Development of tools to increase knowledge and capacity of growers to implement sustainable pest management solutions



FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

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Project Number: **UM 1001**

Development of tools to increase knowledge and capacity of growers to implement sustainable pest management solutions

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Project Number: UM 1001
Period Report Covers: 1/07/10 – 30/6/11
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Date report completed: October 2011

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1 Abstract:

This project provides growers with tools to provide ready access to information gained from GWRDC funded research and the wider research community on management practices to enhance natural enemy abundance and diversity with awareness of non-target effects of chemicals and vegetation within and adjacent to vines. Provision of resources within landscapes for natural enemies should allow their protective role to be enhanced, providing insurance against chemical impacts and indirectly increasing resilience of the industry to climate change impacts. Enhanced contribution of natural enemies to pest control shifts the balance of pest control away from chemical inputs and supports the GWRDC aim of developing increased sustainability and enhanced environmental performance.

2 Executive summary:

This project lies across industry aims of increasing sustainability of production, increasing integrated pest management practices and reducing the Australian wine industry's environmental footprint[1]. GWRDC aims to identify means to increase sustainability of production and environmental performance by developing better strategies for crop protection against pests and diseases, and providing tools to enhance the reputation of the industry as being environmentally sustainable[1]. Information on impacts of chemicals used in vineyards on beneficials is provided through the website, updated with information available to May 2011. Information provided here encourages consideration of chemicals used–ie choice is not simply whether to use a chemical, but to select within a wider range of chemicals and look at the longer term impact of choice. It is useful for both conventional and organic growers as the latter have access to chemicals such as sulphur which are known to have negative impacts on natural enemies especially when applied above 600 g/100L.

Increasing grower awareness of diversity present in vineyards, especially natural enemy diversity, encourages management practices that take natural pest control through beneficials into account. Easy access to resources to facilitate recognition of beneficials supports this overall aim. In line with other agricultural industries, the grape industry recognises the importance of such information. We have taken many images of invertebrates in vineyards and accessed others through our extensive network. The images collected have been uploaded to the website to assist growers to identify natural enemies and their role in vineyards. We aim to increase the value of this natural enemy image library with continued addition of images, particularly as new beneficial species are identified. The network established in the last year will facilitate this process.

Resources (Fact sheets: 'Pesticide impacts on beneficial species' and 'Shelterbelts and remnant vegetation adjacent to vineyards: implications for pest control' are complete
And the first is currently available on the Innovators Network website. The Presentations on chemical use, natural enemy monitoring, identification in vineyards and the role of non vine vegetation in vineyards, destined for the Innovators Network, have been trialled at grower workshops (90 participants) in three regions of South Australia and are currently under revision.

We have produced materials to assist in the production of what was called a 'Ute guide' in the Outputs for the project. Progression of this guide requires further revision and agreement on publication with other parties. We believe this would make an important addition to resources useful for implementing sustainable pest control in viticulture generally. The development of guides with images of natural enemies is being embraced by other industries with recent publications of guides for growers such as the extensive 'I Spy: Insects of Southern Australian Broadacre Farming systems Identification Manual and Education Resource- Common Pests, Beneficial and Exotic Insects of Broadacre Crops' published by NIPI (A4 hard cover) and 'Crop Insects the Ute Guide' - Western, Northern and most recently and most extensive Southern Grain Belt edition (note that the Grape Industry version is now referred to as a Field Guide). The grains Ute Guide provided 190 pages of images including 47 pages of beneficial invertebrates. These included not only natural enemies but also invertebrates contributing to weed control such as several weevil 'predators' of Patterson's

[1] 'Looking ahead' GWRDC Annual Operational Plan 2008-2009

Curse and a dock moth which kills all dock (*Rumex* sp) with large tap roots. As dock is known to provide overwintering sites for light brown apple moth, such invertebrates are likely to be beneficial in vineyards.

