The delivery of IPM for the lettuce industry - an extension to VG05044

Dr Sandra McDougall
Department of Primary Industries

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FINAL REPORT

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NSW Department of Primary Industries

HAL Project No: **VG07076**

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Purpose: To build upon the commercial lettuce IPM demonstrations in 2004-5 (HAL project VG04067) and in Victoria and Tasmania in 2006/7, Sydney 2007/8 (HAL project VG05044) and from all previous lettuce IPM projects to address barriers to IPM adoption.

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1. Media Summary

Lettuce is a valuable crop in Australia, production being valued at $187 million in 2008/9. However, production is threatened by a range of serious insect pests and diseases, including *Helicoverpa* spp. caterpillars, western flower thrips (WFT), tomato spotted wilt virus (TSWV), sclerotinia rots and currant lettuce aphid (CLA). While chemical methods can provide some control of these pests, the development of resistance, environmental issues and concerns about food safety mean these methods may not be viable in the long term. The alternative is Integrated Pest Management (IPM), which uses a combination of beneficial insects, cultural methods and 'soft' pesticides to provide more sustainable control.

This project has developed IPM strategies for lettuce including:

- testing CLA resistant lettuce varieties
- using cereal crops as "nurseries" for beneficial insects
- trials with low toxicity pesticides such as Movento® and Bion®
- evaluating the effects of current pesticides on beneficial insects
- extending effectiveness of natural pesticides
- demonstrations comparing IPM management to conventional farming.

Lettuce grown using IPM consistently had fewer WFT and more beneficial insects, such as ladybirds and lacewings, than a similar crop grown with conventional pesticides. This research has provided farmers with more tools to use against insect pests and diseases, and will help them reduce pesticide use into the future.

A remaining barrier to increased adoption of IPM is the perception that harvested product may have insects on it. Industry members have confirmed their belief that consumers have "zero tolerance" for insects on vegetables. Focus groups indicated that while most consumers were tolerant of insects such as ladybeetles, they were more repelled by soft bodied animals (e.g. slugs) or insects arriving after harvest (flies, cockroaches). The exception was younger consumers, who were extremely intolerant of any insect. These results were confirmed in a National online survey which showed that factors associated with tolerance of insects and interest in IPM methods included:

- aged over 35
- female
- grown vegetables or herbs, currently or in the past
- occasionally purchase organically grown products.

The results show that not only is it possible to grow lettuce using IPM, but also that there could be a niche market for these products. While consumers may not be willing to pay significantly more for IPM grown lettuce, such a label would at least prevent exclusion of these products from retail.

Lettuce growers had opportunites to visit the IPM Demonstration farms in Sydney and Stanthorpe, received regular updates on research trials, regional conditions and developments that impact managing pests in lettuce with a quarterly newletter and all received a copy of a Lettuce Crop Protection Toolkit DVD which included short video casestudies of 7 lettuce growers from across the country discussing IPM on their lettuce farm, as well as a library of over 150 lettuce crop protection resources.

The numbers of growers who are 'calendar sprayers' is approximately 25% which is a reduction from 39% in 2006. The greatest change in practice for lettuce growers since 2006 is the increase in use of crop consultants from 28% to 45% in 2012, the numbers of growers who monitor for beneficial insects from 38% to 59% in 2012 and the numbers of growers who use biological insecticides has increased from 43% to 72% in 2012.

Eighteen recommendations are made for future RD&E into aspects of lettuce IPM including work on soft options for Rutherglen bugs, impacts of agricultural chemistry on beneficials, landscape management for managing pests, need to engage whole market chain to develop market-pull for IPM and contingency plans for managing residue, food safety, insect contaminant issues for example.

2. Technical Summary

Lettuce is a major crop in Australia, with production valued at $187 million in 2008/9 (ABS 2011). This lettuce project built upon a series of previous lettuce integrated insect pest management projects with the aim of demonstrating Integrated Pest Management (IPM) on a commercial scale, researching additional crop management tools and barriers to IPM adoption.

Research gaps included: evaluating management of Currant lettuce aphid (*Nasonovia ribisnigri*); suitability of *Nas*- resistant varieties in two locations; impact of imidacloprid on the key beneficial – *Hippodamia variegata*; and potential of cereals as a nursery crop for aphid beneficials. Other research was to: evaluate two IPM compatible chemicals for managing Western flower thrips (*Frankliniella occidentalis*); evaluate effectiveness of using a sunscreen with *Bacillus thuringiensis* to extend its efficacy window; and to investigate consumer attitudes into insect contamination of lettuce. Project outputs included: developing consultant and grower training resources, case studies of IPM growers, producing the Lettuce Leaf newsletter, producing a DVD including IPM grower casestudies and copies of lettuce IPM print resources in electronic format.

Currant lettuce aphid (*Nasonovia ribisnigri,* CLA) control

Commercial scale IPM demonstration trials, using lettuce susceptible to CLA and not treated with imidacloprid seedling drench, were successfully conducted in Sydney, Stanthorpe and Hay. On only two occasions (Sydney, June and July 2008) were CLA observed in weekly visual montoring or the less frequent destructive samples. In Victoria, a co-relation between numbers of CLA and the aphid predators, brown lacewings (*Micromus tasmaniae*) and hover flies (Syrphids) was observed in IPM managed lettuce. Numbers of CLA and predators declined during the 4 weeks prior to harvest. No commercial IPM lettuce was rejected for CLA contamination.

Increasing the number of natural predators may therefore be critical to controlling CLA in lettuce. Imidacloprid has been previously reported to kill beneficials such as brown lacewings by secondary poisoning. Tests using the aphid predator Spotted amber ladybird (*Hippodamia variegata*) confirmed that adults fed on aphids from untreated lettuce were heavier, oviposited sooner, and laid eggs more frequently than adults fed on aphids from imidacloprid treated lettuce. Other trials tested the potential for cereals to be a source of aphid predators. Although initial screens of cereals for aphids and aphid predators found barley and oats could be suitable, results from subsequent trials of lettuce planted with and without a neighbouring cereal row were not significant due to high variability.

Using CLA (*Nas*) resistant varieties is another strategy. A range of varieties were trialed over weekly plantings for 10 weeks at Hay. In all planting windows at least one variety was suitable. Two separate variety trial plantings were held in conjunction with the Stanthorpe IPM demonstration trials.

Western flower thrips (*Frankliniella occidentalis,* WFT) and Helicoverpa caterpillar (*Helicoverpa armigera* and *H. punctigera*) control

Two new chemicals - spirotetramat (Movento$^{®}$), and benzothiadiazole (Bion$^{®}$) - were trialed for control of WFT / TSWV (Tomato spotted wilt virus) in lettuce. Unfortunately neither proved effective under the trial conditions. However, it is notable that higher numbers of WFT were found in most imidacloprid treated lettuce sites versus the single non-imidacloprid treated lettuce site monitored in Victoria, possibly due to the high number of thrips predators observed at this site.

A Victorian trial examined the use of UV screens to improve the efficacy of Bt (*Bacillus thuringiensis*) sprays against caterpillars. While Bt without sunscreens was deactivated in 300-350 minutes, activity was extended to 400-450 minutes and 450-500 minutes by Nufilm 17$^{®}$ and Nufilm P$^{®}$ respectively.

Insect contamination at retail

Lettuce processors and supermarket buyers confirmed that IPM grown lettuce is perceived as more likely to have insect contamination, and that such contamination results in customer complaints. A number of focus groups confirmed that young women, especially from lower socio demographic groups, are very sensitive to insect contamination. Older consumers were less concerned. However, most consumers failed to notice insects in deliberately infested bags of lettuce mix, even when asked to examine the samples closely.

A National on-line survey of 1,120 grocery buyers also found that factors associated with tolerance of insects and interest in IPM methods included being aged over 35 years, female, having experience growing vegetables, and having occasionally purchased organically grown products.

Extension and adoption

Three field days were held at the Sydney and one at the Stanthorpe IPM Demonstration farms. Eight editions of the Lettuce Leaf newsletter were mailed to all lettuce growers providing regular updates on research trials, regional conditions and developments that impact managing pests in lettuce, and all growers received a copy of a Lettuce Crop Protection Toolkit DVD which included short video casestudies of 7 lettuce growers from across the country discussing IPM on their lettuce farm, as well as a library of over 150 lettuce crop protection resources.

Lettuce grower survey

Lettuce growers were asked to complete an on-line evaluation and benchmarking survey at the end of this project. Passive requests via newsletters or cover letters with the DVD did not result in any grower responses. Growers only undertook the survey when individually asked either via a telephone call or in person. 28 of 42 growers who completed the survey did so answering the survey questions with a survey collector, and the collector entered the results on-line. Growers who self identified as ‘calendar sprayers’ was 21% in 2012, a reduction from 39% in 2006. The greatest change in practice for lettuce growers since the 2006 survey is the increase in use of crop consultants from 28% to 46% in 2012, the numbers of growers who monitor for beneficial insects from 38% to 55% in 2012 and the numbers of growers who use biological insecticides has increased from 43% to 76% in 2012. In the 2012 survey IPM was further divided into ‘low IPM’ or essentially ‘integrated pesticide management’, ‘medium IPM’ which incorporates beneficials insects and an increase in use of preventative non-chemical management practices, and ‘biointensive IPM’ which includes a higher level of monitoring, integration of non-chemical management practices and farm system design. In the 2012 survey 14% self identified as ‘low IPM’, 54% as ‘medium IPM’ and 7% as ‘bio-intensive IPM’. Based on responses to specific pest management questions it is estimated that 14% do not practice IPM at all, 25% practice ‘low IPM’, 57% practice ‘medium IPM’ and 3% ‘bio-intensive IPM’. The extensive crop protection benchmarking component of the survey conducted in 2012 will be very useful in tracking changes in crop protection practices particularly if subsequent surveys use the 2012 survey questions as a standardised set of questions.

Recommendations

1. Future IPM demonstrations within RD&E projects.
2. Landscape management - potential for push-pull systems and use of non-crop vegetation.
3. Predatory mites releases in open hydroponic or field lettuce.
4. Development of effective use of an *attract and kill* approach for *Helicoverpa* spp.
5. IPM options for Rutherglen bug management or disinfestation.
6. Further research into the impact of agricultural chemistry on beneficials.
7. Production of resource materials on maximising efficacy of biological insecticides, on impact of pesticides on beneficials and residue periods.
8. On-going periodic independent testing of new crop protection products to verify efficacy, assess best-fit in IPM recommendations and identify potential risks.
9. Access to trusted and competent IPM technical support in all major lettuce production areas.
10. Develop IPM training/ professional development options for agronomists and crop consultants.
11. Develop lettuce/vegetable contingency plans, realistic quality specifications and identify RD&E needs with market chain players.
12. Develop a ‘market –pull’ strategy for IPM.
13. Study to quantify the level of the insect contamination problem.
14. 4th Australian Lettuce Industry conference with an emphasis on training workshops.
15. Development of a website that hosts crop protection information resources in an easy access form.
16. Industry has an agreed strategy for RD&E providers communicating with growers in all States.
17. Use standardised crop protection benchmarking questions.
18. Standardised benchmarking questions be used to track changes in crop protection practices.

3. Introduction

According to the ABS, lettuce production in Australia was worth $187 million in 2008/9. Lettuce production areas in different states share many of the same insect pests. With the introduction of the vegetable levy the first of a series of lettuce integrated pest management projects was funded in 1998 (see Appendix 3.1) for more details on the series of HAL funded lettuce projects). The early projects focused on Helicoverpa caterpillars (*Helicoverpa armigera* and *H. punctigera*), sclerotinia disease management and tipburn. With the introduction and spread of silverleaf whitefly (*Bemisia tobaci* biotype B SLW), western flower thrips (*Franklienella occidentalis* WFT) and the currant-lettuce aphid (*Nasonovia ribis-nigri* CLA) focus shifted to these sucking insect pests.

The development of an integrated pest management (IPM) strategy that was less reliant on insecticides has been imperative for continued successful production of quality lettuce given WFT (Herron and Gullick 2001, Herron and James 2005), *Helicoverpa armigera* (Gunning and Easton 1993; Young *et al.* 2006), SLW (Gunning *et al.* 1995; Young *et al.* 2006) and CLA (Rufingier *et al.* 1997; Barber *et al.* 1999) all have developed insecticide resistance. An IPM strategy must have regular crop monitoring of insect pests as well as beneficial insects. All reasonable effort needs to be made to reduce the chances of pests colonizing crops to maximise the chances of beneficials to manage the pests. Important cultural management practices include ensuring seeds and seedlings are insect pest and disease free, and removing sources of insect pests and diseases, including finished crops, infested/infected hosts and weed hosts. If insect pest numbers are high enough to be causing damage, the choice of insecticide should consider the impact on the beneficials present, and, where possible, consider options that complement the beneficials. Ideally, the IPM approach is applied to all crop pests, including management of nematodes, weeds and vertebrate pests.

Although IPM practices had been adopted in all States to varing degrees prior to 2004 when the arrival of CLA into Australia saw widespread adoption of a systemic insecticide as a preventative control measure. The risk to adopting an IPM strategy that was more reliant on monitoring and beneficial invertebrates for control of CLA was seen as too great by most growers and markets. The adoption of the systemic insecticide then saw many growers who had previously managed *Helicoverpa* and other caterpillars using a combination of endemic beneficial invertebrates and targeted soft chemistry have to revert to a more chemical intensive management approach. The success of an IPM approach was demonstrated in 2004/5 in Tasmania in (VG04067 '*Integrating lettuce aphid into IPM for lettuce – a commercial trial*') and repeated in Victoria and to a lesser extent in NSW in (VG05044 '*Further developing integrated pest management for lettuce*').

Project methodology

This project was designed to have commercial scale IPM trial-demonstrations in some major production areas as well as research a number of gaps in our knowledge about existing or potential pest management tools, and to understand more fully the barrier the market posed to IPM adoption. IPM demonstration trials were designed to demonstrate that using a basic IPM strategy of routine crop monitoring of crop pests and of important invertebrate beneficials and the use of selective foliar insecticides where necessary would produce commercially marketable lettuce.

The ultimate IPM solution to a specific pest is to have varieties that are resistant to key pests. Many headlettuce growers had previously found *Nas* resistant varieties they had tried did not meet their market requirements. Commercial seed companies typically conduct variety demonstrations only with their companies varieties so two variety trials of *Nas* resistant headlettuce varieties were held in two locations to evaluate suitable growing windows for the resistant varieties as well as allow growers to view side by side the different varieties for their market characteristics.

After CLA arrived into Australia most lettuce growers used imidacloprid as a preventative strategy. However using imidacloprid for all plantings in all production areas is not desirable for a number of reasons including the extreme selection pressure for CLA to develop insecticide resistance, as well as the impact on beneficial invertebrates that had been important for managing *Helicoverpa spp.* and other caterpillar species as well as aphids and thrips. The negative impact of imidacloprid on Brown lacewing (*Micromus tasmaniae*) had been researched in a previous lettuce IPM project but only anecdotal data existed for the negative impact on the White collared ladybeetle (*Hippodamia variegata).* Research was required to confirm whether imidacloprid use was likely to be harmful to this generalist predator.

IPM management of caterpillar pests has included using the biopesticide, *Bacillus thuringiensis kustaki* strain (Btk). Applications of Btk are recommended to be made in the evening to maximise the exposure period to feeding caterpillars prior to UV radiation reducing its efficacy. Evening spraying is unsociable for growers and had previously been identified as a barrier to its effective use. A small laboratory trial was conducted to evaluate the efficacy of two potential sunscreens to add to a commercial Btk formulation.

In hydroponic lettuce the key invertebrate pest is Western flower thrips (*Frankliniella occidentalis*, WFT) which transmits the highly destructive tomato spotted wilt virus. The one registered and highly efficacious insecticide for WFT in hydroponics is spinosad however WFT is showing widespread signs of being lost due to insecticide resistance. Resistance monitoring has shown spinosad resistance in WFT to be increasing, and in 2010 was 200 fold in one strain and 100 fold in four of 14 strains tested (Herron *et al.* 2010). Two insecticides that are relatively soft on invertebrate beneficials, *benzothiadiazole* Bion® and *spirotetramat* Movento® were trialed in hydroponic lettuce as potential options to control WFT or reduce transmission of tomato spotted wilt virus.

