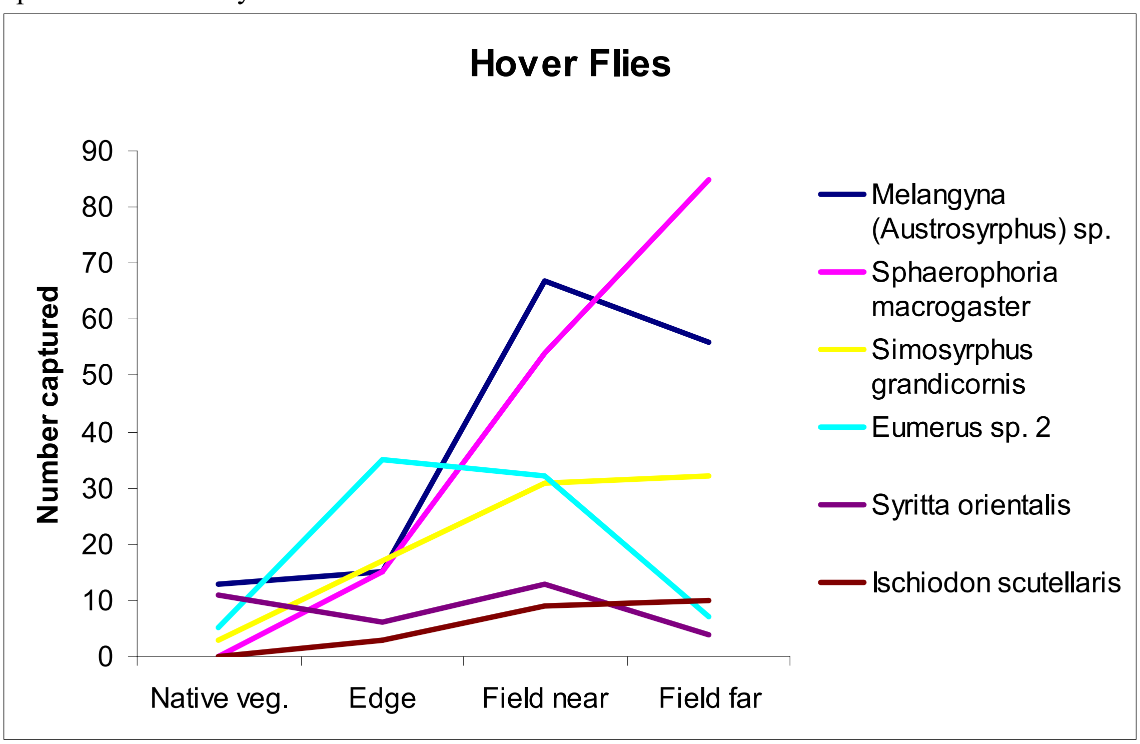

Figure 9. The number of the six most abundant hover fly species captured in Malaise traps from April to July 2006 and represented as Duelli & Obrist 2003 'five-types of distribution patters.

Eurmerus spp2 is more of an 'ecotone species', *Melangyna*, *Sphaerophoria macrogaster*, *Simosyrphus grandicornis* and *Ischiodon scutellaris* are more 'cultural species' and *Syritta orientalis* is a ubiquist (Fig 9).