Future research

We suggest several related strands to be important for future development: continued updating of chemical information, extension to effects on soil health especially impacts of herbicides and extension to the role of invertebrates in fungal disease occurrence. First, new chemistries combined with continuing release of new test results for current chemicals requires ongoing literature review with the aim to revise and update our current information annually. Information on chemical use is provided to growers through the AWRI ('Agrochemicals Registered for Australian Viticulture') both electronically and through distribution of a booklet. The data base has been upgraded to reflect information available in May 2011. This information will be updated further because the chemical industry changes constantly- and potential effects on beneficial organisms also need to be updated in the same way. New chemistries become available, there are changes in chemicals registered for crops and new information regarding environmental effects including effects on non target organisms is being added all the time. For example during this project (June 2010-June 2011), six Agrochemicals updates were provided and a further three in the 3 months since (June 2011-September 2011) there four changes in 2011update and three products removed in update (AWRI Agrochemicals update June 2010) and five new products or constituents added (http://www.awri.com.au/industry_support/viticulture/agrochemicals/news/?news=41). Providing information to growers in response to these changes requires a 'watching brief' to ensure information is added as it becomes available.

Second, while ongoing literature review is important to provide regular updates to the database and ensure information is current, the environmental effects of chemicals would be enhanced by inclusion of soil organisms. Interest in soil management and awareness of the importance of soil as the foundation for a healthy vineyard is increasing. This is a rapidly developing field and information relevant to the industry needs to be collated and incorporated into the current website. This requires a literature review of chemical impacts of herbicides and pesticides on soil beneficial organisms, and delivery of this information to the website, supplementing current information on above-ground beneficial organisms. There has been very limited information regarding impacts of herbicides (and for that matter, adjuvants) on natural enemies and soil health. These are both integral to vineyard management and there is huge grower interest in soil processes as well as a burgeoning international literature, but no credible collation of literature for industry. Some advisors are providing dubious local "advice", but this needs to be based on quality literature and evaluation rather than potentially inappropriate anecdotal evidence.

The interaction between invertebrates and fungi is poorly studied though there are interactions which may have some impact on occurrence or severity of fungal infection events in vineyards. Fungus gnats (Diptera: Sciaridae) eat sufficient fungal spores to be a serious pest in mushroom farms and can occur in large numbers in vineyards, several families of beetles which may occur commonly in vineyards feed on moulds or spores of fungi. Minute bark beetles (Cerylonidae), fungus beetles (Corylophidae), silken fungus beetles (Cryptophagidae), handsome fungus beetles (Endomychidae), lined flat bark beetle (Laemophloeidae), minute brown scavenger beetles (Latriididae) and silvanid flat bark beetles (Silvanidae) all feed on fungi. We have seen such beetles 'grazing' on the fungal spores covering a vine leaf, leaving clear spaces as they feed. The potential effect of these organisms is largely unknown.

3 Background:

Management of pests and diseases remains a key issue for profitability but is also strongly linked to environmental issues within the industry. Developing effective means of shifting from traditional chemical control methods towards increased use of natural enemies provides financial gains as well as reduced off-site impacts. With climate change likely to produce unexpected outbreaks of pests and

diseases, it is important to develop resilient viticultural landscapes[2]. While research is underway towards predicting potential movement of pests under conditions of climate change, insurance is provided by a diverse and abundant suite of natural enemies.

Identification of reliable and cost-effective means to determine abundance and diversity of natural enemies in vineyards (1-3) has allowed us to make substantial progress in identifying ways to support and encourage natural enemy and other biodiversity in vineyards (4-11) and increase sustainability of the industry (12-14). Our aim is to provide accessible resources for growers: natural enemies can make a substantial contribution to pest control: their numbers can be enhanced by consideration of the toxicity of chemicals applied and provision of adjacent woody vegetation (15). Provision of resources to assist recognition of natural enemies will help growers.

The GWRDC plan for 2007-2012 identified 'better strategies for crop protection against pests and diseases' and 'identifying new ways to define and implement strategies to manage the challenges of climate change'. This project has contributed to these issues by developing control options based on more sustainable chemical use and developing recommendations for increasing resilience in pest control in the face of uncertain threats from pests.