In the previous lettuce IPM project growers highlighted the pressure put on them by their markets to continue a primarily chemical approach to pest management. Within this project attempts were made to have a dialogue with both the processing and fresh market buyers of lettuce, to identify their concerns with an IPM approach to pest management in lettuce and where possible find common ground. Insect contamination of lettuce was highlighted as a major concern and barrier to the market encouraging growers to use IPM. Two focus group studies and an on-line consumer survey were undertaken to understand consumer attitudes to insect contamination.

Although this project was only going to interact directly with a small group of lettuce growers and consultants, it was important to interact indirectly with all lettuce growers and related industry people. Since 1999 lettuce growers have been directly mailed a 2-4 page Lettuce leaf newsletter 2 - 6 times per year with information relating to crop protection in lettuce and project updates. This practice continues in this project.

Lettuce is produced in all Australian States, in multiple production areas and is produced in multiple regions at any point in time, constraining the ability to bring growers together face to face to share their experiences. Video is a medium for taking personalised grower accounts to other growers. Since this was understood to be the last of these consecutively funded lettuce IPM projects, it was important to collate our state of knowledge and make it available to all lettuce growers and associated industry people. A website is one option for making electronic forms of information available to growers and Utube is one option for making videos accessible via the web, however access is limited by grower connectivity to the internet. Another option was a DVD or CD rom mailed directly to growers to view on a computer combining both video casestudies of IPM lettuce growers from a range of production areas and production methods, as well as creating an electronic library of information resources.

A final component was to conduct a national lettuce grower evaluation of the project and benchmarking survey to allow a comparison to the 2006 lettuce grower survey.

This final report presents separate reports for the IPM demonstrations, the directed research gap trials, the consumer attitude investigations and the grower evaluation and benchmarking survey, followed by an overall discussion of the research and technology transfer.

4. Lettuce IPM Demonstration in Queensland

Mr David Carey, Dr Lara Senior, Ms Mary Firrell, Ms Madaline Healy, and Mr Adrian Hunt.
Department of Employment, Economic Development and Innovation

Introduction

HAL project VG07076 provided the opportunity to promote and demonstrate the latest IPM techniques to local Queensland lettuce growers and reseller/advisors. The demonstration trial was conducted in Stanthorpe on the property of Taylor Family Produce, major producers of lettuce, Chinese cabbage, broccoli, and celery. The Taylor Family volunteered the use of their property for this demonstration trial as they "wished to learn more about IPM" and see how on farm practices could be improved. Currant lettuce aphid (*Nasonovia ribisnigri* CLA) was first positively identified in Queensland in the 2007-8 production season. CLA occurrence has been documented in the Lockyer Valley, Redlands and Stanthorpe growing areas. CLA was first recorded on the Australian mainland in Victoria in 2005 and soon spread to all states and lettuce production areas. The control method that the lettuce industry adopted at that time (and remains largely so today) was to drench seedlings with a high rate of imidacloprid (Confidor®, 1.1 ml a.i per 1000 seedlings). Some Queensland growers adopted this preventative approach in 2005 (often encouraged by processors) even though the pest took another two seasons to appear in a non-treated Queensland lettuce crop.

When CLA arrived in Tasmania in 2004 a commercial scale IPM trial was established on the Tasmanian Department of Primary Industries, Water and Environment research station at Devonport. This trial demonstrated that lettuce could be grown without the use of a systemic insecticide and that invertebrate beneficials would colonise CLA infested lettuce and allow the production of commercially marketable headlettuce.

This IPM trial in Stanthorpe aimed to demonstrate the same approach to local lettuce growers as well as raise awareness about IPM tools. Demonstrated IPM tools included crop monitoring using a variety of methods to monitor invertebrate pests, invertebrate beneficials, and plant water usage to assist in making choices about appropriate invertebrate pest control options and irrigation decisions. The trial demonstrated natural colonisation of invertebrate beneficials, as well as the impact of releases of commercially reared invertebrate beneficials on a target pest. CLA or *Nas*-resistant lettuce varieties were trialled side by side for growers to evaluate commercial market acceptability of these varieties grown at Stanthorpe.

Material and Methods

A defined production area of approximately 0.4 ha was set aside in an area of the farm with adjacent native bushland (Figure 4.1). This area consisted of four individual blocks which were planted over a period of ten days on three separate planting dates (Figure 4.2). The first blocks were planted on Friday the 29th January 2010 with the second and third plantings occurring on the 1st and 11th February respectively. The second and third plantings also contained a small lettuce variety trial (*Nasonovia ribisnigi* resistant lettuce).

Lettuce transplants for this IPM trial were grown on-farm, but were not imidacloprid-treated. The IPM lettuce area, although beside the commercial cropping area, was offset from it and situated between surrounding native bush. The commercial lettuce crop, adjacent to the "IPM" area, also grew the lettuce variety *Raider,* but it was imidacloprid-treated. The commercial lettuce crop area was planted sequentially over the two weeks preceeding the IPM lettuce planting.

Figure 3-1 View of the IPM Lettuce area with native bushland on either side. Irrigation sprinklers and *Helicoverpa* sp monitoring traps are visible in foreground, with the dam in the distance.

Agronomy

All lettuce were grown according to normal on-farm practice, except that pesticide and fungicide inputs for the IPM demonstration area were selected and scheduled according to pest pressure and beneficial impacts. Appendix 4-2 contains records for pesticide inputs on IPM demonstration and grower standard plantings, and Appendix 4-3 contains weather conditions during the trial period.

Demonstrated Techniques

Crop scouting

The IPM area and the commercial area were scouted and sampled twice a week for the duration of the trial (79 days). Scouting consisted of a full plant inspection to determine pest pressure and beneficial presence. Five adjacent plants were inspected at each sampling spot. Ten random sampling spots were assessed in both the IPM and commercial crops on a Monday and a Thursday of each week throughout the trial period. The results of the monitoring informed the decision about what if any control measure needed to be taken in the next few days or week and to evaluate the impact of previous control measures taken.

Aphids

Aphid numbers, including *Nasonovia ribisnigri* or Currant lettuce aphid (CLA), were assessed twice weekly with the intent being to manage their occurrence according to IPM principles. Once hearting commenced, one lettuce in every ten checked in the field was destructively sampled to detect CLA presence. Had CLA been detected in the trial area a more detailed destructive sampling assessment would have been carried out to determine aphid and beneficial numbers in the IPM area.

Helicoverpa (*Helicoverpa spp.*) pressure

Helicoverpa armigera and *H. punctigera* are the major insect pests of summer-grown Queensland lettuce. In addition to crop scouting pheromone traps were used to give an indication of *Helicoverpa spp.* flight activity in the cropping area for the duration of the trial. Pressure was low to moderate throughout the trial period, but small larvae were hatching most weeks.

Thrips pressure

Yellow sticky traps were deployed to assist in monitoring thrips presence. A number of these sticky traps were also baited with trial blends of thrips pheromone to determine if any of these pheromone blends gave an improved detection of thrips, better than sticky traps alone. Sticky traps were placed at the same location within the crop for three consecutive days of each week throughout the trial period.

Naturally occurring beneficial insects

Malaise traps were erected within the commercial cropping area and between the native vegetation and the cropping area to give a snap shot of what beneficial insects were moving into the crop from surrounding bushland. Malaise trap samples were collected and sorted weekly.

Beneficial wasp release

Weekly releases of the beneficial wasp *Trichogramma pretiosum* were carried out on-farm. Four consecutive wasp releases were carried out beginning the second week after transplanting. One hundred and eighty thousand wasps were released weekly in the IPM crop and a small number were placed in the surrounding bush in an endeavour to establish a local population. This release was aimed at raising awareness of the commercial availability of beneficial insects available for inundative release. This release program reinforced the need to look after beneficials by choosing soft option pest control products compatible with an IPM system while highlighting the potential benefits beneficial insects provide. The structured release of wasps in this way also encouraged growers and advisors to better understand the life cycle of beneficials and pests, so improving their ability to manage crops effectively, and to encourage naturally occurring beneficials.

Soft option products to maximise beneficial insects

Pest and disease pressures were the basis for soft option product selection. The underlying emphasis of the demonstration trial was to maintain and encourage all beneficials within and around the IPM cropping area and to document their presence. To this end, a decision was made to try and rely on pest specific soft option products such as NPV (Vivus max®) and Bt for *Helicoverpa* spp control as long as pest pressure did not become excessive. Aphid control was via specific soft option aphicides such as Pirimor® and Chess®.

Variety trials

Nas-resistant headlettuce has not been widely adopted by lettuce growers because until recently, the relatively few available varieties did not produce a market acceptable lettuce head. The licensing of the *Nas*-resistance technology from Rijk Zwann to the other lettuce seed companies has seen its inclusion into many new lettuce varieties in the past several years. With so many new varieties and the previous poor performance of *Nas*-resistant headlettuce, a side by side evaluation of several different *Nas*-resistant varieties was desirable. Rijk Zwann, Nunhems and Syngenta Seeds provided commercial and trial lines of *Nas* resistant varieties which were assessed for agronomic potential under Queensland growing conditions. Two assessments of these lines were carried out as part of the second and third plantings. These trials were reviewed by growers during the demonstration trial walks and were open to local growers to visit. No CLA were present in the trial area however agronomic data was collected and is available on request from David Carey.

Improved irrigation decisions

Monitoring plant water usage and irrigation requirements can be considered an IPM tool for a number of reasons. Water-stressed plants, particularly overwatered plants can be co-related to increase in some lettuce diseases such as lettuce big vein, and was associated in Tasmania with high populations of CLA on a commercial growers property. Overhead watering can contribute to foliar diseases and minimising leafwettness is a key lettuce fungal and bacterial disease management tool. In Stanthorpe the lettuce growers donot routinely use water monitoring tools so the opportunity was taken to highlight the potential of the simple and cheap irrigation front detection tool, the FullStop®. This device developed and sold by CSIRO, is an effective method of detecting the arrival of the irrigation wetting front at a chosen root depth. Given the sandy soil of the Granite Belt growing region and the fact that the co–operating grower was not familiar with this device, several demonstration units were installed to raise grower and reseller awareness.

Helicoverpa spp. Lure and Kill Trial

A small trial was set up in an attempt to lure *Helicoverpa spp.* moth out of the cropping zone and "attract and kill them" in a non-crop area. This technique may be of value to Queensland lettuce growers who experience large distinct flights of *Helicoverpa spp.* moth over the summer cropping period. Results were inconclusive in this initial attempt, and positioning of the lure and kill area may well have been a factor in the poor outcome. *Helicoverpa spp.* pressure was low in the area of the farm where this technique was tried, and results were inconclusive in this initial trial.

Although growers and resellers were shown the trial results and techniques, they are not discussed in this report, as further work is required to test this technique.

Technology transfer

Demonstration of IPM techniques and exposure to good IPM practice were the aims of this demonstration trial. Taylor Family Produce were happy to be involved in this demonstration trial and to learn more about IPM techniques. Farm staff and management were involved throughout the trial period. Local resellers servicing the farm, and participating seed company representatives, as well as neighbouring lettuce growers also visited and viewed the trial area as the crop matured and during harvest. Physical involvement by farm and reseller staff in the suite of demonstrated IPM monitoring techniques increased their knowledge and understanding of these techniques while underlining their value in improved crop management.

Figure 3-2 IPM trial area 22nd February. The youngest planting in the distance was transplanted 11 days earlier.

Results and Discussion

Crop Scouting

A total of fifty plants were carefully assessed for pest, disease and beneficial insect presence twice a week for the duration of the trial (Table 4-1, see Appendix 4-1 for table of pest & beneficial common and scientific names). Count numbers recorded in the table below begin with the last transplanting, when the initial planting would have been established for 12 days. The random sample in each crop area consisted of 10 separate locations throughout the crop where five neighbouring plants were checked. It must be noted that fast moving beneficials such as spiders, some beetles, lacewing adults and wasps tend to hide and/or move away as soon as the plant is disturbed when counting. This is particularly evident as lettuce plants become larger, with more leaf providing great hiding spots in and around leaf bases. This was a commercial demonstration, so non-destructive sampling meant that as plant size increased, beneficials were more able to escape and hide. This is a factor that needs consideration – crop scouts are unlikely to see all of the beneficials in the crop. They will see a few on younger and middle-aged plants, but not all. Growers need to encourage the presence of beneficials by choosing soft option crop protection products that only kill pest species!

Regular crop scouting, and careful choice and use of specific soft option crop protection products together will maximise the benefit from beneficial insects. The results below, in terms of beneficial numbers observed, occurred towards the end of a commercial production season, in an area that was previously not managed to maximise IPM outcomes, so the trial started with a reduced potential beneficial population! Long term adoption and awareness of IPM principles and regular scouting will provide growers with better knowledge of the number and role of beneficials present in a cropping area.

***Helicoverpa spp.* larvae**

Helicoverpa spp. larvae numbers in the IPM blocks were higher than in the commercial crop on some dates. This is to be expected as NPV (*nucleopolyhedrovirus*) and Bt (*Bacillus thuringiensis*) have no impact on eggs, and small larvae have to emerge and begin to feed before they are controlled. The control of *Helicoverpa spp.* in the IPM blocks was as good as that obtained in the commercial crop. The extra benefit of using soft option products is demonstrated by the large number of spiders, beetles and general beneficial wasps observed in the IPM crop area during scouting. The IPM blocks received a total of six applications of Vivus Max® and Bt over the 79 day cropping period the three lettuce plantings took to mature. Each Vivus Max® application was applied with some molasses to act as a feeding attractant. The commercial area had a total of two Proclaim®, two Avatar® and one Lannate® application.

Aphids

The non-imidacloprid treated (e.g. Confidor®, Senator®, Nuprid®) IPM lettuce would be expected to contain live aphid that had flown into the crop (between the 11th and 14th of February). The application of the soft option aphid-specific product Pirimor® (pirimicarb) provided adequate control without disrupting beneficials. Although 50 percent of plants checked on the 15th of February contained aphids (other than CLA) effective control was achieved without disrupting beneficials.

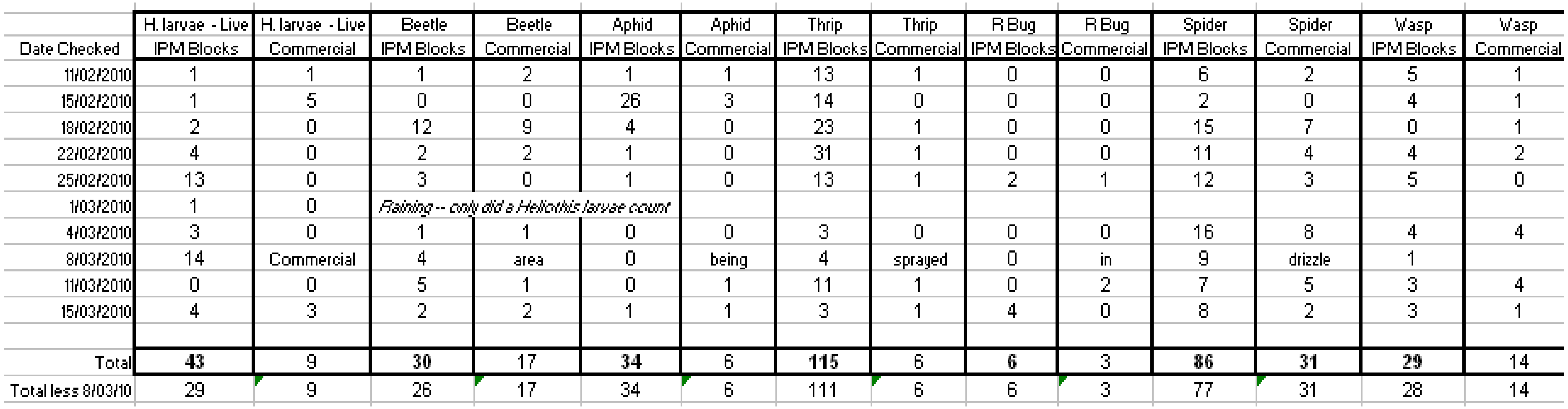
Beetles

Many beetles, other than lady beetles, are beneficials. Ground beetles (most are carnivorous and hunt smaller invertebrates), and rove beetles (predators of insects and other invertebrates) can significantly impact on common insect pests. Although quick to move and hide, rove beetles were observed in the IPM crop along with other non-pest beetle species. More beetles were observed in the IPM lettuce blocks than in the commercial area.

