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Integrated management strategies for diseases and pests of Asian vegetables

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Foreword

Asian vegetable production is a growing and dynamic industry sector in Australia. Although the diffuse nature of the industry makes it difficult to estimate its economic contribution to rural and regional Australia, analysts agree that it has expanded rapidly over the last two decades. Latest estimates have it contributing up to $150 million each year to the Australian economy.

This report presents the first detailed study of diseases and pests of Asian vegetables in Australia. It details key findings that will enable Asian vegetable growers to better manage diseases and pests. As a result of this project, growers will have an increased awareness of potential food safety and environmental hazards associated with traditional plant protection strategies. Consumers will also benefit, as production becomes less reliant on conventional pesticide application.

The report identifies the major diseases and pests that affect Asian vegetables and culinary herbs in production across Australia. It shows that their incidence and severity can vary with temporal, meteorological and geographical changes. For some diseases and pests, researchers achieved excellent control using integrated management strategies, replacing conventional pesticides with biocontrols. However, further research is required to develop alternative controls for other diseases and pests. The study highlighted the need for a full review of pesticide permits to ensure bio-rational products are available beyond their approaching expiry dates.

The report details several specific plant protection issues that may assist to direct future research. In particular, it supports the use of bilingual officers and community advocates to assist growers with poor English skills.

This report, an addition to RIRDC's diverse range of over 1800 research publications, forms part of our New Plant Products R&D program, which aims to facilitate the development of new industries based on plants and plant products that have commercial potential for Australia.

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Several other staff from NSW DPI collaborated on aspects of this project. Included are: Ms Stacey Azzopardi, Ms Melanie Scanes, Dr Sandra McDougall, Ms Sylvia Jelinek, Dr Mary Ann Terras, Ms Brenda Gorrie, Ms Tehgan Crowe, Mr Leigh James, Dr Peter Malcolm, Mr Lawrence Ullio, and Mr Darren Waterson.

Executive Summary

What the report is about

This report presents the first detailed study of diseases and pests of Asian vegetables grown in Australia. It comprises five parts, each detailing separate studies in the following areas:

(A) Pathogen identification & disease management

This study characterises the important diseases, their severity and distribution in Australia. It also presents results from individual experiments designed to develop improved management options utilising genetic, biological and chemical controls.

(B) Pest surveillance and management studies in the Sydney Basin

This section focuses on pest monitoring and pest management trials with growers in the Sydney Basin. These growers represent the largest group from a non-English speaking background (NESB) in the industry. In this report we use the term, LOTE (languages other than English) to describe these growers, but NESB is still used by many people and in the literature.

(C) Working with Victorian LOTE growers to improve adoption of IPM

This section reports on extension activities with LOTE growers in Victoria to facilitate understanding and adoption of improved pest and disease management options. Many regulatory, social and technical issues facing the predominantly Vietnamese-speaking community in the Greater Geelong region are discussed. In particular, the impact of extreme drought conditions during this project and changing local government regulations became an important focus for this region. The Project Officer discusses how he was able to negotiate the grower community through these issues with significant success.

(D) Integrated pest management (IPM) for baby-leaf vegetable production in Victoria

This section presents monitoring protocols and management strategies for pests and diseases of baby-leaf Asian vegetable crops in Victoria (in the Bairnsdale region, East of Melbourne). This region was severely affected by natural disasters during the project period, with bushfires, floods and drought all affecting crop production and disrupting progress of the project team.

(E) Appendix

This section contains various project findings, training activities, impact/change case studies and evaluation documents. A significant output from this project was the development of a number of resources that are being used to improve growers' skills in recognising and managing diseases and pests.

Who is the report targeted at?

This report is targeted at industry and government stakeholders with an interest in the production of safe and environmentally sustainable Asian vegetables in Australia. It contains both scientific details and plain English summaries of experiments conducted and resources developed over the four year study.

Background

Asian vegetable production in Australia is a growing and dynamic industry sector. It has expanded rapidly over the last two decades. It is estimated that the industry contributes around $150 million to the Australian economy each year (Hassall and Associates, 2003). This expansion has been driven by consumer demands, as Australians are embracing Asian vegetables and cuisine. We are increasingly using a range of minimally processed products along with traditional lines. Estimates suggest there are over 1,000 growers of Asian vegetables in Australia, with many from family-based enterprises with poor English and limited plant protection skills. Several government-sponsored initiatives have aimed to improve overall compliance with food safety standards, as well as to assist growers in areas such as water use efficiency, worker safety and reducing environmental impacts. The appointment of bilingual field officers through these initiatives has improved communication with growers and has addressed many issues. This project has seized an opportunity to boost compliance with several important aspects of plant protection. In particular, the Victorian Department of Primary Industry has begun developing integrated pest and disease management (IPM) strategies with these growers. This IPM approach is a critical plank for meeting consumer, worker and environmental safeguards. There are important pest and disease problems specific to Asian vegetables for which no legal control strategies were available at the commencement of this project. Poorly understood pest and disease problems have emerged in both traditional field production systems and new production methods and products, such as Asian baby-leaf production for minimally processed products and hydroponics using the nutrient film technique (NFT). Sustainable options for managing plant protection problems need to be developed and adopted by growers.

Aims/objectives

The aim of this project was to develop integrated disease and pest management strategies for Asian vegetable crops using the following approach:

- Identify the key diseases and pests causing losses in the major production regions across Australia by targeted surveillance
- Develop and evaluate effective disease and pest scouting/monitoring and management practices that are appropriate for the varying production systems, ranging from traditional market garden, broad-acre and high value intensive production
- Conduct on-farm trials to demonstrate IPM improvements
- Facilitate adoption of sustainable disease and pest management strategies using existing resources and developing new packages where needs are identified.

Methods used

The project was primarily based in NSW and Victoria, with activities extending to all major Asian vegetable production regions across Australia. Targeted surveillance and diagnostics were used to identify and validate the key diseases and pests in the different crops and production regions. Ongoing monitoring of crops determined the relative occurrence, phenology and impact of diseases and pests on yield and quality. International literature was also reviewed to establish current status and progress in developing integrated pest management in Asian vegetables worldwide.

Crop scouting methods (e.g. sampling protocols) and monitoring methods were refined, evaluated and correlated with damage levels. Field trials were used to evaluate and demonstrate a range of improved management strategies. These trials included: efficacy testing of biorational chemicals (products that have a minimal impact on beneficial insects and mites); applications of microbial biocontrols and beneficial insects and mites; various changes to cultural practices; and cultivar evaluation for resistance/tolerance to pests and diseases.

Grower training workshops were delivered to improve skills in pest and disease recognition and IPM. Workshops and farm walks were conducted in the Sydney Basin (NSW), Lara (Victoria), Brisbane (Queensland) and Humpty Doo (Northern Territory). Existing translated information on disease and pest recognition and IPM was collated and further resources were developed where required.

Results/key findings

The study demonstrated that IPM strategies were effective for Asian leafy vegetable crops. Scouting for pests was critical to obtain an early indication of pest activity, particularly as many leafy vegetables have a short crop cycle. In the Sydney Basin, IPM strategies achieved equivalent or better management of two-spotted mites and diamondback moth compared to the use synthetic pesticides.

Two foliar diseases were important in Asian leafy brassicas. In the Sydney Basin, white leaf spot was the dominant fungal disease while downy mildew was important in all production areas, particularly in Asian baby leaf production and Chinese broccoli. Given the short crop cycle, forecasting for downy mildew will be important to enable control when conditions are suitable.

Root diseases were important on farms with a long history of production in the Sydney Basin. Club root was the most important disease of leafy brassicas and there are currently few management options other than liming. One cultivar of Chinese cabbage showed tolerance to this disease. Thus far, it is not evident in hydroponically grown crops and growers were encouraged to move to this production technology for leafy brassicas as a means of avoiding club root. English spinach crops were severely affected by a complex of fungal and water mould pathogens in soil production in the Sydney Basin. The study demonstrated that certain chemical seed dressings have potential to reduce losses from these diseases.

Turnip mosaic virus was sporadic but caused major losses in some leafy brassica crops. This was linked to aphid activity and weed reservoirs on farms. Most significantly, much of the surveyed production areas were in severe drought during the project period, excepting for the final summer and autumn. Aphid activity and incidence of this virus were much greater during this latter period. The project team found similar trends with the Asian melon crops and Watermelon mosaic virus infections.

The key pests identified in baby leaf crops were different to expectations. Aphids were not a major issue, while the cabbage cluster caterpillar proved to be a significant pest.

In Victoria and New South Wales, pest pressure was found to change with seasonal conditions. In some cases, pests that were insignificant in the early phase of the project became important in the latter stages. For example, striped flea beetles were more important in the final year on brassica crops. Rutherglen bugs, which were important on some host plants, reached plague proportions at various stages. Possible reasons for this fluctuation are discussed but, like thrips, there are currently no soft chemical or alternative management strategies. However, garland chrysanthemums were shown to be potentially useful as a trap crop for Rutherglen bugs and thrips.

In NSW, the study team collaborated with other Government initiatives to improve grower education and IPM skills. One hundred and fifteen growers were trained to Certificate III in Agriculture. This included growers from Chinese, Vietnamese, Cambodian and Arabic backgrounds. In Victoria, LOTE growers successfully completed the following training: farm chemical users training (17 growers); food safety training (16 growers); and post-harvest training (14 growers). Several IPM workshops and farm walks were conducted across four states.

The study was successful in changing grower practices. Improved farm and crop hygiene practices were evident, particularly in regards to weed control and clean up of crop residues. Growers became more aware of the components of IPM, including the range of pests, understanding that beneficial insects exist and better and targeted use of selective chemicals. Significant change in chemical use practices included the use of personal protection equipment and targeted spraying based upon pest monitoring instead of application based on a calendar schedule. It will be important to ensure these changes are sustained through regular community engagement and education.

Implications for relevant stakeholders:

The industry and grower communities need to be aware that, although the study has identified emerging pests and diseases, these will require further investigation for the development of sustainable management practices. Regular pest and disease monitoring needs to become a standard practice and further education and community engagement will be necessary for this to be sustained. Access to bilingual officers will be critical to facilitate the education and change required to sustain an IPM approach in LOTE communities. The field production of baby-leaf crops has not had to contend with many important soil-borne diseases to date but this is likely to change with intensive production and quick crop successions. In older production areas such as the Sydney Basin certain soil-borne diseases have become endemic and their management is problematic without fumigation. The study did not identify any outstanding microbial biocontrols for the management of these diseases. Better use could be made of strategic crop rotations to minimise or sometimes negate important soil-borne diseases. For example, the study observed that Club root levels were very low in a trial that was conducted on beds that had a previous crop of spring onions. Growers are moving to hydroponic production strategies but this may open up the possibility of new disease problems. The study found root disease problems in coriander grown in hydroponic systems whereas they were insignificant in soil production. The study also found Rutherglen bugs favoured garland chrysanthemum crops growing in hydroponics when compared with field production. These observations will require further validation but new strategies may be developed where they are used as trap crops for these pests

Recommendations

Some pests and diseases were not present early in the project but became significant later. Possible reasons for this include changes in weather conditions during the course of the study and the emergence of new pest threats. Some water-borne diseases have begun to appear in hydroponic systems (mostly in English spinach and coriander production) and these will require further research to develop management strategies. The study has identified more gaps in the legal availability of some reduced-risk pesticides, particularly for robust chemical resistance management. The current minor-use permits have expiry dates that will require either re-issuing or full registration in the near future. Further grower education will be required and the resources developed in this project will be an important component for them to gain a better understanding of IPM principles and strategies.

There is a need for continued work with LOTE growers across Australia to build on the successes achieved to date. The communities in NSW and Victoria have come a long way towards overcoming difficulties with understanding and networking with Government and other agencies but this needs to be consolidated. There is a need to continue to develop pest monitoring and scouting skills for LOTE growers as well as improving their understanding of IPM practices. The 'case manager' approach and use of bilingual officers have proved to be an effective method for building the capability of LOTE growers in Victoria, who are affected by a range of issues and to break the sense of isolation that the community may feel. There is a need to develop quality assurance with LOTE growers to improve the quality of supply and improve the confidence of buyers of Asian vegetables and allow these growers to supply to mainstream retailers. This will also have an impact on the perception and safety of Asian vegetables. Given the range of crops many LOTE growers produce, there needs to be a better understanding of agronomic practices so that incompatible crops are not grown together and appropriate rotations are used to minimise severity of many diseases and pests.

The management of foliar diseases could be improved by the use of disease forecasting strategies. In particular, studies are required to develop alternative management strategies for downy mildews of leafy brassicas and spring onions incorporating weather-based disease prediction and spray scheduling and irrigation.

Introduction

Asian vegetable production in Australia is a growing and dynamic industry sector. It has expanded rapidly over the last two decades and has a current value of over $150 million per year. This expansion has been driven by consumer demands, as Australians are embracing Asian vegetables and cuisine. They are increasingly using a range of minimally processed products along with traditional lines. There are over 1,600 growers of Asian vegetables in Australia, many from family-based enterprises with poor English and plant protection skills (Hassall & Associates, 2003). Several government-sponsored initiatives have aimed to improve overall compliance with food safety standards, as well as to assist growers in areas such as water use efficiency, worker safety and reducing environmental impact. Appointment of bilingual field officers through some of these projects has improved communication with growers and is redressing many deficiencies.

This project has seized this opportunity to boost compliance with several important aspects of plant protection. In particular, the Department of Primary Industries in Victoria has begun developing integrated pest and disease management strategies for these growers. This approach is a critical plank for meeting consumer, worker and environmental safeguards. There were important pest and disease problems specific to Asian vegetables for which no legal control strategies were available at the commencement of this project. Poorly understood pest and disease problems have also emerged in traditional production systems and where new production methods and products are being developed, such as Asian baby-leaf production for minimally processed products. Sustainable options for managing these problems need to be developed and adopted by growers.

Asian baby leaf vegetables are becoming a key component of a number of minimally processed salad and stir-fry mixes. For Harvest Fresh Cuts (HFC), a major producer of minimally processed vegetables, baby leaf makes up 35 per cent of total salad sales with a processed value of $14M and Asian baby leaf vegetables are a major component of the minimally processed baby leaf product. Currently the farm gate value for Asian baby leaf vegetables is $1M and growing at 30 per cent per year, while the farm gate value nationally is around $10M with most going to the food service industry. Minimally processed salads are a rapidly expanding high value and intensive industry.

Growers of Asian vegetables, processors, exporters and the wider community will all benefit from this project. The project will increase productivity for growers, reduce crop losses and provide more continuity of supply for processors and consumers. Economic benefits are difficult to quantify, but there have been several examples in Asian vegetable production where correct diagnosis and application of the effective management strategies has saved whole crops. In other words, there is a potential to reduce losses and increase sales by 20-60 per cent. Food safety will also be improved, as there will be less reliance on pesticides. These benefits will become more noticeable as food products are increasingly scrutinised for chemical residues. Use of IPM strategies will also reduce production impacts on the environment, and decrease risks to farm workers and the surrounding community. This latter point is especially relevant in the peri-urban areas of production.

This report is written in five parts, each detailing separate studies in the following areas: general pathology; entomology in the Sydney Basin; extension activities with LOTE growers in Victoria; baby-leaf Asian vegetable plant protection; and an appendix.

Part A Pathogen identification and disease management

1. Introduction

This section reports on disease surveillance activities across Australia and specific experiments designed to develop improved management options for the major pathogens in the Sydney Basin of NSW.

2. Materials & Methods

2.1 Farm surveys

Field surveys were conducted to determine important pathogens of Asian vegetable crops growing in Australia. The most intensive surveys were in the Sydney Basin production area of NSW between November 2004 and February 2008 on a total of 67 farms. Some properties were surveyed on a continuous basis. Five farms were surveyed in each of Victoria, Queensland and the Northern Territory. Two wasabi farms were surveyed in Tasmania.

2.2 Laboratory diagnosis

Selected plant material from surveyed crops, including root, stem and leaf samples, were collected for the isolation or identification of plant pathogens. Weeds were also surveyed for possible insect vectors and virus reservoirs.

Plants were initially clinically examined with the aid of light microscopy.

Viruses were determined by Electron Microscopy and various immunological methods (ELISA and Immuno test strips (Agdia Corp., USA)).

Bacteria were initially cultured to KB and SPA media and selected for typical culture and gram-stain morphologies, fluorescence under UV-light, oxidase test, and later characterised by several methods (immunological agglutination, Biolog^{TM}, Fatty Acid Methyl Ester grouping and 16srRNA sequences).

Fungal and Oomycete isolates where cultured on various media: *Phytophthora* (potato carrot agar [PCA] plus pimaricin, rifampicin and hymexazole), *Pythium* (PCA plus pimaricin and rifampicin), *Rhizoctonia* and other fungi (water agar [WA] plus rifampicin, ¼ potato dextrose agar [PDA] plus novobiocin, and ¼ PDA plus lactic acid [LA]).

Target pathogens were sub-cultured under aseptic conditions and stored for use in pathogenicity and product efficacy trials. All disease diagnostics and pathogen identifications were conducted using methods accredited to ISO17025 quality standards.

2.3 Experiments to determine pathogenicity and product efficacy

A total of 13 experiments and field trials were conducted on a selection of Asian vegetables to determine:

- relative pathogenicity of isolates collected during surveys, and
- efficacy of microbial biocontrols, growth stimulants and fungicides to control diseases. Products evaluated in efficacy experiments are described and specific trials listed in Table 1.

Table A1. Microbial biocontrols, growth stimulants and chemicals used

Product	Active ingredients	Rate/use-pattern	Assessment Trial #
Biologicals			
Fulzyme™ Plus JH Biotech Inc (Zadco For Quality Gro Ltd)	*Bacillus subtilis* & amino acids	2L/1000L	2,3,11
Microplus™ Organic Farming Systems Ltd	*Streptomyces lydcius* WYEC108 (1 x 10^7 cfu/ml)	0.4kg/10000L 1g/kg seed	4,5
Tri-D-25® JH Biotech Inc (Zadco For Quality Gro Ltd)	*Trichoderma harzianum* and *T. koningii*	1 - 3g / 1L	2,3,11
Pooled *Trichoderma* (isolates from NSW DPI collection, EMAI)	*Trichoderma harzianum, T.koningii, T.virens, T.hamutum* &*T. atroviridae*	28g infested oat grains per pot.	3
Trich-A-Soil® Organic Crop Protectants Ltd	*T.viride* and *T.harzianum* (>1000 million viable spores/g)	10g/L	3
Saion EM1 Sanko Sangyo	Combination of Phototrophic bacteria, *Lactobacillus*, Yeasts and	1/20 of stock solution in	2

Product	Active ingredients	Rate/use-pattern	Assessment Trial #
Ltd	Ray fungi	molasses	
Fungicides			
DPX Dupont	Experimental product	250ul/L as drench, 10ml/kg seed coat	2,3,4,5,7,
Terraclor® Colin Campbell Chemicals	750g/kg quintozene	1g/L	2
Amistar ® WG Syngenta Crop Protectants	500g/kg azoxystrobin	300mg/L	11
Dynasty® CST Syngenta Crop Protectants	75g/L azoxystrobin + 37.5g/L metalaxyl-M+12.5g/L fludioxonil	1 to 5ml/kg seed	4,5,6,7,8
Bion 500SC Syngenta Crop Protectants	500g/L acibenzolar- S-methyl	600ul/kg seed	5,6,9,10
Apron® XL 350ES Syngenta Crop Protectants	350g/L metalaxyl-M	3ml/L	7,8
Tecto®	500g/L Thiabendazole	57.2uL/4g	6,7,
Agral® Syngenta Crop Protectants	600g/L Nonyl Phenol Ethylene oxide	2% solution	11,12,13
Growth stimulants			
Phoscare ® 0-28-25 JH Biotech Inc	28g/L Phosphorous Acid 25g/L soluble potash	35.7ml/L	11

Product	Active ingredients	Rate/use-pattern	Assessment Trial #
(Zadco For Quality Gro Ltd			
Liquid Silica Quantum group	13.25% K_2O 26.5% SiO_2	0.5ml/L	2
Humax JH Biotech Inc (Zadco For Quality Gro Ltd	50% Humic acid 30% Fulvic acid 12% Potassium	1g/L	3

Seeds were purchased from South Pacific Seeds Ltd and Green Harvest Ltd and initially screened for percent germination, vigour and contaminants. Seeds were either treated before sowing or drenched once they were sown with the appropriate treatment. In all experiments treatments were randomised within replicates. Plants were watered daily and fertilised once a week with Nitrosol® (Yates Ltd.).

2.3.1 Trial 1: Pathogenicity of root rot fungi to English spinach

Inoculum was prepared from fungal isolates that were collected from field infections of English spinach. Cultures were incubated at 25^{o}C for 10 days. They were then homogenised with milli-Q water. The equivalent of ½ plate per pot was incorporated into the top layer (3cm) of the potting media. Careful hygiene practices were employed to avoid cross-contamination between pots.

In total, 19 isolates were selected: seven each of *Phytophthora* and *Pythium,* four of *Rhizoctonia solani,* one *Fusarium oxysporum*, and a negative control. The potting medium consisted of peat, perlite and sand at a 1:1:1 ratio (pH 6.8 and EC 1.2).

Ten English spinach (cv. *Winter Giant*) seeds were sown per 3 L (8 inch) pot. Germinating, wilting and dying plants were harvested and the appropriate pathogen re-isolated onto selective agar.

Two time-points for each isolate were analysed separately using the binomial GLM with logit-link allowing for over dispersion. The significance of the fungal isolate effects was assessed using a likelihood ratio test (LRT). If the fungal isolate effects were found to be significant, post-hoc comparisons between isolates are presented.

2.3.2 Trial 2: Chemical and microbial biocontrols for control of root disease of English spinach

Phytophthora isolates 04/795A and 05/986, *Pythium* isolates 04/756 and 05/986, and *Rhizoctonia* isolates 06/201 and 04/793 were chosen. The cultures were grown on agar media and incorporated as stated above in Trial 1. The potting media consisted of peat, perlite and sand at a 1:1:1 ratio (pH 6.0 and EC 410ms).

Ten English spinach (cv. *Winter Giant*) seeds were sown per 3 L (8 inch) pot. There were 19 treatments replicated four times and were randomised on benches into complete blocks.

Germination occurred within four to five days and wilting seedlings were scored and plated onto selective media plates to isolate pathogens of interest. Numbers of wilting, dead and live plants were recorded.

Results of final numbers of plants remaining were recorded for each treatment. The pathogens' vigour was compared to the nil-treatment control as a percentage (%).

Treatment details are presented below in Table A2.

Table A2. Pathogen and treatment combinations used in Trial 2

Treatment #	Isolate	Treatment	Concentration	Volume added
1	Nil	Nil	Nil	Nil
2	*Pythium* 04/756			
3	*Pythium* 05/986			
4	*Rhizoctonia* 06/201			
5	*Rhizoctonia* 04/793			
6	*Phytophthora* 04/795A			
7	*Phytophthora* 05/986			
8	*Pythium* 04/756	Liquid Silica	0.5 ml/L	500 ml/pot
9	*Phytophthora* 04/795A			

Treatment #	Isolate	Treatment	Concentration	Volume added
10	*Rhizoctonia* 06/201			
11	*Pythium* 04/756	Fulzyme™ Plus	2ml/L	
12	*Phytophthora* 04/795A			
13	*Rhizoctonia* 06/201			
14	*Pythium* 04/756	Saion EM 1	1/20 of EM 1	250 ml/pot
15	*Phytophthora* 04/795A			
16	*Rhizoctonia* 06/201			
17	*Rhizoctonia* 06/201	Tri-D25®	1 g/L	500 ml/pot
18	*Rhizoctonia* 06/201	DPX	250 υl/L	500 ml/pot
19	*Rhizoctonia* 06/201	Terraclor®	1 g/L	500 ml/pot

2.3.3 Trial 3 Chemical and microbial biocontrols for **Rhizoctonia** *on English spinach*

Rhizoctonia 04/793 was grown on selective agar (1/4 PDA+ Novo) for seven days at 25^{o}C. English spinach (cv. *Winter Giant*) seeds were sown in a potting medium consisting of peat, perlite and sand at a 1:1:1 ratio (pH 6.2 and EC 450 ms) and thinned to 12 seedlings per pot. Three days after germination, the chemical and biocontrols treatments were added. After a further three days, *Rhizoctonia* plates were homogenised and one plate was added per pot. The inoculum was placed on the top 3 cm layer of the pot. Nil isolate treatments had PCA incorporated at the same concentration.

A total of 12 treatments were replicated eight times. The 3 L (8 inch) pots were placed in a complete randomised block design. Germinating seedlings were recorded as well as wilting and dying plants. Table A3 below indicates treatments and concentrations applied.

The generalised linear model was fitted to mortality data. The errors were assumed to follow a binomial distribution and logit function was used to link the observed values to the parameters to be estimated. A maximum likelihood was used to estimate the parameters. Treatment differences were tested on their logit scale using a least significant difference (LSD) test at the five per cent level.

Table A3. Pathogen and treatment combinations used in Trial 3

Treatment #	**Isolate**	**Treatment**	**Concentration**	**Volume added**
1	Nil	None	water	500 ml/pot
2	*Rhizoctonia* 04/793	None	water	500 ml/pot
3	*Rhizoctonia* 04/793	DPX ½ rate	63 ul/500 ml	500 ml/pot
4	*Rhizoctonia* 04/793	DPX full rate	125 ul/500 ml	500 ml/pot
5	*Rhizoctonia* 04/793	EMAI *Trichoderma*	x 5 isolates (pool)	28 g on wheat seed/pot
6	*Rhizoctonia* 04/793	Trich-A-Soil®	10 g/L	500 ml/pot
7	*Rhizoctonia* 04/793	TriD25®+ Fulzyme™ Plus +Humax	1 g/L 2 ml/L 1 g/L	1 g/L 2 ml/L 1 g/L
8	Nil	DPX full rate	125 ul/500 ml	500 ml/pot
9	Nil	EMAI *Trichoderma*	x 5 isolates (pooled)	28 g on wheat seed/pot
10	Nil	Trich-A-soil®	10 g/L	500 ml/pot
11	Nil	Tri-D25®+ Fulzyme™ Plus +Humax	1 g/L 2 ml/L 1 g/L	500 ml/pot

Treatment #	Isolate	Treatment	Concentration	Volume added
12	*Rhizoctonia* 04/793	Trich-A-soil®+ Fulzyme™ Plus +Humax	10 g/L 2 ml/L 1 g/L	500 ml/pot

2.3.4 Trials 4 & 5 Chemical and microbial biocontrols for control of root rot pathogens of English spinach

The isolates *Pythium* 05/986, *Phytophthora* 05/1011 and *Rhizoctonia* 04/793 were grown on the selective media PCA for 10 days at 25^{o}C. Isolates were homogenised and diluted in sterile water. An equivalent of one plate (250 ml) was mixed into the top 3 cm layer of the potting medium. These 3 L (8 inch) pots were placed in a complete randomised block design. English spinach seeds (cv. *Winter Giant*) were coated with four different treatments, placed with the above pathogens and replicated six times. Seeds were coated and left overnight in a fume hood. 30 seeds were sown per pot in a potting medium consisting of peat, perlite and sand at a 1:1:1 ratio (pH 6.3 and EC 450 ms). Both germinating seedlings and wilting plants were recorded. Due to uneven germination (including Nil control treatments) Trial 4 was terminated and repeated with the same treatments (Trial 5).

Table A4 indicates treatments and concentrations applied in Trials 4 and 5.

Table A4. Pathogen and treatment combinations used in Trials 4 and 5

Treatment #	Isolate	Dressing	Concentration
1	Nil	Talc (gypsum)	0.25g/5g seed
2	*Pythium*	Talc	+100 ul H_20
3	*Phytophthora*	Talc	
4	*Rhizoctonia*	Talc	
5	Nil	DPX	10 ml/kg seed
6	*Pythium*	DPX	50 ul/5 g/Talc
7	*Phytophthora*	DPX	+50 ul H_20
8	*Rhizoctonia*	DPX	
9	Nil	*Streptomyces lydcius*	50 mg/5 g seed +100 ul H_20
10	*Pythium*	*Streptomyces lydcius*	

Treatment #	Isolate	Dressing	Concentration
11	*Phytophthora*	*Streptomyces lydcius*	
12	*Rhizoctonia*	*Streptomyces lydcius*	
13	Nil	Dynasty® CST	50 ul/5 g seed
14	*Pythium*	Dynasty® CST	+50 ul H_20
15	*Phytophthora*	Dynasty® CST	
16	*Rhizoctonia*	Dynasty ®CST	

The primary objective of the trials was to compare the dressing treatments for each pathogen in turn. Separate univariate analysis of seed mortality was conducted at each measurement (germination and final) and each pathogen in turn, making a total of eight separate analyses for each trial. For each analysis, the number of surviving seedlings was analysed using a binomial generalized linear model (GLM) with logit-link, and allowing for over-dispersion. In each analysis, the effects of dressing treatments were fitted.

Fisher's protected LSD approach was used for assessing the significance of differences between individual dressing treatment means for each analysis. That is, a likelihood ratio test (LRT) was first conducted to test the null hypothesis of no significant differences between treatments. If the LRT statistic was significant at the five percent level, post-hoc comparisons between individual dressing treatment means were performed. In this case, average and maximum LSDs at the five per cent level for treatment comparisons are presented.

2.3.5 Trial 6 Chemical seed dressings for control of root rot pathogens of English spinach

The isolates *Rhizoctonia* 04/793, *Pythium* 05/986, *Phytophthora* 05/1011 were grown on selective agar Potato Carrot Agar (PCA). All isolates were grown for 10 days at 25^{o}C. All seed dressings were applied one day before sowing and left to air dry over night in a fume hood. A potting medium consisting of peat, perlite and sand at a 1:1:1 ratio (pH 6.0 and EC 410 ms) was used. The cultures were homogenised and diluted with sterile water. The equivalent of one plate per pot was added per 3 L (8 inch) pot. The culture was mixed in the top 3 cm of soil. Fifty seeds per pot were sown. Germinating seedlings were recorded as well as wilting plants and a final count made. There were 21 treatments replicated six times. Pots were placed in a complete randomised block design. Treatment details are listed in Table A5 below.

Table A5. Pathogen and treatment combinations used in Trial 6

Treatment #	Isolate	Treatment	Concentration/20g seed

Treatment #	Isolate	Treatment	Concentration/20g seed
1	Nil	Nil	1 g Gypsum+ 1 ml H_20
2	*Rhizoctonia* 04/793	Nil	1 g Gypsum+ 1 ml H_20
3	*Pythium* 05/986	Nil	1 g Gypsum+ 1 ml H_20
4	*Phytophthora* 05/1011	Nil	1 g Gypsum+ 1 ml H_20
5	*Rhizoctonia* 04/793	Dynasty ® CST + Tecto®	100 ul+286ul + 614 ul H_20
6	Nil	Dynasty® CST + Tecto®	100 ul+286 ul + 614 ul H_20
7	*Rhizoctonia* 04/793	Dynasty ® CST + Tecto® + Bion 500SC	100 ul+286 ul + 12 ul + 602 ul H_20
8	Nil	Dynasty® CST + Tecto® + Bion 500SC	100 ul+286 ul + 12 ul + 602 ul H_20
9	*Rhizoctonia* 04/793	Tecto®	286 ul + 714 ul H_20
10	Nil	Tecto®	286 ul + 714 ul H_20
11	*Pythium* 05/986	Dynasty ® CST	100 ul / 20 g seed + 200 ul H_20
12	*Phytophthora* 05/1011	Dynasty® CST	100 ul +900 ul H_20
13	Nil	Dynasty® CST	100 ul +900 ul H_20
14	*Pythium* 05/986	Dynasty® CST + Bion 500SC	100 ul + 12 ul + 878 ul H_20
15	*Phytophthora* 05/1011	Dynasty ® CST + Bion 500SC	100 ul + 12 ul + 878 ul H_20
16	*Rhizoctonia* 04/793	Dynasty ® CST + Bion 500SC	100 ul + 12 ul + 878 ul H_20
17	Nil	Dynasty® CST + Bion 500SC	100 ul + 12 ul + 878 ul H_20
18	*Pythium* 05/986	Bion 500SC	12 ul +988 ul H_20
19	*Phytophthora* 05/1011	Bion 500SC	12 ul +988 ul H_20

Treatment #	Isolate	Treatment	Concentration/20g seed
20	*Rhizoctonia* 04/793	Bion 500SC	12 ul +988 ul H_20
21	Nil	Bion 500SC	12 ul +988 ul H_20

2.3.6 Trial 7 Chemical seed dressings for control of root rot pathogens of English spinach

The isolates *Pythium* 05/986, *Phytophthora* 05/986 and *Rhizoctonia* 04/793 were grown on the selective agar Potato carrot agar (PCA) for 12 days at 25°C. These were homogenised and diluted in distilled water and made up to volume, 200 ml was added per pot (one plate per 3 L pot). This was incorporated into the top 3 cm of medium, consisting of peat, perlite and sand at a 1:1:1 ratio (pH 6.3 and EC 450ms). Uncolonised and homogenised PCA was used as Nil pathogen treatments. A pool solution of the fungicides was made and volumes added to individual treatments. The seed was treated and allowed to air-dry overnight in a fume hood. It was sown the next day. A total of 50 seeds were uniformly sown in each pot. There were 16 treatments, which were replicated five times. Details of each treatment are presented below in Table A6.