4 Project aims and performance targets:

The aim of the project was to provide links for growers to research outcomes on increased pest control through enhancement of natural enemy abundance and diversity in vineyards. Increased pest control provided by natural enemies of vineyard pests improves the capacity of natural pest control with potential to both improve control of some of the more difficult pests and reduce input of chemicals with associated environmental and economic costs.
Three areas to provide resources for growers were targeted

1. Development of Fact Sheets for supply through Innovators Network on chemical use, woody vegetation and natural enemy identification
2. Development of the website to provide updated chemical information and assistance with identification of natural enemies for growers
3. Moves towards updated 'ute guide' as a handy reference for growers

Table 1: Planned outputs and performance targets as proposed in original application

Outputs	Performance targets
Guidelines for development of materials for Innovators Network	Consult with GWRDC staff about information and format required and set up ongoing relationships to steer this.
Updated chemical impacts on Collateral management website	Literature reviewed, information used to update and extend information available on website.
Further update to website with natural enemy images added	Images of natural enemies collected or taken and made available through Collateral management website
Regional guidelines for establishing vegetation for beneficials	Develop guidelines from our data on responses of natural enemies to a range of vegetation used in revegetation.
'Ute guide'	Development of a user friendly guide using images of natural enemies
Set of materials for Innovators Network	Develop a program incorporating the information developed in d and e suitable for the network.

5. Method:

There were three proposed outcomes for the project-

[2]GWRDC program 4

1. Development of Fact Sheets for supply through Innovators Network on chemical use, woody vegetation and natural enemies
2. Development of the website to provide updated chemical information and natural enemy identification support to growers
3. Moves towards updated ute guide to inform growers

The project was designed to provide information for growers in an accessible format. This was done by revising and updating the website and producing Innovators Network Resources (Fact Sheets, Technical Notes and Presentations) to be made available through the GWRDC initiative Innovators Network and production of a hard copy guide to natural enemies. Published information on chemicals, non vine vegetation adjacent and within vineyards and natural enemy identification was sought from peer reviewed papers and publications including those from other industries. Information on chemicals was added to an updated website which was rebadged IMPACT for Viticulture (Invertebrate Management of Potential Agro-Chemical Toxicity-maximizing your beneficial bugs) (Formerly Collateral Manage). Resources for the Innovators Network (Fact Sheets, Presentations and Technical Notes) were prepared and trialled to grower groups and Fact Sheets on chemical impacts on beneficials and effects of non crop vegetation made available on the Innovators Network website. Images of beneficials were uploaded to the website and progress was made in turning these into a hard copy guide.

6. Results/Discussion:

1. Chemical impacts on beneficials

Considerable development was seen in the database for allowing easy grower access to chemical impacts in vineyards on the CESAR website at http://cesar.org.au/index.php?option=com_collateral_manage with results of the literature survey collated and presented, references to an additional 30 scientific papers added and the database redesigned and rebadged as IMPACT for Viticulture (Invertebrate Management of Potential Agro-Chemical Toxicity-maximizing your beneficial bugs) (formerly Collateral Manage still at www.cesar.org.au). An important aspect of the data base is that it remains based solely on publications in the peer reviewed scientific literature and does not include information in unpublished and unrefereed reports.

A need for greater recognition of the links between pest and disease control was identified. We know that fungal infections especially powdery and downy mildew are not only the most significant problem in the industry but also result in the largest chemical impact on the vineyard (16). If we want to enhance diversity of natural enemies and other beneficials as well as their abundance in vineyards, effects of fungicides on these groups need to be considered. Two examples demonstrate this: predatory mites provide important control of pest mites and are negatively affected by fungicides containing mancozeb. Hence in a vineyard with potential pest mite problems, reference to the fungicide toxicity information provided by the data base allows consideration of alternative disease control options. Similarly, wettable sulphur at higher label rates (600g/100L) against powdery mildew is identified as a key disruptor of biological control of rust and bud mite in Australian vineyards[3]. Fungicide impacts on natural enemies are included in the database on chemical impacts. However, in view of the importance of fungicides to the industry, we believe fungicide impacts on natural enemies in vineyards warrant its own Fact sheet: Innovator Network resources for fungicides (Fact Sheet, Technical Notes and Presentation). The Pesticide Fact Sheet ('Pesticide impacts on beneficial species') is now available on the Innovators Network http://www.gwrdc.com.au/webdata/resources/files/Pesticide_impacts_on_beneficial_species.pdf