Thrips

Though some species of thrips can be responsible for the spread of virus such as Tomato Spotted Wilt virus, there are also many predatory (beneficial) thrips species. Although thrips numbers were initially higher in the IPM crop no commercial impact was observed at harvest, and numbers decreased as the trial progressed, the crop matured, and more beneficials became established.

Table 3-1 Crop scouting data from the IPM and commercial lettuce blocks. Routine monitoring is used in an IPM strategy to inform decisions on pest management, decide on control options and evaluate previous decisions.



Date Checked	H. larvae - Live IPM Blocks	H. larvae - Live Commercial	Beetle IPM Blocks	Beetle Commercial	Aphid IPM Blocks	Aphid Commercial	Thrip IPM Blocks	Thrip Commercial	R Bug IPM Blocks	R Bug Commercial	Spider IPM Blocks	Spider Commercial	Wasp IPM Blocks	Wasp Commercial
11/02/2010	1	1	1	2	1	1	13	1	0	0	6	2	5	1
15/02/2010	1	5	0	0	26	3	14	0	0	0	2	0	4	1
18/02/2010	2	0	12	9	4	0	23	1	0	0	15	7	0	1
22/02/2010	4	0	2	2	1	0	31	1	0	0	11	4	4	2
25/02/2010	13	0	3	0	1	0	13	1	2	1	12	3	5	0
1/03/2010	1	0	*Raining -- only did a Heliothis larvae count*											
4/03/2010	3	0	1	1	0	0	3	0	0	0	16	8	4	4
8/03/2010	14	Commercial	4	area	0	being	4	sprayed	0	in	9	drizzle	1	
11/03/2010	0	0	5	1	0	1	11	1	0	2	7	5	3	4
15/03/2010	4	3	2	2	1	1	3	1	4	0	8	2	3	1
Total	**43**	9	**30**	17	**34**	6	**115**	6	**6**	3	**86**	**31**	**29**	14
Total less 8/03/10	29	9	26	17	34	6	111	6	6	3	77	31	28	14

Notes.

a) Due to commercial spraying no commercial crop observations were taken on 8/03/10. The bottom row of adjusted figures allow an adjusted comparison of total insect figures in each crop area

b) *Helicoverpa sp* larvae numbers are a total of small, medium, and large larvae. The majority of larvae observed in the IPM blocks while scouting were small, and Vivus Max® provided effective control.

See Appendix 4-1 for common and scientific names of pest and beneficial insects collected in this demonstration trial.

Spiders and wasps

Good numbers of both spiders and wasps were observed in the IPM area as the trial progressed. There was a diverse range of spiders within the IPM crop and these generalist predators were great hunters of a wide range of prey.

The range of beneficial predatory and parasitic wasps in and around this IPM crop is highlighted in the Malaise trap results. These results amazed some growers and consultants and emphasised the abundance of predators and parasites residing in the local bushland. This data also confirmed to growers that many beneficials will move in and out of the cropping zone to provide pest control services but are vulnerable to broad spectrum insecticides.

Yellow sticky traps for thrips

Sticky traps were the standard yellow sticky trap placed at crop height approximately, 15 cm above ground level. Traps were placed along the eastern edge of the youngest lettuce IPM planting, facing the older plantings. Traps were set for three consecutive days each week throughout the trial. Thrips counts were performed in an area of 12 cm^2 directly beside the pheromone lure strip position on the sticky trap (Table 4-2).

Table 3-2 Thrips numbers on sticky traps with different pheromone blends (Traps 1-5), or without pheromones (Trap 6).

	Trap 1	**Trap 2**	**Trap 3**	**Trap 4**	**Trap 5**	**Trap 6**
Date	trap + lure	trap + lure	trap + lure	trap + lure	trap + lure	**TRAP ONLY**
8/02/2010	1	4	2	1	1	0
11/02/2010	6	8	8	15	5	3
14/02/2010	2	6	2	2	2	2
22/02/2010	1	1	0	2	5	0
25/02/2010	5	1	1	1	1	1
4/03/2010	1	0	0	1	0	0
11/03/2010	0	0	2	0	1	0
15/03/2010	6	5	3	6	1	2
Total	**24**	**25**	18	**28**	16	**8**

Sticky traps can be used to monitor for thrips presence, species composition and population number. The above data would seem to indicate that the addition of any of the five new pheromone blends to attract thrips has improved trap performance. The blends on traps one, two, and four seem to have been most effective. The addition of a thrips-specific pheromone lure to improve, detection of thrips would also be of value in protected cropping situations.

Sticky traps are currently problematic to use in the field as a thrips monitoring device, due to wind-blown soil contamination and the sheer number of other insects that blunder into and stick to, the traps.

The data presented here were collected as part of the IPM lettuce demonstration trial that used yellow sticky traps as a means of testing if the trial pheromones improved thrips detection. Unfortunately, thrips on sticky traps are difficult to remove and identify down to species level, so a detailed list of thrips species detected in this trial using this method cannot be reported at this time. However, the results do suggest that pheromone blends one, two and four show the most potential to attract thrips to in-field traps.

Malaise trap

The Malaise traps were bidirectional (a separate sample on each side of the trap) and aligned with the long axis North and South so as to catch insects in the prevailing East/West wind direction as they travelled to, or across, the cropping zone (Figures 4-3 and 4-4).

Each trap was opened and allowed to catch passing insects for three days each week for the duration of the IPM demonstration trial, to give insight into the prevalence of naturally occurring beneficials and to determine the influence of neighbouring bushland on beneficial numbers.

Wasps, beetles and spiders were the most prevalent naturally occurring beneficial insects caught in these interception traps (Table 4-3). Wasps are reported here as one number but this consisted of wasps from four groups that are significant agricultural parasitoids (Ichnemonidae, Braconidae, Specids, and Vespids). Beetles were flying in and out of the cropping zone as were robber flies, pirate bugs and spiders. It is unclear how many spiders climbed up into the catching jars to reach trapped insects, and how many were intercepted while “web flying” on prevailing winds. Many small spider species were trapped, suggesting the trap intercepted their movement rather than them being attracted to existing caught prey. Location and surroundings do seem to have had an effect on the insects caught in each location.

The bush trap (located on the edge of the neighbouring bush) caught the most beetles, wasps, mantids, and robber flies (Figure 4-3). The east side of this trap was approximately ten metres from neighbouring bush and seems to have intercepted a lot of insects moving out from this bushland vegetation. The west side, which faced the crop zone, caught significantly fewer insects moving back into the bush zone.

Table 3-3 Beneficials caught in the Malaise trap over 23 days by location

Location	Robber Fly	Hover Fly	Lace Wing	Pirate Bug	Damsel Bugs	Mantids	Beneficial Wasp	Beetles	Spider
Bush East	8	2	0	4	1	7	**137**	**127**	23
Bush West	10	0	1	1	0	3	60	52	29
Bush Total	**18**	**2**	**1**	**5**	**1**	**10**	**197**	**179**	**52**
Crop East	0	1	0	2	2	2	44	16	41
Crop West (dam)	1	8	1	9	**12**	0	51	25	48
Crop Total	**1**	**9**	**1**	**11**	**14**	**2**	**95**	**41**	**89**

Figure 3-3 Bush Malaise trap with bush to the left (East).

The trap located within the cropping area still intercepted a good range and number of beneficial insects (Table 4-3, Figure 4-4). Note that the West side (right) of this trap was beside a small dam within the cropping area and the water body seems to have influenced insect numbers slightly (Figure 4-4). If bush flies were included in the count this water influence would have been more obvious.

Figure 3-4 Crop Malaise trap with dam on the right (West). More insects are on the dam side.

The Malaise trap catching area was 1.7 m high and 1.2 m long giving a total trapping area on one side of 2.04 m^2, so so over 23 days of the trial, considerable numbers of beneficial insects moved across the entire area.

Let's do some hypothetical maths – Wasp potential.
Based on the above results had a trap been left out for the entire 79 days in the crop zone, then 326 naturally occurring beneficial wasp (79/23 x 95) may have been caught. If the trap was the entire length of a block (170 m), then 32 600 naturally occurring beneficial wasps could have been trapped. That large potential beneficial resource should be looked after through crop scouting and a conscious choice of soft option products. Although theoretical, this wasp availability calculation does highlight the potential value of a healthy beneficial insect population. Not all the wasps collected are likely to be feeding on pests within the lettuce crop and ideally a pest-beneficial ratio is used to evaluate the beneficial potential.

Variety trial

Historically many of the *Nas*- resistant lettuce lines tended to only have a short production period in the Queensland summer season where they performed as well as the standard commercial lines. This variety trial was open to all commercial seed companies who wished to be involved and thought they had a potential *Nas*- resistant summer lettuce candidate. Rijk Zwaan, Nunhems and Syngenta seed companies took up the challenge and entered commercial or semi-commercial lines for evaluation. Results for the Nunhems line are not in the results table (Table 4-4) as the variety used in this trial has been superseded by new material.

Sixty to seventy lettuce of each CLA variety were transplanted in blocks 1.5 m wide by 6 m long with the standard commercial variety *Raider* as part of the last two plantings within the IPM demonstration block Several CLA resistant varieties performed well in this late summer planting. The first planting endured some hot conditions during growth, while the second planting grew into cooler autumn conditions. RZ 45-08 performed well in the initial trial with good lower leaf, good butt size, excellent ground cover, and good colour saw it rating as well as the commercial standard *Raider* (a Seminis variety). *Bernadinas*, another Rijk Zwaan variety, had less lower leaf but was still commercially acceptable. Queensland summer lettuce growers prefer a lettuce with good lower leaf growth as this provides good ground cover, presents well in a box, and prevents soil splash and heart discolouration caused by summer storms.

The second trial transplanted on the 11th of February 2010 grew into cooler conditions, with all trial lines being commercially acceptable at harvest (Table 4-5, Figure 4-5). R.Z *Bernadinas* had good weight with a little less lower leaf than *Raider*. This good weight and reduced lower leaf seemed to indicate a potential for the bagged lettuce market in cooler growing periods. Uniformity of the line *Ice Green* from Syngenta had improved in this later planting, and the variety was commercially acceptable. This improved performance compared to the initial planting may indicate a preference for cooler growing conditions. This variety trial was assessed and viewed by a number of local growers and local reseller suppliers throughout the course of the trial and at maturity, providing an opportunity for discussion, comment and feedback.

Figure 3-5 CLA resistant lettuce assessed 29/03/10.

Rating Scale: 1 = poor
3 = commercially acceptable
5 = excellent

Table 3-4 First trial - CLA resistant variety trial transplanted 1st February 2010

Date assessed	Company	Variety	Uniformity	Head Diameter (mm)	Days to Harvest	Lower Leaf	Bolting (core length mm)	Butt Diameter (mm)	Average Wt (g)	Disease Rating	Overall Rated
15/03/2010	Syn	Ice Green	2	160	3	4	52	25	700	4	2
	R.Z	RZ 45-08	4.5	140	7	4.5	45	30	820	4	4.5
(43 day crop)	R.Z	Bernadinas	4	170	2	3	40	30	760	3.5	3
Commercial Standard	Sem	Raider	4	140	7	4.5	40	40	700	4	4.5

The only disease present was *Rhizoctonia sp*.

Rating Scale: 1 = poor
3 = commercially acceptable
5 = excellent

Table 3-5 Second trial - CLA resistant variety trial transplanted 11th February 2010

Date assessed	Company	Variety	Uniformity	Head Diameter	Days to Harvest	Lower Leaf	Bolting (core length mm)	Butt Diameter (mm)	Average Wt (g)	Disease Rating	Overall Rated
29/03/2010	Syn	Ice Green	3	150	0	4	60	28	875	5	3
(47 day crop)	R.Z	RZ 45-08	4	160	0	4	50	30	870	5	4
	R.Z	Bernadinas	4	180	1	3.5	60	30	950	4.5	4
Commercial Standard	Sem	Raider	4	170	1	4	50	38	925	5	4

The only disease present was *Rhizoctonia sp*.

No Currant Lettuce Aphid was present in any lettuce plantings within the IPM demonstration block or the commercial area.
Seed company name abbreviations: Syn = Syngenta;R.Z. = Rijk Zwaan; Sem = Seminis.

Improved irrigation decisions

The opportunity was taken to highlight the potential of the simple and cheap irrigation wetting front detection tool, the FullStop® (Figures 4-9). This device, developed by CSIRO is a simple method of detecting the arrival of the irrigation water wetting front at a chosen depth. Given the coarse textured, highly permeable soil of the Stanthorpe growing region wetting front detectors may give useful feedback for water and nutrient management. Both foliar and soil borne disease potential can be exacerbated by over irrigation, growers would therefore benefit by adopting a cheap yet effective soil moisture monitoring system to optimise water applications. The co–operating grower and farm irrigation staff were not familiar with this tool, providing a great opportunity to install several demonstration units, demonstrate their benefits to better manage water application and crop disease pressure, and raise local grower and reseller awareness.

Two sets of FullStop® wetting front detectors were placed within the IPM lettuce block just after transplanting. Each set of FullStops® consists of two units, one shallow, to detect and indicate that the irrigation wetting front had reached the desired level in the soil (the mid-root zone) and one deep, to indicate water entering the soil below the desired depth (below the root zone) (Figure 4-7). Once water entered the FullStop® unit it accumulated in a small reservoir and raised a small coloured indicator at the top of the unit to signify the wetting front had reached the detector. Thus, irrigation duration can be adjusted so that only the shallow indicator is triggered by an irrigation event, while the deep indicator, that detects water draining past the root zone, remains inactive. This maximises water use efficiency by targeting irrigation in the plant's active root zone. In this lettuce crop, the shallow unit was placed at 15 cm below soil level and the deep unit at 40 cm - well below the root zone.

The depth of a wetting front is hidden below ground where it is difficult for irrigation managers to monitor without some sort of monitoring device. The FullStop® units provide a simple visual indication of the amount of water (irrigation run time) required to refill the plant root zone. These FullStop® units also allow direct sampling of the collected irrigation water as it moves through the plant root zone, allowing salt and nutrient trends to be monitored (Figure 4-6).

Though not checked by trial staff after each irrigation event (daily except for periods of drizzle), it was interesting to note that the shallow devices were triggered 12 times over the course of the trial and the deep devices only triggered twice. The deep device was triggered once when the usual irrigation operator was sick and another staff member was setting the irrigation program. The second time related to a drizzly day when irrigation water and rainfall drained to depth. This example emphasises the level of skill and experience shown by the regular operator, and highlights the value of these simple indicator devices.

These FullStops® provided a timely indication of soil water movement into the crop root zone to irrigation staff who could adjust irrigation duration and frequency to maximise crop growth and water use efficiency. Several growers and resellers who visited the demonstration site said they had not seen these devices installed and in use before.

Data from this trial installation will be used to assist the co-operating grower and farm staff to fine tune nutrient applications and irrigation run times for future crops.

The graphs show soil solute levels for nitrate and conductivity declined over the length of the cropping cycle as the crop drew down nutrients in the soil (Figure 4-6). At the results at 15 cm depth, crop roots absorbed more nutrients than at 40 cm depth where no crop root activity was to be expected. This demonstrates some of the potentially useful agronomic information that can be collected while maximising irrigation efficiency.