Table A6. Pathogen and treatment combinations used in Trial 7

Treatment #	Isolate	Treatment	Concentration/seed
1	*Rhizoctonia* 04/793	DPX	100 ul/10 g +100 ul H_20
2	*Rhizoctonia* 04/793	Tecto®	14 3ul/10 g +57 ul H_20
3	*Rhizoctonia* 04/793	Dynasty® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20
4	*Rhizoctonia* 04/793	Dynasty® CST + Tecto®	
5	*Rhizoctonia* 04/793	Dynasty® CST + Tecto®+ DPX	
6	*Pythium* 05/986	Apron®	12 ul/4 g + 88 ul H_20
7	*Pythium* 05/986	Dynasty® CST	
8	*Pythium* 05/986	Dynasty® CST + Apron®	
9	*Phytophthora*	Apron®	

Treatment #	Isolate	Treatment	Concentration/seed
	05/986		
10	*Phytophthora* 05/986	Dynasty® CST	
11	*Phytophthora* 05/986	Dynasty® CST + Apron®	
12	Nil	Dynasty® CST + Tecto®+ DPX +Apron®	
13	*Rhizoctonia* 04/793	Nil	200 mg Gypsum +100 ul H_20
14	*Pythium* 05/986	Nil	200 mg Gypsum +100 ul H_20
15	*Phytophthora* 05/986	Nil	200 mg Gypsum +100 ul H_20
16	Nil (PCA)	Nil	200 mg Gypsum +100 ul H_20

The response variable (germination and final counts) for each isolate was analysed separately using a binomial GLM with logit link allowing for over dispersion. The significance of the dressing effects was assessed using the likelihood ratio test (LRT).

2.3.7 Trial 8 Chemical seed dressings for control of **Pythium** *in English spinach*

The isolate *Pythium* 05/986 was grown on the selective agar PCA for 10 days at 25^{o}C. These plates were homogenised and diluted in distilled water and made up to volume. The stock *Pythium* inoculum was then diluted to give varying concentrations of the pathogen (equal to of 1,1/2,1/4,1/10 of a plate/pot). Uncolonised PCA were used for *Nil* pathogen treatments. Media consisted of peat, perlite and sand at a 1:1:1 ratio (pH 6.0 and EC 410 ms). The inoculum was added and incorporated into top 5 cm of each 3L (8 inch) pot.

Fungicides were weighed and volumes added to seed in a plastic bag. Dry chemical formulations were wetted to form thick slurry that was mixed with seed. Treated seed was allowed to air-dry overnight in a fume hood and sown the following day. Fifty seeds were sown per pot. There are 20 treatments, each replicated six times in a complete randomised block design. Details of each treatment are presented below in Table A7.

Table A7. Pathogen and treatment combinations used in Trial 8

Treatment #	***Pythium* concentration**	**Seed treatment**	**Concentration**
1	Nil	Nil	Nil
2	Nil	Dynasty ® CST +Apron ®	30 ul +100 ul/10 g +200 mg Gypsum +100 ul H_20
3	Nil	Apron®	30 ul + 170 ul H_20
4	Nil	Dynasty ® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20
5	*Pythium* 05/986 1 plate	Nil	Nil
6	*Pythium* 05/986 1 plate	Dynasty ® CST +Apron®	30 ul +100 ul/10 g +200 mg Gypsum +100 ul H_20
7	*Pythium* 05/986 1 plate	Apron®	30 ul + 170 ul H_20
8	*Pythium* 05/986 1 plate	Dynasty ® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20
9	*Pythium* 05/986 ½ plate	Nil	Nil
10	*Pythium* 05/986 ½ plate	Dynasty ® CST +Apron ®	30 ul +100 ul/10 g +200 mg Gypsum +100 ul H_20
11	*Pythium* 05/986 ½ plate	Apron®	30 ul + 170 ul H_20
12	*Pythium* 05/986 ½ plate	Dynasty ® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20
13	*Pythium* 05/986 1/4 plate	Nil	Nil
14	*Pythium* 05/986 1/4 plate	Dynasty ® CST +Apron ®	30 ul +100 ul/10 g +200 mg Gypsum +100 ul H_20

Treatment #	*Pythium* concentration	Seed treatment	Concentration
15	*Pythium* 05/986 1/4 plate	Apron®	30 ul + 170 ul H_20
16	*Pythium* 05/986 1/4 plate	Dynasty ® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20
17	*Pythium* 05/986 1/10 plate	Nil	Nil
18	*Pythium* 05/986 1/10 plate	Dynasty ® CST +Apron ®	30 ul +100 ul/10g +200 mg Gypsum +100 ul H_20
19	*Pythium* 05/986 1/10 plate	Apron®	30 ul + 170 ul H_20
20	*Pythium* 05/986 1/10 plate	Dynasty ® CST	100 ul/10 g +200 mg Gypsum +100 ul H_20

The response variable (germination and final counts) for each isolate was analysed separately using a binomial GLM with logit link allowing for over dispersion. The significance of the dressing effects was assessed using the likelihood ratio test (LRT). If dressing rate was found to be significant, post–hoc comparisons between dressings for each isolate are presented.

2.3.8 Trial 9. Club root control in pak choy (cv. Sumo*) with the application of seed dressing of Bion 500SC*

Infested field soil and plant material was collected from a grower's property that was heavily affected by club root. Soil (an alluvial sandy loam) was placed into 2 L pots. Clubbed roots were combined, homogenised and diluted in distilled water and made up to 2.2 L. The growth cabinet was set at 25^{o}C.

Experiment 9a. Treatments consisted of: (1) Nil treatment and (2) a seed dressing of the plant defence activator, Bion 500SC (10 ul/g of seed). The club root homogenate supernatant was decanted and applied at the rate of 100 ml per pot. Fifteen seeds were sown per pot and 1-2 cm of sterile potting mix was placed over the top to facilitate germination. This was replicated 10 times for each treatment. Pots were placed randomly in the growth cabinet and rotated every three to five days.

Experiment 9b. Treatments were the same as described above for Experiment 9a except that the club root homogenate supernatant was applied only to replicates one to three in both treatments. A third treatment included the addition of the club root gall sludge. This was to verify which part of the inoculum was more infectious. Thus there were only three replicates for each treatment. Seed was treated, sown and pots were randomised and moved as described above.

Plants were harvested 40 days after sowing. Clubbing of plant roots were rated according to Table A8 below.

Table A8. Club root disease rating scale used for growth cabinet trials

Grading scale	Root Description
0	No visible clubbing
1	Several small clubs on the tips of the lateral roots
2	Large clubs on the lateral roots
3	Slight clubbing of the main tap root, large clubs on the laterals
4	Considerable clubbing of the main tap root and a much reduced root system
5	Complete clubbing of the whole taproot and virtually no lateral roots.

A binomial GLM with logit-link was used for the analysis of survival rates allowing for possible over dispersion. An average clubroot score was calculated for surviving plants (ignoring the original nature of the data, and assuming that the above scores 0-5 represent numerical values). A weight linear model was used for the analysis of the logit-transformed scores.

2.3.9 Trial 10 Club root control in pak choy (cv. **Sumo***) with the application of seed dressing of Bion50SC*

The infested soil from the previous cabinet trial was reused. Soil was combined and mixed thoroughly and placed into 4 inch pots. The fungicide Bion 500SC was prepared at the following concentrations 10, 5, 2.5, 1, 0.1 and 0ul/g and applied to the seed. The seeds were left overnight to dry. There were 15 seeds sown per pot and three replications of each Bion 500SC concentration. Treatment 1 received a potting mix and excluded the club root pathogen. Treatments 2 and 3 had clubroot-infested soil. The seedlings were harvested after one month and checked for growth abnormalities and club root severity.

2.3.10 Trial 11 Field trial: Control of **Phytophthora, Pythium** *and* **Rhizoctonia** *in English spinach with biological and chemical treatments*

An infected field plot was selected early in the project to see if control of the above pathogens was possible. Plots of 1x2 metres were measured, with the 1/2 metre buffers between plots were left to reduce cross contamination of treatments. Randomised treatments were allocated to certain areas. There are five treatments and seven replicates (refer to Table A9 below).

Table A9. Treatments applied in on-farm English spinach trial

Treatment number	Treatment Name	Concentration added	Volume per 1x2m^2
1	Nil (water)	40 L	5 L
2	Fulzyme^{TM} Plus	80 ml/40 L	5 L
3	Tri- D-25®	120 g/40 L	5 L
4	Fulzyme^{TM} Plus +Tri-D-25®	80 ml+120 g/40 L	5 L
5	Amistar® WG	12 g/40 L	5 L

2.3.11 Trials 12 and 13 Field trials to assess efficacy of genetic, chemical and biological controls for clubroot in Chinese cabbage.

Field plots were selected that had previously had clubroot infected leafy Brassica crops. The beds where segmented into 2 m^2 plots. There are five treatments; each replicated four times using two Chinese cabbage cultivars (one 'resistant' and one 'susceptible' to club root). Details of the treatments are presented in Table A10.

Table A10. Treatments applied in clubroot field trials (12 &13)

Treatment number	Treatment name	Concentration added	Volume added to 2 m^2
1	Nil (water)	Nil	5 L
2	Compost		340 L
3	Hot lime	1 tonne/Hectare	600 g
4	Agral®	800 ml/40 L (T12) 80 ml/40 L (T13)	5 L
5	Phoscare®	1429 ml/40 L	5 L

The hot lime and compost was added and incorporated into the top layer of soil of the selected plots by a rotary hoe. Agral® and Phoscare® was drenched over the seedlings, water was used over Nil controls. The trials were monitored over 45 days.

3. Results and discussion

3.1. Farm surveys & laboratory diagnosis

There were a total of 732 diseased plant samples processed by the Plant Health Research Laboratory at the Elizabeth Macarthur Agricultural Institute, Menangle, NSW (Table A11).

Table A11. Disease records on Australian Asian vegetable crops, 2004-2008

Table A11a. Leafy brassicas and related plants

Crop Name	Scientific name	Disease	Scientific name	% Incidence
Pak choy (Green stem)	*Brassica rapa* subsp. *chinensis*	White leaf spot	*Psuedocerosperella capsellae*	0-90%
		White blister	*Albugo candida*	0-100%
		Downy mildew	*Hyaloperonospora parasitica*	0-50%
		Alternaria leaf spots	*Alternaria* spp.	0-25%
		Blackleg	*Phoma lingam*	0-10%
		Clubroot	*Plasmodiophora brassicae*	0-100%
		Root rot	*Rhizoctonia solani*	0-20%
		Mosaic	Turnip mosaic virus	0-90%
			Cucumber mosaic virus	0-50%
		Bacterial leaf spots	*Erwinia* sp. *Pseudomonas* sp. *Xanthomonas* sp.	0-15%
Buk choy (White stem)	*Brassica rapa* subsp. *chinensis*	White leaf spot	*P. capsellae*	0-90%
		White blister	*A. candida*	0-100%
		Downy mildew	*H. parasitica*	0-60%
		Alternaria leaf spots	*Alternaria* spp.	0-25%

Crop Name	Scientific name	Disease	Scientific name	% Incidence
		Blackleg	*P. lingam*	0-10%
		Clubroot	*P. brassicae*	0-100%
		Root rot	*Rhizoctonia solani*	0-20%
		Mosaic	Turnip mosaic virus	0-80%
		Mosaic	Cucumber mosaic virus	0-30%
		Bacterial leaf spots	*Erwinia* sp. *Pseudomonas* sp.	0-15%
Choy sum (Yellow flowering)	*Brassica rapa* subsp. *parachinensis*	White Leaf spot	*P. capsellae*	0-70%
		White blister	*A. candida*	0-70%
		Downy mildew	*H. parasitica*	0-50%
		Alternaria leaf spots	*Alternaria* spp.	0-15%
		Blackleg	*P. lingam*	0-15%
		Clubroot	*P. brassicae*	0-100%
		Root rot	*R. solani*	0-20%
		Mosaic	Turnip mosaic virus	0-40%
		Bacterial leaf spots	*Pseudomonas* sp. & *Xanthomonas* sp.	0-10%
Gai choy Chinese mustard	*Brassica juncea*	Downy mildew	*H. parasitica*	*0-50%*
		White blister	*A. candida*	0-75%
		Clubroot	*P. brassicae*	0-65%
		Mosaic	Turnip mosaic virus	0-20%
Gai lan Chinese broccoli	*Brassica oleracea* var. *alboglabra*	Downy mildew	*H. parasitica*	0-80%
		White blister	*A. candida*	0-75%
		Clubroot	*P. brassicae*	0-90%

Crop Name	Scientific name	Disease	Scientific name	% Incidence
Wombok Chinese cabbage	*Brassica rapa* subsp. *pekinensis*	White leaf spot	*P. capsellae*	0-60%
		White blister	*A. candida*	0-40%
		Downy mildew	*H. parasitica*	0-10%
		Alternaria leaf spots	*Alternaria* spp.	0-5%
		Blackleg	*P. lingam*	0-5%
		Clubroot	*P. brassicae*	0-100%
		Mosaic	Turnip mosaic virus	0-45%
		Bacterial leaf spot	*Xanthomonas* sp.	0-15%
		Bacterial soft rot	*Erwinia carotovora*	0-15%
Daikon (White) radish	*Raphanus sativus*	Leaf spot	*Alternaria* sp.	0-5%
		White blister	*A. candida*	0-100%
		Mosaic	Turnip mosaic virus	0-80%
		Clubroot	*P. brassicae*	0-100%
		Root rots	*Fusarium oxysporum*	0-100%
			Verticillium dahliae	0-50%
			Pythium sp.	0-100%
Wasabi	*Wasabia japonica*	Leaf spot	*P. lingam*	0-20%
Rocket	*Eruca vesicaria*	White blister	*A. candida*	0-90%
		Downy mildew	*H. parasitica*	0-50%
		Bacterial leaf spot	*Pseudomonas syringae* pv *maculicola*	0-15%
		Bacterial leaf spot	*Xanthomonas campestris* pv. *raphani*	0-15%

Crop Name	Scientific name	Disease	Scientific name	% Incidence
		Mosaic	Turnip mosaic virus	0-5%
			Cucumber mosaic virus	0-5%

Table A11b. Asian melons

Crop name	Scientific name	Disease	Scientific name	% Loss
Sin qua (Angled luffa)	*Luffa actutangula*	Anthracnose	*Colletoctricum orbiculare*	0-80%
		Leaf spot	*Ulocladium cucurbitae*	0-10%
		Root rots	*Phytophthora* sp.	0-10%
			Pythium ultimum	0-10%
			Fusarium sp.	0-10%
		Mosaic	Cucumber mosaic virus	0-25%
Shui qua (Smooth, sponge luffa)	*Luffa aegyptiaca*	Anthracnose	*C. orbiculare*	0-80%
		Root rots	*Phytophthora* sp.	0-10%
			Pythium sp.	0-10%
			Fusarium sp.	0-10%
Seng qua (Long melon & Chinese winter melon)	*Benincasa hispida*	Anthracnose	*C. orbiculare*	0-80%
		Root rots	*Phytophthora* sp.	0-10%
			Pythium irregulare and P.ultimum	0-10%
			Fusarium sp.	0-10%
		Gummy stem blight	*Didymella bryoniae*	0-10%
		Powdery mildew	*Podosphaera xanthii*	0-100%
		Mosiac	Watermelon mosaic virus	0-10%
			Cucumber mosaic virus	0-10%

Crop name	Scientific name	Disease	Scientific name	% Loss
Chi qua (Hairy melon)	*Benincasa hispida* var. *chieh-gua*	Anthracnose	*C. orbiculare*	0-80%
Fu qua (Bitter melon)	*Momordica charantia*	Gummy stem blight	*D. bryoniae*	0-10%
		Powdery mildew	*P. xanthii*	0-100%
		Mosaic	Cucumber mosaic virus	0-20%
		Bacterial leaf spot	*Pseudomonas syringae* pv. *syringae*	0-60%

Table A11c. Other crops

Crop name	Scientific name	Disease	Scientific name	% Loss *
Coriander	*Coriandum sativum*	Root rots	*Pythium coloratum* and *P. spinosum*	0-60%
			Fusarium sp.	0-15%
		Soft rot	*Erwinia carotovora*	0- 25%
		Mosaic	Apium virus Y	0-40%
			Alfalfa mosaic virus	0-40%
			Unknown Rhabdovirus	0-40%
Perilla (Shiso) (red, green)	*Perilla frutescens* var. *japonica*	Root rots	*Rhizoctonia* sp.	0-25%
			Pythium sp.	0-25%
			Fusarium sp.	0-25%
		Sclerotinia	*Sclerotinia* sp.	0-15%
Parsley (Italian &	*Petroselinum crispum*	Leaf blight	*Alternaria petroselini*	0-40%
		Leaf spot	*Septoria petroselini*	0-100%

Crop name	Scientific name	Disease	Scientific name	% Loss
Curly)		Root Rots	*Phytophthora* sp.	0-80%
			Pythium spinosum and *P. ultimum*	0-80%
			Fusarium sp.	0-80%
		Collar rot	*Rhizoctonia solani*	0-40%
		Leaf spot	*Colletoctricum* sp.	0-30%
		Leaf spot	*Pseudomonas syringae*	0-60%
		Mosaic	Apium virus Y	0-25%
			Alfalfa mosaic virus	0-30%
Thai basil	*Bai horapa*	Root rots	*Phytophthora cryptogea.*	0-75%
			Pythium sp.	0-75%
			Fusarium sp.	0-75%
			Macrophomina phaseolina	<1%
			Thielaviopsis basicola	<1%
		Anthracnose	*Colletoctricum* sp.	0-15%
		Leaf spot	*Pseudomonas viridiflava*	0-25%
		Powdery mildew	*Oidium* sp.	0-50%
English spinach	*Spinacia oleracea*	Root rots (complex)	*Phytophthora* spp	0-80%
			Pythium spp	
			R. solani	
			Fusarium sp.	
		Mosaic	Turnip mosaic virus	0-20%
			Unknown Rhabdovirus	0-5%
			Cucumber mosaic virus	0-10%

Crop name	Scientific name	Disease	Scientific name	% Loss
Snake bean	*Vigna unguiculata spp. sesquipedalis*	Root rots	*Pythium ultimum*	0-10%
			R. solani	0-10%
		Leaf spot	*Septoria vignae*	0-65%
		Wilt & stem rot	*Fusarium oxysporum*	0-100%
		Mosaic	Cucumber mosaic virus	0-10%
			Tomato spotted wilt virus	0-15%
Kang kong	*Ipomoea aquatica*	Root rots	*Phytophthora* sp.	0-5%
			Pythium ultimum	0-5%
			R. solani	0-5%
		Leaf spot	*Phoma* sp.	<1%
		Mosaic	Unknown Rhabdovirus	<1%

During the field surveys, some growers had converted to hydroponic (NFT) production of Asian vegetables. Six hydroponic farms were surveyed for root pathogens. Various *Pythium* isolates were isolated and one grower had *Phytophthora* in his system. However, it was noted that none of the leafy brassica crops grown within these systems appeared to be significantly affected by these pathogens over a two-year survey period. Significant losses did occur in English spinach, coriander and parsley. The primary pathogens isolated were *Pythium* spp. Further research is required on the potential for root diseases to cause losses in hydroponic production of Asian vegetables as this form of production is new and it is likely that more aggressive pathogens will emerge.

3.2. Pathogenicity Trials

3.2.1 Trial 1, English spinach pathogenicity trial

Rhizoctonia and *Phytophthora* isolates had no significant effect on seed germination and seedling establishment. Some *Pythium* isolates were strongly pathogenic, causing pre-emergent damping off. *Rhizoctonia* isolates caused the most plant death (70-95 per cent of total seed sown) while the other pathogens reduced plant survival by 50-70 per cent. The fact that all three pathogens were found associated with diseased field plants (in some cases in the same plant) suggests that they form a disease complex and it will be important to develop management strategies that can control each individual pathogen.

Pathogen effects on seed germination and plant establishment are shown in Table A12. Effects on cumulative plant death are presented in Table A13. Tables of means are presented on the logit scale, with back transformed probabilities in brackets. Each table also includes the LRT F test probabilities and LSD (least significant difference) for pair-wise comparisons on a logit scale. Where the LRT F test was significant at the five per cent level, significant pair-wise differences between PHDS are indicated with a 'letter' notation.

Table A12. English spinach mean germination/plant establishment (% of total seed sown)

Phytophthora		***Pythium***		***Rhizoctonia***	
PHDS#	**Mean**	**PHDS#**	**Mean**	**PHDS#**	**Mean**
04/786	-0.63 (34.8%)	04/710	-1.44 (19.2%) bc*	04/701	0.20 (55.0%)
04/793/1	0.10 (52.6%)	04/756	-0.10 (47.5%) c	04/793/1	0.62 (65.0%)
04/795/2	-1.76 (14.7%)	05/163	-1.61 (16.7%) bc	05/1011	0.85 (70.0%)
05/1011/2	-1.26 (22.2%)	05/986	-1.01 (26.8%) bc	06/201	1.55 (82.5%)
05/189/1	-0.74 (32.3%)	06/033	-2.59 (7.0%) ab		
05/189/2	-0.74 (34.8%)	06/143	-3.75 (2.3%) a		
05/986	0.10 (52.6%)	05/189	-1.14 (24.2%) bc		
Av (max) LSD	1.40 (1.64)		1.37 (2.19)		1.39 (1.50)

Phytophthora		*Pythium*		*Rhizoctonia*	
PHDS#	**Mean**	**PHDS#**	**Mean**	**PHDS#**	**Mean**
LRT F Prob.	0.11		0.00045		0.25

* Numbers followed by a different letter are significantly at p=0.05

Table A13. Pathogen effect on mean cumulative plant death

Phytophthora		*Pythium*		*Rhizoctonia*	
PHDS#	**Mean**	**PHDS#**	**Mean**	**PHDS#**	**Mean**
04/786	0.62 (65.0%)	04/710	0.20 (55.1%)	04/701	0.88 (70.6%)
04/793/1	0.85 (70%)	04/756	0.86 (70.2%)	04/793/1	2.0 (88.1%)
04/795/2	0.10 (52.5%)	05/163	0.31 (57.6%)	05/1011	1.78 (85.6%)
05/1011/2	-0.20 (45.0%)	05/986	0.86 (70.2%)	06/201	3.01 (95.3%)
05/189/1	0.41 (60.0%)	06/033	0.20 (55.1%)		
05/189/2	0.20 (55.0%)	06/143	-0.41 (39.9%)		
05/986	0.85 (70.0%)	05/189	0.41 (60.1%)		
Av (max) LSD	1.08 (1.14)		0.97 (1.02)		1.72 (2.06)
LRT F Prob.	0.35		0.16		0.082

3.2.2 Trial 2: Chemical and microbial biocontrols for control of root disease of English Spinach

Further evidence for pathogenicity of the selected fungal isolates can be seen from the treatment effects where the pathogens were applied alone (Table A14). Again, the *Rhizoctonia* isolates were the most severe pathogens (87-97 per cent plant death). Two chemical drench treatments, DPX and quintozene, provided control of *Rhizoctonia* alone. In contrast, both products containing microbial biocontrols (*Trichoderma* spp) were ineffective in this trial. The *Bacillus subtilis* (*Fulzyme*™ *Plus*) treatment reduced losses associated with one *Phytophthora* isolate and the liquid Silica treatment caused stunting within the seedlings compared to the negative control. The Effective Microbes 1 (formulated with molasses) burnt the seedlings and no harvestable data was recorded for these treatments. Results are detailed in Table A14.

Table A14. Mean cumulative death of English spinach from Trial 2

Treatment #	Isolate	Treatment	Mean % Death
1	Nil	Nil	0
2	*Pythium* 04/756	Nil	37
3	*Pythium* 05/986		35
4	*Rhizoctonia* 06/201		87
5	*Rhizoctonia* 04/793		97
6	*Phytophthora* 04/795A		27
7	*Phytophthora* 05/986		35
8	*Pythium* 04/756	Liquid Silica	52
9	*Phytophthora* 04/795A		92
10	*Rhizoctonia 06/201*		99
11	*Pythium* 04/756	Fulzyme™ Plus	45
12	*Phytophthora* 04/795A		7
13	*Rhizoctonia 06/201*		92
14	*Pythium* 04/756	Saion EM 1	100*
15	*Phytophthora* 04/795A		100*
16	*Rhizoctonia* 06/201		100*

Treatment #	Isolate	Treatment	Mean % Death
17	*Rhizoctonia* 06/201	Tri-D25®	92
18	*Rhizoctonia* 06/201	DPX	2
19	*Rhizoctonia* 06/201	Terraclor®	7

3.2.3 Trial 3 Chemical and microbial biocontrols for **Rhizoctonia** *on English Spinach*

The fungicide DPX drench was very effective against *Rhizoctonia* (at the standard rate and ½ this rate of application). The *Trichoderma* treatments significantly reduced mean plant death by 7-30 per cent compared with the pathogen alone. Data is presented in Table A15 below. A different letter follows Logit data if they are significant at the five percent level.

Table A15. Mean cumulative death of English spinach from Trial 3

Treatments	Logit (p)	se	% death
Nil	-12.4e		0
Rhizoctonia DPX ½ rate	-12.4e		0
Rhizoctonia DPX Full rate	-12.4e		0
Nil + DPX Full rate	-12.4e		0
Nil + TriD25® + *Fulzyme*^{TM} *Plus* + Humax®	-3.22d	0.51	3.85
Nil + Trich-A-Soil®	-2.99d	0.446	4.81
Nil +EMAI *Trichoderma*	-2.49d	0.369	7.69
Rhizoctonia + Trich-A-Soil® + *Fulzyme*^{TM} *Plus* +Humax®	0.77c	0.211	68.27
Rhizoctonia + EMAI *Trichoderma*	0.903c	0.216	71.15
Rhizoctonia +	1.71b	0.272	84.62

Treatments	Logit (p)	se	% death
TriD25® + *Fulzyme*^{TM} *Plus* + Humax®			
Rhizoctonia plus Trich-A-Soil®	2.36b	0.349	91.35
Rhizoctonia	3.93a	0.714	98.08

3.2.4 Trial 5. Chemical and microbial biocontrols for control of root rot pathogens of English Spinach

In the analysis of germination counts, the LRT statistic for testing the null hypothesis of no treatment effects was significant for Nil and *Pythium* pathogens (Table A16). For the Nil pathogen, mean germination percentages for the Talc dressing were significantly higher than each of the other dressing treatments. For *Pythium*, Dynasty®CST had significantly higher mean germination counts than each of the other treatments.

In the analysis of final counts, the LRT statistic for testing the null hypothesis of no treatment effects was significant for Nil (P<0.05), *Pythium* (P<0.05) and *Rhizoctonia* (P<0.001) pathogens (Table A16). For the Nil pathogen, mean final percentages for DPX and Dynasty ®CST were significantly lower than for Talc. For *Pythium*, CST had significantly higher mean final percentages than each of the other treatments. For *Rhizoctonia*, mean final percentages for Talc and *Streptomyces lydcius* treatments were each significantly lower than each of the DPX and Dynasty®CST treatments.

Table A16. Mean seedling establishment & survival of English spinach from Trial 5

Germination count				
	Nil	***Pythium***	***Phytophthora***	***Rhizoctonia***
Talc	1.01 (73.3%)	-1.73 (15.0%)	0.43 (60.6%)	-0.09 (47.8%)
DPX	0.04 (51.1%)	-1.65 (16.1%)	0.50 (62.2%)	0.50 (62.2%)
Streptomyces lydcius	0.25 (56.1%)	-1.73 (15.0%)	-0.00 (50.0%)	-0.67 (33.9%)
Dynasty® CST	-0.11 (47.2%)	-0.74 (32.2%)	0.90 (71.1%)	0.38 (59.4%)
Av (max) LSD	0.70 (0.72)	0.79 (0.84)	0.68 (0.70)	0.95 (0.96)
LRT prob.	0.017	0.022	0.082	0.068

Germination count				
	Nil	***Pythium***	***Phytophthora***	***Rhizoctonia***
Final count				
	Nil	***Pythium***	***Phytophthora***	***Rhizoctonia***
Talc	0.31 (57.8%)	-2.55 (7.2%)	-0.13 (46.7%)	-2.83 (5.6%)
DPX	-0.29 (42.8%)	-2.14 (10.6%)	0.09 (52.2%)	-0.16 (46.1%)
Streptomyces lydcius	-0.00 (50.0%)	-2.33 (8.9%)	-0.62 (35.0%)	-2.83 (5.6%)
Dynasty ®CST	-0.36 (41.1%)	-1.35 (20.6%)	0.07 (51.7%)	-0.31 (42.2%)
Av (max) LSD	0.45 (0.45)	0.88 (0.99)	0.60 (0.60)	1.27 (1.67)
LRT prob.	0.019	0.025	0.079	8e-06

3.2.5 Trial 6. Chemical seed dressings for control of root rot pathogens of English spinach

Estimated treatment means were calculated for each of the eight analyses of the trial data and presented in Table A17. Back-transformed means, representing survival percentages, are shown in brackets. Also shown are the average (and maximum in brackets) LSD at the five per cent level for pair-wise treatment comparisons, and the significance of the LRT statistic for testing the null hypothesis of no treatment effects.

Table A17. Mean seedling establishment & survival of English spinach from Trial 6

Germination (% of seed sown)				
	Nil	***Pythium***	***Phytophthora***	***Rhizocotonia***
Nil	1.82 (86.0%)	-1.66 (16.0%)	1.56 (82.7%)	-0.91 (28.7%)
Bion 500SC	1.39 (80.0%)	-1.27 (22.0%)	1.35 (79.3%)	-1.43 (19.3%)
Dynasty ®CST	0.34 (58.3%)	-0.36 (41.0%)	0.45 (61.0%)	-
Tecto®	1.05 (74.0%)	-	-	0.91 (71.3%)
Dynasty ® CST+ Bion 500SC	0.53 (63.0%)	-0.09 (47.7%)	0.68 (66.3%)	0.46 (61.3%)
Dynasty ® CST+ Tecto®	0.85 (70.0%)	-	-	0.49 (62.0%)
Bion 500SC Tecto®	-	-	-	-

Germination (% of seed sown)				
	Nil	***Pythium***	***Phytophthora***	***Rhizocotonia***
Dynasty ® CST + Tecto® +Bion 500SC	0.24 (56.0%)	-	-	0.32 (58.0%)
Av (max) LSD	0.66 (0.77)	1.15 (1.28)	0.62 (0.68)	0.72 (0.78)
LRT prob.	0.00017	0.027	0.0027	3.7e-07
Final count (% of seed sown)				
	Nil	***Pythium***	***Phytophthora***	***Rhizocotonia***
Nil	2.02 (88.3%)	-1.93 (12.7%)	1.30 (78.7%)	-1.99 (12.0%)
Bion 500SC	1.79 (85.7%)	-1.30 (21.3%)	1.27 (78.0%)	-2.44 (8.0%)
Dynasty ® CST	1.17 (76.3%)	-0.20 (45.0%)	0.94 (72.0%)	-
Tecto®	0.96 (72.3%)	-	-	0.39 (59.7%)
Dynasty ® CST Bion 500SC	0.90 (71.0%)	-0.23 (44.3%)	0.99 (73.0%)	0.74 (67.7%)
Dynasty ® CST + Tecto®	1.32 (79.0%)	-	-	0.80 (69.0%)
Bion 500SC +Tecto®	-	-	-	-
Dynasty ® CST + Tecto®+ Bion 500SC	0.71 (67.0%)	-	-	0.68 (66.3%)
Av (max) LSD	1.03 (1.23)	1.38 (1.58)	0.79 (0.82)	0.86 (1.13)
LRT prob.	0.14	0.036	0.7	1.6e-10

In the analysis of germination counts, the LRT statistic for testing the null hypothesis of no treatment effects was significant for each of the four pathogens. For the Nil pathogen, all non-Nil treatments except for Bion 500SC had significantly lower mean germination percentages than the Nil treatment. For *Pythium*, both Dynasty ® CST and Dynasty ® CST + Bion 500SC had significantly higher mean germination counts than the Nil treatment. For *Phytophthora*, Dynasty ®CST and Dynasty®CST + Bion 500SC treatments had significantly lower mean germination percentages than the Nil treatment. Finally, for *Rhizoctonia*, all treatments except for Bion 500SC had significantly greater mean germination counts than the Nil treatment.

In the analysis of final counts, the LRT statistic for testing the null hypothesis of no treatment effects was significant only for *Pythium* ($P<0.05$) and *Rhizoctonia* ($P<0.001$).

For *Pythium*, Dynasty®CST and Dynasty®CST + Bion 500SC treatments had significantly greater mean final percentages than the Nil treatment. For *Rhizocotonia,* all treatments except for Bion 500SC had significantly greater mean final percentages than the Nil treatment.

All isolates were reisolated from their appropriate pots showing viable inoculum was present.

3.2.6 Trial 7 Chemical seed dressings for control of root rot pathogens of English spinach

Tables of means are presented in Table A18a and A18b on the logit scale, with back transformed probabilities in brackets. Each table also includes the LRT F test probabilities and the LSD (least significant difference) for pair-wise comparisons on the logit scale. Where the LRT F test was significant at the five per cent level, significant pair-wise differences between treatments means are indicated using the letter notation.

For the germination counts, significant differences were found between dressings for all isolates. While for the final counts, there were significant differences between dressings for nil and *Rhizoctonia* isolates.