2. Natural enemy images

[3]Use of predatory mites for long term prevention of rust mite, bud mite and other pest mite outbreaks in Australian vineyards. Hoffmann AA, Bernard MB. FINAL REPORT to GWRDC. June 2011

Images of many beneficials were taken by staff and students on the project in the laboratory and during many vineyard visits. These were supplemented by requests and offers of photos from others in the industry. The source of all photos is acknowledged when each photo appears on the website and also when used in printed material. An 'Images of beneficials' button was added to the website with a photo gallery of the beneficials to assist in identification of relevant natural enemies. Discussions are underway with the aim of production of a 'Ute guide' either through inclusion in a new edition of the 'Field Guide to Diseases, Pests and Disorders of Grapes' (17) or by development of an independent guide to Vineyard Insects, similar to that developed for the GRDC.

3. Regional guidelines for vegetation.

Our extensive surveys in south eastern Australian wine regions demonstrate the important contribution of adjacent non crop vegetation to natural enemy abundance and diversity. A Fact Sheet for Innovators Network program of the GWRDC to provide information about region specific vegetation suitable for shelterbelt planting ('Shelterbelts and remnant vegetation adjacent to vineyards: implications for pest control') is currently with the GWRDC.

7. Outcome/Conclusion:

The aim of the project was to provide access for growers to research outcomes deriving from research in vineyards into means to enhance natural enemy contribution to pest control with particular emphasis on the impact of chemicals and adjacent vegetation. Resources were developed from literature reviews and our own previously published work, and tested with grower groups.

7.1 Performance against planned outputs and performance targets

Planned output/performance target: 'Consult with GWRDC staff about information and format required and set up ongoing relationships to steer this for development of tools' and 'Develop a program incorporating the information developed in d and e suitable for the network'. Innovators Network was identified as ideal means of communication and provision of grower resources. Initial discussions were held with Mark Kristic regarding format for provision of resources resulting in complete or ongoing preparation of Fact Sheets, for two of the logical components of the project (Chemical database and adjacent vegetation). In consultation with the GWRDC, it was decided that provision of grower access to the natural enemy or beneficial images is more efficiently provided through the website than in a Fact Sheet. In addition, presentations were trialled to about 90 participants at three workshops in South Australia: Adelaide Hills Mary Retallack (Retallack Viticulture), McLaren Vale Jodie Pain (Viticulture Coordinator McLaren Vale Grape Wine & Tourism Association) and Langhorne Creek Lian Jaensch (Executive Officer Langhorne Creek Grape and Wine Inc).

Planned output/performance target: 'Literature reviewed, information used to update and extend information available on website'. Extensive further literature review resulted in the addition of 30 references to the database with the information used to update the database and extend knowledge available to growers. The website also underwent considerable updating and revision to make it more informative and easier to use.

Planned output/performance target: 'Images of natural enemies collected or taken and made available through Collateral management website'. An additional button or selection option on the website has been activated ('Images of beneficials') providing access to an extensive library of photographs of beneficials taken in vineyards, and some taken in the laboratory. Many images were taken during vineyard visits by personnel involved with the project and other were sourced from our extensive contact base of vineyard personnel and researchers. The images are labelled and in some cases provide additional information regarding the role of the group or the individual. Images are representative of commonly occurring vineyard beneficials, and have proved useful to interested growers.