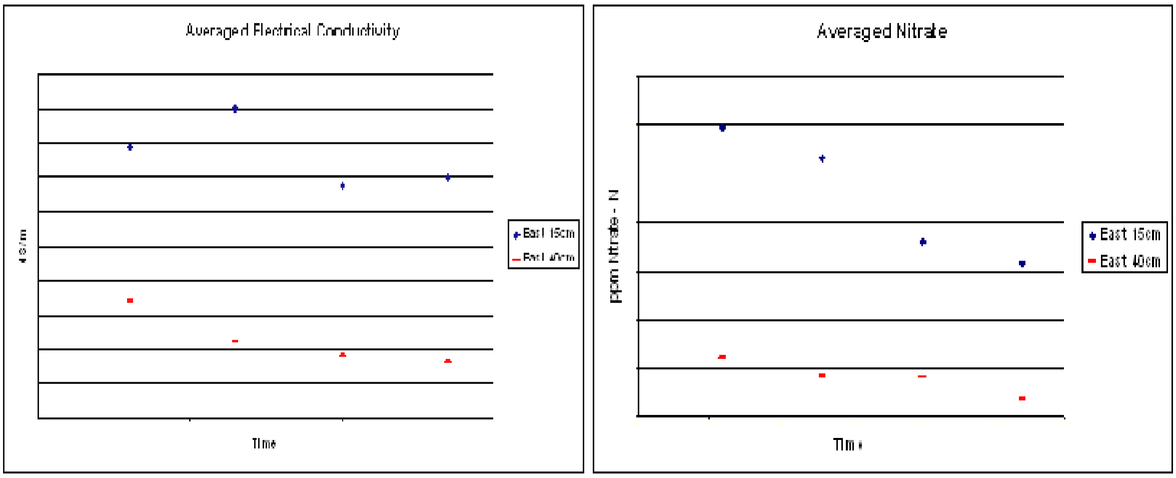


Figure 3-6 Electrical conductivity (graph on left) and Nitrate (graph on right) levels in the soil solution have decreased over the cropping cycle from transplant to harvest. The difference in the shallow (active growth – 15cm depth and marked in blue on graph) and deep (no crop roots – 40cm depth and marked in red on graph) results indicate fertilizer inputs were placed in the crop root zone.

Figure 3-7 The installed Full-Stop® on the right is the shallow detector (15 cm below soil surface) which has flag up (yellow) to indicate water has been detected. The deep unit on the left, installed at 40 cm, has not triggered showing a strong wetting front has not drained to this depth.

Figure 3-8 Shallow (15 cm) FullStop® showing lettuce root growth in and around the unit and water sampling tube on the right.

Figure 3-8 Unit removed after crop harvest. Note roots had grown into the buried unit.

Extension activities

All local resellers and crop scouts were invited to visit and observe the trial demonstration site on either of the two days a week that Qld IPM lettuce demonstration team were present throughout the period of the trial. The two local reseller representatives who visited the farm weekly and scouted insects were encouraged to also scout the IPM trial area. These local resellers, interested local growers, farm staff, and contributing seed company representatives were part of a field walk held to highlight trial outcomes when the first variety trial matured. This field walk consisted of people attending the site at a time throughout the day that suited them, allowing them time to examine the site and talk to the IPM lettuce demonstration team on a one-to-one basis. Seed company representatives were also encouraged to arrange site visits for growers that wished to view the *Nas*-resistant variety trials. This exposed new growers and growers from other districts to the IPM demonstration area and the demonstrated techniques. Growers and resellers attending the field walk were shown over the demonstration crop and shown all crop scouting and insect monitoring techniques. The use of the FullStop® irrigation monitoring tool and it's potential to better manage foliar and soil borne disease pressure was also explained to all attendees as they visited the site. The co-operating farm owner has modified his irrigation practice as a result of this demonstration work.

Media exposure

Media articles summarising the aim, methods and outcomes of the Queensland IPM demonstration trial were sent to both the Stanthorpe Border Post and Gatton Star. A grower fact sheet was produced and distributed locally.

The Lettuce Leaf newsletter issue 40 featured an article and information highlights obtained through the conduct of this on farm trial. A version of this article was also republished in the December 2011 edition of WA Grower magazine.

A video featuring the learning's of the participating grower has been produced and distributed Australia wide as part of the Lettuce Crop Protection Toolkit DVD.

A Technical Note: *FullStop® demonstration in Granite Belt lettuce: a case study,* was produced and has been distributed to growers at subsequent field days and grower information sessions DEEDI have held since September 2011.

Information sessions/meetings

The positive outcomes from this demonstration trial were highlighted at Queensland vegetable grower information sessions at Gatton 20 May 2010 and 31 March 2011, and on 29th March 2011 at Stanthorpe. The information was also presented at a Reseller/Grower day in Gatton. The information will continue to be presented as the opportunities arise at grower meetings and industry events.

Short articles about the role of beneficials, based on the IPM demonstration, were included in mail-outs to Queensland lettuce and brassica growers.

Grower co-operator comments:
"I was impressed with the result and the activity of all the insects available to act as natural predators."

"I think the trial was only exposed to medium pressure *Helicoverpa sp* activity that was increasing as the trial was harvested. This heightened pressure was evident in the increased number of moths in the *Helicoverpa spp.* moth traps in the last ten days of the trial".

"The use of Vivus Max® and Bt combined in the IPM demonstration block provided commercially acceptable control that gave the same lettuce cut as the conventionally sprayed commercial blocks".

"I'd like to see the trials repeated in a high *Helicoverpa* spp. pressure period"

"I enjoyed it and learned from the experience."

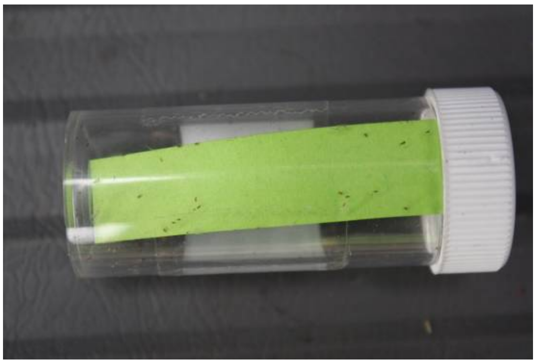
Pictorial highlights of Queensland IPM demonstration trial

Malaise trap catch bottles- note the insect catch on the dam (right) side.

Looking down into the Malaise trap catch bottle on the right (above).

Native local wasp from Malaise trap with mite in jaws.

A sorted sample with flies removed, moths, butterflies and grasshoppers in top left container, and damsel flies top right, four wasp groups, beetles and spiders.


Trichogramma sp wasp in vial.


Commercial wasp release card in plant.

First and second planting with sticky trap, *Helicoverpa sp* trap and malaise trap in background.

Malaise trap placed in the crop area to sample passing insect flights.
Insects caught separately on either side of the trap.

Local resellers inspect crop.

Farm hand inspects crop.

Local growers inspect crop.

Harvested second planting.

Owner is still smiling.

5. IPM Demonstration/Trial – Sydney Basin

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Introduction

Development of integrated pest management (IPM) strategies for managing pests in lettuce in Australia has been underway since 1999. Research initially focused on options for *Helicoverpa* spp. and sclerotinia. Extension activities helped raise awareness about IPM. A combination of events, including heavy crop losses, an experienced IPM consultant working with lettuce growers who were also growing celery, more relaxed control of use legislation for agricultural chemicals and a processor pushing adoption, led to a significant proportion of the Victorian lettuce industry adopting an IPM strategy. The arrival of current lettuce aphid (CLA), *Nasonovia ribisnigri* in 2004 in Tasmania threatened to undermine all the previous investment into IPM. A commercial scale IPM demonstration-trial was conducted on the Devonport DPI&W research station.

In June of 2006 the first winter IPM trial was conducted at Eddie Galea's in the Sydney basin after CLA was first observed on the property in April of that year. Two blocks of lettuce planted on 1st June were monitored weekly and at harvest 30% and 10% of the lettuce had less than 20 aphids per lettuce, an unacceptably high infestation. It was observed that the beneficials numbers increased in September and that the lettuce was quickly cleaned up of aphids after that time. Since the 2006 IPM demonstration most of the lettuce planted was with *Nas*-resistant varieties. When *Nas*-resistant head lettuce was not available, lettuce was treated with Confidor® at the seedling stage. Throughout this period, small plantings of *Nas* susceptible fancy lettuce were planted and monitored, and with no CLA observed since September-October 2008. In 2009 a second IPM demonstration trial was conducted with four consecutive plantings at weekly intervals in September.

Site:
Werombi (S34.00435°, E150.55968°) is ~20km north-west of Camden, in the south-west corner of the Sydney basin, at the foot hills of the Blue Mountains. On the 52 ha of undulating land iceberg lettuce and cabbages, and some regular small plantings of cos, fancy lettuce, endive, and radicchio are cultivated. At times they also grow cauliflower, spinach and pumpkins.

On the north western and western edge of the planting area is native bushland. Three recycling dams are within the cultivated area. The land to the south is weedy grassland.

Materials and methods

Four plantings were planted a week apart from 1st September 2009. Each trial block of *Nas* susceptible lettuce varieties consisted of 10 beds of 4 rows of a Cos lettuce and 10 beds of iceberg lettuce (var *Patagonia*). 1 tray of 198 seedlings was planted per bed before *Nas* resistant varieties were continued along the rest of the bed. Each block was approximately 2000 seedlings. The trial was managed as for commercial plantings. Andy Ryland, Eddie Galea's IPM crop consultant, initially monitored 20-25 plants per week with a vacuum sampler and visually once the lettuce start hearting. At harvest the 15-16 heads were harvested and later stripped leaf by leaf to identify and count insects.

Three field days were held for local growers to follow the demonstration planting through at fortnightly intervals.

Results and Discussion

Table 5-1 lists the suite of pest and beneficial insect or mite species recorded from the vacuum and visual monitoring or harvest assessments.

Table 5-1 Pest and Beneficial insects collected in trial sampling September-November 2009

PEST SPECIES	
Currant Lettuce aphid	*Nasonovia ribisnigri*
Brown Sowthistle aphid	*Uroleucon sonchi*
Onion thrips	*Thrips tobaci*
Western flower thrips	*Franklienella occidentalis*
Common brown leafhopper	*Orosius argentatus*
Vegetable leafhopper	*Austroasca viridigrisea*
Rutherglen bug	*Nysius vinitor*
Helicoverpa spp.	*Helicoverpa punctigera*
Mirid	Miridae
BENEFICIAL SPECIES	
Transverse ladybeetle	*Coccinella transversalis*
Spotted amber ladybeetle	*Hippodamia variegata*
Minute 2 spotted ladybeetle	*Diomus notescens*
Damsel bugs	*Nabis kinbergi*
Brown lacewing	*Micromus tasmaniane*
Green lacewing	*Mallada signatus*
Rove beetles	Staphalinids
Hover fly larvae	Syrphidae
Predatory thrips	*Haplothrips* spp.
Parasitoids	Aphilinidae
Predatory mites	
Spiders	various

Rain conditions prevented visual or vacuum monitoring every week Table 4-2 records the numbers of insects or mites that were observed. Currant lettuce aphid was observed only twice in vacuum samples. Brown sowthistle aphids were picked up in September. *Helicoverpa* spp. eggs and some small larvae were observed in all but one sampling day. Beneficials insects or mites were not observed in the visual monitoring but collected in all the vacuum samples. Brown lacewings were the most frequently observed aphid predator.

No aphicides were applied, and one Vivus® application was made against *Helicoverpa* spp. caterpillars.

Table 5-2 Numbers of insects per lettuce from visual or bugvac assessments

Date	# plants vac	Sampling	planting	CLA	BSA	Onion thrips	other thrips not WFT	*Helicoverpa spp.* (e, s, m, l)	other lepidoptera	BLW Larvae	BLW adults	Ladybird adult	Spider	predatory mites	Damsel bug
8/09/2009	20	visual	1					eggs							
17/09/2009	20	bugvac	1		1W					1	1	1	3	few	
24/09/2009	20	bugvac	1	2W	4W		3	1s		1	2	3	2	few	1
24/09/2009	20	visual	2					eggs		2	2	2		few	2
1/10/2009	20	bugvac	1		2W	2	8	1s	1	3	5	2	4		2
1/10/2009	20	bugvac	2	2				eggs			4				
1/10/2009	20	visual	3												
14/10/2009	20	visual	1												
14/10/2009	20	visual	2												
14/10/2009	20	visual	3												
29/10/2009	20	visual	1												
29/10/2009	25	bugvac	2				3	1s		6	3	8	3		
29/10/2009	25	bugvac	3					2s & e			2	6	2		

W= winged, s=small=1 or 2 instar, e= egg

Just prior to the grower harvesting the lettuce 15-16 lettuce were cut and returned to the laboratory to be stripped leaf by leaf to count any contaminating insects (Tables 5-3 & 5-4.). The first planting was not harvested quite when expected so a second harvest assessment was made.

Thrips, mostly onion thrips, and Rutherglen bugs were present in virtually all lettuce at each harvest assessment, and contributed most to the relatively high numbers of pests per lettuce (averaging between 5.25-17.67 for each harvest assessment) (Table 5-3 and Figure 5-1). CLA was of most interest because it prefers to be within the lettuce head rather than on the outer leaves where most of the other pests are found. In project VG04067 ('*Integrating lettuce aphid into IPM for lettuce- a commercial trial*') it was found that growers and lettuce buyers tended not to notice an infested lettuce with less than 30 aphids probably because they tend to be dispersed and many are very small. In this trial CLA was observed in 5 of the 15 lettuce in the first harvest assessment, and in 9 of the 15 lettuce in the second harvest assessment from planting 1. All the lettuce with CLA had less than 30 aphids and only 1 had greater than 10 aphids present. Planting 2 had higher numbers of CLA, with 11 of the 16 lettuce containing CLA and one of those lettuce had more than 30 CLA with 62 aphids counted. In planting 3, CLA was found in 6 lettuce, with two having more than 10 aphids but neither was greater than 20. Planting 4 had no CLA detected.

Table 5-3 Numbers of pest insects per lettuce from harvest assessment (15-16 lettuce)

Date	planting	CLA	BSA	WFT	Onion thrips	other thrips	*Helicoverpa spp.*	other lepidoptera	Rutherglen Bugs	Green leaf hopper	Brown leaf hopper	Mirid	Total pests
2.11.09	1	2	0.07	0.33	0.27	0.27	0.13	0	8.07	0.13	0.13	0.07	**11.47**
11.11.09	1	1.88	0.06	0.75	0.94	0.19	0.19	0.06	1.19	0	0	0	**5.25**
11.11.09	2	6.94	0	0.44	1.94	0.56	0.44	0	5.44	0	0.06	0	**15.81**
25.11.09	3	2.88	0	0.63	2.50	0.13	0.56	0	0.50	0	0	0	**7.19**
10.12.09	4	0.00	0.00	1.40	9.20	1.00	0.07	0.00	3.80	2.20	0.00	0.00	**17.67**

Beneficials were detected in the stripped lettuce at harvest with brown lacewings and ladybird beetles (both Transverse ladybird beetles and Spotted amber ladybird beetles) being the most commonly observed (Table 5-4 and Figure 5-2). Beneficials were found in most of the harvested lettuce with only 1, 3, 7, 2, and 2 lettuce found without any beneficials in the first and each of the subsequent harvest assessments, respectively. Planting 1, harvest 1 had predatory mites present in 8 of the 15 lettuce stripped. All but 1 of the lettuce that didn't have predatory mites had brown lacewing adults, and only 1 of the lettuce had both. The second harvest of Planting 1 saw fewer predatory mites, 1 each in 4 lettuce, and 8 lettuce had brown lacewings. Again, only 1 lettuce had both insects. Planting 2 had fewer beneficials, 16 spread across 9 of the stripped lettuce. Planting 3 had beneficials in all but two lettuce. Ladybeetles and lacewings were the most numerous. Beneficials were found in all but 2 lettuce in Planting 4, and most of those were ladybird beetles and staphylinid beetles.