Table A18a. Mean seedling establishment of English spinach from Trial 7

Dressing	Nil	*Rhizoctonia*	*Pythium*	*Phytophthora*
None	0.97 (72.5%)[b]	1.79 (14.3%)[a]	-3.20 (3.9%)[a]	0.77 (68.3%)[c]
Apron®	-	-	-2.58 (7.1%)[a]	0.40 (60%)[bc]
Dynasty® CST	-	0.03 (49.2%)[bc]	-1.12 (24.6)[b]	-0.31 (42.4%)[a]
DPX	-	0.10 (52.4%)[bc]	-	-
Tecto®	-	0.37 (59.3%)[c]	-	-
Apron® + Dynasty® CST	-	-	-1.33 (21%)[b]	-0.20 (49.6%)[ab]
Tecto®+ Dynasty® CST	-	-0.08 (48%)[bc]	-	-
DPX +Tecto®+ Dynasty® CST	-	-0.36 (41.2%)[b]	-	-

Dressing	Nil	*Rhizoctonia*	*Pythium*	*Phytophthora*
Apron ® +DPX +Tecto®+ Dynasty® CST	-0.03 (49.2%)[a]	-	-	-
Av. (max) LSD	0.31 (0.31)	0.58 (0.66)	0.80 (1.01)	0.66 (0.69)
F prob	0.00083	7.8e-06	0.00011	0.017

Table A18b. Mean cumulative plant survival of English spinach from Trial 7

Dressing	Nil	*Rhizoctonia*	*Pythium*	*Phytophthora*
None	0.33 (58.1%)b	-21.63 (0.0%)a	-3.82 (2.1%)	0.02 (50.4%)
Apron®	-	-	-3.82 (2.1%)	0.77 (68.3%)
Dynasty® CST	-	-0.18 (45.5%)c	-2.39 (8.4%)	0.52 (62.6%)
DPX	-	-0.13 (46.8%)c	-	-
Tecto®	-	-1.43 (19.3%)b	-	-
Apron® + Dynasty® CST	-	-	-2.60 (6.9%)	0.57 (63.9%)
Tecto®+ Dynasty® CST	-	-0.50 (37.8%)c	-	-
DPX +Tecto®+ Dynasty® CST	-	-0.21 (44.7%)c	-	-
Apron ® +DPX +Tecto®+ Dynasty® CST	-0.08 (48.0%)a	-	-	-
Av. (max) LSD	0.35 (0.35)	0.56 (0.60)	1.46 (1.82%)	0.72 (0.73)
F prob	0.031	1.7e-08	0.065	0.18

Germination of English spinach was enhanced in the presence of *Rhizoctonia* using the chemical seed dressings of Dynasty® CST, DPX and Tecto®. Combining chemical dressings slightly reduced this protection (10 per cent). Final counts indicated that Dynasty® CST and DPX individual treatments had increased survival rates of up to 46% compared to the *Rhizoctonia* positive control.

Germination of English spinach was slightly enhanced in the presence of *Pythium* with chemical seed dressings. The chemical dressing of Dynasty® CST enhanced germination by 20.7 per cent, while Apron® alone was ineffective. The combination of Apron® and Dynasty® CST enhanced germination by 17.1 per cent. Final counts indicated that Dynasty® CST dropped survival rates (by 6.3 per cent) compared to the positive *Pythium* control.

Germination of English spinach was reduced in the presence of *Phytophthora* and chemical dressings. The final counts indicated the chemical dressing of Dynasty® CST enhanced survival rates by 12.2 per cent, Apron® by 17.9 per cent. The combination of Apron® and Dynasty® CST enhanced survival by 13.5 per cent.

3.2.7 Trial 8 Chemical seed dressings for control of **Pythium** *in English spinach*

Tables of means are presented in Tables A19a and A19b below on the logit scale, with back transformed probabilities in brackets. Each table also include the LRT F test probabilities and the LSD (least significant difference) for pair-wise comparisons on the log it scale. Where the LRT F test was significant at the five per cent level, significant pair-wise differences between treatments means are indicated using the letter notation.

There were only significant effects of treatments for the nil isolate level in germination counts. The combination of Apron® and Dynasty® CST appeared to significantly retard germination, suggesting some incompatibility between these two products.

Table A19a. Mean seedling establishment of English spinach from Trial 8

Treatment	Nil	*Pythium* 1/10P	*Pythium* 1/4P	*Pythium* 1/2P	*Pythium* 1P
No Chemical	-0.19 (45.4%)[b]	0.07 (51.7%)	-0.37 (40.9%)	-0.44 (39.1%)	-1.54 (17.7%)
Apron®	-0.04 (48.9%)[b]	-0.18 (45.5%)	-0.23 (44.2%)	-0.33 (41.9%)	-0.91 (28.7%)
Dynasty® CST	-0.40 (40.1%)[b]	-0.23 (44.3%)	0.38 (59.4%)	-0.03 (49.2%)	-0.28 (43.1%)
Apron® + Dynasty® CST	-1.11 (24.8%)[a]	-0.38 (40.6%)	-0.27 (43.4%)	-0.23 (44.3%)	-0.40 (40.1%)
Av. (max)	0.62	0.49	0.62	0.76	1.28

Treatment	Nil	*Pythium* 1/10P	*Pythium* 1/4P	*Pythium* 1/2P	*Pythium* 1P
LSD	(0.64)	(0.50)	(0.62)	(0.77)	(1.38)
LRT F prob	0.014	0.3	0.079	0.69	0.19

Table A19b. Mean plant survival of English spinach from Trial 8

Treatment	Nil	*Pythium* 1/10P	*Pythium* 1/4P	*Pythium* 1/2P	*Pythium* 1P
No Chemical	-0.29 (57.1%)	-0.07 (48.4%)	-1.34 (20.7%)a	-1.73 (15.1%)a	-1.77 (14.6%)
Apron®	-0.13 (53.2%)	-0.08 (48%)	-0.63 (34.8%)ab	-2.03 (11.6%)a	-1.50 (18.3%)
Dynasty® CST	-0.22 (55.4%)	0.16 (54%)	0.02 (49.6%)bc	-0.58 (35.8%)b	-0.67 (33.8%)
Apron® + Dynasty® CST	-1.10 (47.6%)	0.28 (55.7%)	0.35 (58.6%)c	-0.42 (39.6%)b	-0.12 (47%)
Av. (max) LSD	0.66 (0.66)	0.68 (0.68)	0.85 (0.90)	0.86 (0.99)	1.38 (1.49)
LRT F prob	0.62	0.68	0.0049	0.0023	0.07

Increasing the amount of pathogen had a strong effect on germination and therefore final survival rates. At ¼ and ½ plate levels of *Pythi*um there were significant differences between chemical treatments. In both cases, Dynasty® CST and Apron® plus Dynasty® CST gave significantly greater survival rate compared to the pathogen control.

3.2.8 Trial 9. Club root control in pak choy (cv. Sumo) with the application of seed dressing of Bion 500SC

Table A20 presents mean scores on the logit scale, with back transformed probabilities or scores in brackets. The table also includes the LRT F Test probabilities and the LSD (least significant difference) for pair-wise comparison on the logit scale. Where the LRT-F test was significant pair-wise differences are indicated using a letter notation.

For both experiments, Bion 500SC at 10ul/g seed produced a phototoxic effect, causing stunting and curling of leaves. A *Pythium* species also had an effect on the survival count which was naturally occurring from the field soil.

There were no significant differences between Bion 500SC and control treatments for either survival or average clubroot score in both experiments. However, there was one potential outliner for the clubroot score data in the second trial. If removed prior to analysis, the difference between treatments was significant, with each of the Bion 500SC treatments having a significant lower score than each of the control treatments. This suggests that further trials could be conducted with lower chemical rates.

Table A20. Efficacy of Bion 500SC seed dressing to club root of pak choy (cv. *Sumo*)

Treatment	Survival	Clubroot score	Clubroot - outliner
Control + supernatant	0.08 (68.9%)	-0.20 (2.26)	-0.20 (2.26) [b]
Bion 500SC + supernatant	0.04 (51.1%)	-1.56 (0.87)	-1.56 (0.87) [a]
Control + sludge	-0.22 (44.4%)	0.43 (3.03)	0.43 (3.03) [b]
Bion 500SC+ sludge	0.69 (66.7%)	-0.41 (2.00)	-2.68 (0.32)[a]
Av (max) LSD	1.99 (2.05)	1.75 (1.96)	1.22 (1.58)
F- Prob	0.59	0.19	0.0034

3.2.9 Trial 10. Club root control in pak choy (cv. Sumo*) with the application of seed dressing of Bion 500SC*

The response to the seed treatment was highly variable and there was no significant effect of varying concentrations of Bion 500SC on the survival rates or average clubroot score. It was also noted that Bion 500SC produced stunted plants compared to the nil treatment within the same soil. Up to and over 50 per cent stunting occurred in all concentrations of Bion 500SC applied. Table A21 presents means on the logit scale, with back transformed probabilities or scores in brackets. The table also includes the LRT F Test probabilities and the LSD (least significant difference) for pair-wise comparison on the logit scale. The LRT F- test probability tests the null hypothesis of no linear trend against the log-transformed rate of Bion application.

Table A21. Efficacy of Bion 500SC seed dressing to club root of pak choy (cv. *Sumo*)

Treatment	Survival	Clubroot score
Nil	0.69 (66.7)	1.40 (4.01)

Treatment	Survival	Clubroot score
0.1ul/g seed	0.41 (60.0%)	1.56 (4.14)
1ul/g	0.00 (50.0%)	0.15 (2.69)
2.5ul/g	1.61 (83.3%)	1.41 (4.02)
5ul/g	1.01 (73.3%)	1.79 (4.28)
10ul/g	-0.13 (46.7%)	1.07 (3.72)
Av (max) LSD	1.62 (1.83)	2.66 (3.21)
F-prob	0.90	0.95

3.2.10 Trial 11. Field trial: Control of **Phytophthora, Pythium** *and* **Rhizoctonia** *in English spinach with biological and chemical treatments*

Plots were viewed on a weekly basis over 45 days. Wilting plants were collected and pathogens isolated. These included *Phytophthora, Pythium aphanidermatum, Fusarium* and *Rhizoctonia*. Uneven germination did occur. Larger plants were noticed growing in treatment numbers 4 and 5. Smaller plants were noticed in other plots especially on the sides. No data was taken due to the plots being harvested before final assessment could be carried out.

3.2.11 Trial 12 and 13 Field trials to assess efficacy of genetic, chemical and biological controls for clubroot in Chinese cabbage

Agral® burnt and killed the seedlings soon after the application. The Chinese cabbage 'resistant' cultivar had a better growth rate than the susceptible one. The final analysis when harvesting showed a very low disease occurrence, with only 2/10 plants showing minor clubroot in the 'susceptible' cultivar versus 0/10 plants in 'resistant' cultivar. It was decided not to harvest remaining plants due to low disease severity.

Due to low disease severity this trial, was set up again in another plot on the same farm. Treatments, concentrations (excepting Agral®) and replications were the same. This time the 'resistant' cultivar was smaller in size, with both cultivars suffering soft rot from bacterial infection of *Erwinia carotovora* (due to wet and humid conditions). Negative controls were harvested, once again no major clubroot symptoms occurred and only small nodules on roots were observed. A quick screen within other plots also confirmed a low disease occurrence. No data was accumulated.

Part B. Pest surveillance and management in the Sydney Basin

1. Surveillance for important pests

1.1 Introduction

In the Sydney Basin, Asian vegetables are grown primarily on small-sized (5-10 hectare) market gardens. They are mostly Chinese and Vietnamese speaking growers who depend on family labour for their production. There are very few exceptions where growers have larger-scale production (10-20 hectare) using hired labour.

When the initial surveys were carried out, all the crops in all the farms were grown in soil. Most crops were grown in the open, while some crops, particularly in the Vietnamese farms, were grown under cover in polyhouses. Later in the project, some growers started using hydroponic systems (nutrient film technique in PVC channels) to grow some leafy vegetables.

Many crops, such as brassicas, are grown throughout the year, while others such as melons, chillies and eggplants are not grown in the cooler months.

1.2 Methods

Several visits were made to 23 farms throughout the course of this project. Plants were shaken over a white tray and insects were examined with a binocular magnifier. Suspected pests and beneficials were collected and stored for closer examination and identification later in the laboratory. Growers were also interviewed (in many cases with the assistance of a bilingual officer) to determine their pest control strategies and pesticide use.

Thrips were slide mounted and identified using published taxonomic keys at the EMAI laboratories of the NSW Department of Primary Industries. Some insects were sent to the Insect Identification Unit at Orange Agricultural Institute of the NSW Department of Primary Industries for further identification and confirmation.

1.3 Results and discussion

The insects and mites collected and identified during the survey are listed below in Table B1.

Table B1. Insects and mites identified from major Asian vegetable crops grown in the Sydney Basin 2004-8

Crop/ Weed	Insect/Mite Scientific Name	Insect/Mite Common Name	Comment
Choy sum	*Frankliniella occidentalis*	Western flower thrips	WFT
	Thrips tabaci	Onion thrips	
	Thrips imaginis	Plague thrips	
English spinach	*Bryobia graminum*	Clover mites	Acari: Tetranychidae
	T.tabaci	Onion thrips	
	F. occidentalis	WFT	
	Frankliniella schultzei	Tomato thrips	
	Baris alboseriata –	Weevil	European species widely distributed in Spinach and Beet
Onion	*T.tabaci*	Onion thrips	
Flower Head	*Cortinicara* sp.	Minute mould beetle	Coleoptera:Lathridiida e
Shallot	*F. occidentalis*	WFT	
	Chirothrips sp.	Cocksfoot thrips	Unconfirmed
Chinese broccoli – (seed crop)	*Brevicorynae brassicae*	Cabbage aphid	
	Plutella xylostella	Cabbage moth	
	T. imaginis	Plague thrips	
	T.tabaci	Onion thrips	
	Phyllotreta undulata,	Striped flea beetle or Brassica flea beetle)	
Coriander	*F. occidentalis*	WFT	
	F. schultzei	Tomato thrips	
	T. imaginis	Plague thrips	

Crop/ Weed	Insect/Mite Scientific Name	Insect/Mite Common Name	Comment
	T.tabaci	Onion thrips	
	Aeolothrips sp.	Banded thrips	Predatory on aphids, thrips and mites
	Micromus tasmaniae	Brown lacewing	Predacious
	Nabis (Tropiconabis) kinbergii		Nabidae: Hemiptera Predatory on caterpillars
Mint	Entomobryidae	Spring tail	
	T. imaginis	Plague thrips	
	Helicoverpa sp.	Budworm	
	Nisotra sp.	Flea beetle	
Mustard (flowering)	*T. imaginis*	Plague thrips	
Thai basil	*T. imaginis*	Plague thrips	
	F. occidentalis	WFT	
	T.tabaci	Onion thrips	
Parsley	*F. occidentalis*	WFT	
	T.tabaci	Onion thrips	
Dill	*F. occidentalis*	WFT	
	T.tabaci	Onion thrips	
Garlic chives	*Chirothrips* sp.	Cocksfoot thrips	Unconfirmed
	T.tabaci	Onion thrips	
	Neotoxoptera oliveri	Marigold aphid	
Snake beans	*Aphis craccivora*	Cabbage aphid	
	T.tabaci	Onion thrips	

Crop/ Weed	Insect/Mite Scientific Name	Insect/Mite Common Name	Comment
	Chirothrips sp.	Cocksfoot thrips	Unconfirmed
Perilla	*Tetranychus urticae*	Two-spotted mite	
Chives (Flowering)	*T.tabaci*	Onion thrips	
	F. schultzei	Tomato thrips	
	Aeolothrips sp.	Banded thrips	Predatory on aphids, thrips and mites
Hairy melon	*T.tabaci*	Onion thrips	
	Chirothrips sp.	Cocksfoot thrips	Unconfirmed
Eggplant	*Nisotra submetallica*	Submetalic flea beetle)	
	F. occidentalis	WFT	
	T. imaginis	Plague thrips	
	Tetranychus urticae	Two-spotted mites	
Okra	*Oxycarenus arctatus*	Coon bug	Introduced pest species
Taro	*Parapalaeosepsis*	Ant flies	Not pest – Common around dung
	T. urticae	Two-spotted mite	
Chilli	*F. occidentalis*	WFT	
Bitter melon	*F. occidentalis*	WFT	
	T. imaginis	Plague thrips	
	T.tabaci	Onion thrips	
	Aeolothrips sp.	Banded thrips	Predatory on aphids, thrips and mites
Long melon	*T. tabaci*	Onion thrips	

Crop/ Weed	Insect/Mite Scientific Name	Insect/Mite Common Name	Comment
Radish	*T. tabaci*	Onion thrips	
	Aeolothrips sp.	Banded thrips	Predatory
Chrysanthem um	*Nysius vinitor*	Rutherglen bug	
Sow thistle (Weed)	*U. sonchi*	Brown sow thistle aphid	

The key pest on leafy Brassica crops for which regular (mostly weekly or at least every 10 days) insecticide spraying was carried out was *P. xylostella,* (Cabbage moth or Diamondback moth). Due to this frequent spraying, other pests such as cabbage white butterfly do not reach pest status and hence are not considered by the growers as pests.

In the first year of the project, *P. undulata* (kutschera), striped flea beetle or brassica flea beetle, was not detected. However, during the following years, damage caused by these beetles to seedlings became significant, raising concerns and requiring control action.

On farms where garland chrysanthemum was grown as a leafy vegetable, *N. vinitor* (Rutherglen bug) multiplied to plague proportions, moving into other leafy vegetable crops when the chrysanthemum crop was cut and caused serious feeding damage.

On farms growing a variety of Asian herbs in polyhouses, the key pest targeted by regular spraying was *T. urticae* (two-spotted mites). On farms where chillies were grown, *F. occidentalis,* western flower thrips, was a serious pest introducing and spreading Tomato spotted wilt virus. Since there were other projects studying the management of this pest in the Sydney Basin, this pest problem was not included in this project.

2. On-farm trials for management of two-spotted mite on Perilla

2.1 Introduction

Perilla is a genus of an annual herb that is a member of the mint family, Lamiaceae. The most common species is *Perilla frutescens var. japonica* which is mainly grown in India and East Asia. There are both green-leafed and purple-leafed varieties which are recognized as separate species by some botanists. A purple-leafed variety is grown in the Sydney Basin by Vietnamese-speaking growers. Crops are grown by transplanting seedlings in multiple rows on raised beds (approximately 1 x 25 m), inside polyhouses.

The only pest encountered on *Perilla* crops was the two-spotted mite (TSM), *T. urticae.* All stages of the mites feed from the under-surface of leaves causing white or greyish streaks and making most of them unmarketable. When the infestation is severe, leaves at the bottom become dry and papery. The warmer conditions inside the polyhouses suit mites to breed throughout the year.

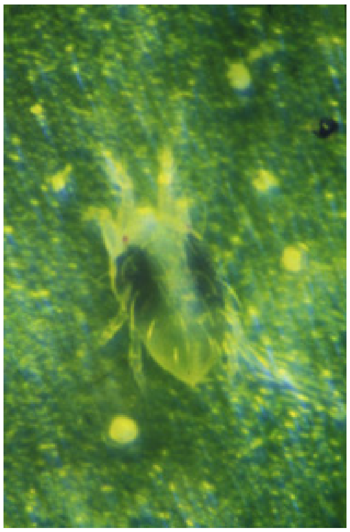

Figure B1. An adult two-spotted mite

Figure B2. Typical polyhouse with Perilla crop growing

Most growers spray their crops on a weekly basis, irrespective of whether they are infested or not. Insecticides used against pests on other crops are also used on *Perilla* crops. However, as TSMs are not insects (they are related to spiders), many of these insecticides are ineffective and often cause outbreaks because the predatory insects feeding on TSMs are killed. Although insecticides like dimethoate and miticide (e.g. Vertimec®) have been used successfully by some growers for TSMs it should be noted that there are currently no products registered specifically to be used on *Perilla* crops.

The use of Chilean predatory mites, *Phytoseiulus persimilis,* is an alternative option that is commercially available to growers. The predatory mites feed on all the stages of the TSMs and do not feed on plants.

Figure B3. A predatory mite feeding on an adult two-spotted mite

2.2 Methods

Paired plots of *Perilla* crops grown under cover on 1x25 m raised bed from three different farms were used for the study. In each farm one crop was maintained under the grower's current TSM spray schedule, which is a weekly application of Vertimec®. For the other crop, predatory mites were introduced at a rate of 5000 mites/plot when the TSM population reached a mean level of 4-10 mites/½ leaf. Predatory mites were supplied on bean leaves that were placed on *Perilla* plants at evenly spaced intervals across the whole plot.

Weekly sampling of leaves was taken from both plots and 20 half-leaves from each plot were saved individually in 70 per cent alcohol. Adult TSMs found on the half-leaf were counted in the laboratory under a dissecting microscope.

TSM count data was analysed using a generalised linear model with errors assumed to follow Poisson distribution. A log-link function was used to relate the data to treatment effects. Weekly sampling data from each farm was analysed separately.

2.3 Results and discussion

The population dynamics of TSMs with miticide sprays versus predatory mite release is shown below in Tables B2-B4 and Figures B4-B6.

Table B2. Comparison of weekly two-spotted mite counts for farm 1

	Treatment 1			Treatment 2				
Week	**Log(lamda)**	**SE**	**Mean**	**Log(lamda)**	**SE**	**Mean**	**Chi square**	**P(Chi)**
1	-3.00	1.00	0.05	0.05	0.22	1.05	22.4	0.000
2	-1.90	0.58	0.15	-7.69	6.35	0.00	4.2	0.041
3	-7.69	6.35	0.00	-1.90	0.58	0.15	4.2	0.041
4	-2.30	0.71	0.10	-7.69	6.35	0.00	2.8	0.096
5	-3.00	1.00	0.05	0.30	0.19	1.35	30.2	0.000
6	-7.69	6.35	0.00	1.41	0.11	4.10	113.7	0.000
7	-3.00	1.00	0.05	1.50	0.11	4.50	115.1	0.000
8	-0.80	0.33	0.45	1.40	0.11	4.05	66.3	0.000
9	-1.61	0.50	0.20	1.25	0.12	3.50	71.5	0.000
10	-3.00	1.00	0.05	0.59	0.17	1.80	42.1	0.000
11	-0.43	0.28	0.65	1.12	0.13	3.05	33.8	0.000
12	-0.92	0.35	0.40	2.11	0.08	8.25	175.0	0.000
13	0.83	0.15	2.30	2.70	0.06	14.85	205.1	0.000
14	1.30	0.12	3.68	2.55	0.06	12.80	103.5	0.000
15	1.37	0.11	3.95	3.03	0.05	20.65	248.5	0.000
16	2.13	0.08	8.40	2.35	0.07	10.50	4.7	0.031

Treatment 1 = Predatory mites release   Treatment 2 = Grower's spraying schedule

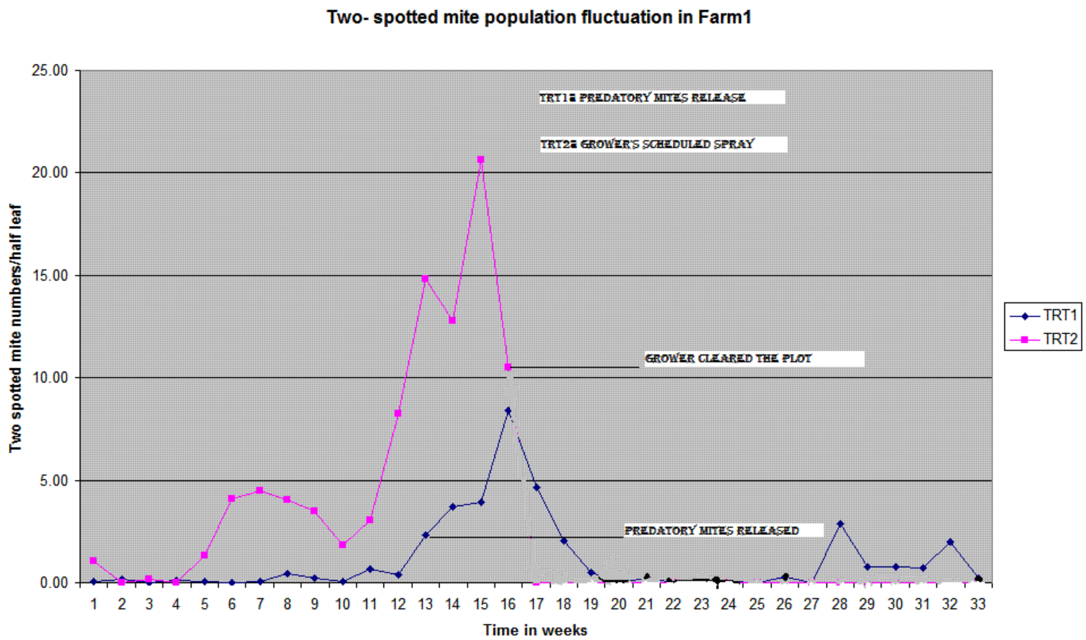

Figure B4. Two spotted mite counts (mean ½ leaf) over time on Farm 1

Table B3. Comparison of weekly two-spotted mite counts for Farm 2

	Treatment 1			Treatment 2				
Week	**Log(lamda)**	**SE**	**Mean**	**Log(lamda)**	**SE**	**Mean**	**Chi square**	**P(Chi)**
1	-7.69	6.35	0.00	0.00	0.22	1.00	27.72	0.000
2	-7.69	6.35	0.00	0.77	0.15	2.15	59.61	0.000
3	-7.69	6.35	0.00	2.28	0.07	9.80	271.70	0.000
4	-1.61	0.50	0.20	1.81	0.09	6.10	139.20	0.000
5	0.77	0.15	2.15	2.58	0.06	13.25	178.00	0.000
6	1.56	0.10	4.75	1.56	0.10	4.75	0.00	1.000
7	1.31	0.12	3.70	2.93	0.05	18.75	220.50	0.000
8	2.03	0.08	7.60	2.96	0.05	19.25	104.50	0.000
9	2.05	0.08	7.80	3.15	0.05	23.40	163.30	0.000
10	1.93	0.09	6.90	2.19	0.07	8.95	5.32	0.021
11	1.44	0.11	4.20	0.92	0.14	2.50	8.72	0.003

Treatment 1 = Predatory mites release   Treatment 2 = Grower's spraying schedule

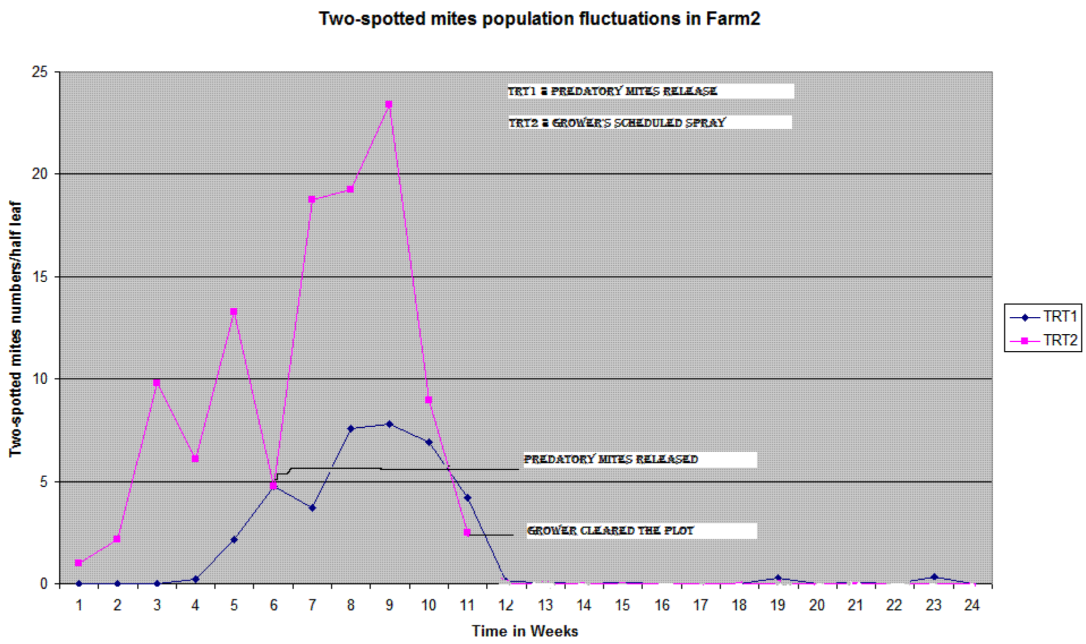

Figure B5. Two-spotted mite counts (mean ½ leaf) over time on Farm 2

Table B4: Comparison of weekly two-spotted mite counts for Farm 3

	Treatment 1			Treatment 2				
Week	**Log(lamda)**	**SE**	**Mean**	**Log(lamda)**	**SE**	**Mean**	**Chi square**	**P(Chi)**
1	-3.00	1.00	0.05	-3.00	1.00	0.05	0.00	1.000
2	-8.70	0.00	0.00	-8.70	0.00	0.00	0.00	1.000
3	-8.70	0.00	0.00	-8.70	0.00	0.00	0.00	1.000
4	-2.30	0.71	0.10	-8.70	0.00	0.00	2.77	0.096
5	-3.00	1.00	0.05	-8.70	0.00	0.00	1.39	0.239
6	-1.61	0.50	0.20	-8.70	0.00	0.00	5.55	0.019
7	-2.30	0.71	0.10	-8.70	0.00	0.00	2.77	0.096
8	-1.90	0.58	0.15	-1.90	0.58	0.15	0.00	1.000
9	-1.90	0.58	0.15	-1.39	0.45	0.25	0.51	0.477
10	-1.90	0.58	0.15	-1.39	0.45	0.25	0.51	0.477

	Treatment 1			Treatment 2				
Week	Log(lamda)	SE	Mean	Log(lamda)	SE	Mean	Chi square	P(Chi)
11	-0.22	0.25	0.80	-8.70	0.00	0.00	22.18	0.000
12	-0.22	0.25	0.80	-2.30	0.71	0.10	12.40	0.000
13	-3.00	1.00	0.05	-2.30	0.71	0.10	0.34	0.560
14	-0.36	0.27	0.70	-2.30	0.71	0.10	10.12	0.001
15	-8.70	0.00	0.00	-1.20	0.41	0.30	8.32	0.004
16	0.10	0.21	1.10	1.24	0.12	3.45	25.49	0.000
17	0.62	0.16	1.85	0.14	0.21	1.15	3.30	0.069
18	0.18	0.20	1.20	1.34	0.12	3.80	28.41	0.000
19	0.30	0.19	1.35	-1.39	0.45	0.25	16.62	0.000
20	-0.29	0.26	0.75	0.18	0.20	1.20	2.10	0.148
21	0.99	0.14	2.70	1.36	0.11	3.90	4.39	0.036
22	0.67	0.16	1.95	0.72	0.16	2.05	0.05	0.823
23	-0.80	0.33	0.45	0.05	0.22	1.05	4.94	0.026
24	-3.00	1.00	0.05	1.05	0.13	2.85	70.30	0.000
25	-8.70	0.00	0.00	0.37	0.19	1.45	40.20	0.000
26	-8.70	0.00	0.00	1.08	0.13	2.95	81.79	0.000
27	-3.00	1.00	0.05	1.13	0.13	3.10	77.07	0.000
28	-8.70	0.00	0.00	-0.60	0.30	0.55	15.25	0.000
29	-0.69	0.32	0.50	-0.92	0.35	0.40	0.22	0.637

Treatment 1 = Predatory mites release   Treatment 2 = Grower’s spraying schedule

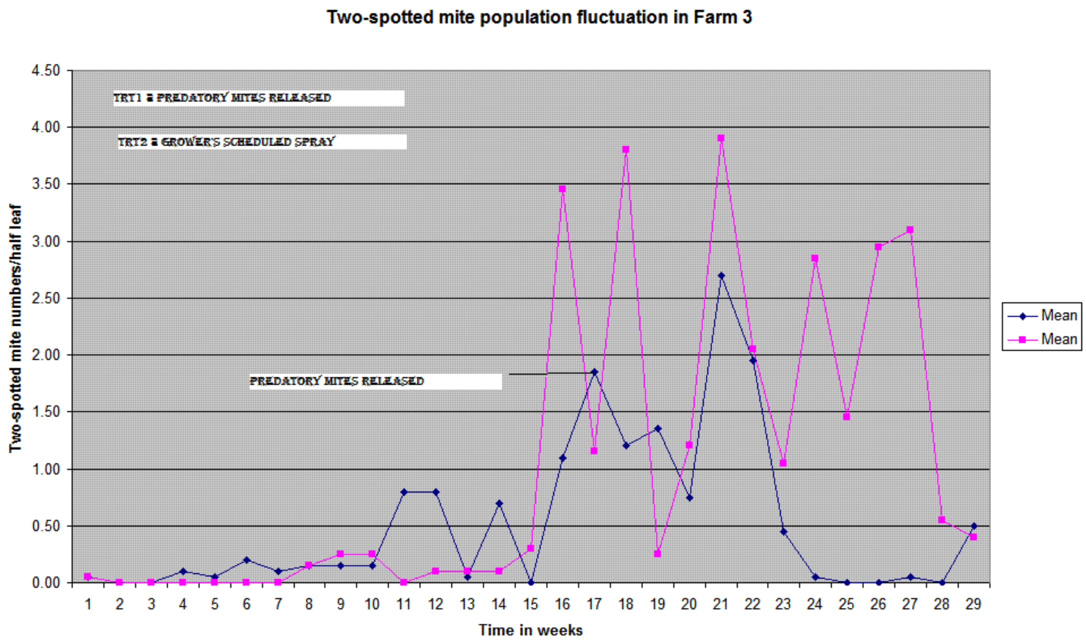

Figure B6. Two spotted mite counts (mean ½ leaf) over time on Farm 3

On Farms 1 and 2, growers cleared their chemical treatment plots halfway through the trial period, as the TSM population exploded beyond the level of harvesting any marketable crop. As a result, statistical analysis could not be done beyond week 16 and 11, respectively. However population estimates were recorded until week 33 and 24, respectively, from the predatory mite-released plots and this data was included in the graphs above showing the population dynamics. On Farm 3, spraying for TSMs was minimal until later in the season. Therefore both these crops were maintained throughout the study period, since there was no population explosion as occurred on the other farms.