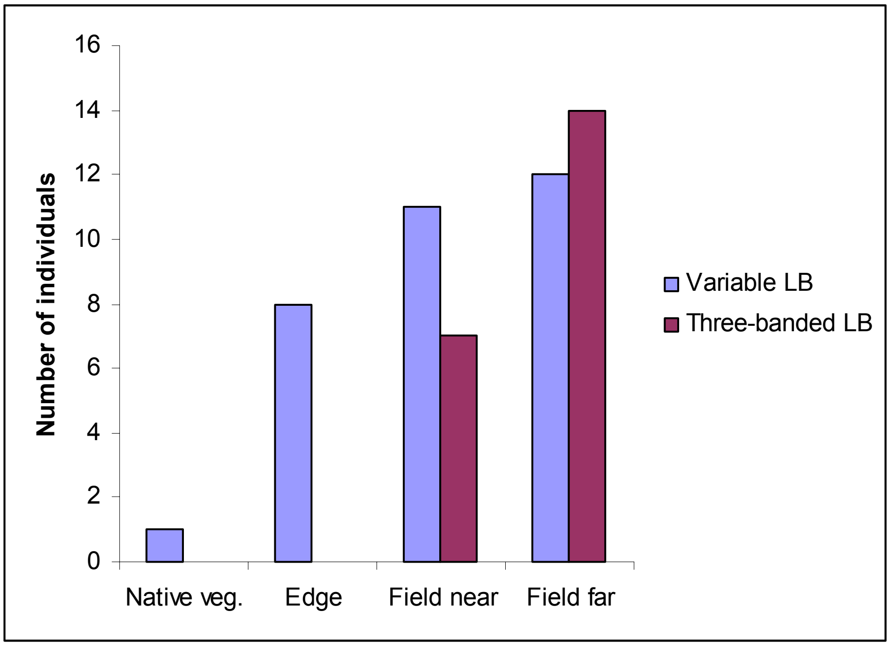

Figure 10. The number ladybird beetles captured in Malaise traps from April to July 2006.

Malaise traps are designed to catch strong flyers such as parasitic wasps, and flies and not as good for beetles. However, two species of ladybird beetles that eat aphids were captured in the traps. The variable ladybird beetle was found in all habitats and similar to a 'cultural species.' The three-banded ladybird beetle was only found in agricultural habitat so the exact opposite of the 'stenotopic species.'

Pests of agricultural crops were also captured in the Malaise traps including the jassid, *Cicadulina bimaculata*, *Helicoverpa* spp., and a few *Pieris rapae*. The jassid was most often captured in the fields, then edge and a few in the native vegetation suggesting it is a 'cultural species' (Fig 11).

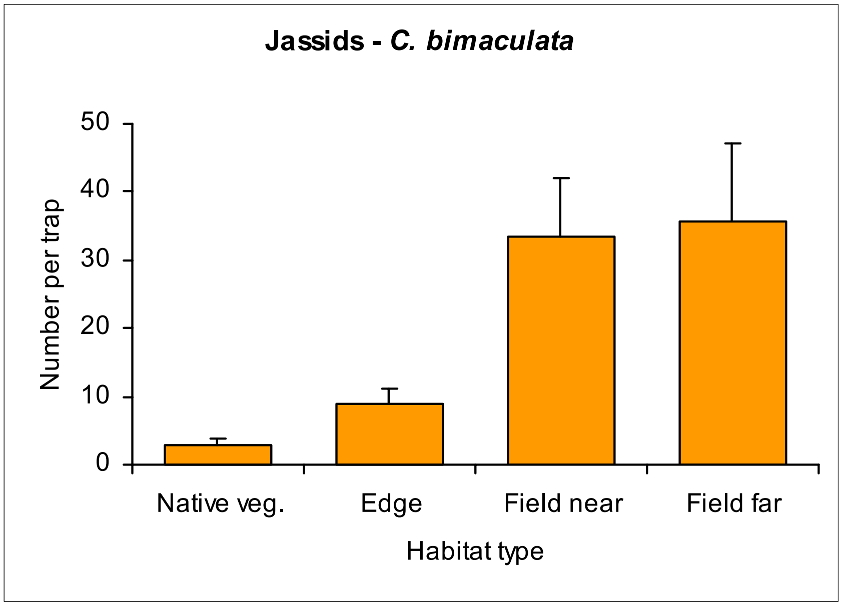

Figure 11. The average number of jassids, *Cicdulina bimaculata*, captured in Malaise traps from April to July 2006.

Jassid numbers dropped in the middle of June 2006 (Fig 12).