Planned output/performance target: 'Develop guidelines from our data on responses of natural enemies to a range of vegetation used in revegetation'

Our research (and that of many others both in Australia and internationally) indicates the important role of adjacent vegetation in enhancing natural enemies in crops. During the course of this project we identified many resources available to growers at the local level and lists of these are being put together in Innovators Network Resources to make available easy summaries for growers. Many grower groups including McLaren Vale Grape Wine & Tourism Association, Langhorne Creek Grape and Wine Inc., Grampians Winemakers Viticultural Group, Yarra Valley Wine Growers Association, and Mornington Peninsula Vignerons Association provide resources. Authorities such as Catchment Management Authorities, National Resource Management (NRM), Greening Australia and others provide local resources to inform growers of the locally available, recommended and likely to be successful plants. The Entwine Freshcare Resource Manual Environmental Viticulture, Winemakers Federation of Australia resources provide links and some groups such as the McLaren Vale and Barossa Winegrape Growers have prepared excellent grower resources (eg 'Enhancing biodiversity in the vineyard Adelaide and Mount Lofty Rages Natural Resources Management Board (Mary Retallack)', the Fosters Group produced Biodiversity Conservation Guidelines with the Australian Conservation Foundation, an excellent list of available resources at http://www.wfa.org.au/entwine_website/files/resources/Fosters-Biodiversity-Guidelines.pdf. and there are others. Reference to these resources is included in our Guidelines to establishment of adjacent vegetation.

Planned output/performance target: 'Development of a user friendly guide using images of natural enemies'. We have produced materials (see above 'Images of natural enemies collected or taken') to proceed with production of our collected images in what was called a 'Ute guide' in the Outputs for the project. Progress from collected material to a publication requires further revision and agreement on publication with other parties. We believe this would make an important addition to sustainable pest control in viticulture generally.

In addition to the completed and planned outputs, we have continued to publish outcomes of our research in vineyards with 10 peer reviewed and 3 industry publications produced over the lifetime of this project.

7.2 Practical implications of the research

Outcomes of this project provide growers with readily accessible, informative tools to enhance decision making when selecting from the 'normal' range of vineyard management practices to achieve both economic and environmental benefits. When there is an interest in enhancing natural enemies, first and foremost the nature of chemical use has to be considered. Chemicals may be essential for disease and pest control but choices can be made about the chemicals used and consideration of toxicities will allow growers to increase abundance and diversity of natural enemies and increase their contribution to pest control. Adjacent vegetation can be easy to provide and planted in areas identified as unsuitable for vines or to provide shelter. Such vegetation is good for natural enemies while providing other benefits to the industry and to the community more generally. So, the management practices targeted here have potential for production benefits as well as increasing diversity of invertebrates to contribute to pest control and also potentially improve soil health. In addition, reducing chemical impacts, increasing vegetation associated with vineyards and using native cover crops also have broader environmental and sustainability advantages at a time when environmental outcomes are increasingly relevant.

Recognition of the practical implications of this research is demonstrated by the interest shown both in Australia and internationally. We made it not once but twice to the IPM-Net news –an international news letter designed to draw attention to important current research world wide (www.ipmnet.org) underwritten by the U.S. Agency for International Development's IPM-Collaborative Research Support Program. We have been contacted by several American Universities in particular UC Davis, Oregon, Oklahoma and Michigan including a visit from Vaughn Walton (OSU) to discuss all aspects of our vineyard work with an invitation (LJT) to speak to growers in the US on this practical ways to enhance vineyard biodiversity and sustainability next year.