Predatory mite treatment

Miticide treatment

Figure B7. Typical perilla plants from the two different treatments

On Farms 1 and 2, the TSM population was always significantly lower in the treatment 1 plot (predatory mite release) than in the treatment 2 plot (grower miticide spray), even before the predatory mites were released. However, TSM populations continued to increase in the miticide sprayed plots while it was maintained at very low levels after predatory mites were released. This shows the TSM problem in *Perilla* crops is mainly induced by growers' indiscriminate spraying practices. On Farm 3, although the overall TSM population level was much lower than in Farms 1 and 2, it declined significantly after the predatory mites were released and remained very low until the end of the study period. This shows that the use of predatory mites is superior to the use of chemical spraying for the management of TSMs in *Perilla* crops.

3. On-farm trials for the management of diamondback moth on leafy Brassica crops

3.1 Introduction

Leafy brassica crops are grown mostly in the open ground on raised beds. Within the last two years some growers have started growing some of these crops in hydroponics systems. Most of these crops mature rapidly, in four to eight weeks, depending on the temperature. Therefore there is little chance for any insect pest population to build up within a crop, as is the case of the Western brassicas. However insect populations can build up due to continuous cropping and the close proximity of neighbouring farms. As these crops are grown for their leaves, tolerance to leaf damage caused by insects is minimal. Therefore growers generally spray insecticides on a weekly basis as a preventative measure.

Diamondback moth (DBM), *Plutella xylostella* (Linnaeus) is the key pest of these crops and the insecticides used to control it also control other pests. Therefore many growers do not recognise the potential for these pests to cause damage. Although Avcare's Insecticide Resistance Action Committee (AIRCA) has a resistance management strategy in place to delay the development of resistance to newer insecticide groups, many growers are not aware of it.

Figure B8. A mature diamondback moth larva

This project aims to demonstrate to growers that, by monitoring for the presence of DBM, they could reduce their spraying frequency and use alternative "soft" insecticides for control.

3.2 Methods

Paired plots (approximately 2x25 m) of gai lan (Chinese broccoli) and choy sum crops were chosen for a trial on three farms. On each farm, pest management was carried out by the grower according to his current spray schedule in one gai lan and one choy sum plot (Treatment 2). In the other set of plots, spraying was carried out according to an IPM (threshold-based spraying) strategy whereby they were inspected weekly for the presence of DBM larvae or their damage (Treatment 1).

Twenty plants were inspected weekly and if more than five plants were infested, spraying was carried out. The soft insecticide, Xentari® (a *Bacillus thurungiensis*-based product) was initially applied, with the anticipation of using other insecticides later if needed.

When the crops were ready for harvest, 20 plants in each plot were randomly selected and inspected for DBM damage and the presence or absence of damage in each plant.

Proportional data of plants with damage was analysed using a Generalized Linear Model with errors assumed to follow binomial distribution. A logit-link function was used to relate the data to treatment effects.

3.3 Results and discussion

The number of Xentari® sprays needed in any of the three farms ranged from one to three only, and no other insecticides were needed. Growers used three to four sprays of any of the following insecticides: Ambush®, Nitofol® or Avatar®. The percentage of infestation was less in the threshold based spraying with Xentari® (Treatment 1) than the grower's schedule based other insecticides spraying (Treatment 2).

On Farms 1 and 2 the percentage infestation was significantly less in Xentari® treatments but on Farm 3 it was not significantly different. The choy sum crop was less attractive to DBM and the percentage infestation was very much lower than in gai lan crops. As a result the overall difference in infestation between the treatments was not significant. The results are presented in the Tables B5 and B6 below.

Table B5. Chinese broccoli trial

Farm	T'ment	Logit (P)	SE	% DBM Infestation	Chi square	P (Chi)
1	1	-0.405	0.456	40.0	21.95	0.000
1	2	9.200	0.000	100.0		
2	1	-1.386	0.559	20.0	6.90	0.009
2	2	0.405	0.456	60.0		
3	1	-1.386	0.559	20.0	1.14	0.286
3	2	-0.619	0.469	35.0		

Treatment 1: Threshold based spraying. Treatment 2: Grower's schedule based spraying.

Table B6. Choy sum trial

Farm	T'ment	Logit (P)	SE	% DBM Infestation	Chi square	P (Chi)
1	1	-10.600	0.000	0.0	2.88	0.090
1	2	-2.197	0.745	10.0		
2	1	-10.600	0.000	0.0	1.41	0.235
2	2	-2.940	1.030	5.0		
3	1	-0.619	0.469	35.0	0.11	0.736
3	2	-0.847	0.488	30.0		

Treatment 1: Threshold based spraying. Treatment 2: Grower's schedule based spraying

Figure B9. A grower managed plot of gai lan crop

Figure B10. A gai lan plot managed by project team and based on monitoring

These trials indicate that most of the spraying carried out on leafy brassica crops in the Sydney Basin against DBM can be avoided if the growers make their decision to spray based on crop monitoring. It was noted that volunteer brassica plants and weeds on these farms, which are not sprayed, act as a reservoir for parasitoids of DBM. Therefore they can complement a "soft" insecticide like Xentari®.

Based on these results a "*primefact",* NSW Department of Primary Industries information pamphlet was prepared to provide the information to the growers.

4. Observations of Rutherglen bug as a pest of Asian vegetables

4.1 Introduction

Rutherglen bug, *Nysius vinitor* Bergroth, is generally considered an invading pest. It breeds on adjoining weeds and invades vegetable crops in swarms when the weeds dry off.

Early surveillance for insects on farms in the Sydney Basin revealed serious damage caused by Rutherglen bug to leafy brassicas and English spinach. These insects were found feeding on leaves in groups, causing leaves to dry out and in some cases causing loss of the whole plant.

Figure B11. An adult Rutherglen bug

Figure B12. Rutherglen bugs feeding on garland chrysanthemum

Figure B13. Damage caused by Rutherglen bug feeding on Daikon radish

Crop monitoring revealed that the Rutherglen bug was a problem on only a few farms, where chrysanthemum is grown as a leafy vegetable. Therefore the population dynamics of this insect was studied at one farm where chrysanthemum was grown throughout the season.

4.2 Methods

Weeds around the crop were examined weekly starting from early in the spring for the presence of Rutherglen bug and any signs of breeding. Sampling was carried out on chrysanthemum crops on one farm to estimate the population dynamics of the

Rutherglen bug. Because the chrysanthemum crop was grown in the field as well as in a hydroponics system, one crop from each system was sampled every week.

Sampling involved shaking insects from an equal number of plants on to 29 cm diameter white tray and adults were quickly counted. Forty random samples were taken from each crop every week.

Rutherglen bug counts were analysed using a generalized linear model with errors assumed to follow a Poisson distribution. A logarithmic link function was used to relate the response variable to the fitted terms. All parameters were estimated using a residual maximum likelihood (REML) estimation. All analyses were run on ASReml version 2.

4.3 Results and discussion

Rutherglen bug was found on fireweed, shepherd purse and sow thistle weeds in the farm in early spring, but was found to be breeding on fireweed only. Rutherglen bug started to appear on chrysanthemum crops at the same time as on these weeds. It was also found breeding on chrysanthemum crops. When the crop was harvested, adult Rutherglen bugs dispersed looking for a suitable host to feed upon. If other chrysanthemum crops were not available on the farm they moved to any other leafy vegetables and started feeding on leaves causing serious damage.

Rutherglen bug feeding did not cause significant damage to chrysanthemum crops and as a result the grower never attempted to control the pest. This resulted in the population building up on the farm. By mid November the population on the farm reached plague numbers and the grower was forced to spray. One spray of Maldison 500® at a rate of 200 mL/100 L brought the population down to manageable level.

Table B7, below, shows the predicted means of Rutherglen bug counted on the tray from both the hydroponics and field systems, while Table B8 shows the comparison of the mean populations of Rutherglen bug counted on the tray from both the systems.

Table B7: Predicted means of Rutherglen bug counted on the tray from both the hydroponics and field systems

System	Time	Ln (mean)	SE	Back Transformed mean
Hydro	25.09.07	0.223	0.189	1.25
Hydro	02.10.07	1.295	0.111	3.65
Hydro	09.10.07	1.589	0.096	4.90
Hydro	16.10.07	1.039	0.126	2.83
Hydro	13.11.07	3.431	0.038	30.90
Hydro	20.11.07	3.860	0.031	47.48

System	Time	Ln (mean)	SE	Back Transformed mean
Hydro	03.12.07	0.811	0.141	2.25
Hydro	08.01.08	1.399	0.105	4.05
Hydro	15.01.08	1.906	0.082	6.73
Hydro	29.01.08	1.295	0.111	3.65
Hydro	19.02.08	-1.492	0.446	0.23
Hydro	05.03.08	-1.897	0.546	0.15
Hydro	18.03.08	-1.897	0.546	0.15
Field	25.09.07	-1.050	0.357	0.35
Field	02.10.07	-1.050	0.357	0.35
Field	09.10.07	0.281	0.184	1.33
Field	16.10.07	1.065	0.124	2.90
Field	13.11.07	1.644	0.093	5.18
Field	20.11.07	2.864	0.051	17.53
Field	03.12.07	2.227	0.069	9.28
Field	08.01.08	1.021	0.127	2.78
Field	15.01.08	1.115	0.121	3.05
Field	29.01.08	1.663	0.092	5.28
Field	19.02.08	-2.996	0.946	0.05
Field	05.03.08	0.501	0.165	1.65
Field	18.03.08	1.012	0.128	2.75

Table B8. Comparison of the mean populations of Rutherglen bug counted on the trays from both production systems

System	Ln (man)	SE	Back transformed mean
Hydro	0.889	0.074	2.43 a *

Field	0.638	0.088	1.89 b *

* Values followed by different letters are significantly different at P(<0.001)

Figure B14 below shows the population dynamics of the Rutherglen bug during the study period. The overall mean number of Rutherglen bugs found during the sampling period was significantly higher in the hydroponics system than in the field system. One explanation for this result is that although the grower was not spraying Rutherglen bug, the field plots of chrysanthemum were situated between other brassica crops which were sprayed on a weekly basis and spray drift could have had some effect on the population; keeping it lower.

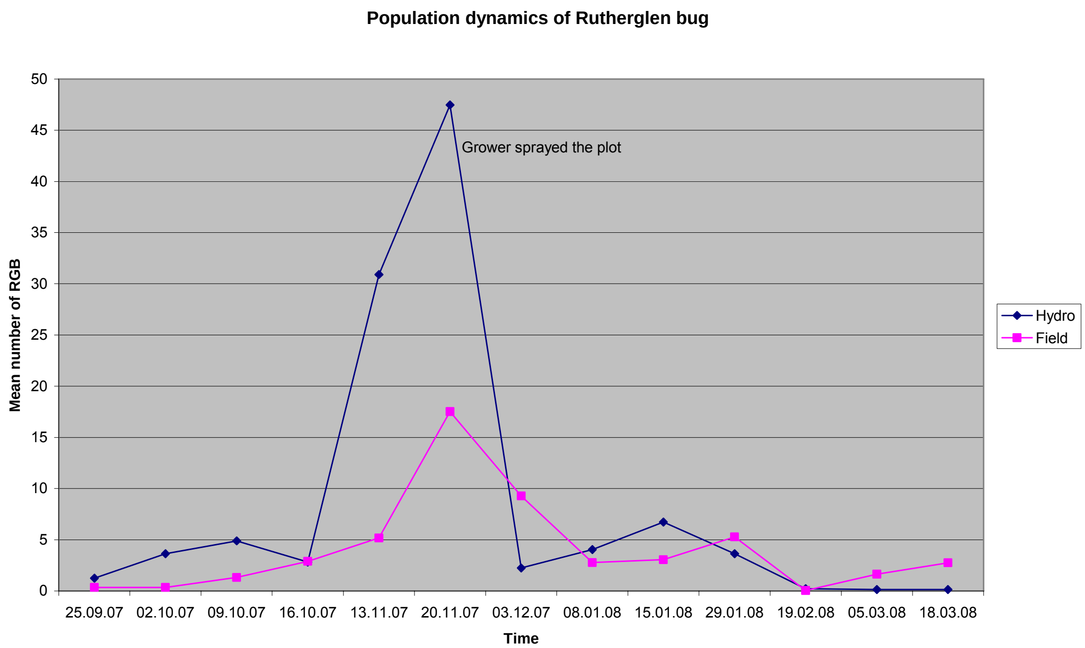

Figure B14. Population dynamics of the Rutherglen bug during the study period in both the hydroponics system and the field system

Our observation on this farm shows that the population level of the Rutherglen bug has increased over the years during the project. Unless sustainable control measures are developed, this pest may become a serious pest of other crops on farms where chrysanthemums are grown.

Information on Rutherglen bug is included in the poster “Common pests of leafy Brassicas” (Rajakulendran, V. & McDougall, S. 2008).

5. Observations on striped flea beetle as a potential pest

5.1 Introduction

Flea beetles are sometimes numerous in vegetable crops, but their damage does not generally reduce yield. Adult feeding, which results in tiny holes in the leaves, causes the damage.

This pest was not encountered during initial surveys in the first year of this project and growers did not complain about it. However, during the second and third year of the project some farmers started complaining about this pest.

Further investigations revealed the striped flea beetle or brassica flea beetle, *Phyllotreta undulate* Kutshera, was causing shot-holes on the seedling leaves of leafy brassica crops.

Figure B15. An adult striped flea beetle

Figure B16. Damage caused by striped flea beetle to a choy sum seedling

As the plants grow the holes enlarge and this makes many leaves of the plants unmarketable. Eggs are laid in the soil near the roots and larvae feed on secondary roots and pupate in the soil. Feeding by larvae does not seem to have much effect on the growth of the plants.

Because more growers started complaining about this insect, a study was undertaken to determine the extent of damage caused and the population dynamics of this pest within the crop as well as on the surrounding weeds.

5.2 Methods

Starting early in the spring, weeds around the crops in several farms were closely examined for flea beetle damage and also for adult beetles.

On three farms (Farm 1, 2 and 3), successive pairs of new gai lan and choy sum crops were monitored to estimate the extent of damage over the season. On Farm 4, successive pairs of choy sum and daikon radish were used for the same purpose.

When the crops in these plots were at the four-leaf stage, 20 randomly selected 1m lengths of a crop row were examined. The total number of plants and number of plants with flea beetle damage was counted. When the same crops were ready for harvest, 40 randomly selected plants from each plot were examined and the total number of leaves on a plant and the number of leaves with flea beetle damage on each plant was counted. This procedure was repeated whenever new pairs of crops of same age were available on these farms.

"Affected plants" was analysed as a proportion to total plants (at seedling stage) and "affected leaves" was analysed as a proportion to total leaves fitted using a generalized linear mixed model (GLMM) with errors assumed to follow a binomial distribution. A logit-link function was used to relate the response variable to the fitted terms. The model may be written as follows:

Logit (P) = fixed (Farm + Crop + Interaction) + Random (batch within farms + batch X crop)

5.3 Results and discussion

There were no flea beetles found on any weeds on these farms. Coincidentally, there were no brassicas growing as weeds on these farms. This correlates with published literature, which states that striped flea beetles breed only on brassica weeds.

Tables B9 and B10 below give the proportion of plants and leaves affected by the striped flea beetle.

Table B9. Proportion of plants affected by striped flea beetle on gai lan, choy sum and daikon radish seedlings

Farms	Crops	Logit (P)	SE	Back transformed
Farm 1	Gai lan	-1.156	0.489	0.2394a*
	Choy sum	0.107	0.489	0.5267a
Farm 2	Gai lan	-2.422	0.444	0.0815a
	Choy sum	-1.821	0.438	0.1393a
Farm 3	Gai lan	-1.845	0.563	0.1365a
	Choy sum	-0.883	0.562	0.2925a
	SED	0.706		
	LSD(5%)	1.411		
Farm 1		-0.525	0.346	0.3718a
Farm 2		-2.121	0.312	0.1070b
Farm 3		-1.364	0.398	0.2036ab
	SED	0.499		
	LSD (5%)	0.998		
	GaI lan	-1.808	0.289	0.1409a
	Choy sum	-0.866	0.288	0.2961a
	SED	0.408		
	LSD (5%)	0.816		
Farm 4	Choy sum	-1.929	0.450	0.1268a
	White radish	-1.609	0.451	0.1667a
	SED	0.215		
	LSD (5%)	0.430		

* Values followed by the same letters are not significantly different

The damage caused to seedlings in these crops ranged from eight per cent to 52.7 per cent. There was no significant difference in damage caused by the flea beetle between gai lan and choy sum or between choy sum and daikon radish.

Damage caused to the seedlings was significantly more on Farm 1 than the other two farms. Farm 1 had areas with weeds in between the crops and this could have contributed to a build up of the pest on unsprayed volunteer brassica plants growing in these areas.

Table B10. Proportion of leaves affected by striped flea beetle on gai lan, choy sum and daikon radish at harvest time

Farms	**Crops**	**Logit (P)**	**SE**	**Back transformed**
Farm 1	Gai lan	0.065	0.419	0.5163a*
	Choy sum	0.173	0.417	0.5432a
Farm 2	Gai lan	-1.577	0.329	0.1713a
	Choy sum	-1.276	0.324	0.2183a
Farm 3	Gai lan	-1.005	0.421	0.2680a
	Choy sum	-1.458	0.420	0.1888a
	SED	0.706		
	LSD (5%)	1.411		
Farm 1		0.119	0.370	0.5297a
Farm 2		-1.426	0.288	0.1937b
Farm 3		-1.232	0.371	0.2259b
	SED	0.487		
	LSD (5%)	0.974		
	Gai Lan	-0.839	0.226	0.3018a
	Choy sum	-0.854	0.225	0.2987a
	SED	0.212		
	LSD (5%)	0.424		

Farms	Crops	Logit (P)	SE	Back transformed
Farm 4	Choy sum	0.191	0.371	0.5476a
	White radish	-0.087	0.371	0.4784a
	SED	0.153		
	LSD (5%)	0.306		

* Values followed by the same letters are not significantly different

The damage caused to leaves at harvest time ranged from 17.10 per cent to 54.7 per cent6. There was no significant difference in damage caused by the flea beetle between gai lan and choy sum or between choy sum and daikon radish.

As in the case of seedlings, damage caused to the leaves was significantly more in Farm 1 than the other two farms, possibly for the same reason.

Figure B17 gives the proportion of seedlings infested by striped flea beetle. In both crops, the infestation was high at the beginning of the season but declined as the season progressed.

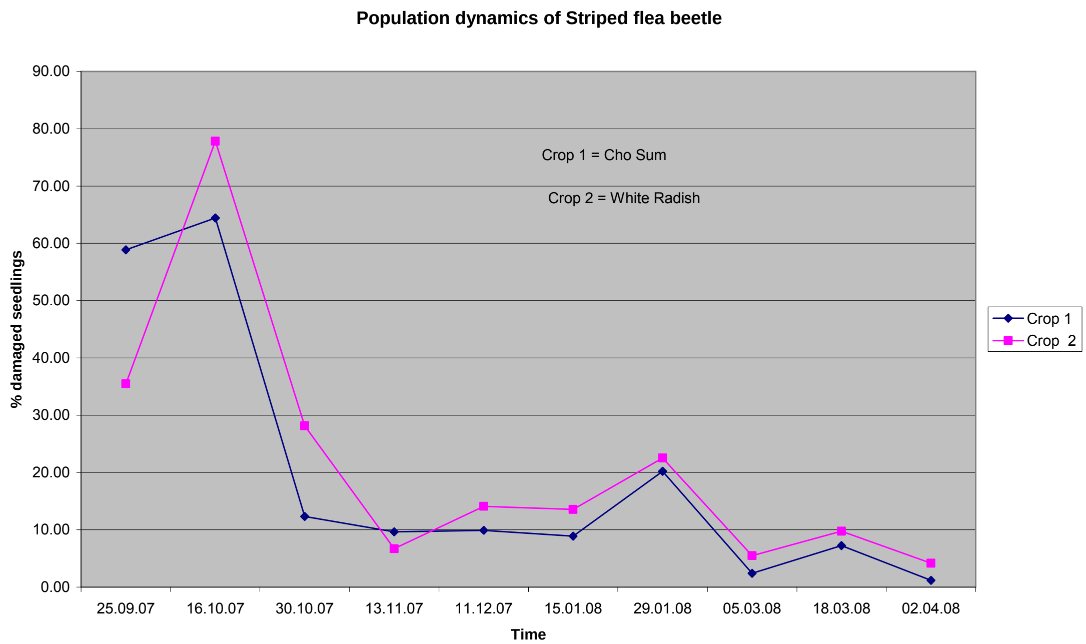

Figure B17. Population dynamics of striped flea beetle as expressed by the proportion of infested seedlings throughout the season.

Throughout the season infestation ranged from one per cent to 78 per cent and declined during rain periods. As the larval stages are in the soil and the season experienced heavy and frequent rainfall, it may have caused larval mortality, maintaining a low population. The growers' weekly spraying activity would also have had an impact on the flea beetle population.

During a drier season this situation could change and this pest may become a serious problem. Striped flea beetle was not a problem on farms at the commencement of this project. This pest has likely moved onto these farms from alternative hosts and has slowly built up in numbers and has reached a level now needing control action.

Information on striped flea beetle is included in the poster "Common pests of leafy Brassicas" for the benefit of the growers.

Part C Extending Integrated Pest Management to Victorian LOTE growers

1. Introduction

In Victoria, Asian vegetables are produced by mainstream growers and LOTE growers (mainly of Vietnamese origin). Mainstream growers predominantly produce Asian brassicas (Chinese cabbage, Chinese broccoli, buk choy, pak choy, Chinese flowering cabbage and mustard green) and coriander. LOTE growers also produce Asian brassicas plus other vegetables such as water convolvulus (kang kong), Ceylon spinach, amaranth and a myriad of Asian herbs including Thai basil, coriander, garland chrysanthemum, garlic chives, hot mint, perilla, pennywort and spearmint. Traditionally, LOTE growers have supplied Asian grocery shops in Melbourne suburbs such as Richmond, Springvale, Footscray and Box Hill.

In the early 1980's, with waves of refugees from South-East Asia coming to Australia, there was a growing demand for Asian herbs and vegetables. Although there are similarities between Chinese cooking and that of people from South-East Asia, the latter group prefers a greater number and variety of Asian herbs and vegetables in their cuisine.

Initially, these vegetables could only be produced by those who were familiar with their growth habits and the farming practices needed for their production. Crops such as perilla, hot mint, buffalo spinach, lizard tail, Thai coriander etc. are grown almost exclusively by Vietnamese farmers and are an essential part of Vietnamese cuisine (Dang et al., 2007).

The vegetable crops these LOTE growers produce are labour intensive. There are many different types of vegetables produced and each has its own agronomic and pest and disease issues and post-harvest handling requirements. Approximately 78 different types of fresh Asian vegetables have been identified in Melbourne retail outlets (Vujovic *et al.* 2002).

Many LOTE growers have difficulty reading in their own language and sourcing information. They often rely on their children for translation when seeking assistance or information and when doing business. It is therefore fair to assume that South-East Asian LOTE growers experience difficulty with reading and speaking English. This is exacerbated when technical words are used in the horticultural industry making reading instructions, buying chemicals and identifying pests and diseases difficult.

When this project was first proposed most of the LOTE growers had not completed a farm chemical user course, let alone have quality assurance accreditation. This limits their market opportunities, as they generally supply an already oversupplied Asian retail markets, and reduces their opportunity to supply supermarket chains, which require a continuous supply of safe, quality Asian vegetables. It has also led to issues in relation to residue violations.

Many LOTE market gardeners are often characterised by the following features (Hassall and Asscoiates, 2003; Morgan, 2003):

- difficulties with communication
- being socially and politically isolated from mainstream horticulturists
- operating on very small to small farms (less than 5 ha)
- limited market opportunities and adoption of technical improvements due to multiple factors, such as poor profitability, limited understanding of technical issues and, insecure land tenure
- traditional practices
- growing small volumes of a large number of vegetables types each with limited market demand
- growing labour intensive crops.

This means that such market gardeners:

- are less accessible to government assistance, particularly on technical issues
- often have poor understanding of English and are thus unable to communicate with training, regulatory and governmental authorities and this often leads to farm mismanagement along with mistakes and violations of quality assurance or environmental regulations.

In the past there have been a number of reports of maximum residue limit (MRL) violations by LOTE growers. This has highlighted an obvious need for education and communication work in relation to safe use of pesticides. The issue of undesirable MRLs in Asian vegetables and unsafe use of pesticides has potential to damage the vegetable industry and diminish public confidence. It is in the industry's interest that Australia invests in the areas of education andcommunication for LOTE growers.

Access to information is restricted for many LOTE growers due to barriers imposed by language, culture, race, religion and, their mistrust and/or previous poor experiences in trying to source information from government organisations. Removal of the language barrier is one way to improve information access and improve relationships with organisations that can assist in the provision of information. Effective communication of research results to LOTE growers helps ensure that this sector is aware of and adopts the best agronomic and environmental practices in vegetable production, ultimately leading to an increase in value and the environmental and economic sustainability of the industry (Dang et al., 2007).

There are a relatively small numbers of LOTE vegetable growers in Victoria – about 50 in total. The largest language group is Vietnamese (25), with the remainder being Arabic, Cambodian and Chinese families growing mostly Asian brassicas and tomatoes. There are a few Chinese growers in the Dandenongs and some Cambodian growers located around Shepparton (Ausveg, 2005).

The objective of this component of the project was to contribute to the development of a sustainable Asian vegetable industry by improving LOTE growers' decision-making processes through the following activities:

- Improving access to information (easy to use and translated).
- Encouraging growers to collaborate in knowledge and experience sharing.
- Supporting grower development with appropriate training and training material.
- Increasing grower understanding and knowledge of chemical use and the use of integrated pest management.

While these were the initial objectives, the methodology and issues changed over the course of the project. The project officer, in working closely with the LOTE community of growers, became involved with a number of other issues affecting them and effectively became a "Case Manager" and adopted this approach. By working closely with the growers and developing a rapport, the project officer was a person to whom the growers could turn to for help to resolve issues with council, agencies and in particular in responding to the impact of the drought. The impact of the drought restricted access to water and imposed some significant production constraints that needed to be addressed in the context of the project that if not addressed would have affected project delivery.

2. Methodology

The study was conducted using the following methodology:

- Prior to training, growers' skills, reasons for using chemicals and their understanding of pests and diseases were determined. This information was used to design a training program that built upon their current level of skill and knowledge.
- Workshops were conducted for growers on IPM and supported by translated material (Vietnamese). Special emphasis was put on tools for pest monitoring (scouting) and decision making.
- Follow-up farm visits were undertaken to work with individual growers to facilitate greater adoption of IPM techniques.
- Development of an IPM strategy for growing Asian vegetables in polyhouses was initiated. This was supported by printed material suitable for LOTE growers.
- Farm Chemical Users Refresher courses (FCURC), specially designed for LOTE growers, were conducted. They were supported by visual, practical and translated (Vietnamese) material as well as on farm visits to all growers.

The project officer worked in a "Case Manager" support role to assist the growers to respond to a range of issues. These issues included:

- The impact of the drought and resultant water restrictions would have had potentially left growers with no water and consequently no production.

- Changes to the classification of polyhouses by the local shire that potentially meant that existing houses could have become illegal structures and no new houses could be built.

- The LOTE growing community needed to negotiate the above issues with a range of government agencies and authorities and sought help to do so.

The project impact was evaluated by several methods. Practice change was measured using a survey on the current level of grower knowledge that was present when the project commenced and assessing the changes at the end of the project. Impact and change stories were collected to demonstrate practice change and impact as well as the use of industry knowledge. In July 2004, when the project started, a benchmark survey was designed by the Project team to determine and document current practices and other data concerning the skills, attitudes and needs of the farmers. The survey was conducted in September 2005 in conjunction with (and following) a farm chemical user course. Observation and verification also played a critical part of the survey and was performed during farm visits.

3. Results

3.1. Initial assessment of Vietnamese growers farming practices, skills, knowledge, attitudes and needs

At the commencement of the project there were 20 Vietnamese farms in the Geelong region (now around 30) with the greatest concentration in the Lara regions on the eastern side of Geelong.

Of those 20 farms, the growers owned 16; the remaining growers either rented farms or leased land. Average farm size was about 13.5 acre with the exception of two large farms. There were 41 types of Asian vegetables grown by LOTE growers and hydroponics tomatoes (See Appendix C for a list of vegetables and herbs grown by LOTE growers). On many farms, vegetables and herbs were grown together, with many being grown in greenhouses.

Difficulties often arose on farms with limited space, as crops with differing growth patterns and pest and disease issues were frequently co-located. In most instances, growers did not differentiate between crops with distinctive variations in growth patterns, agronomic requirements and growth cycles. For example, perilla, a shrub where mature plants often grow as high as 1.2m, were frequently intercropped with baby bok choy, a short crop about 15cms tall which has a considerably reduced growth cycle. Growing incompatible crops can cause favourable conditions for disease development, retard growth of one or both crops, and create difficulties during harvest. (Dang et al., 2007).

The majority of growers were growing between four and eight vegetable commodities with several growing only one or two products. Decisions on the types of crop grown were based on the market requirements, price and on information gathered through community channels (often based on rumours) via Queensland or the Northern Territory. Often this leads growers to cultivate similar types of crops, hence leading to oversupply and a drop in market price due to the limited size of the domestic market (Dang et al., 2007).

Production characteristics of the growers:

- Crops were grown in the open and in greenhouses.
- 45 per cent of Asian vegetables by area were grown in greenhouses.
- 25 per cent of growers grew their crops exclusively in the open field, while 50 per cent had both greenhouse and open field operations.
- The majority of greenhouses used for Asian vegetable production were old style, 6-8 m in width and 40-50 m long (2.5-3.5 m high) and clustered together.
- More recently built greenhouses were much better in design and had been developed by a construction engineer and approved by local council planning.
- Generally, mini overhead sprinklers were used for irrigation in the open field, whereas mini overhead sprinklers and drip irrigation are used in greenhouses.
- One third of growers applied fertilisers and pesticides through irrigation (fertigation), using mini sprinklers.
- Nearly all growers use town water (potable water) for irrigation.

Knowledge and skills in pest and disease management and chemical use:

- There is no active crop monitoring for pest and diseases.
- Growers usually react when pest or disease in detected in the crop or they apply weekly spraying based on the previous experience with the crop and pest or disease.
- A small number of growers could recognise some pests and diseases of Asian vegetables, but no grower could recognise beneficial insects.
- All growers lacked a clear knowledge of plant lifecycles and disease cycles.
- All growers used knapsacks apart from one that used a boom sprayer for the application of chemicals.

Post harvest practices:

- 75 per cent of growers had produced washing/packing facilities on their farms (most common was makeshift washing facilities consisting of old bath tab and water hose).
- Only two growers had a cool room.
- All packing was done manually.
- Some products like, for example, Chinese broccoli were sold loosely by weight or packed into bunches. If product is packed into bunches it is usually done in the

field during harvest or could be harvested loose washed, then bunched and packed into boxes.

3.2 Community development – Vietnamese grower group

Chong Trinh from Corio near Geelong was the first Vietnamese grower of Asian vegetables in the district. He started in the early 1980's with his brother Than and a group of friends that worked on the farm as a casual labourers. Prior to this, Asian vegetables in Victoria (mainly Asian brassicas), were grown by a few Chinese growers and some mainstream growers. Chinese growers supplied Melbourne Chinese restaurants and some Asian grocery stores, while mainstream growers sold their Asian vegetables at Melbourne wholesale market.

Two years after Chong Trinh started successfully growing Asian vegetables, two more farms branched out from the original farm. His brother Than Trinh and Vo Houng (formally working for Chong) started their own farm. The demand for Asian vegetables grew rapidly in the 1980's as people from South-East Asia settled in various Melbourne suburbs, in particular Footscray, Springvale and Richmond. By the mid 1990's there were 15 LOTE growers around Geelong.

Currently in 2008 there are 32 LOTE growers in the same region. Of those 32 growers, 29 are Vietnamese, one is Cambodian and two are Lebanese (Arabic).

As a result of the activities carried out by the project officer and, in particular, the use of a "Case Manager" approach to issues facing the growing community, the growers could see the benefits of working together as a group.

Different individuals had attempted to form a Vietnamese Growers Association on several occasions since 1997. In late August 2006, this project facilitated a growers meeting at which a Vietnamese Growers Association was successfully formed. Michael Tran was chosen to be the first president; the association had 18 members. The association was registered, rules and regulations written, and the executive committee democratically elected. This will be a significant advantage to the growers and allow them work together, network and address industry issues more effectively.

3.3 Information delivery

3.3.1 Information transfer through direct contact

The success of the project depended on the communication between the Project Officer and individual LOTE growers, in particular leading growers. This was developed initially through farm visits, regular phone contact, during meetings, training sessions and workshops.

At the beginning of the project all growers were visited by the Project Officer, to establish a face-to-face level of communication and to promote the project to growers. From previous experience and advice from people who had dealings with LOTE growers, the most important thing is to establish face-to-face communication and to earn their respect.