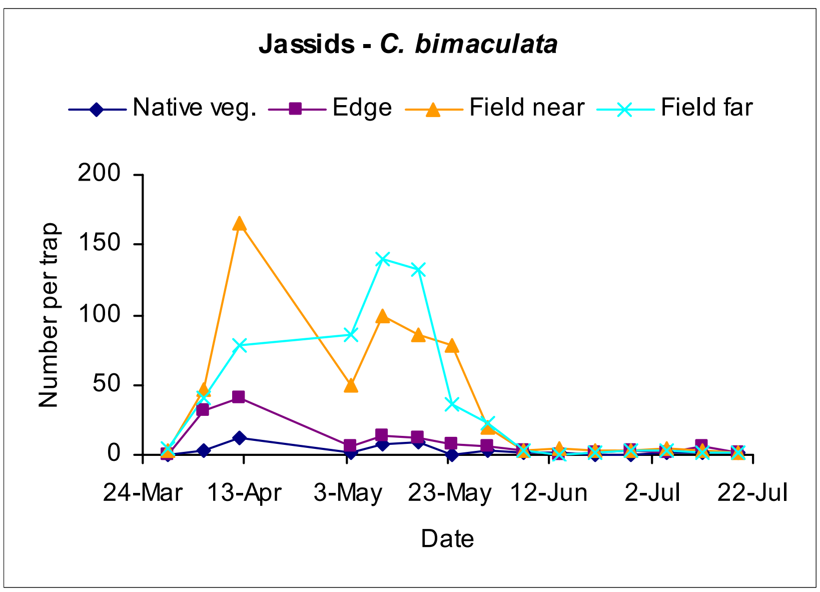

Figure 12. The average number of jassids, *Cicdulina bimaculata*, captured in Malaise traps from April to July 2006.

Heliothis spp., was captured primarily in the field, but near the edge, but at low densities (Fig13). Cabbage white butterfly were rarely captured (Fig 13).

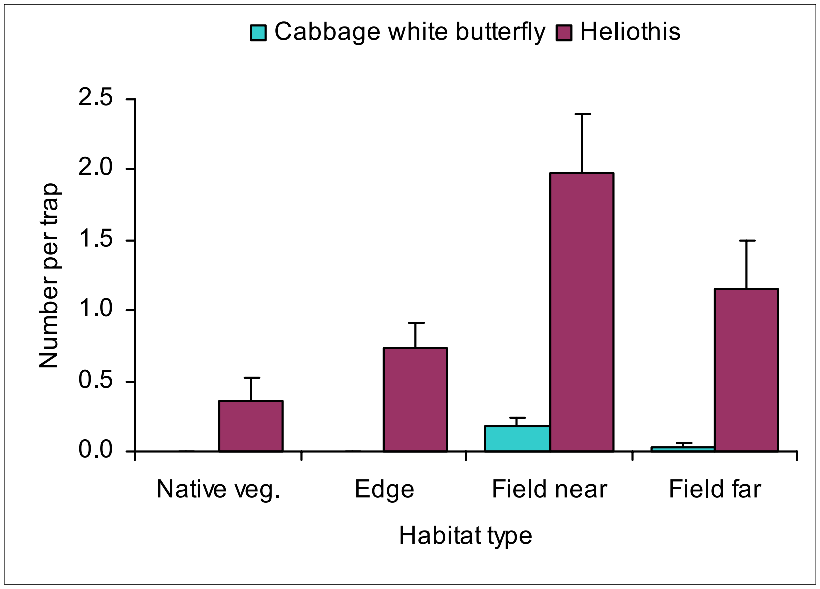

Figure 13. The average number of Cabbage white butterfly (Pieris rapae) and *Heliothis* spp. captured in Malaise traps from April to July 2006.

Heliothis spp was most active April until May, but were still present in the cooler months (Fig 14).