Closer to home, practical implications of our work were reinforced by references in other work eg Generating premium wine prices from vineyard biodiversity" *By Gary Leeson, Organic Crop Protectants Pty Ltd* "significant biodiversity work has been by Prof Ary Hoffman and Dr Linda Thomson (University of Melbourne, CESAR). They have investigated how adjacent vegetation provides habitat for beneficial insects that predate mealybug, weevils, LBAM, mite and scale pests. The pair has estimated that native vegetation up to 5m high can support up to 50,000 natural enemies per lineal metre!" And :"Just as important, has been Dr Thomson's and Prof Hoffmann's research on how some commonly used vineyard pesticides can seriously impact native beneficial insect populations. For example, sulphur used in a vineyard at 600g/100L is toxic to most major parasitoids, plus other predatory insects identified in their study. Dr Thomson has also shown that vineyards where herbicides are used contain considerably fewer earthworms, and of significantly smaller size, than vineyards not using herbicides. These findings support the argument for adopting permanent swards and mulching. The sub-lethal effects of many pesticides are relatively unknown — but the list is improving. What will remain unknown for some time is the sub-lethal effects of chemical combinations on sensitive eco-systems. This is why vineyard managers should consider adopting practices that promote biodiversity, and only use pesticides that are highly selective, with no, or minimal, residual effects.

We provided input to the WFA Entwine Freshcare resources, provided teaching input to several university Viticulture courses, and were invited to speak to groups and provide input to other published vineyard projects, such as Soil Management for Yield and Quality (Project Number: SAR 04/02) *Insect populations and abundance "*In collaboration with Dr. Linda Thomson from CESAR (Centre for Environmental Stress and Adaptive Research) at the University of Melbourne, the Barossa, Coonawarra and Swan Hill sites were intensively sampled for invertebrate populations, to determine how they might change due to changes in habitat generated through the different cover cropping practices. Further detail on the methodology used is to be found in the paper provided in this report".
We provided the invertebrate assessment in publications arising from this project and others:

- Chris Penfold, 2010. Native grass cover crops. Australian & New Zealand Grapegrower & Winemaker 554:48-50 Acknowledgements "Linda Thomson and her team at CESAR provided natural enemy data and analysis
- Chris Penfold, 2010. 'Should I try saltbush for a cover crop' Australian & New Zealand Grapegrower & Winemaker 552: 16-18 50 Acknowledgements "Linda Thomson and her team at CESAR provided natural enemy data and analysis
- Matthew Bailey, 2010. Insectarium/vegetation corridors in established vineyards. Australian & New Zealand Grapegrower & Winemaker 556 25-28. Acknowledgement Dr Linda Thomson from Melbourne University's Centre for Environmental Stress and Adaptation Research (CESAR) department has been assisting in the identification of insects and technical support

7.3 Economic and environmental benefits to the industry

The industry recognizes the value of developing a sustainable approach to grape growing particularly with reference to both increasing vegetation and decreasing chemical impacts There are environmental benefits in identifying means of shifting the balance in pest control towards natural enemies and decreasing chemical applications. Natural enemies of vineyard pests are well known to growers and if we can increase natural enemies there is potential to increase control, especially of difficult pests. At the same time we can reduce pesticide inputs with resulting economic savings, and also reduced environmental impacts on vineyards and the surrounding environment.

With regard to native vegetation we note 'Vineyards have historically been established on land already modified for agricultural production, such as grazing, cropping and dairy. Although the wine industry has not been directly responsible for the clearing of large tracts of native vegetation, the industry does accept a role in reinstating areas of native habitat in the landscape' [4]. Here we have

[4]Winemakers Federation of Australia Policy Position **'***Statements on Biodiversity*'

shown that reestablishing or maintaining vegetation has value to the industry as it enhances biodiversity including natural enemies.

Sustaining Success - 2002 set as a priority environmental issues including both the use of insecticides, fungicides and herbicides and maintaining and enhancing natural ecological systems and protecting biodiversity. Here we demonstrate overlap in achieving these goals, through sensitive use of chemicals (less toxic chemicals applied) and establishment/maintenance of vegetation to achieve environmental and pest control aims. Australia's 'clean and green' image is seen as critical to the industry's competitive advantage[5] as consumer demand for products which are natural, and environmentally friendly[6]. This research points to a way of reducing chemical input, decreasing the accumulation of chemicals within the soil and surface runoff of chemicals into neighbouring waterways. Social benefits associated with a cleaner and healthier environment flow from such environmental benefits. Vegetation softens the environmental impact of vineyards by providing a buffer between the vineyard and the community. Vegetation adjacent to vineyards provides habitat for desirable vertebrates and invertebrates, maximising biodiversity, and enhancing positive community perception of the industry. Our research indicates ways to manage these environments for maximum benefit to the growers.