Table 5-4 Numbers of beneficials per lettuce from harvest assessment (15-16 lettuce)

Date	planting	**Hoverfly Larvae**	**BLW Larvae**	**BLW adults**	**Ladybird Eggs**	**Ladybird adult**	**Spider**	**predatory mites**	**PredatoryThrips**	**Staphylinid Beetle**	**Damsel bug**	**Wasp**	**Greenlacewing larvae**	**Total beneficials**
2.11.09	1	0	0.07	0.53	0	0.27	0.07	0.67	0.00	0.13	0.33	0.20	0	**2.27**
11.11.09	1	0	0.06	0.88	0	0.31	0.06	0.25	0.06	0.13	0.06	0	0	**1.81**
11.11.09	2	0.13	0.19	0.06	0	0.25	0.00	0.13	0.06	0.19	0	0	0	**1.00**
25.11.09	3	0	0.31	0.81	0.06	1	0.44	0	0.13	0.31	0	0	0	**3.06**
10.12.09	4	0.07	0.00	0.47	0	1.53	0.73	0	0.20	1.07	0.00	0.0	0.07	**4.13**

Figure 5-1 Average numbers of pests per lettuce at harvest for plantings 1-4

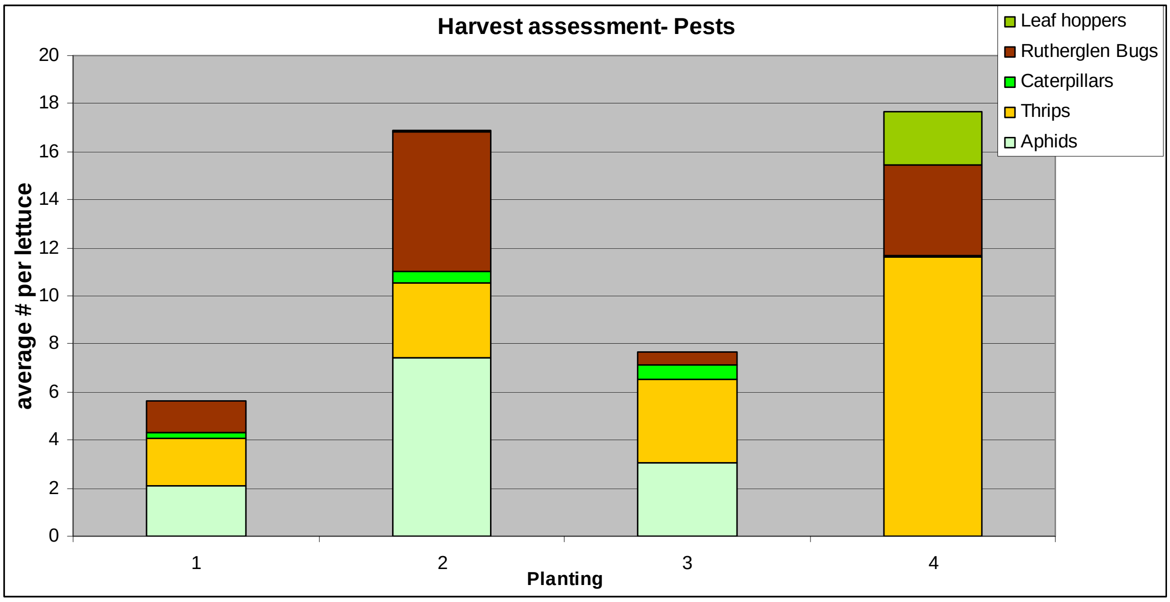
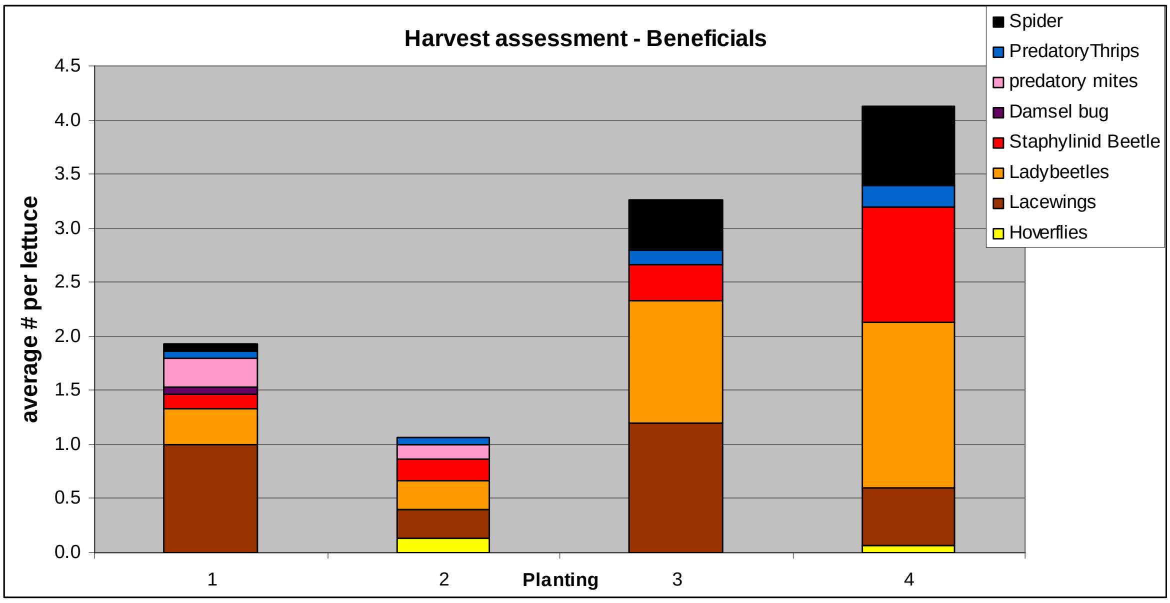


Figure 5-2 Average numbers of beneficials per lettuce at harvest for plantings 1-4



Field days

Three field days were scheduled to follow through plantings at fortnightly intervals: 6th October, 22nd October and 5th November 2009.

The first was scheduled to have a consultant session in the morning and a grower session in the afternoon with a joint lunch. It was to review IPM basics, review the trial plantings, and update on latest IPM research from other groups. One consultant arrived. Although close to 20 growers and consultants send an RSVP, it was the first fine day after a period of rain and after a long weekend.

The second field day was attended by 25 growers and industry people (seedling, seed or input suppliers or consultants). The day was modified to have a shortened version of the IPM basics session. Participants looked at insects collected with the BugVac vacuum sampler from the trial lettuce with Sandra McDougall (NSW DPI). Andy Ryland, (Beneficial Bug Company) (now IPM Consulting) explained his monitoring results and recommendations for the insect management of Eddie's lettuce. Sylvia Jelinek (NSW DPI) discussed the basic principles of regular monitoring, using selective chemistry and role of beneficials in managing insect pests in lettuce. Then Tony Napier (NSW DPI) proceeded with the planned spray application review activities. He conducted small group exercises for calculating dilutions, calibrating spray booms and using water sensitive paper for assessing spray coverage. After lunch there was an information session on the WaterSmart and NutrientSmart projects and a brief update on other components of the lettuce project.

The third field day was scheduled again to have a morning consultant session and an afternoon grower session with a combined lunch. The focus of the day was lettuce disease management. Twenty-two growers and consultants participated. Len Tesoriero and Leanne Forsyth, (NSW DPI resident plant pathologists from Camden) led the discussion on management of lettuce diseases. They discussed fungicide issues that were of importance to the field lettuce industry. Lettuce breeder Stephen Mitchell (Enza Zaden) discussed variety resistance, with a focus on Downy Mildew (*Bremia lactucae).* IPM accreditation for growers and IPM consultants was promoted by Leigh Pilkington and Sylvia Jelinek (NSW DPI), with an overview by Andy Ryland (BBC) on how the accreditation scheme would work for growers and consultants alike in the Sydney Basin.

Both the participating grower, Eddie Galea and his consultant Andy Ryland were included as a video case study on lettuce IPM for the Lettuce Crop Protection Toolkit DVD. An article was included in the NSW IPM Newsletter issue 9 in January 2010.

Field Day in pictures

Andy Ryland, Beneficial Bug Company gives a run-down on IPM and the IPM Demonstration trial to local growers and agronomists.

Sandra McDougall demonstrating the bug-vac or vacuum sampler.

Viewing the bugs collected with some local growers

Tony Napier explaining good spray application and the calibration exercise

Bucket collection from boom calibration

Measuring the nozzle output

Spray coverage exercise

Using water sensitive paper and water in the spray boom to test coverage

Water sensitive paper on plant

Under lower leaf- poor coverage

Under upper leaf –reasonable coverage

Under upper leaf – excellent coverage

6. Monitoring CLA populations on untreated susceptible lettuce in NSW

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Introduction

In 2007/8 very few growers or crop consultants were seeing signs of currant lettuce aphid (*Nasonovia ribis nigri*, CLA). Since most of the industry was using imidacloprid (Confidor®) as a seedling drench, one would not expect to see CLA. Many of the hydroponic growers were not using Confidor® and had some plantings of *Nas*-susceptible lettuce, usually fancy lettuce varieties, which could be sprayed effectively with foliar sprays if CLA did infest.

In Hay, NSW all growers used Confidor® on *Nas*-susceptible lettuce after CLA was confirmed in October 2006. Lettuce is grown in Hay from early February until November. The only known hosts for CLA that could bridge across the hot Hay summer were wide chicory (*Chicorium intybus*) and possibly prickly lettuce (*Lactuca serriola*). Neither are very prolific over summer. Some of the Hay lettuce growers purchase their seedlings from commercial nurseries. It was therefore hypothesized that CLA would have to re-infest the area each year, given the harshness of the summer and the relative scarcity of potential bridging hosts. This could not initially be tested given that no grower was prepared to forgo Confidor® treatment throughout 2007 and 2008. In 2009, after getting agreement from one grower to plant a single seedling tray of untreated lettuce each week, another grower chose not to treat any of their lettuce with Confidor®.

In 2008 a PhD project funded under the Plant Biosecurity CRC erected six 8 m tall suction traps in an attempt to model CLA movement. Two traps were located in northern Tasmania, one in Cranbourne, Victoria, one at Yanco, NSW, and two in South Australia – one of which was a mobile unit. These traps were designed to collect samples into daily batches.

Materials and methods

Two commercial crop consultants were utilized to monitor non-Confidor® treated *Nas*- susceptible lettuce and Confidor® treated lettuce, in Sydney and Hay, NSW.

In Sydney, a commercial grower, Eddie Galea maintained some plantings of lettuce that were neither treated with Confidor® nor *Nas*- resistant varieties. Usually one or other of the fancy lettuce varieties fitted this category and from October 2008 he planted a tray (198) of untreated head lettuce (var. *Patagonia*) when larger plantings were not being planted. Andy Ryland from Beneficial Bug Company monitored Eddie's lettuce on a weekly basis and kept specific records from the untreated lettuce. The initial plan was to conduct monthly destructive samples but this was suspended when no CLA were detected in monitoring.

In Hay from March-November 2009, a crop consultant, Rob Weppler from Riverina IPM, monitored on a weekly basis commercial *Nas*-susceptible and untreated lettuce. Destructive samples of 15 Confidor and 15 non-Confidor® treated lettuce were made on 4 occasions, and one additional sample of 15 non- Confidor® treated lettuce was made.

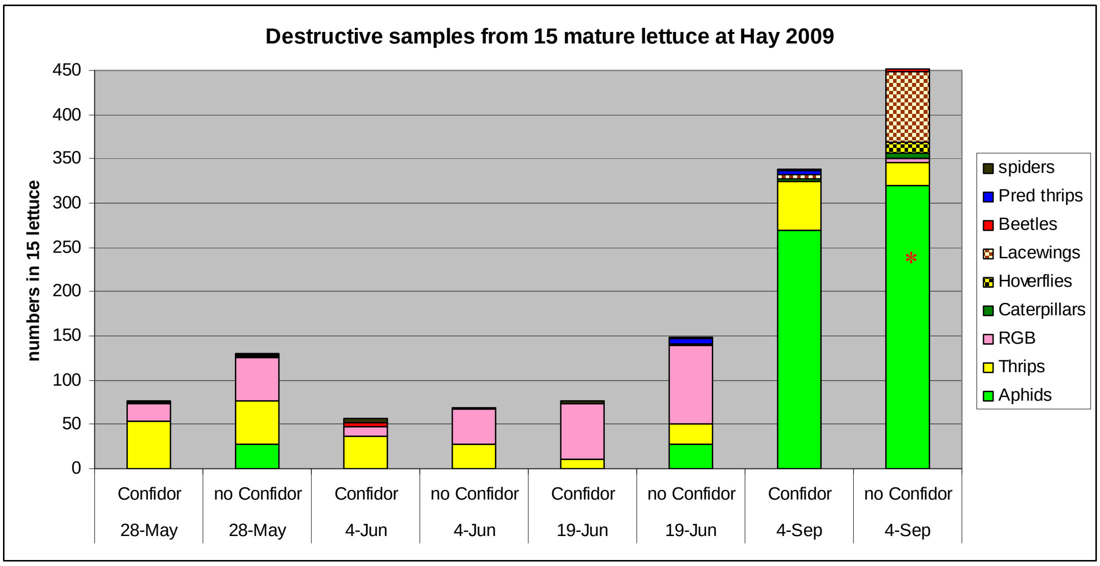
The Yanco suction trap samples were sorted at Yanco and all aphids identified by Alan Boulton (NSW DPI). The other suction trap samples were mailed to Craig Feutrill (PhD candidate at University of Adelaide) for sorting and identification.

Results

Hay

At Hay, approximately 25 plants were vacuumed, and 25 plants visually inspected, per 2-3 ha block. Approximately 7 blocks per week were inspected across three farms - one used *Nas*-susceptible varieties and did not treat with Confidor®. One pre-hearted and one pre-harvest crop was inspected. No CLA was detected in lettuce during the monitoring at Hay. Nine destructive samples of 15 heads each were taken. In all but one case 15 were taken from Confidor® treated, and 15 from non-Confidor treated lettuce (Figure 6-1).

Figure 6-1 Results from destructive samples taken from paired Confidor® and non-Confidor® treated lettuce



* Note this sample had another 1000+ brown sowthistle aphids

Primarily brown sowthistle aphids (*Uroleucon sonchi* BSA), were observed in the non-Confidor® treated lettuce in low numbers on 28th May and 19th June. A destructive sample taken from non-Confidor® treated lettuce on 28th July 2009 saw an increase in BSA to 408 in 15 lettuce, which included 5 lettuce that had greater than 30 per head. The 4th September destructive sample saw BSA in the Confidor® treated lettuce, and 150+ BSA in all 15 of the non-Confidor® treated lettuce. This later sample also saw a large increase in beneficials. It was noted that in a block where harvest was delayed by a week, the beneficials had cleaned up the BSA.

Sydney

In Sydney in June 2008, two winged CLA were sampled from 50 head lettuce (var. *Patagonia)*Table 6-1. On 18th July 2008, 'some' CLA were vacuumed from 100 red mignonette lettuce. It wasn't until 24th September 2009 and again on 1st October 2009, that CLA were observed in a vacuum or visual assessment, and 2 out of 20 lettuce were collected on those dates. These coincided with larger areas planted to CLA-susceptible head lettuce for a second IPM demonstration (see chapter 4. IPM Demonstration/Trial-Sydney Basin). After the demonstration trial was harvested, the regular weekly monitoring of small susceptible plantings hadn't resulted in any further detections of CLA.

Destructive samples were made in September, October, November 2008, January, November and December 2009. On 12th September 2008, a red mignonette variety that was planted 14th June had 10 of 12 lettuce with 'high' (61-120) or 'extreme' (>121) numbers of CLA. The sample assessed 16th October 2008 was a hearting lettuce (var. *Patagonia*) which had been planted 14th August, and had only 1 of 16 lettuce with 'medium' (31-60) numbers of CLA, and had an average of 3.75 CLA per lettuce. A 15th September planted *Patagonia* variety had 3 CLA in 14 heads harvested on November

12th. A *Casino* variety headlettuce planted 2nd December 2008 and harvested 14th January 2009 had no CLA in 14 assessed heads.