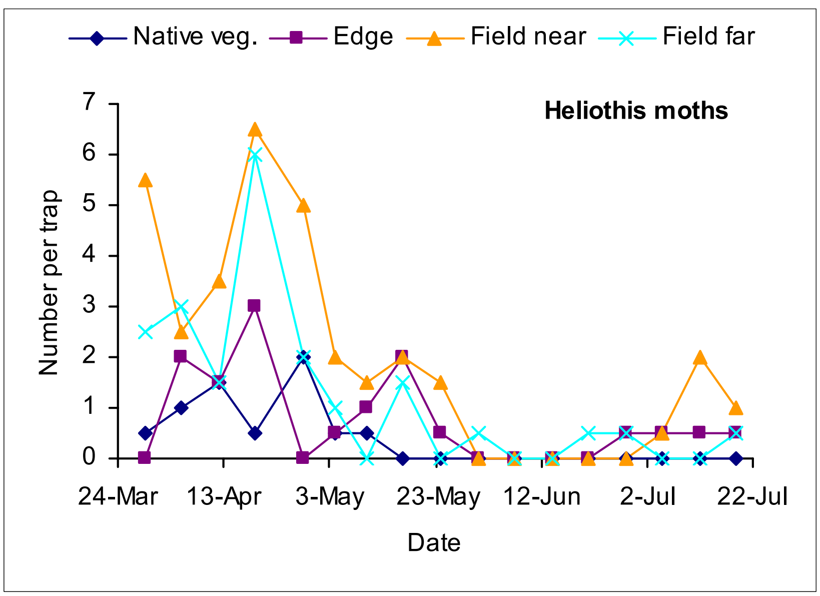

Figure 14. The average number of *Heliothis* spp captured in Malise traps from April to July 2006.

Discussion

Invertebrate survey and multi-habitat users

During our two workshops and field day we learned from growers that their top insect pest concerns, ones that they monitor for and spray to control, were *Heliothis* spp, silver leaf whitefly, jassids, diamondback moths, and thrips. From our sampling survey and Malaise trap captures we frequently encountered large populations of jassids, *Cicadulina bimaculata*, on the exotic grasses that are abundant throughout the region. We rarely encountered silver leaf whitefly, diamond back moth or thrips. This was possibly due to the drought. Therefore, exotic weeds in the region are most likely source populations of jassids colonising sweet corn, beans and other vegetable crops, hence we would consider management strategies to reduce exotic grasses near crops. The strategy may be as frequent grazing (where possible), burning or mowing or more long term such as revegetating with native deep-rooted perennials that would have multiple benefits; the topic of our recent proposal submission to HAL.

Our results also showed that most species of pests and natural enemies are multi-habitat users, and there appears to be species-specific preference for different habitats. This tells us that pest control strategies need to be considered at the scale of the crop, the farm and the surrounding habitats. Furthermore, key parasitoids of pests and predators (some species of hover flies) are clearly using edge habitat (area between native remnants and the crop) and the native remnants. Whether or not these habitats are essential and result in better capture of the ecosystem service of pest control remains unanswered. In addition, the parasitoid, *Diplazon*, attacks hover flies (larvae are predators of aphids) and could reduce aphid suppression because the presence of this parasitoid kills more hover flies, so less are available to kill aphids. These issues and others will be the focus of our currently funded HAL project 'Phase II: Native vegetation to enhance biodiversity, beneficial insects and pest control in horticultural systems' running from October 2006-December 2007.

Trees were the dominant native plant in the landscape in the Lockyer Valley. Insect populations were low and planting trees is often a poor revegetation strategy for weed suppression. Our strategy in SA was to use shrubby, low-growing plants that had multiple benefits and met a range of criteria (see introduction) particularly that they are workable around farm practice and containment facilities. Trees most often impede moving farm machinery and can cause havoc with irrigation systems. Therefore, our next steps will be to selectively plant and evaluate low growing shrubby species that meet the criteria listed in the introduction.

In general, replacing weeds with particular species of native plants has the potential to improve pest control for two main reasons. Firstly, many Australian native plants are not likely to be host plants for these exotic pests, hence pest populations can not develop on them. This is particularly true for Australian plants in the Myrtaceae family. All major horticultural crops (with the exception of Macadamias) and approximately 90% of their insect pests are exotic. Secondly, native plants can provide habitat (eg. shelter, alternative food and alternative prey) for natural enemies of insect pests. This may allow for the build up of natural enemy populations close to the crop resulting in more individuals colonising the crop earlier. Given that several species do use the edge between the remnant and crop means that revegetation efforts along fence lines, riparian zones (particularly around degraded waterways, under powerlines may provide enough habitat to both remove weedy sources of pests and create necessary habitat for natural enemies.