When the project started in 2004, eight growers out of the 20 had difficulty communicating in English. To improve communication with those growers we used the most proficient grower as a delivery vehicle to ensure two-way communications. The services of a Vietnamese speaking bilingual officer were used once a year at facilitated meetings to build on this communication. A bilingual officer Dr Ho Dang, from NSW Department of Primary Industries, was used to set up and deliver (communication/translation) workshops and courses to Vietnamese growers. A day or two prior to the workshop/course the bilingual officer, accompanied by the Project Officer, visited as many growers as possible to promote and explain the benefits of attending the proposed information session. Growers with language difficulties were visited first.

This proved an effective method of establishing links with growers and developing their confidence that attendance at the workshops and courses would deliver information in a way that they would be able to participate in and utilize.

3.3.2 Workshops, training, farm walks and demonstrations

Field days, workshops, training courses and demonstrations were arranged in consultation with growers to address their needs. The most urgent needs such as a Farm Chemical Users Course were delivered in the first year of project. Training for other subjects occurred later.

The list of courses and workshops delivered is listed in Appendix C.

3.3.3 Water Use

The shortage of water in Geelong, as a result of the drought, significantly affected LOTE growers. Up until this point, the growers were using potable town water for irrigating crops with no other alternative available. When water restrictions were imposed, the Project Officer facilitated the growers' applications for permits to use town water. At Stage 3 restrictions, growers were still allowed to use town water but it meant that they were restricted to three hours daily with a permit. In November 2006 growers went from Stage 3 water restrictions to Stage 4, which further reduced their options and they could only irrigate their crops for a maximum for two hours daily with a permit and had to implement at least a 10 per cent water saving.

Without the permit the growers would have been unable to produce crops and would have gone out of production. The project also helped them to meet targeted water savings and implement improved irrigation methods via community meetings and workshops and on farm demonstrations.

3.3.4 Interstate training trips to assist LOTE growers

1. Trip to Sydney:

On 26 July 2005 the Project Officer organised a one-day study tour to Sydney for Vietnamese growers. Eighteen growers took part in this exercise. Alison Anderson, Industry Development Officer for vegetable growers in NSW, Ho Dang and Len Tesoriero, from NSW Department of Primary Industries, hosted the tour. The growers visited the Sydney Wholesale Market, which is the largest in Australia.

At the market's NSW DPI premises, the growers attended a seminar on the importance of plant diagnostics, farm hygiene and factors and conditions contributing to the spread and incubation of pests and diseases.

The visiting group then moved on to Joe Elbustani's farm at Bringelly. Joe is an experienced hydroponic tomato and cucumber producer. Growers were interested in his polyhouse set-up, production methods, approach to pest and disease management, packing-shed and tomato grading-machine.

The next stop was a Vietnamese-speaking grower's farm at Badgerys Creek. Here growers exchanged their experiences with farm owner Mrs Mai Hong Lac. Topics discussed included drip irrigation on raised beds; market issues; set-up of polyhouses and Asian vegetables lines grown at Badgerys Creek (taro for shoots, *Perilla*, long coriander, Asian basil and guava bean).

The grower's trip highlighted the opportunities for the development of stronger relations, both socially and commercially, among growers and the NSW Department of Primary Industries. Growers received positive learning opportunities regarding market opportunities and issues, integrated pest and disease management techniques, recycled water, farm hygiene practises and innovative production methods.

Figure C1: Visit to Sydney wholesale market

2. Trip to Adelaide:

On 19 September 2006, the Project Officer organised a one-day study tour to Adelaide (Virginia) for Vietnamese growers. Seventeen growers took part in this exercise. Our tour was hosted by Tracey Tran (consultant from E.E. Muir & Sons) from South Australia. She is also a bi-lingual Vietnamese speaker. The growers visited Virginia Water Recycling facility, Virginia Horticultural Centre, E.E. Muir & Sons chemical store, Virginia nursery, and several polyhouse (hydroponic) farms where growers saw some of the industry's best practice in design, management of growing environment in the polyhouse industry.

3.3.5 Training programs

Some of the achievements of this project are:

- 17 LOTE growers successfully completed Farm Chemical Users Refresher courses (FCURC)
- 16 growers completed a Food safety course
- 14 growers completed a post-harvest handling course.

The Project Officer organised 37 growers meetings and training activities (Appendix C), prepared supporting material for those meetings and training activities and made hundreds of individual farm visits. In addition he was involved in organising visitors to LOTE growers and interstate visits for LOTE growers to Sydney (attended by 18 growers) and Adelaide (attended by 17 growers).

3.3.6 Visitors to Vietnamese farms

Throughout the project, many groups and individuals visited LOTE growers' farms. Some of the visitors were:

• Representatives and officials from Government agencies and political organizations e.g. Environmental Protection Authority, NSW Department of Primary Industries, SA Department of Primary Industries, State and Local Governments.

• Representatives from supermarket chains, restaurants, food reporters and critics etc.

• American scientists and extension officer

• Chinese government officials

• Farmers from Japan

• Philippines local government delegation

• Individual Vietnamese growers from SA and NSW.

• East Timorese Agricultural officers

The range of visitors, including politicians and other visitors, demonstrated directly to the growers how they can have more impact by working together as a group and forming an association. The growers received more attention from government agencies and a range of other interested groups.

Figure 2: Hon. Bob Cameron, Minister for Agriculture visiting Asian vegetable growers at Lara

3.3.7. Evaluation - Changes after 4 years

The number of growers has increased since the project started to 32 in 2008. Of those growers, 29 are Vietnamese, one is Cambodian and two are Lebanese (Arabic), with most growers still predominately producing in the Lara region.

Of those 32 farms, the growers owned 31. Average farm size was about 15 acres. The number of vegetable commodities grown by LOTE growers has stayed around the same (41 types of Asian vegetables grown by and hydroponics tomatoes, see Appendix B for a list of vegetables and herbs grown by LOTE growers).

For the past few years there has been a trend of reducing the number of vegetable commodities produced, with growers specialising in certain commodities and finding their own place on the market. There are 10 growers that specialise in a single commodity: four are growing hydroponics tomatoes; one grows Lebanese cucumbers; one grows greenhouse tomatoes; one grows mint; and one grows garlic chives.

The number of crops grown in greenhouses at the time of second survey increased from 45 to 50 per cent, with more growers planning to build new greenhouses. As before, 25 per cent of growers grew their crops exclusively in the open field, while 37.5 per cent had both greenhouse and open field operations and 37.5 per cent use greenhouse only for vegetable production.

The vast majority of growers used mini overhead sprinklers in the open field. In greenhouses it is about 25 per cent mini overhead sprinklers and 75 per cent drip irrigation, which is a significant change. Nearly all growers are continuing to use town water (potable water).

Farm hygiene is improving every year among LOTE growers. Prior to 2004 most growers had rubbish and crop residues spread on every part of the farm. Weed control on such farms was non-existent. Following a number of training courses like FCURC, IPM and interstate visits growers realise benefits of farm hygiene.

Seventeen LOTE growers achieved significant practice changes following successful completion of the FCURC in the first year of project. The most significant changes were achieved with the use of personal protection equipment (PPE), particularly when mixing and spraying. For instance, Van Sanh Phan used to wear only a dust mask when applying chemicals, but he now uses a half face respirator when mixing and applying chemicals. His chemicals were not stored properly; they were in various locations stored unsafely. Today Van Sanh Phan is proud of his chemical storage. He has converted an old van into a chemical storage area. Now chemicals on his farms are in an area where nothing can get contaminated, chemicals are segregated, kept under lock and the storage area is labelled appropriately.

Over the past few years growers have started using more selective insecticides in place of the broad spectrum. These growers are also started to monitor their pests and spray only when required instead of weekly sprays or calendar sprays

The growers have remained in production despite the drought and imposition of Stage 4 water restrictions. They have also significantly improved their irrigation practices and achieved the targeted 10 per cent improvement.

Figure C3: Grower visit to South Australia

4. Discussion

General

The relationships and trust established with the LOTE growers and the industry and has become more of a more case manager approach, assisting growers with a range issues such as dealing with drought, applying for access to water and building regulations for polyhouses with council and the Country Fire Authority. Significant practice changes have also been made in chemical use and management as well as more sustainable production methods.

Good agricultural practices

The results of grower survey show that some growers have made considerable efforts to improve their farming practices, their management of pests and diseases and to reduce their water use by using drip irrigation instead of sprinklers.

Grower attendance at training has greatly improved, compared to the start of the project. This indicates that growers' motivation to learn intensified once they had acquired useful knowledge and after they perceived that there could be benefits from additional learning. Younger growers, once they made decision to stay on the farm and continue family business, have become very active in the industry and some of them are regarded as community leaders. Many younger growers aged from 20 to 40 years (a number are second generation of farmers) are more progressive. Among the younger growers, many are seeking ways to improve their farming practices.

Community empowerment

This project and the Project Officer working with LOTE growers have developed a positive two-way working relationship. Many growers expressed their gratitude to the Department of Primary Industries for funding this project. The Bilingual Officer has extended their world beyond that of their community. The Project Officer has become a point of contact not just regarding production/agronomy issues of Asian vegetables but also issues regarding other government agencies like local council, water authority, fire authority and others.

This project continues to foster relationships between LOTE growers and the Geelong Council (Building Surveyor, Statutory Planning) and Country Fire Authority. With the Geelong City Council, we continue to assist growers with issues related to building regulation for polyhouses for vegetable production. We assisted the Country Fire Authority to reaching LOTE growers and raising awareness of bushfire and making preparation for this fire season. There were several meetings with involvement from those two organisations.

Aspects of the Project Officer activities and personality

Success also depended on the Project Officer's ability to simultaneously understand and fulfil the needs of both governments and growers. This dual understanding was also considered to be a key factor in the success of another project in the Riverland, where there was a need to raise awareness of chemical issues (Bunker, 1992; Morgan, 2002).

The process of trust building and development between the Project Officer and LOTE growers could take some time but, once established, it is there to stay for a long time.

Factors that will earn you trust and respect amongst LOTE growers:

- Giving timely assistance to growers. For example, growers needed urgent advice how to control either pests or diseases but very often before that pest or disease needs to be identified. In some instances without timely assistance growers could suffer significant crop losses.

- Regular visits to farms are the key. These visits allowed the Project officer to develop an extensive knowledge of each farm and establish good rapport with the individual growers. Some growers do not ask questions at group meetings or couldn't attend a meeting, but on the farm with a rapport they often feel able to ask questions or show the crop with symptoms.
- Mutual respect is very important, having in mind cultural differences between the Project Officer and LOTE growers. The Project Officer was invited to attend a wedding of one of the young Vietnamese growers. To show mutual respect toward growers, the Project Officer accepted the invitation and attended the wedding ceremony.

Figure C4: Farm visit, Tong, Steve Moore (Muirs) and Slobodan Vujovic in Cung cung

Asian vegetables web site

The Victoria Department of Primary Industries' Asian vegetables web site was established in 1997 and is still going strong. During the time of this IMS project officer was given responsibility to manage it. The Asian vegetables web site consists of 65 individual web pages with images and information relating to pest, diseases and general information about Asian vegetables.

Recently the department subscribed to the Neilson Netrating program, a web statistic program for measuring web site performance. Using this program we can measure Page Impression, Unique Browser, User Sessions, Unique Browser Frequency, User Session Duration, Page Duration and many other things like geographical location of web guests. In the month of June, the website had 3990 visitors. The top 15 pages within the website that were visited were: Vegetable thesaurus (1165 visitors), Disease of Asian vegetables (117), Home page (86), hairy melon (70), tapioca (64), okra (56), Chinese boxthorn (55), yam (55), water convolvulus (48), Chinese broccoli (47), Lizard's tail (47), pests of Asian vegetables (45), bok choy (44), Ceylon spinach (44) and Chinese cabbage (43).

The Asian vegetable web site was visited by people from 68 different countries. Most visitors come from Australia (45%), USA (23%), UK and France (5%), Vietnam (4%), Malaysia (2.4%), Netherlands (2%), Canada (1.2%), Philippines (1.5%), and Indonesia and China (1%). Most of our web site was translated to Chinese, French and Spanish by Google translation services.

The statistics indicate that most people use search engines to find the website typing a single word or phrases into the search engines. The top 3 search phrases are: Asian vegetables (used 257 times), Asian vegetable names (178 times) and vegetable names in Vietnamese (58 times). Two top search key words were: Asian (used 547 times), and vegetables (507 times).

This example illustrates the current interest in Asian vegetables and people's attempts to find out more information about them.

5. Outcomes

Intended Outcomes

These are outcomes that could be associated with defined aims of the project but some of the following are also associated with the unintended outcomes.

1. Growers are tending to specialise in crops to improve marketing and returns by developing their own market niche.
2. There is an increase in the number of greenhouses being built, and more importantly, these now have a planning permit and are designed.
3. Farm hygiene has improved significantly, particularly with respect to weed control and the clean-up of crop residues.
4. Significant change in chemical use practice, including the use of personal protection equipment.
5. Significant improvement in the storage of chemicals.
6. Increased awareness of the components of IPM including the range of pests, understanding that beneficial insects exist and increased and better targeted use of selective chemicals.
7. Growers are more likely to look at their crop for pests before spraying rather than following a calendar or weekly spray schedule.
8. Post-harvest handling training has been achieved by 14 growers.
9. Food safety course has been delivered to 16 growers.

Unintended Outcomes

These are outcomes that have been an unintended spin-off from working the LOTE growers and have occurred as a result of the project being in place.

1. The project officer established a “case manager” type approach to resolve issues of conflict for the LOTE grower community.
2. Formation of a growers group.
3. Continued viability of the growers in the face of the drought and significant water restrictions.
4. Improved communication and liaison between growers, local council and other agencies such as water boards and a better understanding between each of the groups.
5. Irrigation practices have improved, with better irrigation scheduling and water use, and a 50 per cent increase in the use of drip irrigation in greenhouses.

6. Recommendations

LOTE Growers - Victoria

1. There is a need to for work with LOTE growers in Victoria to continue to build on the successes achieved to date. The community has come a long way towards overcoming difficulties in understanding and networking with government and other agencies but this needs to be consolidated and continue building the industry capability.

2. The Asian vegetable industry is small and diverse and many LOTE growers have communication difficulties. As relatively few crop protectants are registered for use, these growers require more assistance than other mainstream vegetable producers.

3. There is a need to continue to develop pest monitoring and scouting skills for LOTE growers, as well as their understanding of integrated pest management practices. This knowledge needs to be underpinned by suitable translated material to provide the supporting information.

4. The Case Manager approach has proved to be an excellent method for building the capability of LOTE growers, as they are affected by a range of issues and this helps to break the sense of isolation that the community may feel.

5. There is a need to develop quality assurance with LOTE growers to improve the quality of supply, improve the confidence of buyers of Asian vegetables and allow these growers to supply to mainstream retailers. This will also have an impact on the perception and safety of Asian vegetables.

6. Given the range of crops many LOTE growers produce, there needs to be a better understanding of agronomic practices and pest and disease control so that incompatible crops are not grown together.

Part D Integrated pest management for Asian baby-leaf vegetables

1. Introduction

Asian baby leaf crops are grown on a large scale for salad mix and may be minimally processed and marketed as ready-to-eat bags or bulk in boxes. The main Asian baby leaf crops are pak choy, mizuna, tat soy, and also rocket, bocane and chard. The crops are grown in monoculture with plantings sown weekly. Crops are direct-seeded and sown as a meadow and either hand harvested or mown by machine with up to several harvests per crop.

Grower reports are that pak choy and tat soy are the crops that suffer the most pest damage and, therefore, project work will concentrate on these two crops. However, the information will be relevant to the range of baby leaf crops grown.

The time from seeding to harvest is short and in summer can be as little as four weeks, extending out to six or seven weeks in winter. Insect damage can cause malformation of the leaf, pimples in the leaf, perforations, spots or holes. Pests could include mites, thrips, leaf miner, aphids and larvae of *Helicoverpa* spp and *Plutella* (diamondback moth - DBM). If damage is severe, the whole crop can be rendered unmarketable and result in total crop loss. The percentage of crop affected ranges from 10-60% and often the damage is not observed until it is too late. Given the short cropping time frame, the aim has to be prevention rather than cure. These are intensive, high value crops and continuity of supply is critical for maintenance of the product in the market place. These products are produced for chains that demand continuity and quality of supply to ensure shelf life.

Pest damage is causing losses to growers and problems for processors in supply and potential loss of shelf life. Currently, control using broad-spectrum insecticides is variable and can be ineffective. This can be due to timing and targeting the wrong pest so that by the time damage is seen it is often too late. There are a range of issues that need to be addressed or cause management problems:

- There is a need to identify suitable scouting and monitoring methods for pests.
- There is a need to identify the key pests for pak choy and tat soy rather than relying on assumptions. This will be essential in order to develop appropriate IPM strategies.
- These are minor crops and there is an issue of registration and withholding periods particularly in view of the short production times.
- Insect pest resistance (eg, *Helicoverpa*, *Plutella*, and western flower thrips) is another factor that needs to be taken into account in relation to control strategies.
- Control methods need to be assessed including conventional and an IPM approach.

- Appropriate control programs need to be identified and developed based on an integrated pest management approach.

- Because these crops are grown for minimally processed product lines there is only a minor margin for crop damage.

- Critical seasonal times for key pests need to be identified.

- The level and types of beneficial activity in these crops needs to be identified.

2. Evaluation of Existing Practices

Prior to commencing the field work, an evaluation of existing production practices in baby leaf crops was carried out for five growers in East Gippsland.

The crops are all field grown, with some protected cropping using netting to avoid wind and sun damage to crops. This also creates a protected cropping environment with more even production conditions and less stress placed upon the crop.

All growers expressed that they understood the meaning of an IPM strategy, however the spray strategy used was “as needed”, with one grower using a calendar as well as an “as needed” spray program. All growers monitored for pests, either themselves and/or using a consultant, with two growers claiming to also monitor for beneficial insects. All growers used a diagnostic service from time to time.

The key pests that the growers identified included: diamondback moth, leaf miner, thrips, aphids, *Helicoverpa* spp, cabbage white butterfly and leafhoppers.

All growers used broad spectrum insecticides for the control of pests; all used targeted pesticides at times and also used biological pesticides on occasions (with one exception).

None of the growers released beneficials or planted crops with the intent to attract beneficials. The growers that used consultants said that they did sometimes modify their spray practices because of beneficial insects. All growers practised crop rotation although mainly for disease rather than pest control.

3. Scouting and Monitoring – Asian baby leaf crops

3.1 Introduction

Key pests and beneficials will be identified and numbers assessed using monitoring methods such as trap and crop sampling methods and these results will be supported by crop scouting. The number and type of pests within the crop will also be correlated with the type of crop damage that occurred.

3.1.1 Monitoring Existing Crops

The project will identify the pests that are causing crop damage and assess their impact. Field crops were monitored to identify the presence of beneficials, key pests and the damage caused. In year one, the focus was on identifying the presence of key pests and linking the incidence of damage to pest levels in the crop. Monitoring methods were assessed for their applicability. A range of monitoring methods were used including pheromone, yellow sticky, pan and pitfall traps.

3.1.2 Scouting

In plantings as dense as baby leaf crops, it was identified that modification of the approach of assessing a given number of plants at several locations within a crop would be required in order to scout pest and beneficial levels within a crop.

Traditional crop scouting methods involve assessing a number of plants at different locations within a crop, for example, three plants at locations at random covering the whole crop area with at least 30 observations. This method is not suitable for a meadow planting. A method for scouting crops needed to be developed which is practical, ie, must be reasonably quick and can be carried out without resorting to technical equipment but would also give a reliable guide to pest pressure.

3.2 Methods

3.2.1 Year 1

A range of traps were used to monitor the presence of beneficials and pests. These include traps targeted at specific pests and more general catch traps.

Specific targeted traps included pheromone traps, which release female pheromone and are aimed at trapping the male moths of specific species, these included:

- Pheremone trap for diamondback moth or DBM (*Plutella xylostella*) (Figures D1 and D2)
- Pheromone trap (Scentry®) for *Helicoverpa* spp (*H. armigera*, *H. punctigera*)

General traps included:

- Pitfall traps – these are containers which are dug into ground leveland catch mainly ground dwelling insects and mites and spiders.
- Pan traps – this is usually a yellow or white container filled container water and detergent (to break surface tension) to attract and capture a range of winged insects including pests and beneficials.

- Yellow sticky traps – are targeted at flying insects such as thrip, aphid and wasps (Figure D1).

Figure D1. Yellow sticky trap and DBM trap in background

Figure D2. DBM pheromone trap

Traps were positioned in crops and monitored weekly for a number of specific periods throughout the season. Monitoring commenced in October and extended until April due to insect activity.

There were two components of scouting carried out in year one. The first was to assess and evaluate an appropriate scouting method for baby leaf crops. Individual plant assessment was not a practical option given the nature of the plantings. It was decided to evaluate the use of a quadrant as an alternative to individual plants.

Three quadrant sizes were evaluated ranging from 50x50 cm to 35x35 cm and 20x20 cm. The quadrants were made using 18mm pvc pipe to produce a simple and resilient frame. The number of throws varied with the different quadrant sizes due to the time differences to scout within each of the different quadrant sizes and the area covered. Five throws per crop were used for the 50x50 cm, seven per crop for the 35x35 cm and 10 for the 20x20 cm quadrant.

The second component of the scouting was to assess the presence of pests and beneficials in the crop and the correlation with the trap data. In addition the type of damage was noted and for correlation with pest levels to identify the critical incidence of damage and the key pests. A number of individual crops were scouted at different times of the season to monitor the changes in pest incidence throughout the summer season.

Damage was classified into disease presence or physical damage. Disease was likely to be either downy mildew or white blister and physical damage was categorised as sucking, chewing or piercing of leaves.

3.3 Results

3.3.1 Scouting Methods - Evaluation of Quadrants

The critical issues that needed to be addressed were ease of use, ability to scout within the quadrant in a short time and consistency of repetitive pest numbers in each sample.

For an experienced crop scout, the 20x20 cm quadrant takes around 20 minutes to check for 10 throws, 35x35 cm quadrant takes around 25 minutes for seven throws while the 50x50 cm size takes considerably longer at 30 minutes plus for five throws.

Figure D3. Quadrant (20x20 cm) in pak choy

Comparison of scouting results using the different sized quadrants is shown in the following tables for the range and number of insects present. The results showed a good correlation between the 20x20 cm with the 50x50 cm quadrant over two scouts for a range of pests and beneficials present (Tables D1 & D2).

Table D1. Comparison of pest and beneficial numbers between 20x20 cm and 50x50 cm quadrants

Pest or Beneficial	Number per square metre	
	20x20 cm Quadrant	50x50 cm Quadrant
Crop: Pak choy		
Cabbage centre grub	0	0
Cabbage centre grub eggs	15	8.8
Helicoverpa	7.5	6.4
Aphid	62.5	52.8
Thrips	17.5	16.8
Predatory mites	25	12
Parasitised aphid	7.5	0
Wasps	12.5	3.2
Leaf miner	5	0
Crop: Tat soi		
Cabbage centre grub	2.5	0
Cabbage centre grub eggs	17.5	1.6
Helicoverpa spp	5	6.4
Aphids	85	20
Thrips	12.5	6.4
Predatory mites	15	0.8
Parasitised aphids	5	0
Wasps	10	2.4
Leaf miner	2.5	0
Correlation coefficient	0.76	

However in comparing the levels of individual pests, such as aphids, there was much more variability in results from using five throws of the 50x50 cm quadrant in comparison with 10 throws of the 20x20 cm quadrant.

For the comparison between the 20x20 cm and 35x35 cm quadrant using seven throws for each, the correlation between the two quadrant sizes was better than using than the above comparison.

The variability between these two quadrant sizes was similar when comparing the scouting results for specific pests, although the comparison was based on seven throws for both the quadrant sizes. Using 10 throws for the 20x20 cm quadrant would result in a more accurate assessment of pest and beneficial numbers.

Table D2. Comparison of pest and beneficial numbers between 20x20 cm and 35x35 cm quadrants

Pest or Beneficial	Number per square metre	
	20x20 cm Quadrant	35x35 cm Quadrant
Crop: Tat soi		
DBM eggs	0	0
DBM larvae	15	8.8
Aphid	7.5	6.4
Thrips	62.5	52.8
Jassids	17.5	16.8
Leaf miner	25	12
Parasitised aphid	7.5	0
Lady beetles	12.5	3.2
Wasps	5	0
Cabbage butterfly		
Correlation coefficient	0.85	

3.3.2 Trapping and Scouting

Scouting and trapping data was compared for pests that tend to occur consistently in high numbers throughout the season, such as diamondback moth, aphids and thrips. The graphs below show the relationship with trapping and scouting data for several key pests.

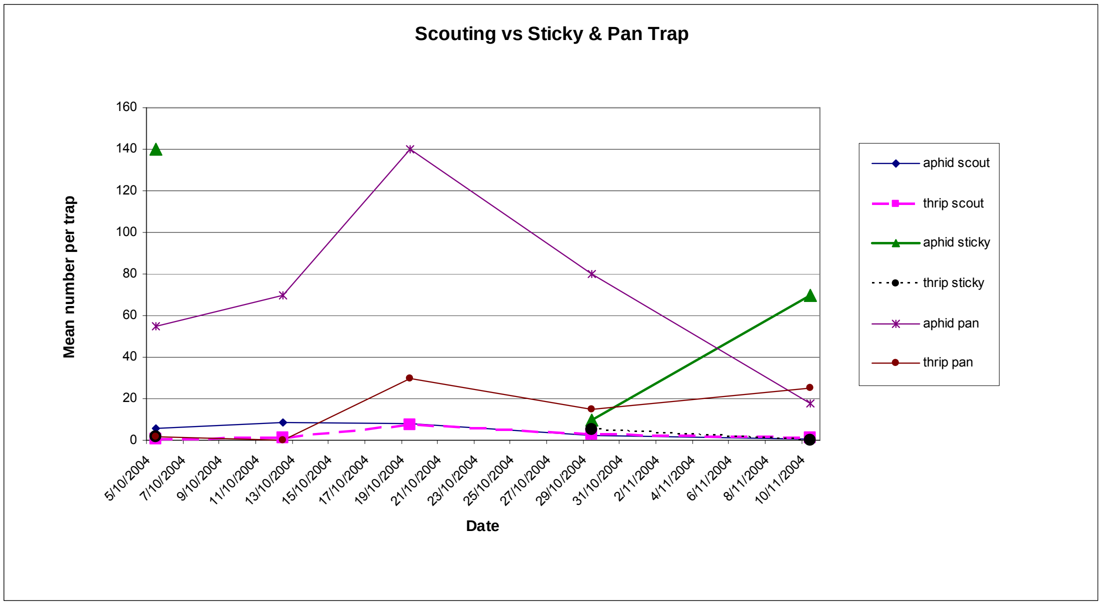

Figure D4. Comparison of trapping and scouting data for aphids and thrips using sticky and pan traps.

Figure D4 shows some variability in aphid and thrips numbers for scouting within the crop and the pan and sticky traps. However several sticky traps were blown away and counts lost for several sample dates.

Sticky traps are easier to monitor and use than pan traps, however yellow sticky traps are brittle and can be damaged by strong winds. Correlation between the traps was good and with scouting numbers for aphids and thrips within the crop. The correlation coefficient was 0.82 for the numbers within the crop and the sticky trap.

The graph for diamondback moth (Figure D5) shows a clear relationship between the pan and the pheromone trap and the pest numbers (eggs or larvae within the crop). There is a significant correlation with trap numbers and the presence of the pests within the crop, with a correlation coefficient of 0.87 for scouting and moth numbers within the pheromone trap.

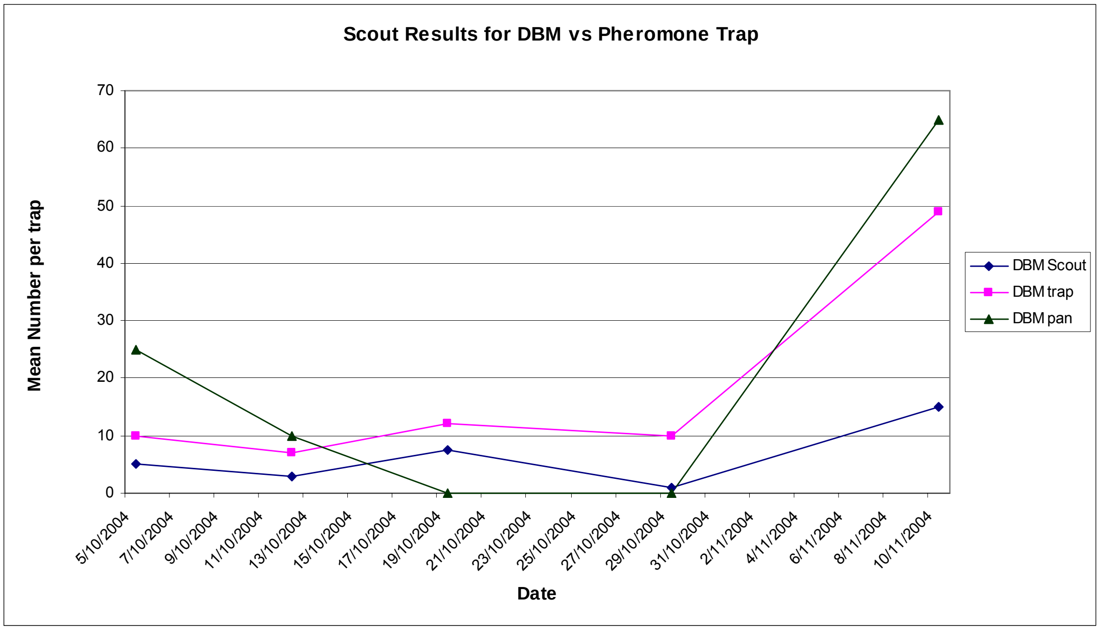

Figure D5. Comparison of scouting results for diamondback moth and pheromone trap numbers.

Pan traps can be more effective for trapping larger numbers of insects than the sticky trap but sticky traps are easier to handle and monitor. Care needs to be taken to ensure that they are not damaged by wind. The range of traps used demonstrated that they would be effective in demonstrating activity of a range of pests and beneficials and the need to scout crops. However high trap levels do not necessarily indicate that pest numbers in the crop will be high, but do indicate that the pest will be present.

3.3.3 Seasonal Variation

Results for the seasonal variation of pest pressure for a range of pests were obtained from the trap data. However results from the summer of 2006/07 were unable to be obtained due to the major bushfire event and the response of the project team to the emergency.

Diamondback moths are considered to be a major pest causing chewing damage and pheromone traps were used as a targeted trap to ascertain pest pressure. The seasonal variation is shown in the graph below (Figure D6). Monitoring through to 2006 provides an example of the seasonal variation. Numbers build up in early spring, with population peaks around late November, and then continual presence over summer and autumn. The traps provide indications of peak activity for moths that will provide an indication to growers and agronomists of the need to monitor crops more frequently for egg lays.

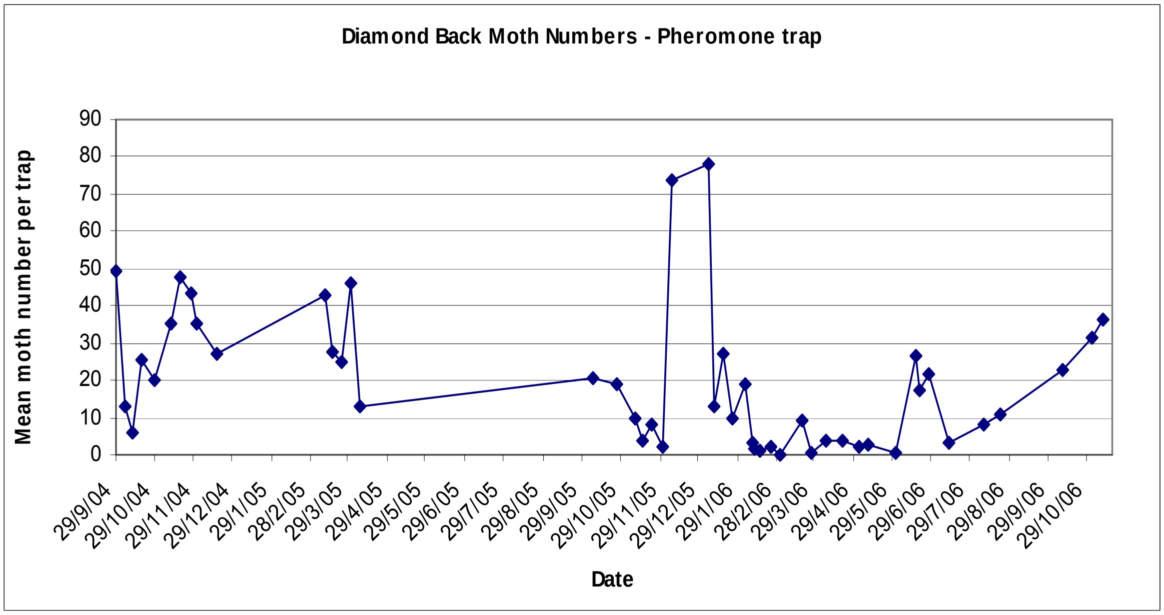

Figure D6. Seasonal variation of diamondback moth numbers (no trap counts between April and August 2005)

The pan trap data, for traps placed within crops for the same period, shows the seasonal presence of the major pests and beneficials (Figures D7 & D8). Pan traps collect a broad range of insect pests and beneficials and can collect higher numbers than yellow sticky traps. Pan trap data for pests and beneficials is presented in the graphs below.