8. Recommendations:

Apart from the need to provide growers with the most up to date information on aspects of vineyard management that impact on beneficial invertebrates, there is a need for developing stronger linkages between areas of research funded by the industry. For example, through such linkages, effects of soil and ground cover treatments on invertebrates were addressed. Often taking advantages of these opportunities does not require much funding, but rather it is the recognition of the opportunity that is important. For example, Powdery and Downy Mildew Innovators Network Tools make no mention of fungicide impacts on natural enemies. As the industry has invested in addressing the relationship between fungicides and pest outbreaks, inclusion of such information would seem advantageous and add value to other resources developed as part of this initiative. A further example is the advice to growers in several initiatives to minimise chemical use. Reference here to consideration of chemical being used should be added –impact on natural enemies needs to be considered, and not simply whether spraying should take place.

There is an increasing grower focus on the soil ecosystem as a vineyard resource that is fundamental to sustainably producing quality fruit. We would like to see the chemical impacts more extensively applied to soil organisms through a comprehensive literature review of invertebrates present in vineyard soils and management impacts on these (especially chemical applications). There is also considerable scope for informing growers about the effects of changes to the interrow region on invertebrate biodiversity. There is a lot of interest in planting cover crops and very little Australian research on invertebrate effects. The attractive flowering crops like buckwheat are demonstrably successful in enhancing parasitoids in New Zealand but anecdotal evidence from growers in Australia points to varied results. At the very least, a compendium of grower experiences should be put together to assist in decision making. Ideally, replicated studies should be set up across different vineyard regions, testing the impact of flowering cover crops and native grasses against more traditional crops on biodiversity and natural enemies, and also assessing whether these interventions are practical given increasing levels of climatic variability that can influence establishment of a crop.

Finally, while climate change will bring shifts in distribution of pests, there are also widely distributed pests whose importance will change due to changes in local climate and vine management. Information on of these effects on invertebrates will assist in informed pest control, providing knowledge required to support a healthy suite of natural enemies to enhance protection but also to inform about potential effectiveness on pest species. An example is the large auger beetle which we

[5]Winemakers Federation of Australia 10 year marketing strategy *'the Marketing Decade'* released in 2000
[6]Winemakers Federation of Australia *Strategy 2025*

have been modelling for the climate change project. This pest is widely distributed, so any influence of climate change on distribution is likely to be minimal, while altered effects on vineyards is more likely to come from changes in the interaction between the pest and the vine. Hence ongoing collection of information relevant to potential vineyard pests, their relationship with vines and the interrelationship with management strategies will help prepare industry for pest-related climate change challenges. While research is being undertaken to predict likely pest and natural enemy movement is important, steps toward a healthy suite of diverse and abundant natural enemies increases protection against new pest incursions as distributions change.

Appendix 1: Communication:

Some outcomes of the project exist now-the updated database and the image gallery. There was insufficient time in the short period available for this project (I year) to complete all data inputs and to finalize all planned communication outcomes. The Pesticide Fact Sheet (Pesticide impacts on beneficial species' is available on the Innovators network website. The Cover crop Fact Sheet ('Native cover crops in viticulture') includes a section on beneficials provided by us and the Fact Sheet on effects of adjacent vegetation('Shelterbelts and remnant vegetation adjacent to vineyards: implications for pest control') is in press. Availability of these resources through the GWRDC website Innovators Network, communicates outcomes to a wide audience of growers. Field days and workshops are always valuable opportunities not only to inform of our research findings but also to discuss these with growers and we are always keen to accept invitations. Our workshop at the 2010 AWITC conference was fully subscribed and related work on vineyard pests was presented at a second workshop at the conference. Outcomes have been presented at 3 field days, attended by approximately 95 growers and agronomists in South Australia.