Table 6-1 Dates, variety and sampling method when currant lettuce aphids found in lettuce checked weekly from June 2008-June 2010 in Werombi, Sydney

DATE	Variety	CLA	Number sampled	Method
19 June 2008	Patagonia	2 winged	50	visual
18 July 2008	Red mignonette	Some	100	bugvac
12 Sep 2008	Red mignonette	2844	12	stripped
15 Oct 2008	Patagonia	60	16	stripped
9 Nov 2008	Patagonia	3	14	stripped
14 Jan 2009	Casino	0	16	stripped
24 Sep 2009	Patagonia	2 winged	20	bugvac
1 Oct 2009	Patagonia	2	20	bugvac
2 Nov 2009	Patagonia	30	15	stripped
11 Nov 2009	Patagonia	28	15	stripped
11 Nov 2009	Patagonia	104	15	stripped
25 Nov 2009	Patagonia	43	15	stripped

The four *Patagonia* plantings that were the basis for the 2009 IPM Demonstration, including the two plantings that contained CLA when vacuumed in September and October 2009, had destructive samples taken after they had hearted prior to harvest. Planting 1 (P1) had two destructive samples taken a week apart. Each composit 15 lettuce sample stripped had a total of 30 (P1), 28 (P1), 104 (P2) and 43 (P3) CLA, which averaged between 1.88 and 6.94 in each lettuce. The fourth demonstration planting (P4), had no CLA detected in 15 lettuce stripped on 10th December 2009.

Suction Trap

Only 1 Nasonovia ribisnigri CLA aphid had been identified from the many thousands of aphids collected in the daily samples from the six suction traps that had been in operation since October 2008-2010 (Craig Feutrill pers. com) and from October 2008- August 2011 at the Yanco site.

Discussion

Although the sampling was not as consistent as is desirable, it had to fit in with the commercial scouts' monitoring requirements, vagarities of weather, and fixed monitoring days. The data suggest that CLA is not a consistently devastating pest as first thought when it first colonized each production area. It disappeared from Hay, probably because there was no alternate host crop. However if growers in Hay all stop using Confidor®, then they will need to have a monitoring program, given some growers do bring in lettuce seedlings from other production areas. The winter and spring of 2009 saw very high numbers of brown sowthistle aphid, but the lettuce affected were destined for processing, so the outer leaves were removed at harvest and the hearts met processor specifications. CLA did colonise the susceptible lettuce in Sydney but only in some of the spring plantings, and generally only in low numbers. On the basis of this, even non-IPM growers should consider narrowing the window that Confidor® is used on field grown head lettuce, and to concentrate on the early spring plantings.

7. Currant Lettuce Aphid studies in Victoria

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Summary

Currant lettuce aphid (*Nasonovia ribisnigri*) and its control using an IPM strategy was studied in several commercial lettuce crops in Victoria. Sites were in two production areas, Werribee South and Cranbourne. Numbers of aphids and other species (especially beneficial species) were monitored over two production seasons in Victoria by IPM Technologies P/L. Currant lettuce aphid was controlled without insecticide drenches at these sites by a range of predatory species of insects. Brown lacewings (*Micromus tasmaniae*) were the most important predators at these sites.

Introduction

Currant lettuce aphid was first recorded in Victoria in 2005, and soon spread to crops throughout both Werribee South and Cranbourne districts. The control method that the bulk of the industry adopted at that time (and remains largely so today) was to drench seedlings with a high rate of imidacloprid (Confidor®, 1.1 ml ai per 1000 seedlings). This was given approval by the APVMA, but the permit noted that the industry should develop an IPM alternative.

Some growers in Werribee South and Cranbourne had been using an IPM approach on their lettuce crops prior to the arrival of currant lettuce aphid and their use of aphicides in the previous 5 years had been almost zero. Several growers were prepared to grow non-drenched susceptible lettuce, but most were required to use the drench because of interstate trade.

Materials and methods

Studies were undertaken in commercial crops in Werribee, and additional observations were made in Cranbourne. In 2005–2007 the number of currant lettuce aphids, brown lacewings and hoverflies were counted in 15 lettuces sampled from the week after transplant until harvest. This was done in the field, by destructive sampling and visual inspection, leaf by leaf. It was carried out on commercial crops where no Confidor® drench had been applied, and susceptible varieties were grown.

The 2008 study was to assess the number of key invertebrate species present at harvest in iceberg lettuce. The 2009 study was to monitor aphid and other invertebrates (especially western flower thrips) weekly for the life of an iceberg lettuce crop (about 7 weeks).

For the 2008 study the number of aphids and other invertebrate species were recorded weekly in commercial crops in Werribee between January and April at 7 sites. There were 6 sites where Confidor® drenching was used on seedlings (non-IPM sites) and one IPM site where no Confidor® drench was used. In this study 10 lettuces were sampled each week from plantings where the crop was being harvested. Each lettuce was examined in the field by inspecting each leaf, and checking for the presence of western flower thrips (*Franklinella occidentalis*, WFT), other thrips, including predatory thrips, and predatory mites. Each thrips found was collected and placed on a yellow sticky card which was covered with a strip of cellophane and returned to the laboratory where they were identified. The number of each of these species present was recorded for each lettuce.

For the 2009 study the same type of species were recorded. In this study lettuces were sampled from 4 sites in Werribee South (3 non-IPM sites and one IPM site) for a 6 week period from 2 weeks after transplant until harvest. This was carried out in February-March 2009.

In addition to seedlings not being drenched with Confidor®, the IPM crops were not sprayed with any broad-spectrum insecticides for any pests, and products such as Dipel® (*Bacillus thuringiensis*) and GemStar® (nuclear polyhedrosis virus) were used for caterpillar control as required. The non-IPM crops were sprayed with a range of insecticides for caterpillars, that included broad-spectrum insecticides. In 2007-2008 some crops were sprayed with pymetrozine (Chess®) in the early stages. No aphicides were used in 2005–2006.

Results

IPM lettuce crops are grown commercially in both Werribee and Cranbourne using undrenched, CLA susceptible varieties as well as the use of some resistant varieties. "IPM-grown" here means no use of broad-spectrum insecticides for any pest. In addition to currant lettuce aphid, other pests that frequented the field sites were *Helicoverpa spp.* (*Helicoverpa armigera* and *H. punctigera*), loopers (*Chrysodeixis argentifera*) and cutworm (*Agrotis spp.*). Rutherglen bug (*Nysius vinitor*), redlegged earth mite (*Halotydeus destructor*) and other aphid species were occasional problems at some sites.

These pests were all dealt with using an IPM strategy, and overall, problems with currant lettuce aphid at harvest were minimal. Brown lacewings and hoverflies were the main predators controlling currant lettuce aphid. Figure 7-1 illustrates how these predators controlled currant lettuce aphid over the production season in 2005–2006. No aphicides were applied. Note that the samples were taken prior to harvest, and the actual numbers of currant lettuce aphid at harvest were less than indicated (see Figure 7-2), and no lettuce were rejected from these sites because of currant lettuce aphid.

Figure 7-1 Total brown lacewings plus total hoverflies (BLA + HF) compared to total CLA in a commercial iceberg lettuce crop in Werribee South, 2005–2006

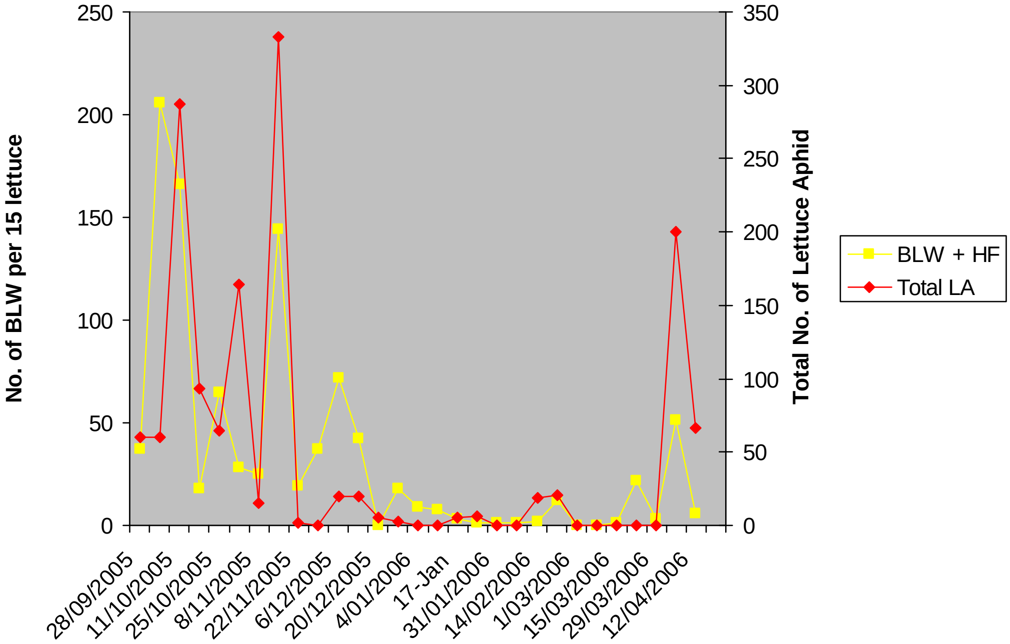
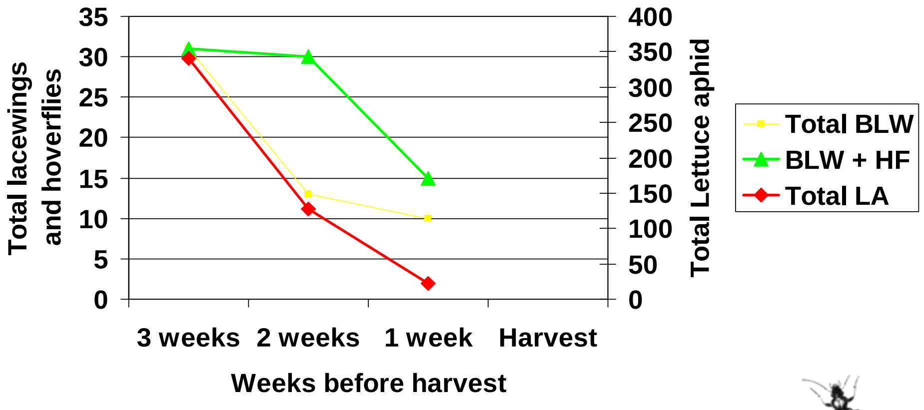


Figure 7-2 Reduction in lettuce aphid numbers approaching harvest, 2005-2006. BLW = brown lacewings, HF = hoverflies, LA = currant lettuce aphid



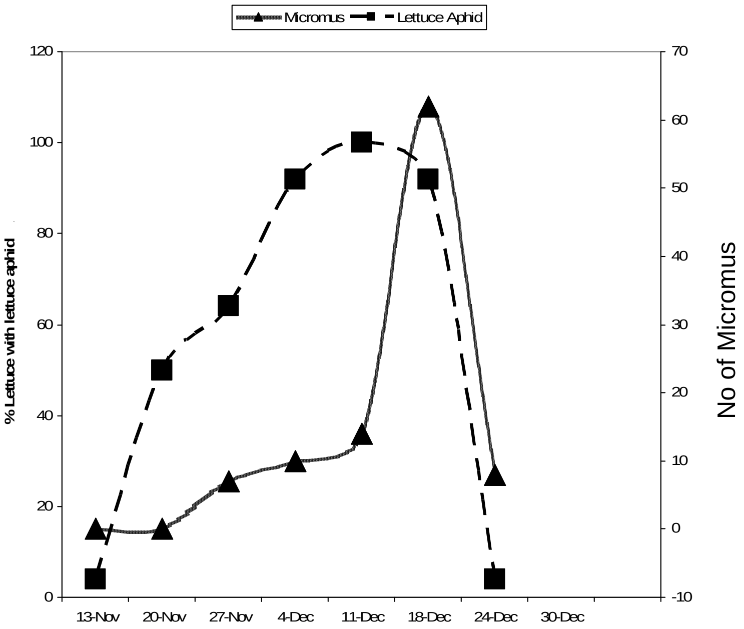
IPM Technologies Pty Ltd

A field day was held near Cranbourne at Peter Schreurs and Sons farm to demonstrate how lettuce aphid had been controlled in Cos lettuce since the arrival of currant lettuce aphid. A video of this field day was produced by the IDO. That farm had grown Cos lettuce continually since that time and still had never used Confidor® drenched seedlings, but had relied on an IPM approach to deal with all pests.

The same result has been achieved in Werribee South with participating growers since the arrival of currant lettuce aphid. In the last production season (2007-2008), we obtained the same results, although unlike the first year, pymetrozine (Chess®) was sprayed on the very young plants in the first week after planting. Brown lacewings were the main biological control agents involved in controlling currant lettuce aphid again. Results for one planting are shown in Figure 7-3.

Once again the final assessment was made a week before harvest, and the grower reported that there were no currant lettuce aphid found in the crop at the time of harvest. Similarly brown lacewings also left the crop once their food source (currant lettuce aphid) was exhausted.

Figure 7-3 Numbers of Micromus found in 10 lettuce and the percentage of lettuce with currant lettuce aphid present throughout the life of one planting.



Numbers of western flower thrips were higher in non-IPM crops than the IPM crops in both studies in Werribee (Figures 7-4a-d, 7-5, 7-6a-f and 7-7). Thrip feeding predatory mites, predatory thrips and the predatory beetle, Dalotia (Staphilinid) were found more commonly in the IPM crops than the non-IPM crops (Figures 7-4a-d and 7-6a-e). Tomato thrips (*Franklinella schultzei*) and plague thrips (*Thrips imaginis*) were also only observed on some IPM crops.