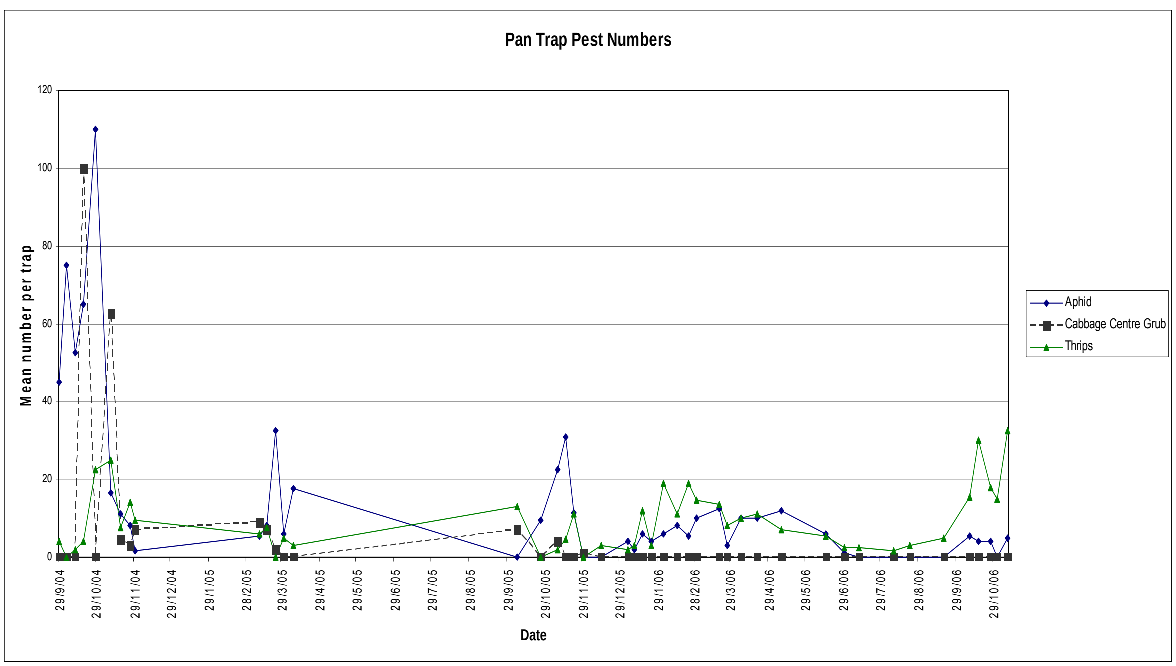

Figure D7. Pan trap numbers for key pests over time

Aphid and thrips activity increases in spring and remains present throughout the season, with variable levels of pest pressure depending on the season. The graph shows very high numbers of cabbage centre grub in 2004 and this pest occurs in early spring but pest pressure will vary from year to year. The high levels of cabbage centre grub were confirmed with scouting results and indicated that damage that may have been attributed to diamondback moth may well be due to cabbage centre grub in early spring.

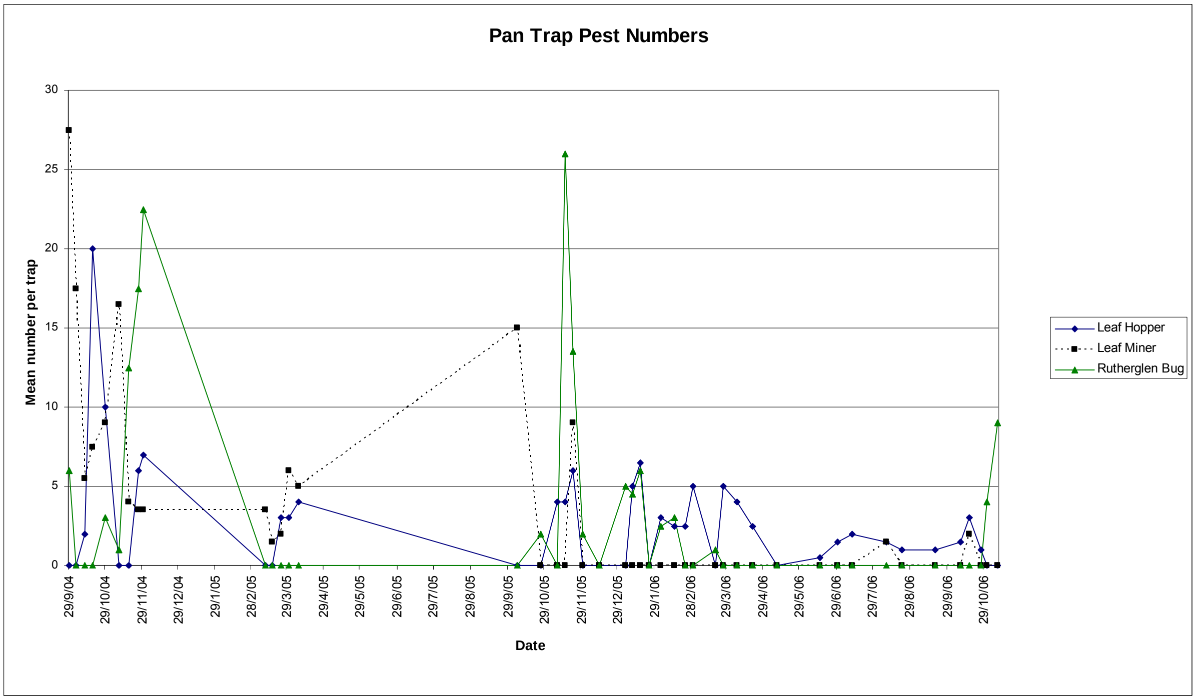

Figure D8. Pan trap numbers for key pests over time

Leaf miner and leafhoppers are other active pests (Figure D8) and are present most of the year, with higher numbers over the summer production period. Rutherglen bug, as above, can be present in very high numbers and scouting has confirmed very high pest pressure in the crop. They are significant pests due to the potential to develop high pest pressure, which can reduce the vigour of the crop and also cause post harvest contamination. Pan trap results confirm their active presence and relative levels.

The major beneficials that occurred in the pan traps are shown in Figure D9. Beneficial numbers tend to follow and be similar in activity to those of the key pests. There will also be a lag for the increase in beneficial numbers and lag in subsequent decline when pest numbers fall off. Trapping was not carried out over winter from April to September in 2005. There was a range of wasp species present, which feed on aphids and lepidopteran pests. Wasp numbers in total were good and they tend to be present year round.

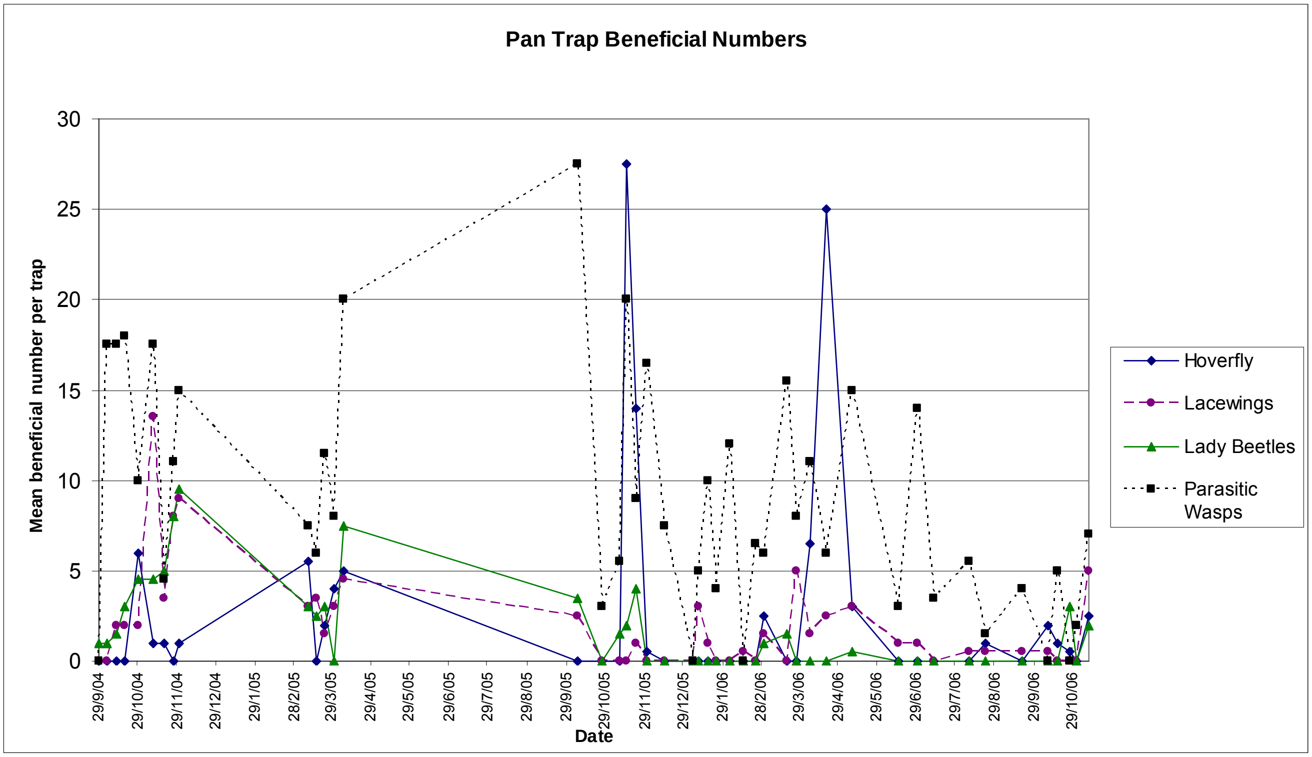

Figure D9 Pan trap numbers for key beneficials over time.

3.4 Discussion

Results from the combined trapping, scouting and vacuum data have identified the range of pests and beneficials that are present within the crop and, in particular, the key pests and beneficials that are present in the highest numbers. Continual scouting was not possible given the time and resources in the project but was carried out during the first two years to support and correlate trap and quadrant assessments. Subsequent scouting was carried out in association with the cultivar and best management trials, rather than continual monitoring of the crop through the season. The list of pests and beneficials that were identified are listed in Table D3.

Table D3. Key pests and beneficials in Asian baby leaf crops.

Pests	Beneficials
Key pests	**Key Beneficials**
Diamondback Moth Cabbage Centre Grub Aphids Thrips Leaf Miner Rutherglen Bug Cabbage white butterfly	Wasps Spiders Lacewings Hover fly Lady beetles
Minor Pests	**Minor Beneficials**
Helicoverpa spp Jassids Flea beetle Shore Flies Fungus gnats Green Mirid Cabbage Cluster Moth Mites Carabid beetle	Pirate bugs Soldier beetle Tachnid flies Rove beetle Soldier Beetle Red & blue beetle Assasin bug Damsel Bug Big Eyed Bug

The major types of crop damage or factors affecting crop quality were identified as part of scouting, trap monitoring, crop assessments and results from field trials. These crop quality issues include:

Chewing damage: This is predominately caused by caterpillars of moths and butterflies such as diamondback moth, cabbage centre grub, cabbage white butterfly, *Helicoverpa* spp and cabbage cluster moth. The leaf has a tattered and torn appearance or symmetrical round holes and under severe pressure may have a netted appearance.

Figure D10. Chewing damage caused by caterpillars

Leaf mines: Two species of flies were identified as causing the damage *Liriomyza betae* and *Scaptomyza flava*, the maggots of which burrow into the leaf creating leaf mines which may have a zigzag pattern. There are natural parasitoids of the pests in the field.

Figure D11. Leaf mines

Leaf piercing: The leaf has an appearance of pin like holes, which can be numerous and cover significant areas. The holes are much smaller than those caused by caterpillars and are caused by the different stages of Rutherglen bug piercing young leaves. Rutherglen bugs are sap-sucking insects but cause leaf damage resulting in the pinprick holes as the leaves grow.

Figure D12. Leaf piercing, showing numerous leaf holes

Sucking damage: Thrips nymphs, aphid nymphs and young feed on the underside of leaves. The leaf tissue becomes thickened and leathery due to sap being sucked out. Thrips have piercing and sucking mouthparts and tend to cause silvering, dimpling and distortion of the leaf. Aphid damage tends to result in more yellowing of the leaf.

Figure D13. Sucking damage

Leaf hopper damage: These are also sucking insects but their feeding causes a yellowish flecking of the leaves often in clusters. They feed on the underside of the leaves and will hop rapidly to other leaves if disturbed.

Figure D14. Leaf hopper damage

Downy mildew: A fungal disease, which causes leaf yellowing. This is the main disease that affects crop quality in baby leaf tat soy and pak choy. It appears first as yellowish spots on the top of leaves and may appear angular due to limitation by the leaf veins. The underneath of the leaf surface may have a downy grey brown appearance. This can significantly affect quality and shelf life in minimally processed product in bags.

Figure D15. Downy mildew

The overall aim of the evaluation of scouting and monitoring methods was to assess simple and practical methods that growers or crop scouts could use to readily assess pest and beneficial levels and pressure within a crop. The methods must be accurate but not be too time consuming.

The comparison of different quadrant sizes showed that the best size, which provided the most time efficient and reasonable assessment of pest levels, was the 20x20 cm quadrant. It is better to do more throws and sample a smaller area than larger samples and a smaller number of throws.

Monitoring and scouting identified the key pests and beneficials. This will provide direction as to the types of traps to use and pests to target. The aim of the traps is to monitor pest pressure and presence. Trapped numbers will provide a good indication as to new flights or local emergence and will provide a guide to the frequency and intensity of crop scouting that will be needed. *Helicoverpa* spp did not seem to be a major pest in any year for baby leaf crops so it would not seem necessary to have pheromone traps for its monitoring. However diamondback moth was a major pest over the period of the project and the use of pheromone traps would be a useful method of monitoring pest pressure.

Major pests identified included cabbage centre grub and Rutherglen bug, however growers had not identified these at the start of the project as significant pests. Leaf miner, while identified by growers as a key pest, does not significantly affect quality and did not seem to be a critical pest. The project identified that there are natural parasitoids in the field to control leaf miner and that broad spectrum insecticides are of limited effect given that the pest is relatively protected once inside the leaf.

A range of other traps were used but the most useful was the yellow sticky traps for ease of use and handling. The only drawback is their fragile nature, where they can snap of and be blown away. Pan traps were also very effective but the insect samples break down quickly in the water and as numbers can be much higher than on the sticky traps, their use requires more expertise and time. There were good correlations with the traps and other monitoring methods such as vacuum sampling and scouting. At the end of the day, the aim is to have a comparative measure of pest pressure.

While trap numbers may have been high for various pests, this did not always translate into high pest numbers at scouting. This may be due to a number of reasons such as rainfall or irrigation washing off pests or good predation or parasitism by beneficials. It does highlight the importance of not relying on trap results to manage pests or determine control strategies.

The seasonal variation of pests shows that the key pests are present throughout the main production period of spring through to autumn, with peak periods of pest pressure occurring. Beneficial numbers did tend to follow the pest peaks as would be expected but wasps (parasitic) were present in good numbers throughout the production period. Pollen from weeds, lucerne and pasture crops in the area probably supplemented their food source. Numbers of the parasitic wasps, mainly *aphidea* were in higher abundance when trials were close to a lucerne crop.

The monitoring and trapping did identify the key pests of the main baby leaf crops, tat soy and pak choy. One key pest that was unexpected was cabbage centre grub. It is likely that some of the chewing damage in early spring has been incorrectly attributed to diamondback moth. In particular some high diamondback moth numbers in traps did not result in high numbers within the crop. As indicated earlier *Helicoverpa* spp did not appear to be major pests.

Rutherglen bugs emerged as a significant pest, causing piercing damage. This occurs when the bugs feed on young leaves causing damage and small holes that enlarge as the leaf grows. It is also a key pest because of its potential to be present in very high numbers, causing post harvest contamination issues (it is difficult to wash out of the leaves for salad packs). Its presence is significant because there are no soft chemicals available for control. To institute an effective IPM program will involve alternative control methods, such as trap-crops which were assessed in the final year of the project.

Thrips and aphids, as expected, caused damage, as did leaf miner, although leaf miner damage does not have a major impact on quality and there are also leaf miner parasitoids naturally present.

Importantly many growers discount downy mildew as a problem, but in our assessments this disease occurred at levels and with an impact that would significantly affect post harvest quality. A wide range of pests were identified but only a small number were highly significant in terms of pest pressure and damage. There were also a large number of beneficials observed which indicates that with good management IPM in baby leaf crops may be a feasible option.

4. Cultivar Evaluation

4.1 Introduction

It has been identified that some types of Asian babyleaf vegetables, such as tat soi and pak choy, are very attractive to some pests. Crop monitoring in year one was used to confirm this. Past research has shown that there are differences between cultivars of various species in relation to susceptibility to pests and diseases. Given that pak choy and tat soy appear to be more prone to attack by some pests than other baby leaf crops it also is possible that different cultivars of these crop types may be less attractive or resistant to these pests. This may be an option for pest and disease control.

4.2 Method

Cultivars were sourced from seed companies and planted out in several sequential cultivar comparison trials. Only one cultivar of tat soi is available but there are a number of pak choy varieties. The trials were left untreated for pest control.

4.2.1 Trial 1

Trials were hand planted 23 November 2005 in a random block design. Trials were hand planted due to the number of cultivars and small plots. Beds had to be measured accurately and 11 furrows marked at even intervals per bed. (Refer to trial design and replicates at Appendix J).

One tat soi variety was included, due to its perceived susceptibility to DBM, thrips and leaf miner damage. The other six varieties included were all pak choy varieties: *Komodo, Migako, Shanghai, Joi Choi, Chinese, Envy*. Varieties were chosen with respect to commercial availability, and general availability of seed.

The trial was scouted twice, on 7 and 13 December 2005, harvested on 15 December and, the next day, was vacuum sampled. The trial was planted as seed and harvested 23 days later. Trapping data was kept in conjunction with the trial, so damage could be correlated to trap data, scouting data, and vacuum samples. Sub-samples from the trial plots of 50gm were taken for damage assessment.

Figure D16. Cultivar trial plots

4.2.2 Trial 2

The trials were hand planted on the 17 March 2006, as per Trial 1. Plots were 1.5 m long with a 0.25 m buffer and six cultivars were evaluated.

Tat soi and the pak choy cultivars, *Komodo, Shanghai, Wonder, Chinese, Envy. Migako* and *Joi Choi*, were not used due to unavailability of seed. *Wonder* is a variety that the grower was currently using. Not all the cultivars used in the first evaluation were available for the second trial due to lack of seed availability or small seed lots in the first instance.

The trials were scouted on the 31 March and 07 April 2006 and were harvested and vacuum sampled on the 18 April 2006. Samples were taken for analysis, as per Trial 1.

4.3 Results

4.3.1 Trial 1

Scouting Results

The main beneficials observed when scouting the cultivar trial were wasps, with a range of species present. There were high numbers of DBM and *Helicoverpa* eggs present at the first scout of the trial and even higher numbers of DBM eggs present at the second scout. However the high number of eggs did not translate into high numbers of larvae for each of those pests (Figure D17). The main larvae present were cabbage centre grub and DBM.

Thrips and leaf miner were the main sucking pests present on all cultivars except for *Chinese,* which had high numbers of leafhoppers (Figure D18).

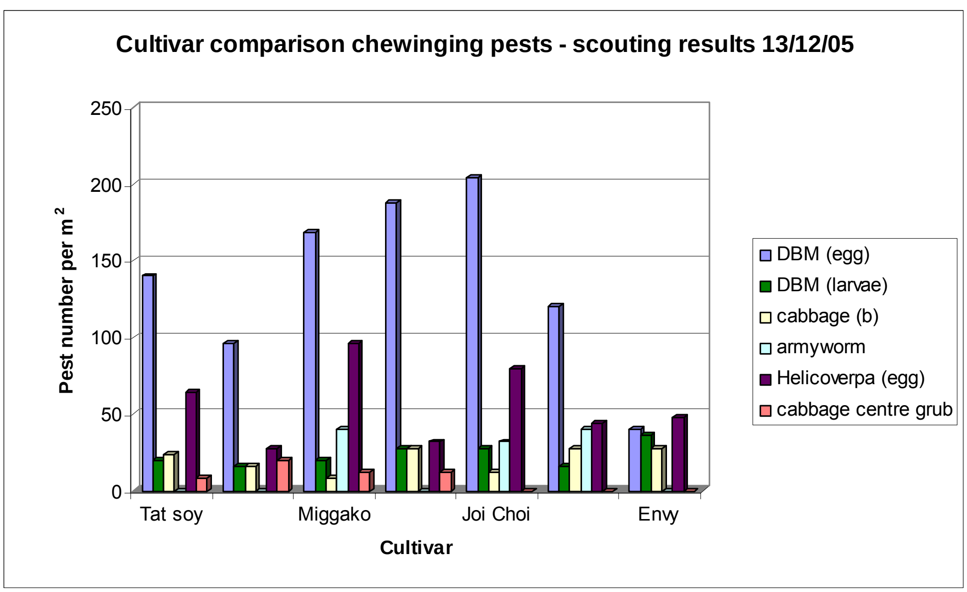

Figure D17. Cultivar comparison of scouting results for chewing pests

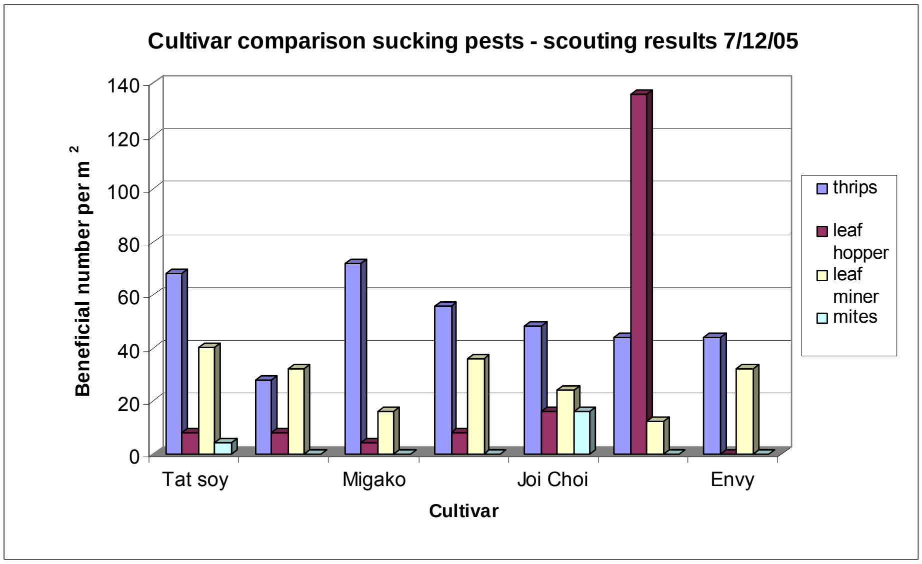

Figure D18. Cultivar comparison of scouting results for sucking pests

Trapping

The pan traps showed periodic high activity of aphids, Rutherglen bugs, DBM and cabbage centre grub moths (Figures D19 and D20). A range of beneficials were also present, including high numbers of lady beetles and wasps, which prey respectively on aphids and DBM (larvae and eggs) (Figure D21).

Sticky trap sampling also indicated the presence of beneficials; hoverflies, wasps and lady beetles. Beneficial numbers on the sticky traps mirrored the levels of aphids, thrips and plant hoppers at the different sampling times.

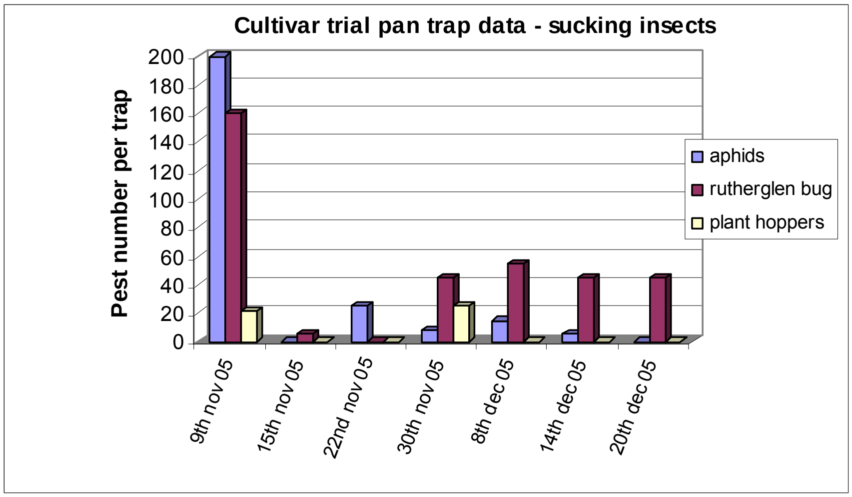

Figure D19. Pan trap sucking pest numbers for the cultivar comparison

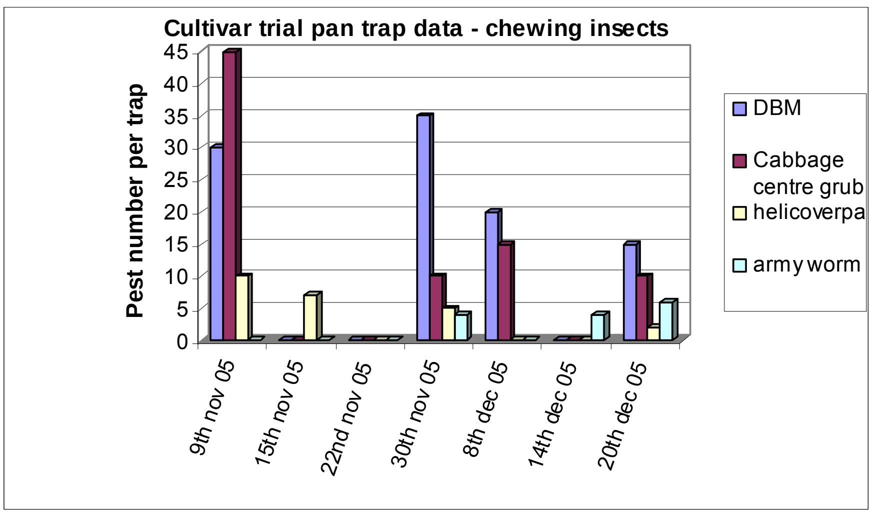

Figure D20. Pan trap chewing pest numbers for the cultivar comparison

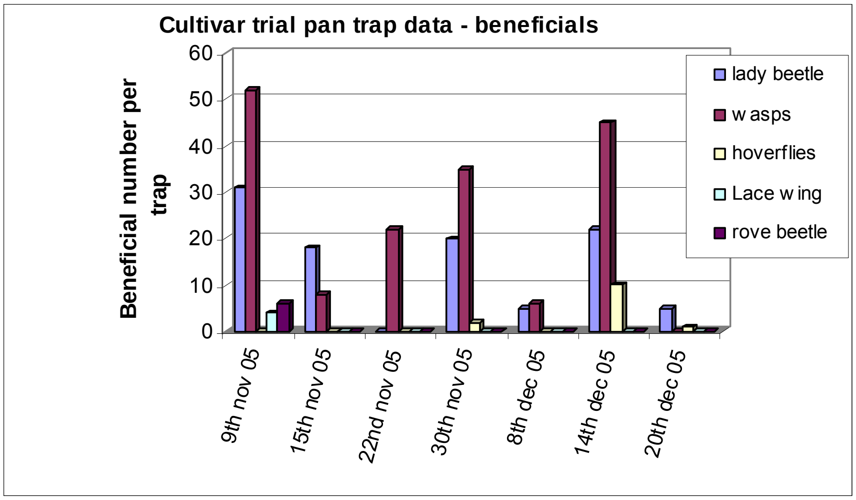

Figure D21. Pan trap beneficial numbers for the cultivar comparison

Harvest Results

Plots were vacuum sampled at harvest and very high numbers of Rutherglen bugs were present across all cultivars, as were DBM moths and larvae.

Significant differences were observed between cultivars for piercing damage only, however there were observable differences which were not quite significant for thrips damage. Tat soi had significantly higher levels of piercing damage than the pak choy cultivars. Of the pak choy varieties, *Shanghai* had more damage than *Migako*. *Envy* showed lower levels of thrips damage (Figure D22).

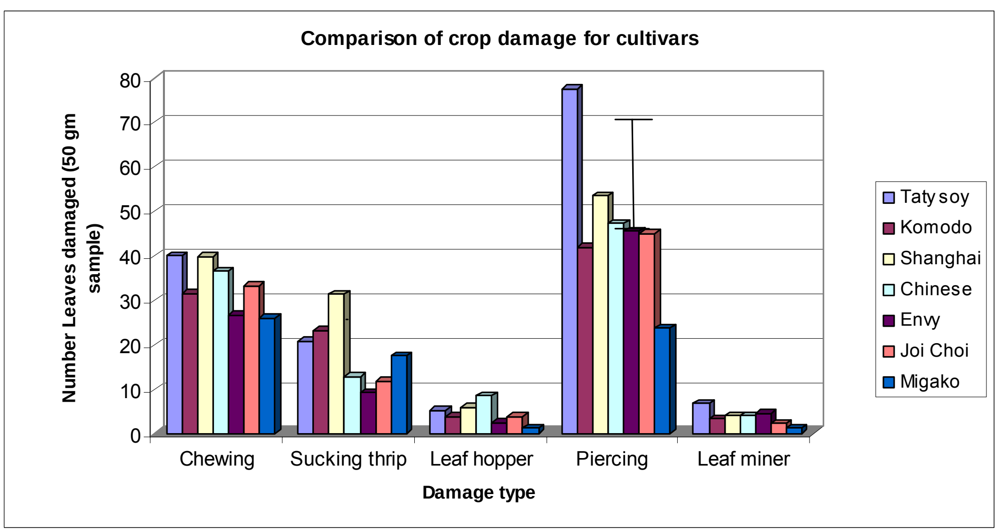

Figure D22. Comparison of crop damage between cultivars.

There were no significant differences in chewing damage, leaf hopper or leaf miner damage but cultivar *Migako* was at the lower end of the range for all these comparisons. Given that the levels of DBM did not differ significantly between varieties, it was not expected that damage levels for chewing would differ. *Migako* appeared to be the cultivar least susceptible to pest attack and *Envy* also performed quite well.

4.3.2 Trial 2

Scouting showed some differences between the cultivars for pest pressure. *Wonder* showed lower levels of diamondback moth at both scouts compared to other cultivars (Figure D23a and D23b). With the exception of *Wonder*, DBM eggs and larvae were present in good numbers on most cultivars. However, as observed in the first trial, high egg numbers does not necessarily result in high larval pressure.

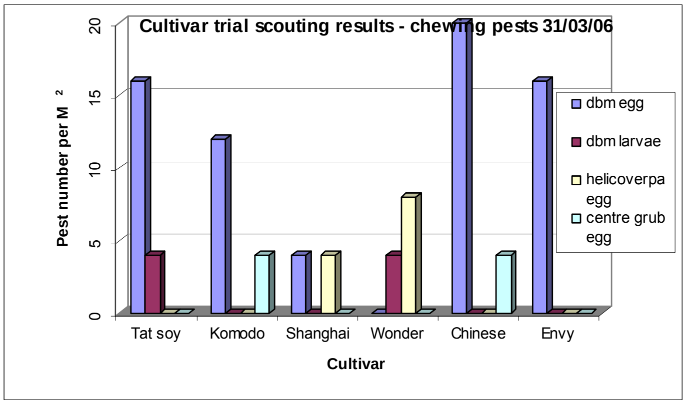

Figure D23a. Cultivar comparison of scouting results for chewing pests (first scout, 31/3/06)

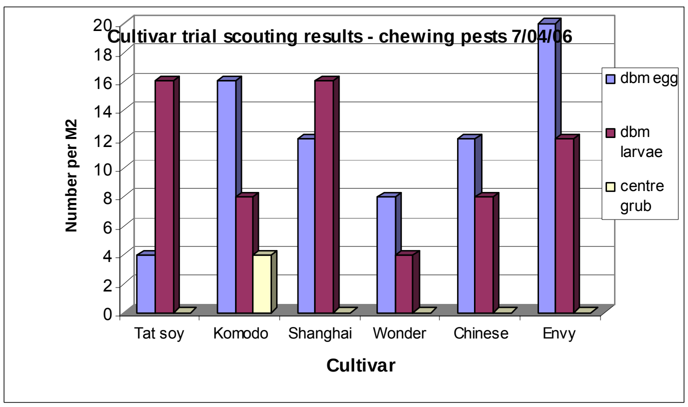

Figure D23. Cultivar comparison of scouting results for chewing pests (second scout 7/4/06)

For the sucking pests, *Chinese* and tat soi had no aphids present at either scout although the cultivar *Chinese* did have some parasitised aphids present at the second scouting (Figure D24a and D24b).