What's known from other parts of the world

Some aspects of Revegetation by Design are similar to work being done in other parts of Australia and other parts of the world, yet at the same time quite unique. In Europe and the USA, native remnants and hedge rows have been show to play an important role in pest population reduction (Tscharntke et al 2004, Gurr et al 2004). Two approaches have been taken. The first has been to suggest that diversifying vegetation within a field, among fields and among a farm can reduce pest population build up as long as the pests of interest can not use the majority of the vegetation as host plants to feed, reproduce and grow populations.

Alternatively, if the pests are generalists and use a wide range of host plants, manipulating vegetation to disadvantage the pests is not likely to result in the reduction of pest populations. However, if the pests are more specialised in there diets, then diversifying the vegetation may result in reduced populations.

The second approach has been to manipulate vegetation in a field, on field margins or on-farm to advantage the natural enemies. In the UK, this has been done by creating perennial grass islands in the middle of grain crops, which allow for the build up of predatory beetles that forage on soft bodied insect pests such as aphids and grubs (New 2005).

There has also been work in the US that has shown how the edge of a native forest adjacent to crops provides habitat for parasitic wasps that are natural enemies of grubs (Marino and Landis 1996). In Australia, some researchers have planted exotic plants in mid rows to provide nectar for natural enemies with the hopes of having them live longer and kill more pests.

Furthermore, there is work in Germany and the Netherlands that shows that a high proportion of non-crop vegetation such as woodlands and perennial grasslands in an agricultural landscape results in natural enemies eating and attacking more pests (Tscharntke et al 2004). Hence numerous researchers from around the world are focusing on ways to manipulate vegetation on-farm and in surrounding landscapes to disadvantage the pests and advantage the natural enemies that attack and eat them.

Some aspects of the Revegetation by Design project are unique. Australia has amazing floral and faunal diversity, and many plants are very distantly related to the horticultural plants we grow. This is not necessarily the case in other parts of the world, where a wide range of insect pests are native to the region and feed on a wide range of host plants. Australia's floral diversity appears to be one of the key ingredients of the Revegetation by Design concept.

Links with Revegetation by Design SA and broad scale adoption

This project, VG 05014, is a follow-on from the 'Revegetation by Design' project that Dr. Schellhorn developed and lead in SA. One objective from this study was to identify issues in common with SA so that general concepts could potentially be applied at wider geographic scale. Although the Lockyer Valley of south east QLD is one of the largest vegetable producing regions, it is very different from the vegetable production and circumstances on the Northern Adelaide Plains (NAP). In parts of the Lockyer Valley, particularly around the Laidley-Mulgowie region, remnant vegetation dominates the landscape. This is not the case in the NAP of SA where less than 0.01% of native vegetation remains.

In addition, in NAP arguably three exotic thrips species, western flower, onion and tomato and virus that they vector, tomato spotted-wilt, are the key insect-disease association that has threatened to cripple their vegetable industry. In the Lockyer Valley after surveying growers at workshops their top five insects would be *Heliothis* spp, silver leaf whitefly, jassids and diamond back moth. Thrips are the fifth most important.

Furthermore, in the Lockyer Valley growers are primarily growing in the field, whereas in NAP more than 95% of tomato, capsicum, zucchini growers use containment facilities, which have been notorious for the amount of weeds surrounding them, and we demonstrated that those weeds host huge populations of exotic thrips.

In the Lockyer Valley in areas of high agricultural intensification, the predominant native vegetation is trees. In the more agriculturally intensive zones around Gatton, only some native trees are present along creeks and waterways. In the native remnants around Laidley and Mulgowie, very little native understory remains and in most cases has been crashed grazed and burned and is heavily dominated by exotic grasses, primarily the exotic grass green panic.