Figure 7-4a Thrips and predators per lettuce – 29th Jan 2008

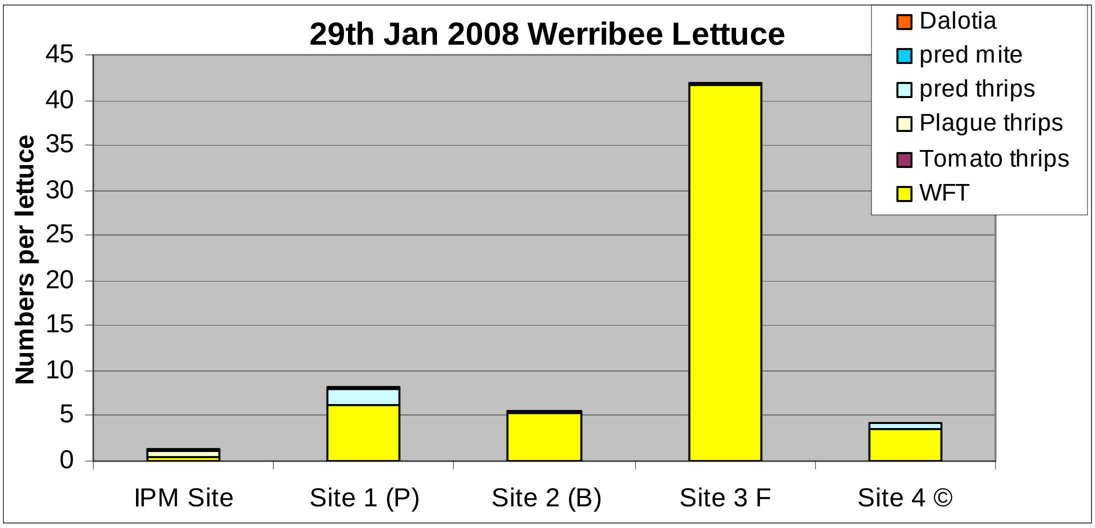


Figure 7-4b Thrips and predators per lettuce – 5th Feb 2008

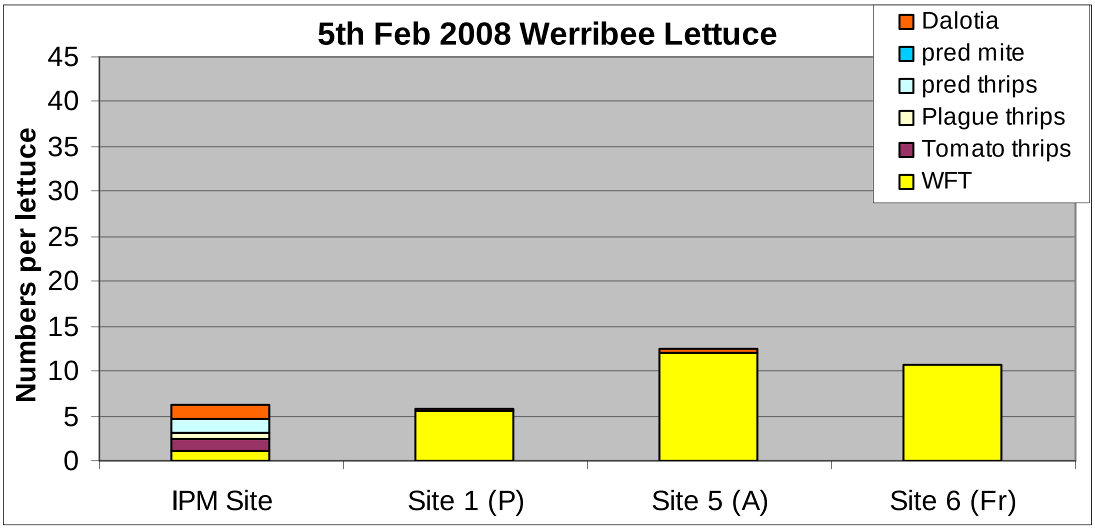


Figure 7-4c Thrips and predators per lettuce – 11th Feb 2008

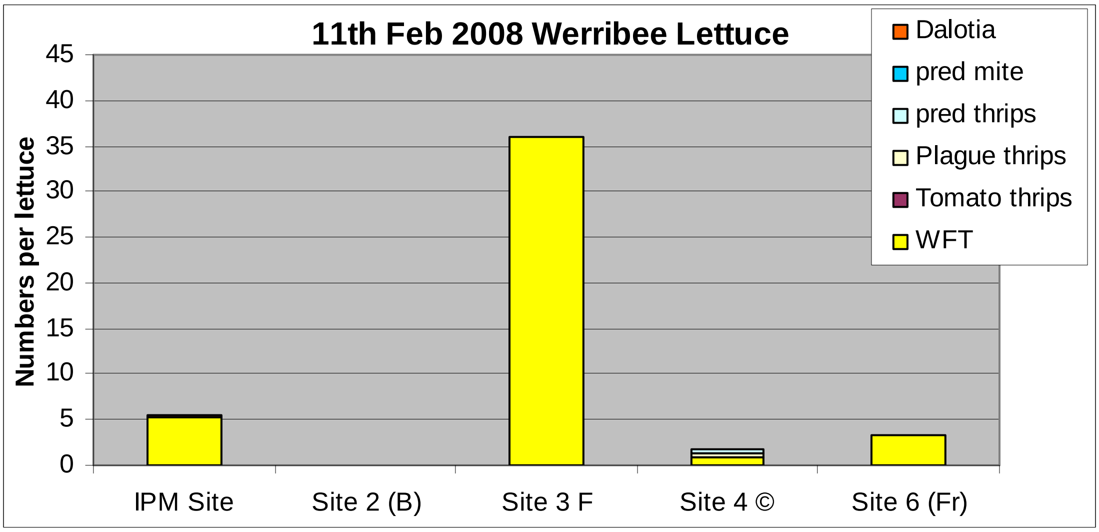


Figure 7-4d Thrips and predators per lettuce – 19th Feb 2008

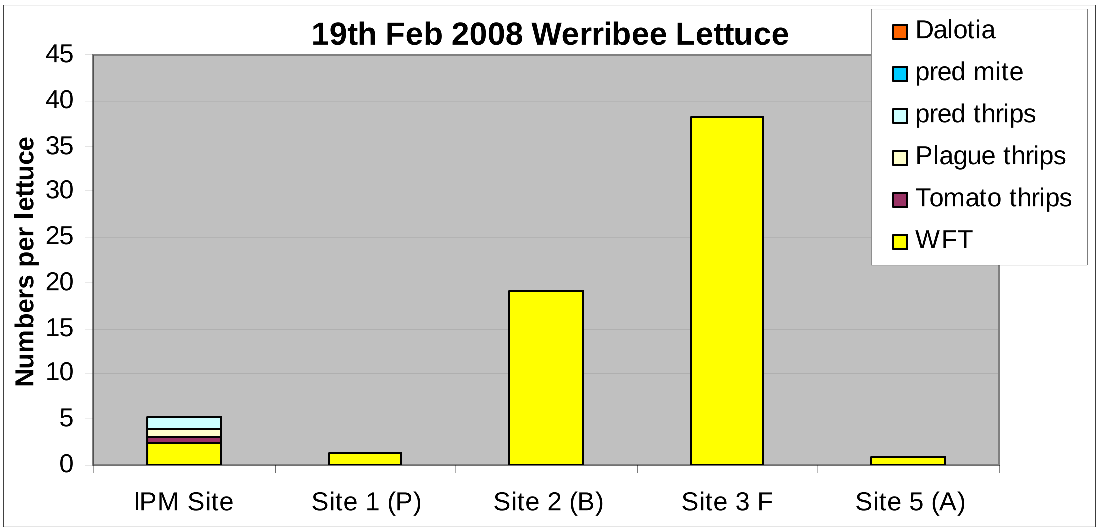


Figure 7-5 Western flower thrips per lettuce at harvest between January and May 2008 on six non-IPM and one IPM farms