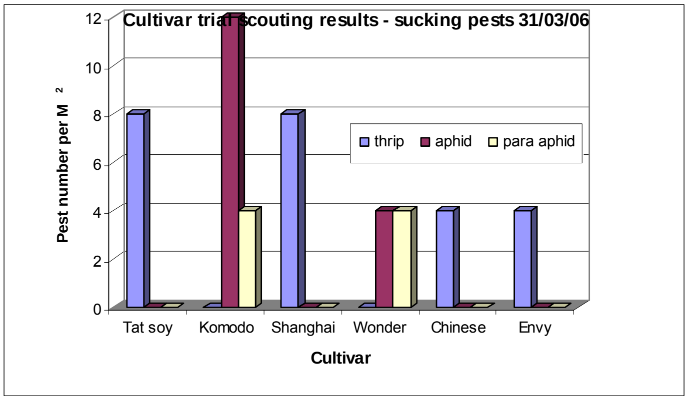

Figure D24a. Cultivar comparison of scouting results for sucking pests (first scout, 31/3/06)

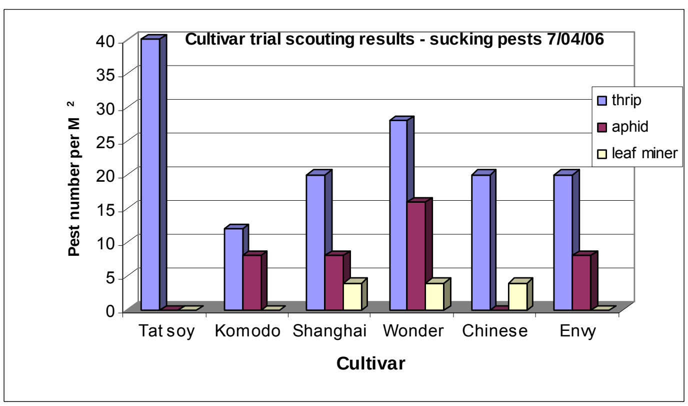

Figure D24b. Cultivar comparison of scouting results for sucking pests (second scout, 7/4/06)

Trapping Results

Results for the range of pests and beneficials present were very similar for both pan and sticky traps. The data for the sticky traps that is presented here since the numbers of pests and beneficials caught on sticky traps tended to be slightly higher in number than in the pan trap on this occasion (Figures D25 and D26).

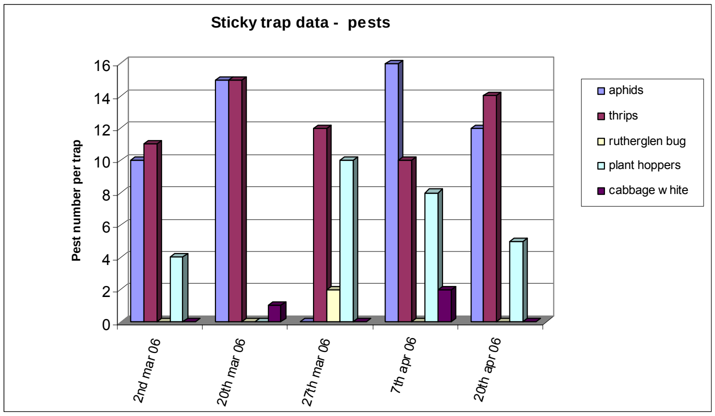

Figure D25. Sticky trap pest numbers for the cultivar comparison

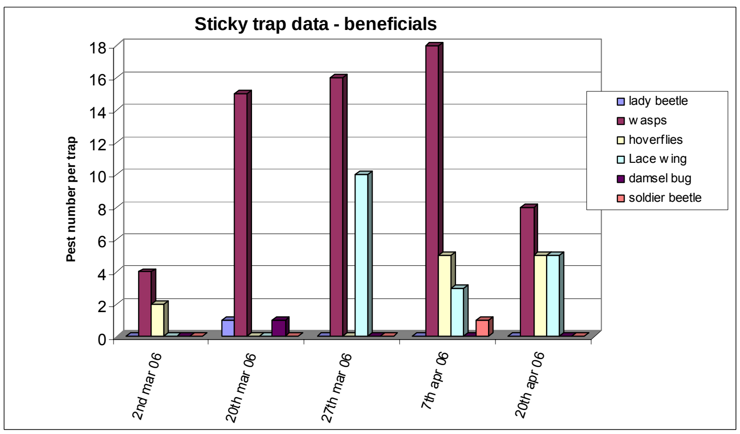

Figure D26. Sticky trap beneficial numbers for the cultivar comparison

Harvest Results

The results of vacuum sampling at harvest identified the presence of DBM, Rutherglen bug, aphid, leaf hopper and thrips. A range of beneficials were present including wasps, lace wings, spiders, rove beetle, two-spotted ladybird beetle and their larvae. A range of wasps were identified, including *Cotesia* (cabbage white butterfly parasitoid), *Telenomus* (general parasitoid of moths and butterflies), *Diadromus collaris* (DBM parasitoid), *Aphididae* (aphid parasitoid), *Microplitis demolitor* (parasitoid of caterpillars) and *Diadegma* (DBM parasitoid).

There were no significant differences between cultivars for chewing or piercing damage, and while there were observable differences between cultivars for thrips sucking damage, the differences were not quite significant. However, *Envy* and *Chinese* appeared to have less damage than tat soi and *Wonder,* which appear to be more susceptible to thrips (Figure D27). There were significant differences for the incidence of downy mildew, with significantly more evident on tat soi than the pak choy cultivars (Figure D27).

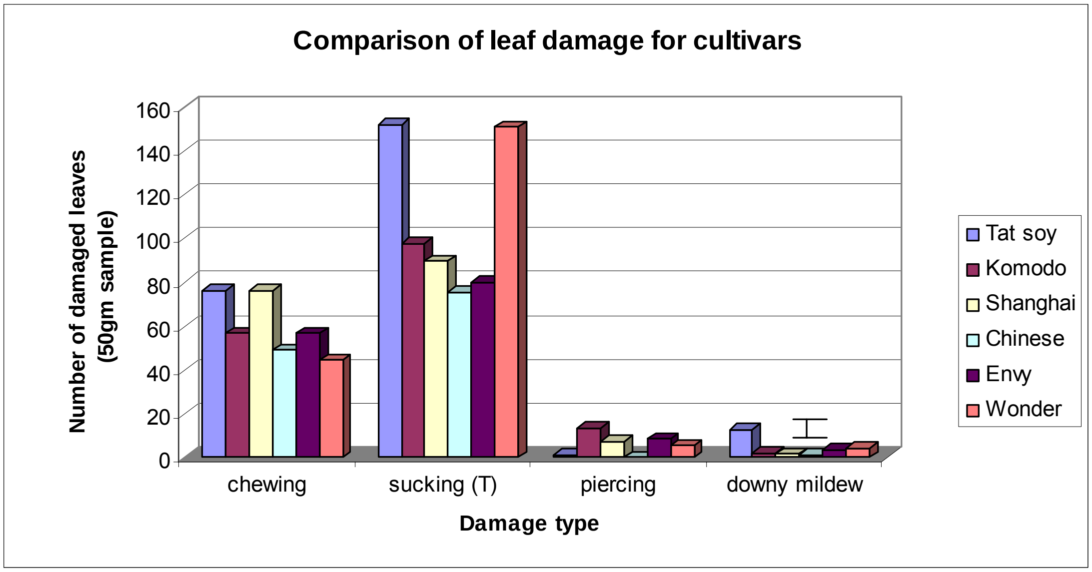

Figure D27. Comparison of crop damage between cultivars

4.4 Discussion

The trials demonstrated that there are differences between cultivars in their susceptibility to attack by some pests and diseases. The difference between the two trials is due to the variability in pest pressure at the time they were carried out. The results indicated clearly that tat soi, as reported, is quite prone to attack from a range of pests. In both trials, the cultivar *Envy* appeared to be less susceptible to some pests and diseases.

The trials also demonstrated that significant egg levels of DBM did not necessarily result in large numbers of larvae or significant damage. In this case there was some effective control due to the presence of beneficial, which demonstrates the need to combine pest monitoring and trapping with scouting of crops.

The results indicate that there are likely to be differences between cultivars, although the differences were limited in the trials carried out. These trials were small plots with a number of varieties and if this was to be evaluated further, trials would need to have more replicates, larger plots and fewer cultivars. However discussions with growers indicated that cultivar selection depended upon availability and price, which could vary significantly, so that this was not an option worth exploring further.

The key IPM strategy identified from these trials is to isolate tat soi plantings from pak choy, instead of planting side by side, as is quite often done. This may help reduce the incidence of pest pressure from tat soy spilling over to adjacent plantings of pak choy.

5. Best Management Options Biological Trial

5.1 Introduction

This trial aimed to evaluate the use of known best management practices in conjunction with the release of predatory insects that feed on some of the specific pests being targeted.

The IPM biological trial was seeded with *Cucumeris*, *Hypoaspis* and *Dalotia*.

Cucumeris are part of a large group of predatory mites called P*hytoseiids* that feed on larval stages of thrips and some mites. Adults live for about three weeks. The adult predatory mite is cream in colour, younger stages are clear. Both forms are pear shaped and move quickly. *Cucumeris* feed on first and second instar thrips larvae. Their targeted pests are onion, plague and western flower thrips. Apparently adult *Cucumeris* consume two to three first instar thrips per day.

Hypoaspis is a soil dwelling predatory mite that also feeds on thrips. Adult *Hypoaspis* are between 0.5 mm and 1 mm long, with females larger and much more common than males. Adult females are light brown in colour. The lifecycle of *Hypoaspis* can take between seven and 30 days depending on temperature. It can survive for up to seven weeks without insect prey, by feeding on organic matter, plant debris and nematodes. They live in the top 1-2 cm of soil and also move quite quickly. Their preferred target is western flower thrips and they can aid in control of thrips by feeding on thrip pupae in the soil, but are not relied on for total control.

Dalotia is a soil dwelling beetle, it is a generalist that feeds on a wide range of small insects and mites but is primarily an egg predator. *Dalotia* adults are 3-4 mm long, glossy black, brown and slender; larvae are creamy white when small and pale brown when larger. All stages move rapidly when disturbed. A characteristic of this beetle group is that the adult curves its abdomen upwards like a scorpion when running or disturbed. Adults live 21 days, laying eight eggs per day during peak period. *Dalotia* mainly target fungus gnats and shoreflies, although they also feed on western flower thrips larvae.

5.2 Methods

The trial was planted on the 30 November 2007 and was 36 metres long (four sprinkler rises) and four rows in total, with bed width being one metre wide. Three treatments were applied in a randomised block design for three treatments, with the fourth treatment, the grower plot, separated so that the standard treatment could be applied by the grower, which could not otherwise have been done (Figure D28).

The crop used was tat soi, pest pressure and incidence is similar to pak choy. The tat soi seed was direct drilled by the grower to ensure consistency of planting and once the seed was sown, the grower watered all treatment plots with solid set irrigation. The grower's plots were treated under normal grower practice and the grower irrigated all plots.

Crops were scouted after the appearance of first true leaves on the 7 December 2007 at the same time as the previous BMO trial as plantings were at the same date and in close proximity. Scouting was used as a method to determine timing and mode of treatment for the BMO biological trial. Sticky trap data was also used as an indicator for presence and abundance of pests and beneficials.

Scouting levels showed a level of thrips pressure that would have a marketable impact on the crop. Aphids and DBM levels and egg lay were also of concerns. Sticky trap data from this trial period also indicated the increasing pest pressure.

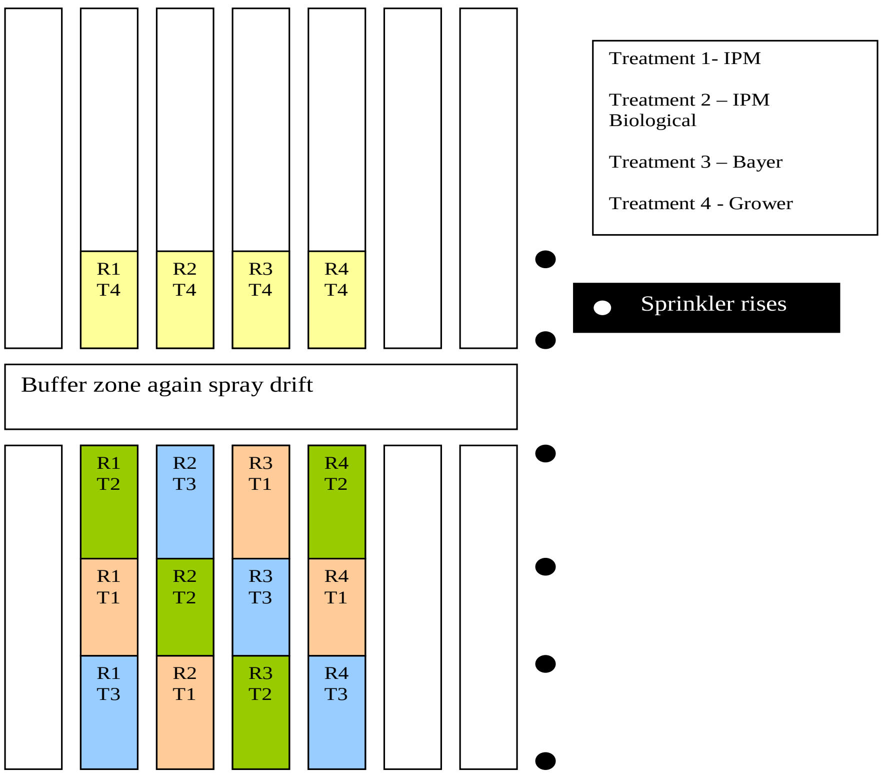

Figure D28. Trial Plan

BMO Treatment

As a result of the pest pressure, spinosad was used for thrips control, even though there was good wasp activity, and Bt (Xentari®) was used for early instar stages of DBM.

Biological Treatment

As a result of the DBM pressure, Xentari® was applied in conjunction with the release of *Cucumeris*, *Hypoaspis* and *Dalotia.*

NCO Treatment

Experimental treatment of BY108330 (sucking insects), NN10001 (Lepidopterous insects) and wetting agents was applied on the same date (10 December 2007) both insecticides were applied for sucking and chewing pests.

Grower Treatment

These plots were sprayed every seven days with dimethoate and spinosad.

The plots were checked on 17 December 2007, and due to fast growth rates, were harvested on 21 December. Five random samples were taken from each plot, using a 25x25 cm quadrant. Harvested material was assessed by taking 50 g random leaf samples from each of the five sample quadrants. Each leaf was assessed for damage incidence, including chewing, piercing, sucking and any disease such as downy mildew. The percentage of damage by each type was determined by dividing the incidence of damage by the number of leaves in the 50 g sample.

Four vacuum samples were also taken of each plot also using a 25x25 cm quadrant and a reverse blower with mesh.

5.3 Results

Scouting/trapping/vacuum results

Vacuum results showed that the Biological treatment had significantly more aphids than the other treatments, although not enough to warrant treatment. The results for the Grower treatment were similar to the Bayer and BMO (Table D4).

There were no significant differences in the numbers of Rutherglen bugs for the BMO, Biological and Bayer treatments, however there were significant numbers observed in the Grower treatment. DBM numbers were evenly distributed between treatments, as were thrips, plant hoppers and leaf miners.

There were no significant differences between treatments with beneficial populations at vacuum harvest. However the Biological treatment had higher levels of all beneficial populations and retained presence of *Cucumeris* and *Dalotia* throughout the trial. Bayer and Grower treatments appeared to have the lowest presence of general beneficial activity.

Table D4. Number of pests and beneficials (per m^2) from the vacuum sample

Treatment	BMO	Biological	Bayer	Grower
Pest				
Diamondback moth	52	48	56	80
Rutherglen bug	760	480	600	1000
Thrips	16	28	8	8
Aphids	8	40	16	12
Plant Hoppers	52	40	40	64
Leaf Miner	4	4	12	8
Beneficial				
Wasps	72	104	36	32
Lacewings	72	84	52	36
Spiders	0	24	4	0
Lady Beetle	16	24	8	0
Cucumeris	0	28	0	0
Dalotia	0	24	0	0

Harvest Results

There were significant differences between treatments at harvest for chewing damage, with the BMO and Biological treatments showing significantly less damage than the NCO treatment. The Grower treatment showed even higher levels of damage (Figure D29).

There were significant differences between the BMO, Biological and NCO treatments, with increasing incidence of damage in that order. The levels for the Grower treatment were similar to that of the NCO treatment.

There were no significant differences between treatments for piercing damage and levels were similar for all treatments, even though Rutherglen bug populations were higher in some treatments and appeared to be worst in the Grower treatment.

Downy mildew was present in all plots, with significantly more in the NCO treatment and similar levels to in the Grower treatment. There is no clear explanation for this.

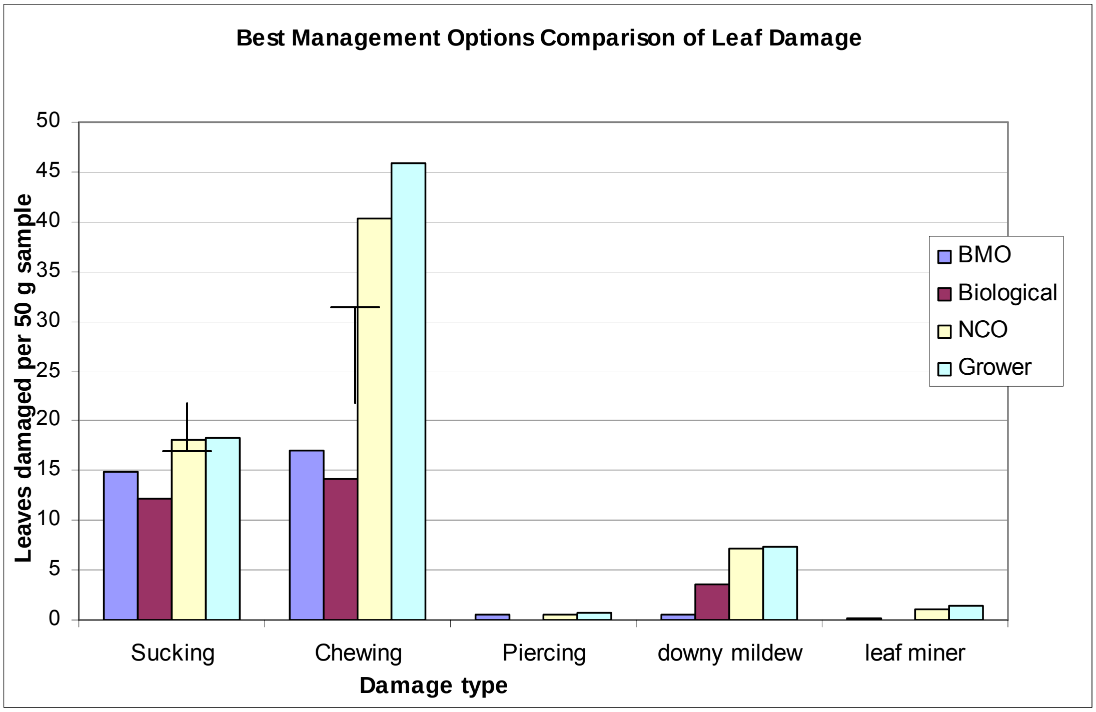

Figure D29. Comparison of damage at harvest for the four treatments

5.4 Discussion

Results from this trial showed that the BMO and Biological treatments performed similarly, with both showing lower levels of chewing and sucking damage than the Bayer and Grower treatments. Key pest levels were also similar for both these treatments although there did appear to be lower numbers of Rutherglen bug in the Biological treatment. However, piercing damage and leaf mines were not an issue for any treatments did not have an impact on the level of marketable product.

The results of this trial show that it may be an advantageous to introduce beneficials into field crops. There has been some doubt as to the efficacy of releases in the field while releases into a contained environment such as polyhouses have been recognised for some time and are successful.

The results indicated that the release of the biological controls of *Cucumeris*, *Dalotia* and *Hypoaspis* had some impact on sucking damage and as a treatment had the potential to be effective. However, there were no significant differences in thrips numbers between treatments.

Considering three separate types of beneficials were released at once, it may be hard to determine which one, or which combination, is the most effective and this would be worth further investigation. It would also be useful to see if any of these predators occur naturally or over-winter once released. It would be worthwhile conducting a cost-benefit-analysis of releasing beneficials into crops as opposed to using softer, more targeted, chemistry. There is potential to carry out timed releases during the season as baby leaf cropping is done sequentially and it should be possible to sustain the beneficial populations, provided soft chemical options were used.

The trial also demonstrated the efficacy of using Bt at the correct intervals. If Bt is used at the early instars of the DBM cycle, it can be very effective. The results were not clear if spinosad is effective for thrips control, however if used, it is important to be mindful of parasitic wasp presence, especially if relying on wasps for the control of aphids and lepidopteran pests.

The results clearly showed that the conventional method of pest control for the key pests that cause sucking and chewing damage is less effective than a BMO program based on scouting, monitoring and protecting beneficial species. The experimental chemistry appeared to provide some control, but the end result was generally similar to the standard conventional practice. Application rates may need to be considered.

Control of Rutherglen bugs is difficult and broad-spectrum chemistry does not have a significant impact as they are very mobile and quickly reinfest a crops. However, in this trial, even though high numbers of Rutherglen bugs were present, their damage was not as high as expected. This may have been due to the greater amount of green feed and crops available compared to the previous year. Levels in previous years were much higher (2005/06) and in those years there was considerably more damage. Rutherglen bugs have the potential to be present in extreme numbers and consequently can have a significant impact on the crop.

Once again, downy mildew was present and although not at a very high level, it remains an important issue that can affect the marketability of the crop.

6. Field Assessment of Beneficial Mites for Thrips Control

A trial was initially set up to assess the use of predatory mites, *Cucumeris* and *Dalotia,* for thrips control in November 2006. However this was a significant drought year and staff were deployed to fire duties for the majority of the summer season (see Appendix F). As a result, these trials were abandoned but repeated in February 2007.

6.1 Introduction

Cucumeris is a commercially produced predatory mite and is part of the phytoseiids group of predatory mites. They feed on larval stages of thrips and some target greenhouse thrips, onion thrips, plague thrips and broad mites.

Cucumeris eggs will hatch in two to four days, depending on temperatures. Total development time is eight to eleven days at 25˚C and adults live for about three weeks.

Cucumeris feeds on first and second instar thrips and larvae, consuming two to three thrips per day.

Cucumeris has been proven effective for the control of western flower thrips in protected cropping (they favour humid conditions around 65 per cent or above). They are sensitive to broad-spectrum chemistry such as organophosphates and synthetic pyrethroids, so it is essential to use softer targeted products if chemical control is to be used in conjunction with predator releases.

6.2 Methods

Cucumeris trials were set up on the 29 February 2007. There were three treatments: a Biological plot (only using soft chemistry and beneficial releases), a Control (that also aimed to act as a buffer between biological and grower plots) and a Grower's plot (using grower standard practice).

Trials were set up on the grower's property. The grower direct-sowed the tat soy seeds and watered the trials but left the management of the other two treatments to DPI. Plots were not replicated because it was not possible to contain the predator releases to specific plots and some movement would be expected. The trial area was six beds all 27 m long.

Control Plots – no treatment
Biological Plots – *Cucumeris* release plus the use of Bt if necessary.
Grower Plots – application of malathion and spinosad

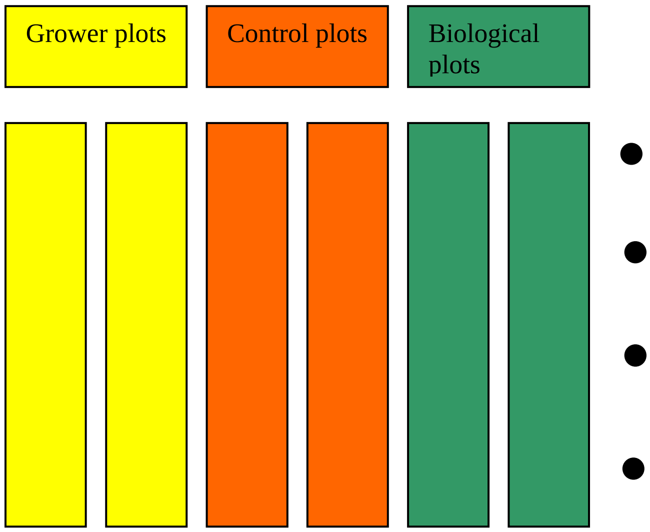

Figure D30. Trial Plan

Cucumeris was released at the sign of the first true leaves developing on the tat soy seedlings. Cucumeris, which arrives in bran, was mixed in with vermiculite to ensure evenness of spread across the plots.

The trial site was scouted on 14 March 2007 and DBM was present at levels that required control. Thrips and parasitic wasps were also present. To protect the wasps and *Cucumeris*, Bt (Xentari®) was applied twice on biological plots to control of DBM. During the course of the trial the grower's plots received two treatments of malathion and spinosad.

Crops were scouted again on the 26 March 2007 and *Cucumeris* was still evident.

Crops were harvested on 5 April 2007 and samples were taken using 25x25 cm quadrants. Four random samples were taken from each treatment. Vacuum samples were also taken from each treatment using a 20x20cm quadrant.

Vacuum samples were analysed to identify species and quantity of pests and beneficials. Leaf samples were analysed by taking a random 50 g samples from each of the four samples in that treatment.

6.3 Results

Vacuum Results

A much greater diversity of beneficial activity was observed in the biological plot, compared to the control and grower plots (Table D5). It was expected that the control plots were affected by spray drift from the treatments to the grower plots. More aphid activity was observed in the grower plots and there were some parasitised aphids.

Table D5. Mean number of pest and beneficials in the vacuum sample (per m^2)

Treatment	Aphid	Parasitised aphid	Plant hopper	Plutella larvae	Fungus gnats	wasps	Lacewing	*Cucumeris*
Grower	36	4	0	0	16	0	0	0
Control	16	0	0	0	0	0	8	0
Biological	20	0	8	20	44	16	4	16

Harvest Results

There were no differences between treatments assessed at harvest for pest damage or disease issues assessed (Figure D31).

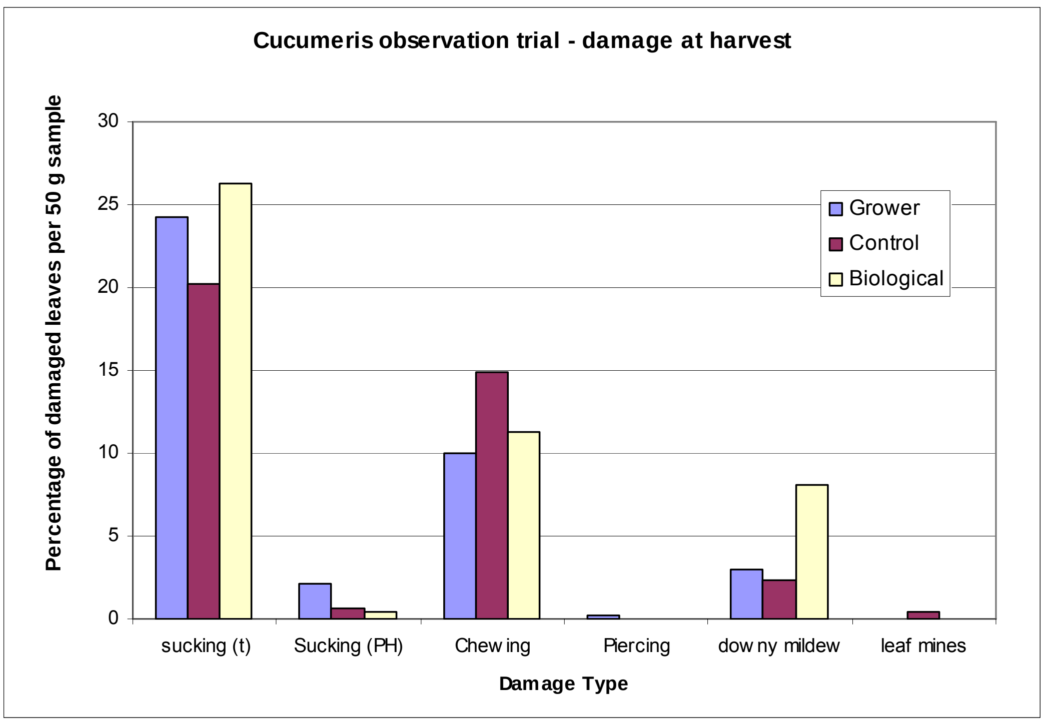

Figure D31. Comparison of harvest damage for the treatments

There was variability in the amount of sucking damage within the treatment plots and consequently there were no observable differences between treatments. The control treatment had had consistently higher levels of chewing damage across the four samples taken with the other two treatments more variable in the amount of damage.

6.4 Discussion

The results from this trial did not discern any observable difference between treatments and *Cucumeris* did not reduce the incidence of sucking damage. However even the control treatment did not show any major differences in damage, although it is likely that it was affected by spray drift.

Limitations of the trial may have been that the *Cucumeris* were released too early, with not much cover available to them (the crop was very sparse), and as a result, may have moved on to a higher coverage crop. Also pest levels were not high at the time of release and this may have had an effect on the trial results.

Cucumeris are sensitive to organophosphates and considering they were very close to the conventional growing practices this may have affected their survival.

It would be worthwhile to test *Cucumeris* again and compare its performance with conventional practices. However, isolation from spray drift, the amount of plant cover and levels of thrips should be considered in further tests.

The dilemma with beneficial releases is that pests need to be present, but if numbers are too high, the damage will already be done to the crop and the release would be too late. To be practically effective it would be essential that the *Cucumeris* population would continue to survive and grow on the sequential plantings.

7. Assessment of chrysanthemum as a trap crop

7.1 Introduction

It was observed, in conjunction with NSW colleagues, that growers cultivating culinary chrysanthemums and other Asian vegetables such as pak choy and tat soi, appeared to have reduced numbers of Rutherglen bug on crops growing nearby. It was observed that there were significantly higher populations of Rutherglen bugs on the chrysanthemums to such an extent that they appeared to be the preferred host.

Trap cropping involves planting a crop to attract pests, and in doing so, protect the main cash crop from damage. The aim is that that the trap crop is a preferred host for the specific pest.

Trap cropping is usually a perimeter or intercropping planting. Perimeter cropping completely surrounds the main crop, with the purpose of preventing a pest attack from any direction. It is more effective on pests that are found near the borderline of the farm.

Row intercropping is planting the trap crop in alternating rows within the main cash crop, e.g. every ninth row or so.

Trap crops also act as a reservoir for beneficials, with small numbers of pests allowing the beneficial populations to survive. Traps crops may be sprayed out to control the pests or maintained to continue the reservoir of beneficial species.

Flowering chrysanthemums will also act as a pollen (protein) source for beneficial insects and consequently will attract thrips and beneficial insects such as wasps, lacewings, lady beetles and parasitic wasps and predatory beetles.

Trap crops have been used in cotton and solanaceous crops for some time, with much success (Cotton CRC 2005).

The aim of this trial was to test the efficacy of chrysanthemums as a trap crop for tat soi and pak choy to reduce the numbers of Rutherglen bugs. The Rutherglen bugs, when in plague proportions, not only affect the vigour of the crop but are also a post harvest contaminant as they are hard to wash out of product.

Rutherglen bugs are sap-suckers, and live on weeds and pastures or other green crops and can reach plague proportions. Rutherglen bugs have been identified as a key pest in baby leaf crops but control is difficult as there are no soft options and they are very mobile and can quickly reinfest a crop.

7.2 Methods

Trials were initially established in 2006 but due to drought, establishment was difficult and the crop failed. Subsequent trials were abandoned due to fires in 2006/07 (see Appendix F). Consequently, as previous chrysanthemums trials were unsuccessful using direct seeding, it was decided to use transplants to ensure evenness and survival.

Five thousand transplants were grown and planted in plots adjacent to future baby leaf crops of tat soi and mizuna. The grower worked the beds and irrigated the crop. Transplants were planted in the field at roughly 10 cm spacings, with nine plants across the row. Chrysanthemums were planted on the side of the prevailing winds.

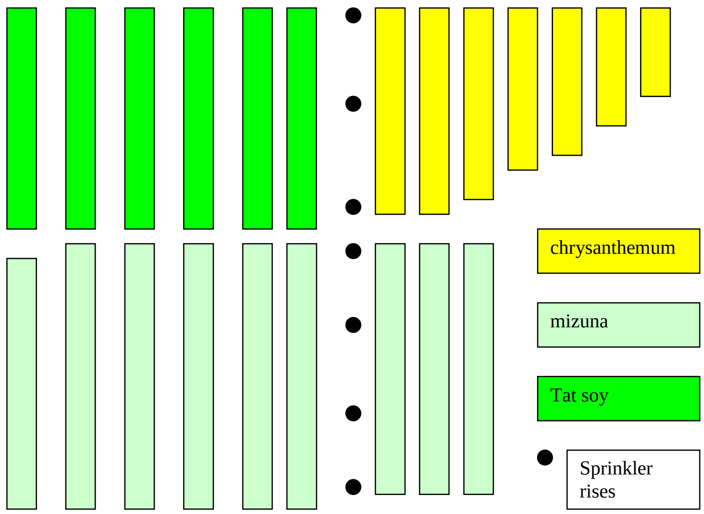

Figure D32. Design of the chrysanthemum trial

Chrysanthemum and baby leaf crops were scouted on 22 October 2007, with 20 plants scouted from chrysanthemum and tat soi crops. Crops were scouted again on 31 October using 20 plant samples from mizuna and chrysanthemum. At this point in time chrysanthemum was in flower.

Vacuum samples were taken from the chrysanthemum and mizuna crops on the 14 December using 20x20 cm quadrants and a reverse blower. Four samples from each crop were taken. Chrysanthemums were not treated with any chemical during the trial. The grower carried out pest control on mizuna and tat soi. The pesticides spinosad and malathion or dimethoate were used.

Figure D33. Chrysanthemum trial, flowering at time of vacuuming

Figure D34. Chrysanthemum trial at second scout (31/10/07)

7.3 Results

Trapping/Scouting results

Trapping results showed a very high activity of thrips and Rutherglen bugs in the area and there was also a good number of beneficials active (Table D6).