We have published 3 industry articles to communicate research outcomes to growers and 10 peer reviewed articles, as well as a poster. Publications are listed below and copies of the published articles are attached where available (indicated *).

Future. We would like to see the database appear on a website with greater grower access. It is currently located on a university website, placing all grower resources in the GWRDC website would seem sensible. We see value in growers having easy access to pest and natural enemy images such as those provided by the GRDC. It is also important to continue literature searches for continued development of our database as well as to provide additional information on cover crops and adjacent vegetation.

Publications

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*Thomson LJ, McKenzie J, Sharley DJ, Nash MA, Tsitsilas A, Hoffmann AA, 2010. Effect of woody vegetation at the landscape scale on the abundance of natural enemies in Australian vineyards. Biological Control 54:248–254

*Thomson LJ, Hoffmann, AA, 2010. Natural enemy responses and pest control: importance of local vegetation. Biological Control 52:160–166

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Industry Publications

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*Linda Thomson and Ary Hoffmann, 2010. Cost benefit analysis of shelterbelt establishment: natural enemies can add real value to shelterbelts. Australian & New Zealand Grapegrower & Winemaker 554:38-44.

*Linda Thomson and Ary Hoffmann, 2010. Potential pest and natural enemy responses under climate change. Australian & New Zealand Grapegrower & Winemaker 563:30-32

Poster

Penfold CM and Thomson L, 2009. Pursuing sustainability – the role of native cover crops. Poster presented at the *4th International SASEV Conference on Enology and Viticulture Beyond 2010*, Cape Town, South Africa, 28-30 July

Presentations

Our workshop at 14th Australian Wine Industry Technical Conference 3 July - 8 July 2010 Adelaide, South Australia titled '**Enhancing natural enemy populations: vegetation, chemicals and climate change'** included three presentations from our work on vegetation- (Linda Thomson: Enhancing natural enemies in your vineyard-vegetation), on climate change (Linda Thomson and Ary Hoffmann: Viticultural pests and natural enemies under climate change) and chemical impacts (Michael Nash, Ary Hoffmann and Linda Thomson: Enhancing natural enemies in your vineyard-chemical impacts). The workshop also featured presentations from two viticulturalists, Matthew Bailey from Taltarni (The insectarium at Taltarni) and Rob Sutherland from De Bortoli (Experience with low chemical use at De Bortoli) plus an opportunity for participants to see "Vineyard predators up close" in a hands on workshop later in the program.

We also presented in the **Non-traditional grapevine pests workshop** 14th Australian Wine Industry Technical Conference 3 July - 8 July 2010 Adelaide, South Australia **(**Adrian Rakimov, Linda Thomson and Ary Hoffmann: Soft scale insects in Australian vineyards).

Linda Thomson, 2010. Woody vegetation and abundance and diversity of some natural enemies in vineyards. Australian Entomological Society's 41st AGM Scientific Conference Perth WA September 2010.

Database

Thomson LJ, Nash MA, Hoffmann AA, 2011. IMPACT for Viticulture (Invertebrate Management of Potential Agro-Chemical Toxicity-maximizing your beneficial bugs). Web based pesticide information tool for grape growers http://cesar.org.au/index.php?option=com_collateral_manage

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Fact sheets

- Pesticide Impacts on Beneficial species. Linda Thomson http://www.gwrdc.com.au/webdata/resources/factSheet/Pesticide_impacts_on_beneficial_species.pdf

- Shelterbelts and remnant vegetation adjacent to vineyards: implications for pest control. Linda Thomson, Michael Nash and Ary Hoffmann. In press.
- Contributed impacts of native cover crops on invertebrates to Native cover crops in viticulture. Chris Penfold and Cassandra Collins. http://www.gwrdc.com.au/webdata/resources/files/Native_cover_crops_in_viticulture.pdf

Appendix 2: Intellectual Property:

None identified. The research outcomes have all been published and provided as a public benefit.

Appendix 3: References

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Appendix 4: Staff.

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