These differences lead to the conclusion that the results from NAP in SA might have broad scale application around other containment facilities in geographic regions where exotic thrips have plagued the industry such as the Sydney basin. However, one key message that must be explored before wide scale adoption can occur is whether a small scale on-farm change in vegetation management can result in changes in pests and diseases in the crop.

There is great promise in the adoption of Revegetation by Design to achieve long term insect and weed control, natural resource management and gaining a marketing edge by product differentiation. For example, marketing strategies for 'vegetables grown with the bush in mind' have the potential to capture consumer values and establish preferential purchasing in a competitive domestic and foreign market.

Revegetation by Design is a concept that in theory has merit and wide scale public and industry appeal, but we do not have sufficient scientific knowledge to promote it for its intended primary function; pest control. It is not known whether a small scale on-farm change in vegetation management can result in changes in pests and diseases in the crop. Therefore, it is conceivable that growers could make significant vegetation management changes on-farm, yet there is no change in pest populations because the surrounding landscape has the greatest influence, thus always dominate any local farm management, particularly colonisation of pests.

Several questions need to be answered before the Revegetation by Design concept can be implemented. First, can on-farm changes in vegetation management change pest and natural enemy dynamics or does the surrounding landscape have the greatest influence, thus always dominate any local farm management? Two, if on-farm changes in vegetation management do result in fewer pests and slower colonisation of the crop and / or more natural enemies and faster colonisation of the crop, are growers willing to adopt revegetation strategies? Third, is there a cost benefit for long-term pest and weed control using the cultural control of Revegetation by Design? Fourth, do consumers identify with and value links with the Australian bush and native flora, and hence make purchasing decisions around these issues?

Investing in answers to these questions has the potential to move the vegetable industry towards innovative land stewardship specific to regional issues and pest complexes that results in industry change, innovation and enhanced marketing.

As we complete identification of the majority of our 66 species from our Malaise traps we are preparing the work for publication. As part of the publication we are focusing on biodiversity indices and analysis that have not been presented in this report. The completed manuscript will be presented to Horticulture Australia prior to submission for publication.

Technology Transfer

Grower and Community Group Engagement

There were numerous activities throughout the year to engage and communicate the concept of 'Revegetation by Design' and integrating native vegetation with pest control with the community. In addition we also liaised with key resource people and stakeholders.

First, we had numerous meetings and tours around the district with SEQ Catchment including Kate Montgomery and her team. Second, we met with Margie Millgate, Natural Resources Network Coordinator, Growcom, on numerous occasions to discuss the project and results which allowed her to communicate with her stakeholders and inform them about the type of work being done. This also allowed her to gage interest across stakeholder groups and feed this back to us. Without exception, people from natural resource backgrounds were interested in our work.

Second, Dr. Schellhorn gave an invited talk at the 1st annual Australian Vegetable Industry Conference 2006 held in Brisbane.

Third, we were a stop for two groups of approximately 25 people visited during the 'Tour day' of the conference. We took details from growers interested in having us set up native vegetation experiments on their farms – basically planning for the five year proposal just submitted.

Fourth, in collaboration with Ms. Bronwyn Walsh of DPI&F we held a workshop at Gatton on 27 July 2006 and included presentations from Brendan Nolan DPI&F and Marc Coombs CSIRO on silver leaf whitefly and the parasitoid released to control it, *Eretmocerus hayati*. There were over 50 people in attendance, reportedly one of the best attendances on record, and a press release followed (App. A).

Fifth, Dr. Schellhorn and Ms. Walsh gave a presentation at Mulgowie Farms (one of the largest vegetable producers, packers and distributors) where Mr. Emerick invited several growers from the district and attendance was 32 people.

Six, Dr. Schellhorn is currently in discussion with SEQ Catchment about a voluntary contribution towards on-ground revegetation strategies that link riparian areas with agricultural fields. More details should be available soon.

In general over the past year we have been actively engaging the community and growers about the concept, how it integrates with their production systems and their level of interest in a partnership to further investigate the approach. We currently have too many interested growers and would be unable to set up experiments on all of their farms.