Table D6. Trapping data for chrysanthemum trial (number per trap)

Date '07	**Pests**						**Beneficials**				
	Ruthglen bug	thrips	Leaf miner	aphids	Plant hopper	plutella	Hover fly	Lacewing	Assasin bug	Rove Beetle	Wasp
22/10	6	200	3	10	2	0	2	1	0	0	5
31/10	45	180	2	15	4	5	5	2	2	3	8
10/11	34	45	0	2	3	4	4	4	2	4	10
18/11	55	110	5	8	3	4	8	3	1	0	15
04/12	35	120	13	6	3	10	5	4	1	2	4

Scouting was carried out twice - once when only small numbers of chrysanthemums were in flower and then again when three quarters of the plants were in flower. Rutherglen bugs were in plague proportions on the chrysanthemum plants and low on the tat soi. There were also leaf miners on the chrysanthemum and good populations of lady beetles and wasps showing that the plants were an excellent reservoir for beneficial species (Figure D35).

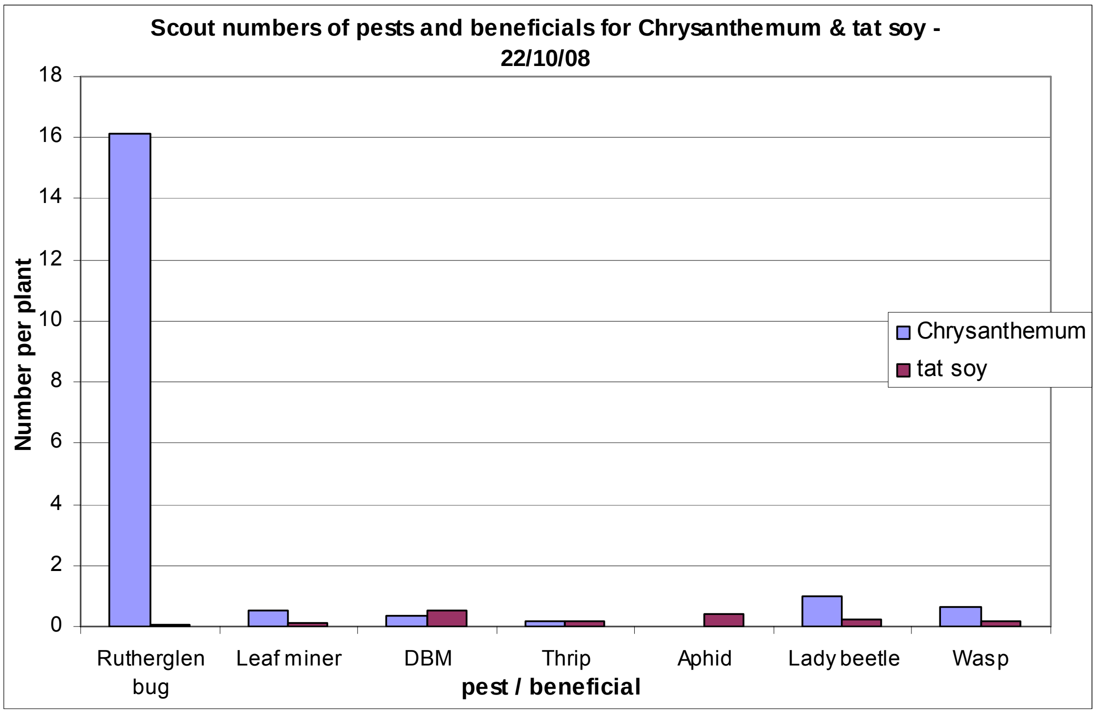

Figure D35. Number of pests and beneficials per plant for tat soi and chrysanthemum

As can been seen from Figure D36, when the chrysanthemums were in flower, they hosted a large population of thrips. The chrysanthemums also hosted greater populations of beneficials, especially wasps and lady beetles. While Rutherglen bug populations had dropped significantly they were still in much greater numbers on the chrysanthemums than on the tat soi. The thrips and Rutherglen activity on the tat soi appeared almost negligible in comparison to the chrysanthemum.

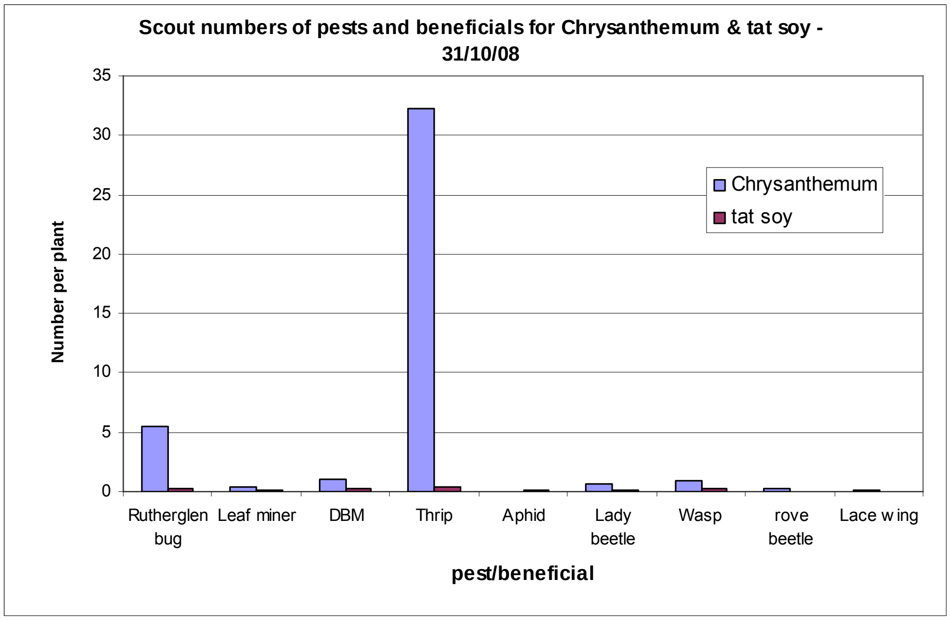

Figure D36. Number of pests and beneficials per plant for tat soi and chrysanthemum at flowering

Vacuum results

The vacuum samples were taken on the 4 December 2007 from chrysanthemum and mizuna as the tat soi had been harvested. There were large differences in pest/beneficial numbers between chrysanthemum and mizuna crops, especially for Rutherglen bug, thrips and wasp activity. There were differences in DBM numbers between crops, with mizuna showing higher numbers of these pests. However, it is the Rutherglen bug and wasp activity that is most graphic in Figure D37.

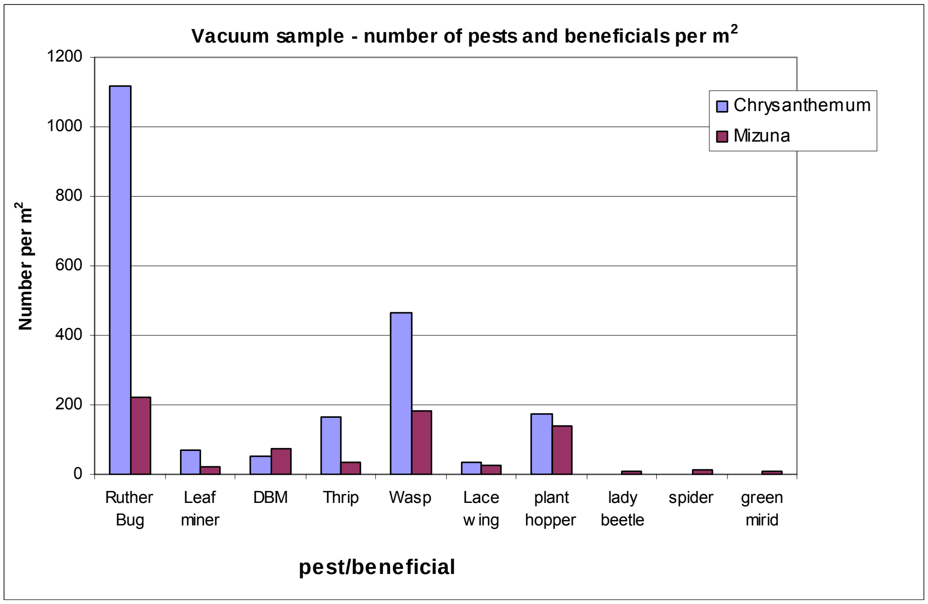

Figure D37. Number of pests and beneficials (per m^2) from vacuum sampling

7.4 Discussion

The trial showed that chrysanthemum was definitely highly attractive to Rutherglen bugs compared to the Asian brassica crops such as tat soi and mizuna and this was the case at all stages of crop growth. Rutherglen bugs infested the chrysanthemums from transplanting onwards. The number of Rutherglen bugs present in the mizuna and tat soi crops were minimal in comparison.

Thrips numbers were high in the field as could be seen by the numbers in the scouting, vacuuming and sticky traps that were present throughout the trial period. Once the chrysanthemums had commenced flowering they were a preferred host for thrips as the flowers were a significant pollen source.

The chrysanthemum crop also hosted a good range of beneficial insects, especially wasps, that was significantly higher than in the mizuna. It was expected that the presence of the wasps would be of benefit to the baby leaf crops for aphid and DBM control and that the chrysanthemum crop would act as a significant reservoir for these beneficials.

Also, as expected, the mizuna and tat soy crops had more DBM activity because brassica crops are the preferred host. The presence of DBM on the chrysanthemums may be due to either passing through the crop or attraction to the pollen.

The trap crop could be used to spray out to control or significantly reduce populations of Rutherglen bugs and, at flowering, there is potential for thrips control. This could be done periodically as Rutherglen bugs are quite mobile and can quickly reinfest a crop after spraying has been carried out. The penalty would be the loss of beneficial species such as wasps. The other option is to leave the trap crops to attract the key pests and act a reservoir for beneficial species.

Further evaluation of the use of trap crops to control these difficult pests should be a priority. The issue is an appropriate management strategy to effectively control pests and to conserve beneficial species as much as possible. The advantage of the chrysanthemum crops is that they will be in the ground for an extended period of time and could be a significant reservoir for beneficials over the winter period. The results of this work demonstrate that further trials to evaluate a range of management procedures are warranted.

As thrips and Rutherglen bug have limited IPM control options, using chrysanthemum as a trap crop would appear to be the best means of control for these pests.

Figure D38. Chrysanthemum plots

References

Cotton CRC 2005. Integrated pest management guidelines for cotton production systems in Australia, 2nd Edition, 79 pp.

Dang, H.T. and Malcolm, P.J. (2007). Impact of a bilingual extension officer – working with farmers from non-English Backgrounds (NESB). RIRDC Publication No 07/131.

Hassall and Associates Pty. Ltd. (2003). Asian Vegetable Industry. A Situation Assessment. RIRDC Publication No 02/168. 82 pp.

Hogan R. and Cumming B. (1997). More than a question of numbers. Working with women and people from NESB towards total catchment participation. A report of the Landcare Participation Program 109 pp.

Morgan W. (2003). Communicating with Asian NESB vegetable growers. A pilot project for adoption of best practices. RIRDC Publication No 12/168.

Parker F. (2000). The safe use of farm chemicals by market gardeners of Non-English Speaking Background. Developing an effective extension strategy for the Sydney Basin. RIRDC publication No 00/180.

RIRDC (2005). R & D plan Foods 2005-2010. RIRDC Publication No 05/002.

Appendix

Appendix A: Impact / Change Stories

Story Title: "**Asian growers and their understanding of Ag chemicals**"

Name of person recording story: Slobodan Vujovic

Date story was told: October 2005

Who was involved? Vietnamese growers, DPI and a private consultant

Where did this happen? In Lara

What happened?

It has comes to our attention that a group of Asian (Vietnamese) vegetable growers have been struggling in the area of agricultural chemicals in terms of the correct usage and handling.

DPI decided to give support to these growers by providing structural training in form of a Farm Chemical Users Course.

The team provided training to 17 Vietnamese Asian vegetable growers from the Geelong area. This course was specially designed for LOTE growers and consisted of 13 two-hour sessions. The course was supported by regular on-farm visits to all growers by a DPI project officer.

The DPI officers were able to respond to the needs of the group by offering a range of training and assessment options which included: classroom based sessions, which often consisted of small and large groups using paper based materials that had occasionally involved hands-on activities such as calculating chemical application requirements and experiencing a range of PPE; farm visits, which included on-site activities such as risk assessments; chemical store visits; on-site assessments for learners whose language skills and previous training experiences were limited.

Why do you think this is a significant change?

Growers have noticed that they have greater confidence in their ability to use chemicals in a safe manner. All participants indicated that they now protect themselves better by using more personal protective equipment (PPE) and by using PPE in more work situations. For instance, Van Sanh Phan used to wear only a dust mask when applying chemicals, but he now uses a half face respirator when mixing and applying chemicals. His chemicals were not stored properly; they were in various locations and stored unsafely. Today Van Sanh Phan is proud of his chemical storage, he has converted an old van into a chemical storage area. Now chemicals on his farms are in an area where nothing can get contaminated, chemicals are segregated, kept under lock and the storage area is labelled appropriately.

How does the story meet DPI and industry objectives and goals?

Aside from these specific benefits to growers and those around them, Vietnamese growers have improved their communications with the DPI, government compliance officials and the chemical store managers in their areas. The DPI has benefited from the strengthening of their partnership with the target community which has allowed, (and should continue to allow) the transfer of knowledge and building of risk management capability.

Story Title: "**Building permits for greenhouses**"

Name of person recording story: Slobodan Vujovic

Date story was told: May 2006

Who was involved? NESB growers (Vietnamese & Lebanese), DPI and private consultants (building & fire) Geelong city council

Where did this happen? In Geelong

What happened?

In the municipality of the City of Greater Geelong there are thirty vegetable growers. Half of those growers use greenhouses (polyhouses) for vegetable production. Some of those structures are 10 to 20 years old. At the time when those greenhouses were constructed there weren't any council laws to guide or regulate them. Recently the Geelong Council made a decision to regulate polyhouses for vegetable productions as a building structure use. The council started targeting growers with existing greenhouses serving notices to the growers because of the illegal buildings (greenhouses).

The growers who wanted to build new greenhouses needed to go through a completely new process of applying for a building permit. The only problem was that there were no clear rules from the council pertaining to what growers needed to do to comply with the regulation.

The DPI VegCheque officer organised a meeting that was attended by representatives from: the two councils (City of Greater Geelong and Golden Plains Shire), a structural engineer, a fire engineer, a CFA representative, a DPI Officer and the affected vegetable growers.

The first problem of regulating existing greenhouses was solved quickly. The growers agreed to hire a Structural Engineer to draw the plans for their existing buildings (greenhouses) and lodge the plans with the council.

The second problem was two growers who wanted to build new greenhouses were waiting six months for council's decision. Up to this point those two growers spent a considerable amount of time and money especially in regards to how the greenhouse would behave in a fire. The DPI was able to respond to the needs of the growers by arranging a meeting and facilitating the discussion that had a satisfactory ending for all parties involved.

Why do you think this is a significant change?

Growers do not like this process were they have to comply with certain regulations. But once when the process is completed they can see value in it. Hai Hong Nguyen grower from Corio said due to this process I know the exact area of my hot houses, the age of a certain component (like plastic) and time when those components need to be replaced. Growers are also more aware of the fire hazards surrounding their hot houses, things like old plant material, old plastics and wood lying around.

It is a significant change for those two growers, as their vegetable production was on hold for six months; in addition to that they have spent up to $10 thousand in consultancy fees.

What difference did it make already/ will it make in the future?

How does the story meet DPI and industry objectives and goals?

Aside from these specific benefits to growers, which are: to allow them to do what they are doing best produce good quality vegetables. The growers from Non-English speaking background in this instance Vietnamese and Lebanese growers have improved their communications with the DPI, council officers and other local authorities (CFA). The DPI has benefited from the strengthening of their partnership with the target community which has allowed, (and should continue to allow) the transfer of knowledge and building of risk management capability.

Story Title: **Trip to Adelaide**

On 22nd of September 2006 VegCheque organised a one-day study tour to Adelaide (Virginia) for Vietnamese growers. 17 growers took part in this exercise. Our tour was hosted by Tracey Tran (consultant from E.E. Muir & Sons) from SA. She is also a bi-lingual Vietnamese speaker. The growers visited Virginia Water Recycling facility, Virginia Horticultural Centre, E.E. Muir & Sons chemical store, Virginia nursery, and several polyhouse (hydroponics) farms where growers saw some of the industry best practice in design, management of the growing environment in the polyhouse industry.

The Adelaide trip was funded by *Farmbis* and participating growers, and it was administered by DPI RTO. The trip costed $500 per participant - half of that cost was met by Farmbis and the other half by growers.

As a result of this tour, two growers used knowledge they acquired to make a better decision in choosing a polyhouse that suits their needs.

Story Title: **Trip to Sydney**

In September 2005 VegCheque organised a one-day study tour to Sydney for Vietnamese growers. The trip was made possible thanks to the funds provided by AgTrain (DPI) $3000. 18 vegetable growers with a Vietnamese background participated, some were non-English speaking. All were from the Lara/Geelong area.

The outcomes derived from the grower's trip highlighted the opportunities for development of stronger relations both socially and commercially among growers and DPI. Growers received positive learning opportunities regarding market opportunities and issues, integrated pest and disease management techniques, recycled water, farm hygiene practises and innovative production methods.

As a result of this tour several growers are investigating possibilities to implement water saving measures (collecting water from polyhouses and use for irrigation).

Story Title: **NESB Chemical use**

DPI VegCheque team together with Swinburne University of Technology TAFE and Edulink (Ian Barber) provided FCUC to group of Vietnamese growers.

The collaboration was possible through funding from RIRDC, HA and Workplace English Language and Literacy (WELL) program.

The team provided training to 17 Vietnamese Asian vegetable growers from Geelong area (Lara). Six growers attended Farm Chemicals User Refresher Course and eleven growers attended Full FCUC (for the first time). By the end of the program, 16 of 17 learners were able to demonstrate competence in a unit of competency (sucessfuly complited course). One grower has not passed his final assessment but the assessor has agreed to give him one more opportunity to demonstrate his competence and he passed at a later date.

The trainers viewed this course as a pilot project for future work with groups of growers from a single ethnic group. This course was specially designed for NESB growers and consisted of 13, two hour sections. The course was supported by regular on farm visits to all growers by DPI project officer. The group's ethnic homogeneity allowed the trainers to use a translator at the initial set up meeting, and then informal occasional translating by the most proficient English/Vietnamese growers in the group. The Industry Training Consultant from Swinburne University, worked on the language side of training, making sure that course material was in appropriate (simple) English.

Training commenced on 24/7/2004 and finished on 30/5/2005. There was a lengthy hiaitus in the middle of the training while the growing and picking season was at its height. There was some concern that there would be a drop off in attendance after the break but attendance remained steady throughout.

As a result of this training, growers have identified that they have greater confidence in their ability to use chemcials safely. All participants indicated that they now protect themselves better by using more personal protective equipment (PPE) and by using PPE in more work situations. For instance, one worker used to wear only a dust mask when applying chemicals, but he now uses a half face respirator when mixing and applying chemicals. Another was using only a respirator when spraying in a hot house - he now uses a full protective suit as well.

Growers noted that they are more accurate when measuring chemicals, they have made changes so that they handle their chemicals in an area where nothing might become contaminated and they have changed their chemical storage areas so that the chemicals are segregated, kept under lock and the storage area is labelled appropriately. One learner stated that he now changes the filters on his respirators regularly and they all keep accurate documentation such as MSDSs. As well, some learners indicated they now check the weather before applying chemicals and another makes sure no one comes near him when he is spraying.

Story Title: **NESB formed an association**

In late August 2005, DPI VIC facilitated a growers meeting at which growers formed a Vietnamese growers association. Michael Tran was chosen to be the first president, the association has 18 members. Prior to this, growers had several unsuccessful attempts to form an association.

The Vietnamise Vegetable Growers Association represents all vegetable growers in the State of Victoria. The VVGA provides a level of assistance to growers on matters such as: Financial, Market, local Government and Farm safety. More importantly VVGA provides a unified voice for all Vietnamese growers especially growers with dificulties to communicate using the English language. The assosiation is ethnicly based by is open for growers from other ethnic groups to join.

Story Title: **Capable and resilient communities NESB**

The Asian vegetable growers from Victoria have been receiving assistance by the DPI VegCheque extension program for the past six years.

The main objectives of VegCheque program are: sustainable Asian vegetable industry conducted by LOTE growers that is able to produce: quality Asian vegetables, safe to eat and free of pests and diseases and economically profitable.

The Vietnamise growers from Victoria are mainly based in Lara near Geelong (50km south-west from Melbourne). There are 30 growers at present producing Asian vegetables (70%) and hydroponic tomatoes (30%). Asian vegetables includes: Water convolvulus, Ceylon spinach, amaranth, Asian brassiscas (Chinese cabbage, Chinese chard, Chinese flowering cabbage, and Mustard) and Asian hearbs like Thai basil, coriander, garland chrysanthemum, garlic chives, hot mint, perilla, Pennywort, spearmint and few others all year round. Traditionally Vietnamese growers supply Asian grocery shops in Melbourne areas such as Richmond, Springvale, Footscray, and Box Hill.

Some of these growers are looking to expand their markets to sell their vegetables to supermarkets and other retailers and wholesalers.

VegCheque is working together with growers to achieve these goals.

Example: Food safety issues.

Growers recognise the importance of food safety, the majority of their vegetables are eaten raw or minimally processed and as that fall into a high-risk food category.

Hai Hong Nguyen from Corio said: “I am very grateful for the investment that DPI and other agencies are making towards us. My goal is to become a quality assured grower and be able to sell my garlic chives to supermarkets”.

Story Title: **Some of innovative techniques/approaches used with the NESB growers to overcome Language difficulties:**

-Translators and translated material

-Industry consultant (simple) English

-Bilingual officers

-Work in small groups (with group leader)

Aside from thes specific benefits to themselves and those around them, they have improved their communication with the DPI, government compliance officials and the chemical store managers in their areas. They recognise that they are capable of undertaking training and several have indicated an interest in accessing a Quality Assurance training program.

Although not their employer, the Department of Primary Industries has benefited from the strengthening of their partnership with the target community which has allowed, and should continue to allow, the transfer of knowledge and building of risk management capability. This project has also provided a pilot program for analysing different training delivery methods for small groups of growers from a single ethnic group.

Appendix B: List of vegetables and herbs grown by LOTE growers

Amaranth	Garlic chives
Green-leaved amaranth	Flowering garlic chives
Asian basil	Hot mint
Bitter melon	Kinh gioi (Vietnamese name)
Bitter melon leaves	La lot (Vietnamese name)
Buffalo spinach	Lemon grass
Cang cua (Vietnamese name)	Lizard's tail
Celtuce	Long coriander
Ceylon spinach	Mint
Chilli leaves	Mustard green
Chinese boxthorn	Pea shoots
Chinese broccoli	Pennywort
Chinese celery	Perilla
Chinese chard	Pumpkin leaves
Baby Chinese chard	Snowpea
Shanghai Chinese chard	Spearmint
Chinese flowering cabbage	Vietnamese lettuce
Baby Chinese flowering cabbage	Water convolvulus
White Chinese flowering cabbage	Water parsley
Coriander	Watercress
Garland chrysanthemum	

Appendix C: Training activities and meetings for LOTE growers in Victoria

Activity	Day	Period	No. of growers	Topics

Activity	Day	Period	No. of growers	Topics
Farm Chemicals User Course	1	24 Aug 04	15	Farm Chemicals User Course section 1
Farm Chemicals User Course	1	14 Sep 04	16	Farm Chemicals User Course section 2
Farm Chemicals User Course	1	28 Sep 04	17	Farm Chemicals User Course section 3
Farm Chemicals User Course	1	5 Oct 04	17	Farm Chemicals User Course section 4
Farm Chemicals User Course	1	12 Oct 04	15	Farm Chemicals User Course section 5
Farm Chemicals User Course	1	26 Oct 04	14	Farm Chemicals User Course section 6
Farm Chemicals User Course	1	9 Nov 04	16	Farm Chemicals User Course section 7
Farm Chemicals User Course	1	21 Feb 05	17	Farm Chemicals User Course section 8
Farm Chemicals User Course	1	1 Mar05	16	Farm Chemicals User Course section 9
Farm Chemicals User Course	1	8 Mar 05	15	Farm Chemicals User Course section 10
Farm Chemicals User Course	1	15 Mar 05	16	Farm Chemicals User Course section 11
Farm Chemicals User Course	1	22 Mar 05	16	Farm Chemicals User Course section 12
Farm Chemicals User Course	1	30 May 05	15	Farm Chemicals User Course section 13
Community meeting	1	9 Jun 05	12	Greenhouses permits
IPM seminar	2	21 Jun 05	15	Dr Victor Rajakulendran and Dr Ho Dang presented seminar on IPM in Asian vegetables

Activity	**Day**	**Period**	**No. of growers**	**Topics**
Trip to Sydney	1	26 Jul 05	18	Study tour
IPM seminar	1	14 Sep 05	12	Dr Caroline Donald DPI VIC presented seminar on Club root disease in Asian *brassica* crops Patrick Ulloa VGA spoke about Roll of IDO (VGA), introduction to QA
Food Safety Course	1	13 Dec 05	14	Mr Patrick Ulloa delivered Food Safety Course with support and translation from Dr Ho Dang NSW DPI
Hydroponic Tomatoes IPM workshop	1	19 Apr 06	9	Hands on workshop delivered by Dr Brendan Rodoni, Mr Mirko Milinkovic DPI VIC with support and translation from Dr Ho Dang NSW DPI
Asian vegetables IPM workshop	1	20 Apr 06	20	Hand on workshop delivered by Joanna Petkowski, Lavinia Zirnsak DPI VIC with support and translation from Dr Ho Dang NSW DPI
Community meeting	1	8 Aug 06	20	Greenhouses permits, water issues, fire issues
Community meeting	1	22 Aug 06	12	Vietnamese growers association
Trip to Adelaide	1	19 Sep 06	17	Study tour
Seminar on MRL testing	1	10 Oct 06	10	Nick Gall Agrifood Technology presented seminar on MRL testing and Slobodan Vujovic presented info on Whitefly
Workshop on fertiliser and irrigation	2	6 Feb 07	16	Dr Ho Dang DPI NSW presented info on fertiliser

Activity	Day	Period	No. of growers	Topics
				requirements Melly Pandher DPI VIC presented info on Financial Counselling and Adam Buzza DPI VIC presented info on Irrigation practices
Seminar on Horticulture Code of Conduct	1	17 Apr 07	12	Celia Himmelreich from Australian Competition & Consumer Commission presented info on Horticulture Code of Conduct
Postharvest handling seminar	1	16 Jun 07	14	Slobodan presented info on Vegetable Postharvest Storage, Temperatures Different Cooling Systems and Modified Atmosphere Packaging
Growers meeting	1	21 Aug 07	10	General agronomy
Community meeting	1	13 sep 07	16	Greenhouses permits, water issues, fire issues
Asian vegetables IPM workshop	2	2 Oct 07	14	Len Tesoriero DPI NSW and Glenys Wood DPI SA conducted IPM workshop on pest and disease of Asian vegetables supported and translated by Ho Dang DPI NSW
Community meeting	1	30 Oct 07	12	Country fire issues
Growers meeting	1	28 Feb 08	9	General agronomy, QA

Activity	Day	Period	No. of growers	Topics
Seminar on Enviroveg program and Soil health program	1	18 Mar 08	12	Helena Whitman and Hannah Burns from Ausveg presented info on Enviroveg program and Soil health program

Appendix D: Benchmarking Survey Questions

Benchmarking Survey

Grower: ______________________ Phone: ______________

Address: ______________________ Fax: ______________

GPS Coordinates: S____________ E____________

Farm Size ____________acres Average Plot Size ____________

Crops:				
1.	____________	area: ______	Season	____________
2.	____________	area: ______	Season	____________
3.	____________	area: ______	Season	____________
4.	____________	area: ______	Season	____________
5.	____________	area: ______	Season	____________

✓ **Please tick all boxes that apply to your farm for the following questions:**

1. **Growing Conditions**

a) Do you grow crops outside or in a greenhouse?

Greenhouse ❑ area or % __________

Outside ❑ area or % __________

What **crop management strategy** do you use?

"calendar" sprays ☐ chemical IPM ☐ biological IPM ☐

2. **Crop Monitoring**

a) Do you monitor your crops for pests? yes ☐ no ☐

If *yes* do you monitor: yourself ☐ consultant ☐ reseller ☐

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐

Do you use a routine protocol yes ☐ no ☐
Comment:___________________

Do you keep monitoring records yes ☐ no ☐
Comment:___________________

Do you use Sticky Traps? yes ☐ no ☐
Comment:___________________

b) Do you monitor for beneficial insects yes ☐ no ☐
Comment:___________________

c) Do you monitor for diseases yes ☐ no ☐

If *yes* do you monitor: yourself ☐ consultant ☐ reseller ☐

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐

Do you use a routine protocol yes ☐ no ☐
Comment:___________________

Do you keep monitoring records yes ☐ no ☐
Comment:___________________

Do you use a diagnostic service? yes ☐ no ☐
Comment:___________________

d) Do you monitor for weeds? yes ☐ no ☐
Comment:___________________

If *yes* do you monitor: yourself ☐ consultant ☐ reseller ☐

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐

Use a routine protocol yes ☐ no ☐
Comment:___________________

Keep monitoring records yes ☐ no ☐
Comment:___________________

e) Do you monitor nutrient levels: Soil? yes ☐ no ☐ Plant tissue? yes ☐ no ☐

If *yes* do you monitor: yourself ☐ consultant ☐ reseller ☐

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐

Use a routine protocol yes ☐ no ☐
Comment:___________________

Keep monitoring records yes ☐ no ☐
Comment:___________________

3. Pest and Disease Problems

a) What are your major pest and disease problems?

Pest or Disease	Crop	Estimation of Costs/Losses

4. Chemical Use

a) What factors are important for your choice of pesticide?

cost ☐ broad as possible activity ☐ specific as possible ☐

resistance management ☐ impact on beneficials ☐ maximise kill of pest ☐

b) Do you calibrate your sprayer or change nozzles? sometimes ☐ regularly ☐

never ☐

c) When do you spray?

early mornings ☐ days ☐ evenings ☐ nights ☐

regular schedule ☐ when time permits ☐ vulnerable pest stage ☐

depends on pest numbers ☐ depends on pest & beneficial numbers ☐

d) What best describes your spray rig?

standard overhead boom ☐ modified boom ☐ boom with droppers ☐ air-assist ☐

aerial ☐ backpack ☐ spray wand ☐ other (specify)____________

e) Do you follow label instructions for re-entry periods? yes ☐ no ☐

f) Do you use chemicals from the Synthetic Pyrethroids group? yes ☐ no ☐

g) Do use Schedule 7 chemicals, labelled 'Dangerous Poison'? yes ☐ no ☐

h) What level of PPE do you use while using chemicals? ______________________________

i) Have you got a certificate for chemical handling and usage (eg. SMARTrain, ChemCert courses) yes ☐ no ☐ Issue date? (valid for 5 years) ____________

j) Do you use: wetters ☐ stickers☐ UV protectants ☐

k) Do you use biopesticides such as Bt (e.g. Dipel®, Xentari®) or NPVs (e.g. Gemstar® or Vivus®)?

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐ never ☐

l) Do you use new chemistry e.g. Success®, Avatar®, Prodigy® or Proclaim®?

Regularly/weekly ☐ sometimes (once/month) ☐ occasionally (1-2/season) ☐ never ☐

5. Variety selection

Is disease or insect resistance a key factor in choosing the vegetable variety to be planted?

yes ☐ no ☐ Comment: ______________________________

____

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6. Farm Hygiene

a) Do you chip out diseased plants? regularly ☐ sometimes ☐ never ☐

If *yes* do you remove them from the field? regularly ☐ sometimes ☐ never ☐

b) Do you control weeds around your field/shed? regularly ☐ sometimes ☐ never ☐

c) What are the key reasons why you control weeds?

Looks good ☐ Pest control ☐ Disease control ☐

d) If you don't control weeds is that because it is:

Too much work ☐ Good for beneficials ☐ Not necessary ☐

e) Do you bust pupae or use other physical controls? regularly ☐ sometimes ☐ never ☐

Comment:

___

7. Biological Control

a) Do you release beneficial insects? regularly ☐ sometimes ☐ never ☐

b) Do you plant crops to attract beneficial insects? regularly ☐ sometimes ☐ never ☐

c) Do you modify your spray practices because of beneficial insects?

regularly ☐ sometimes ☐ never ☐

e) Do you modify your planting/harvesting or management of your crop because of beneficial insects? regularly ☐ sometimes ☐ never ☐

8. Crop Rotations

a) Do you rotate your crops?

If *yes*, is this for disease control ☐ pest control ☐ market demands ☐

Comments:___

___

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9. Farm Topography

Is your farm?

❑ Flat ❑ Undulating ❑ Slight Slope ❑ Steep Slope

a) How do you rate your water drainage?

❑Rapid ❑Good ❑Average ❑Poor

Comments:____

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10. Water Management

a) Where do you source your water?

❑ Dam ❑ Town Water ❑ Rain water tank

If you use Dam water – Does farm runoff enter your dam ❑ Yes ❑ No

If yes is the runoff from your own farm or from nearby farms?

❑ Own farm ❑ Other Farm

Comments:____

____

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b) Do you treat your water prior to use? ❑Yes ❑No

c) Do you get your water analysed for nutrient or disease?

❑ Regularly ❑Occasionally ❑ Never

Comments:

____

____

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d) Does your dam suffer from:

❑ Algae ❑ Aquatic weeds ❑ Macrophyte plants

e) When do you irrigate?

❑ Morning ❑ Afternoon ❑ Interval – Specify:______________________________

f) What type of irrigation do you use?

❑ Moss Sprinklers ❑ Mini Sprinklers ❑ Drip ❑ Galvanised Pipes

❑ PVC Pipes ❑ Other – specify_______________________________________

What type of development/agriculture surrounds your farm?

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Additional Comments

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