Recommendations

Our outcomes from VG05014 included: 1)support from industry / community to conduct the next phase of the research that will assist the horticultural industry with environmental management that results in positive benefits both for industry and the environment. Through our activities above, where we have show cased some of the results from Revegetation by Design SA and our recent findings from Revegetation by Design: QLD bush working for you, we have many interested growers / partners.

Our second outcome was that growers want to revegetate on their properties. There are numerous growers interested, particularly if we can provide the science that shows when it works and when it doesn't. We even have one of the largest producers, packers, suppliers – Mulgowie Farms – on board and happy to have us use parts of their property for experiments and revegetation.

However, demonstrating that on-farm vegetation manipulation disadvantages the pest and results in lower pest populations and lower pest control costs still needs rigorous testing. Several questions need to be answered before the Revegetation by Design concept can be implemented. First, can on-farm changes in vegetation management change pest and natural enemy dynamics or does the surrounding landscape have the greatest influence, thus always dominate any local farm management? Two, if on-farm changes in vegetation management do result in fewer pests and slower colonisation of the crop and / or more natural enemies and faster colonisation of the crop, are growers willing to adopt revegetation strategies? Third, is there a cost benefit for long-term pest and weed control using the cultural control of Revegetation by Design? Fourth, do consumers identify with and value links with the Australian bush and native flora, and hence make purchasing decisions around these issues? The work to date both in Australia and overseas certainly suggest that the Revegetation by Design approach is a promising and an important component of pest management, and may create a market advantage.

Acknowledgments

I would like to acknowledge: Anna Marcora for her excellent technical support, particularly her ability to take initiative, Mark Wade for his leadership on the project, and Maarten Vodde for his hard work and deligence. I thank Mulgowie Farms for allowing us to conduct our Malaise trap survey on their property. Particular thanks go to Andrew Johanson and The Emmericks. I would like to thank several people who dedicated their time even though they were not funded from the project: Bronwyn Walsh, DPI &F, contributed to grower meetings and workshops, including press releases and grower engagement; Margie Millgate, Growcom, took considerable time in helping us meet growers that are interested in the concept; SEQ Catchment staff, Kay Montgomery and Steve Lyngcoln were extremely helpful for vegetation assessment and identification. Finally I wish to acknowledge the grower levies, without their contribution this work would not be possible.

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Appendix A.

PRESS RELEASE 14 August 2006
Revegetation by design: the Queensland Bush Working for you

Research, by CSIRO Scientist, Nancy Schellhorn and her team, will see growers spending less time and money on pest control while producing high value crop that has a market advantage. Ms Schellhorn said this could be possible by managing the pest and natural enemy populations beyond the crop and capturing the benefits of pest control by natural enemies.

"Native vegetation, especially grasses and native bushes can provide habitat and resources for beneficial insects and replace weeds that harbour horticultural pests."

"Plus there are the added benefits of diversifying farm business through providing seed, cut flowers or bush tucker, managing natural resources such as reducing soil erosion, managing weeds and establishing a market edge through an 'environmental stewardship' product " said, Nancy at a DPI&F information evening in Gatton last month.

Surveying two existing habitats around grower's crops in the Lockyer Valley showed that from 20 native species and 5 weed species there were insect pests and natural enemies present. There was up to 10 times more pests and natural enemies in exotic grasses and bush weeds than in the native vegetation around crops.

The survey represents the beginning of her research towards understanding and then manipulating the environment around a vegetable cropping system to provide strategic pest management as well as the other benefits of native vegetation.

Nancy said it was also important to find out about the practicalities of native vegetation on farming properties so one of the next steps in her research will be to work with a group of 2-3 vegetable growers to try suitable native plants on their properties and hold workshops with a wider group to discuss native vegetation on vegetable properties. The project's activities will link closely with other natural resource management bodies and landscape users, such as Shire Councils and energy suppliers, who are also interested in the uses and benefits of native vegetation.

Further information on this research is available from Nancy Schellhorn, CSIRO Research Scientist, Phone (+61 7 3214 2721) , Email nancy.schellhorn@csiro.au