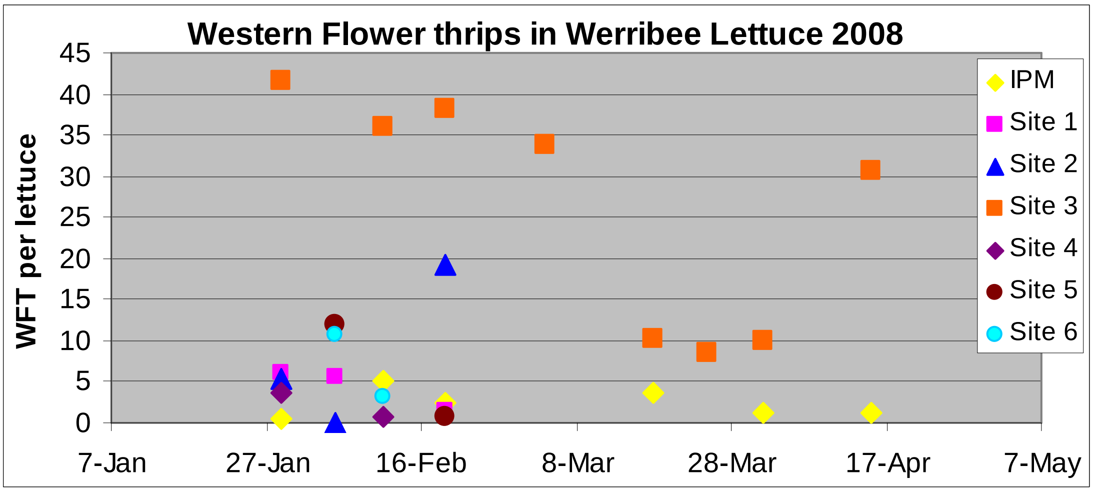


Figure 7-6a Thrips and predators per lettuce – 3rd Feb 2009

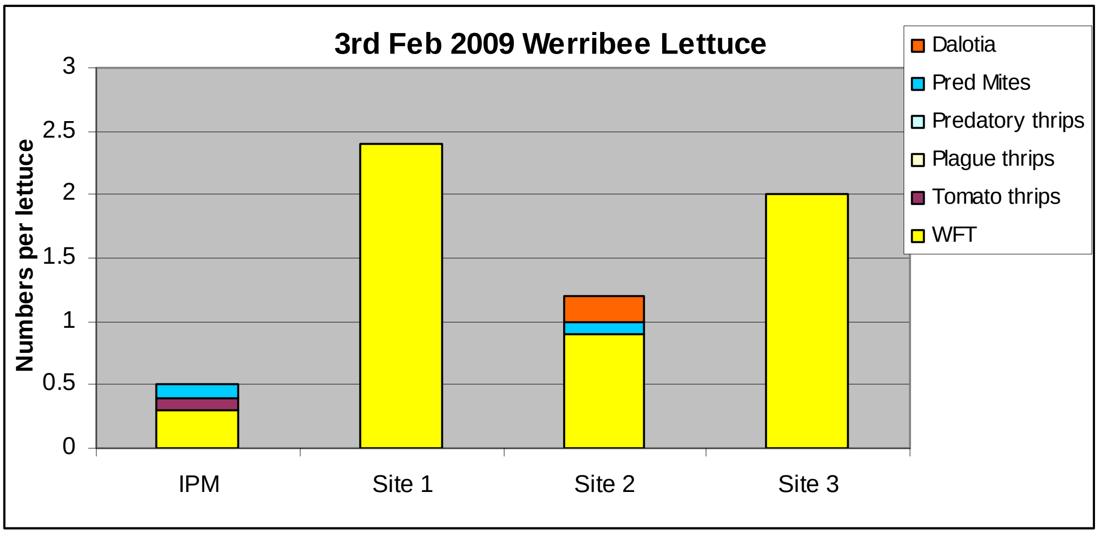


Figure 7-6b Thrips and predators per lettuce – 10^{th} Feb 2009

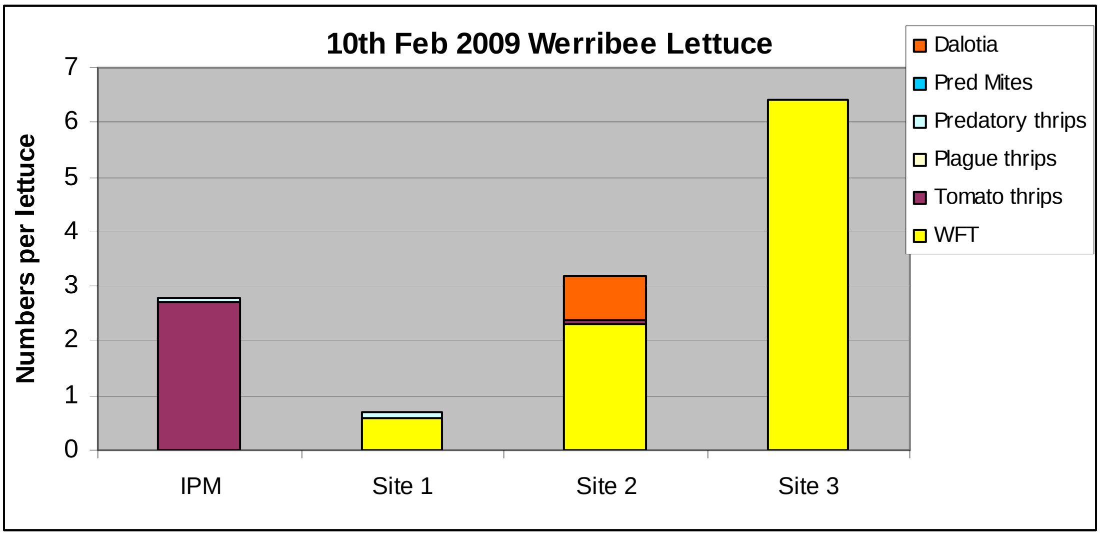


Figure 7-6c Thrips and predators per lettuce – 17th Feb 2009

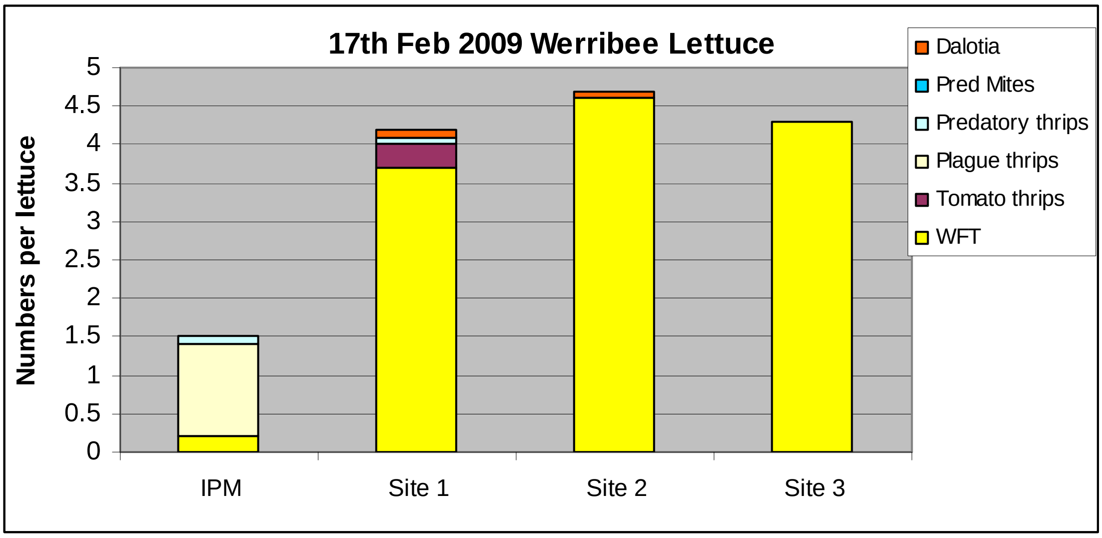


Figure 7-6d Thrips and predators per lettuce – 24th Feb 2009

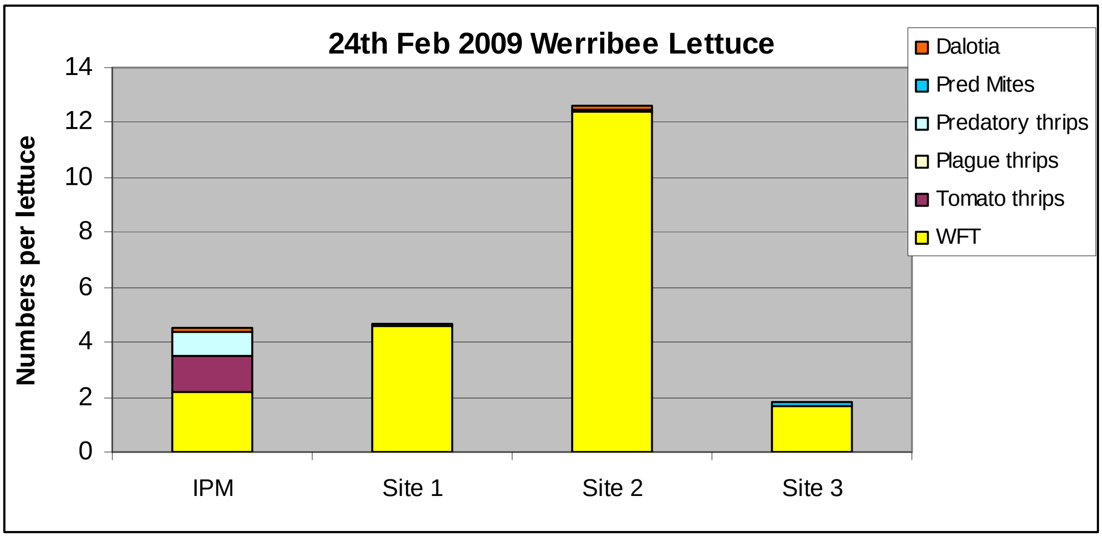


Figure 7-6e Thrips and predators per lettuce – 3rd Mar 2009

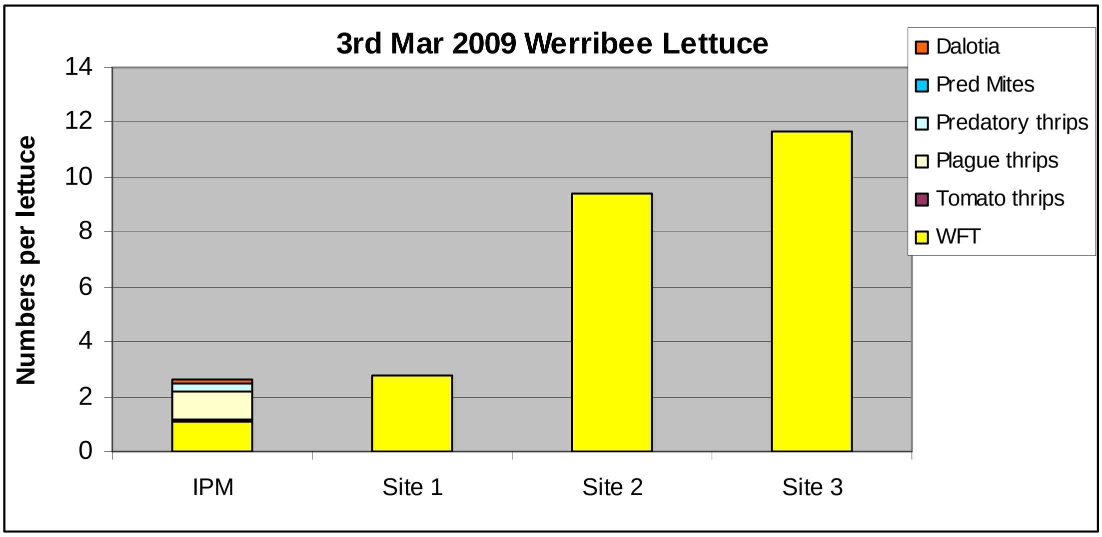


Figure 7-6f Thrips and predators per lettuce – 10th Mar 2009

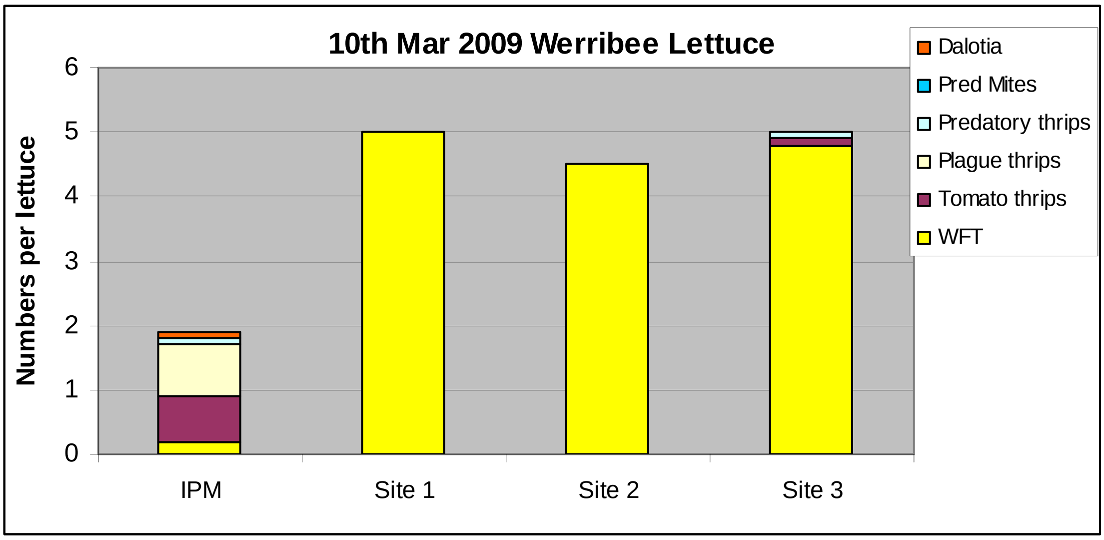
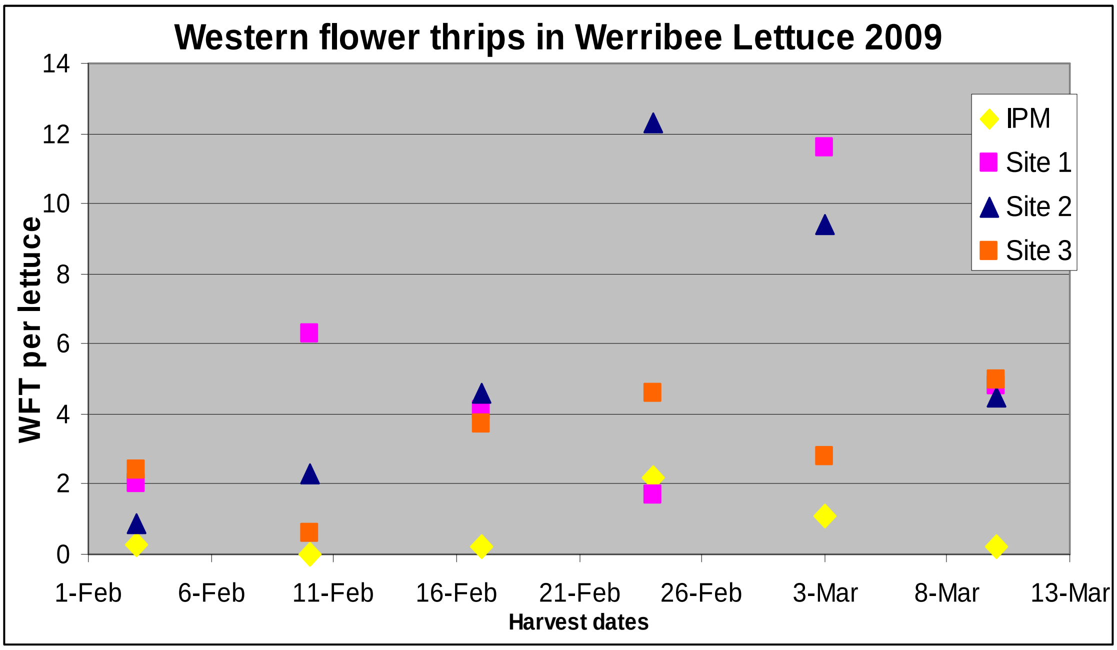


Figure 7-7 Western flower thrips per lettuce at harvest between February and March 2009 on three non-IPM and one IPM farms



Discussion

Commercial crops of lettuce have been grown successfully using IPM in both Werribee and Cranbourne every year since the arrival of currant lettuce aphid. This includes production of undrenched, susceptible varieties as well as the use of some resistant varieties. "IPM-grown" here means no use of broad-spectrum insecticides for any pest. Currant lettuce aphid can clearly be controlled without imidacloprid drenches as part of an IPM strategy dealing with all pests. However, utilizing the naturally occurring predators of currant lettuce aphid relies on there being no insecticides applied for other pests that will kill beneficials or reduce their performance. Laboratory bioassays that were conducted to assess the impact of imidacloprid drenches on brown lacewings, the main predator of lettuce aphid in Victoria, within VG04067 (*Integrating lettuce aphid into IPM for lettuce- a commercial trial*), found that brown lacewings were killed by secondary poisoning, as they fed on insecticide affected prey (Cole and Horne, 2006). These results were later confirmed by researchers in New Zealand (Walker, Stufkens and Wallace 2007).

The growers involved in these trials pointed to the added difficulty of controlling *Helicoverpa spp.* caterpillars with selective products such as GemStar® or Vivus® which are susceptible to UV degradation and wash-off. So fitting these sprays in with other farm practices, including irrigation, is not always easy. If these products were UV-stable then it would make overall control of pests, including currant lettuce aphid, much more practicable. In response a laboratory study of two potential 'sunscreens' was conducted and is reported in the next chapter (7. The potential of UV screens to improve the efficacy of Bt sprays).

8. The potential of UV screens to improve the efficacy of Bt sprays

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Introduction

Bacillus thuringiensis (Bt) is a species of bacterium commonly found in insect-rich environments such as soils and grain processing and storage facilities (Lambert & Peferoen 1992). Bt overproduces proteins that crystallize and are released into the environment (Lambert Perefoen 1992). These crystals (Insecticidal Crystal Proteins- ICPs) when ingested by certain insects, cause septicemia and result in the death of the insect (Lambert & Perefoen 1992). This level of specificity that makes Bt-based products the safest pesticides for use around humans (Hawkett *et al.* 2004). Specifically, the sub-species kurstaki is active against a large number of moth species and was discovered in 1970 (Dulmage 1970).

The market for Bts and other biopesticides still forms less than 1% of the crop protection market in 2000 (Navon 2000). The reason for this is most likely due to the number of constraints that affect field effectiveness such as the environmental conditions, and also the fact that the toxic protein is an oral insecticide (Navon 2000). For an oral insecticide to be effective, it needs to be ingested and as the the larvae mature, the lethal dose increases and so efficacy is reduced (Navon 2000). Other constraints on Bts includes “wash-off” as a result of irrigation, rain or dew, but the main constraint is the inactivation of the crystal protein of the Bt by UV light (300-380nm). Research has suggested that Bt can be UV degraded in a matter of hours (Hawkett *et al.* 2004).

To maximise exposure of target caterpillars to Bts many vegetable growers will spray Bts in the evening which is not always a socially acceptable time and a barrier to its effective use (Donald *et al.* 2000).

As long ago as the 1970’s, research was being undertaken not only to establish the specific wavelengths that caused crystal toxin deactivation, but also to find products that minimize the detrimental effect of UV light (Griego & Spence 1978). There have been a number of additives formulated to protect Bt formulations from environmental de-activation and increase its efficacy. These include wetting agents, stickers, synergists, phagostimulants and sunscreens or UV protectants (Navon 2000).

If Bt, or the ICPs it produces, was to be effectively protected from UV light, and as a result could be sprayed earlier in the day, and growers were already getting excellent coverage with their Bt applications then it would be more attractive option for lettuce and other vegetable growers and enable more effective implementation of biologically based IPM systems.

Objectives

The main focus of this project was to determine to what extent the bioinsecticide Bt can be protected from UV degradation. Initially the rate at which degradation occurs will need to be established and whether this rate can be slowed. Two UV protectants were tested, Nufilm P® and Nufilm 17®. The dose response curves of both of these compounds were compared with the dose response curve of unprotected Bt. The results might be expected to show some level of delay in UV degradation rates when the UV protectants are being used if they are effective. The difference between the two UV protectants was expected to be minimal as the products have been developed by the same company, are chemically very similar and claim to be almost equally as effective as each other. It was also expected that the Bt toxin will without protection begin to degrade after about 200 minutes of UV exposure and to be nearly completely inactive after 400 minutes. If it can be shown that UV degradation can be slowed by these protectants, then this might allow for further research to determine their effects on field usage of this potent control agent.

Materials and methods

Each of the following experiments followed standardised methods as follows:

Preparation of pesticide

The *Bacillus thuringiensis* -based product used was Dipel® a product by Yates and was mixed up in 500 ml spray bottles using distilled water. The insecticide was powder based and measured out using a microbalance accurate to 3 decimal places. Wetter 600® was added to the solution at 0.1 ml/L as a surfactant to improve the coverage of the insecticide when sprayed onto the cabbage. When Dipel® was sprayed without a surfactant the chemical beaded and ran off, lending to a decrease in efficacy. The bottles were shaken thoroughly and then left to sit for half an hour and shaken again to allow for the powdered product to entirely dissolve.

Application of pesticide

The 5 cm diameter cabbage leaf feeding discs were hung vertically on small wire hooks and then sprayed 4 times on both sides or until saturation. The spray nozzle was rinsed and re-used between tests for experimental consistency. The excess spray was allowed to drip off the discs and they were left at a temperature of 18–20°C for 3 hours until completely dry. No fans or heat sources were used to dry the feeding discs. Care was taken not to let the discs become contaminated. They were held by the hooks and not allowed to touch each other or any surfaces in the lab.

Time

Consistent times were kept for all feeding and cleaning of the larvae to keep any stress related activity as regular as possible. The time elapsed between cutting the disc and feeding appeared to affect the palatability of the cabbage due to drying and shriveling over time. As a result, the feeding discs were always cut just prior to being sprayed. UV exposure is based on time exposed to UV light which altered the experimental conditions for each set of feeding discs. It was expected that the discs exposed to UV for the longest amount of time would be marginally drier and less palatable to the larvae. This factor could not be easily reduced. Once the larvae were added to the testing cups they were left to feed on the cabbage for 24 and 48 hours before the dead larvae were counted.

Testing cups

A piece of dry tissue paper was placed under the lid of every cup to reduce the humidity inside the cup. All of the testing cups were stored on the same shelf at the same temperature in the lab.

Measurement

After 24 and 48 hours of feeding the cups were opened and the number of dead larvae in each cup was counted. A dead larva was determined as being stiff, black and unresponsive to the touch, whereas a living larva was determined as being green, soft, and responsive to the touch. UV degradation was measured as a loss of efficacy over time.

Statistical analysis

The values found were used to produce mean values and standard deviations which were graphed against dilution to produce a dose response curve. The dose response curve was transformed by doing a probit analysis using SPSS to produce probit regression values. A trendline was fitted to these values and the equation of this line was used to find the concentration equal to the probit value zero (50% mortality).

LD50 of *Bacillus thuringiensis*

Dipel® was prepared and applied as set out above at dilutions of *Bacillus thuringiensis* 0.000 g/L, 0.015 g/L, 0.020 g/L, 0.025 g/L, 0.050 g/L, 0.100 g/L, 0.150 g/L, 0.200 g/L, 0.250 gai/L, 0.500 g/L, 1.000 g/L, 2.000 gai/L with 5 testing cups at every dilution, each cup containing 5 larvae.

Effect of UV Exposure on Cabbage and Survival of Plutella

To ensure that pesticide alone was responsible for the death of the larvae, green cabbage was cut with a cookie cutter of diameter 5 cm and exposed to UV light of 200 nm. Five pieces were removed every 20 minutes from 0-200 minutes, and then every 50 minutes from 300-500 minutes, and then at 800 minutes, and placed into testing cups with 5 larvae in each cup. After 48 hours the larvae were counted and none were found dead. This was performed as a control to rule out any other UV related factors as being harmful to the larvae.

UV Degradation of *Bacillus thuringiensis*

The insecticide was mixed up at a dilution of 0.15 g/L (the calculated LD50) and prepared and applied as set out in Preparation of Pesticide and Application of Pesticide methods. Once dry the feeding discs were placed into a UV chamber and exposed to UV light at a wavelength of 200 nm. The light was at a height of 20 cm above the discs which were hanging vertically on thin wire hooks so that all sides were being exposed. Five discs were removed every 20 minutes from 0 to 200 minutes, and then every 50 minutes from 200-500 minutes, and then at 800 minutes and placed into testing cups with 5 larvae in each cup. A piece of dry tissue paper was placed under the lid of every cup to reduce the humidity inside the cup. All of the testing cups were stored on the same shelf at the same temperature in the lab.

UV Degradation of *Bacillus thuringiensis* with Nufilm P®

The insecticide was mixed up at a dilution of 0.15 g/L with Nufilm P® being added to produce a dilution of 1 ml/L. The solution was prepared and applied as above. Once dry, the feeding discs were placed into a UV chamber and exposed to UV light at a wavelength of 200 nm. The light was at a height of 20 cm above the discs which were hanging vertically on thin wire hooks so that all sides were being exposed. Five discs were removed every 20 minutes from 0 to 200 minutes, and then every 50 minutes from 200-500 minutes, and then at 800 minutes, and placed into testing cups with 5 larvae in each cup. A piece of dry tissue paper was placed under the lid of every cup to reduce the humidity inside the cup. All of the testing cups were stored on the same shelf at the same temperature in the lab.

UV Degradation of *Bacillus thuringiensis* with Nufilm 17®

The insecticide was mixed up at a dilution of 0.15 g/L (the calculated LD50) with Nufilm 17® being added to produce a dilution of 1 ml/L. Once dry the feeding discs were placed into a UV chamber and exposed to UV light at a wavelength of 200nm. The light was at a height of 20 cm above the discs which were hanging vertically on thin wire hooks so that all sides were being exposed. 5 discs were removed every 20 minutes from 0 to 200 minutes, and then every 50 minutes from 200-500 minutes, and then at 800 minutes, and placed into testing cups with 5 larvae in each cup.

Results

LD50 of *Bacillus thuringiensis*

Table 8-1 The means and standard deviations of dead larvae observed 48 hours after pesticide was sprayed at various dilutions.

Concentration g/L	Mean Dead	Standard Deviation
0	0	0
0.015	0	0
0.02	0.2	0.44
0.025	0.4	0.54
0.05	2.8	0.44
0.1	3.8	0.83
0.15	4.4	0.54
0.2	4.6	0.54
0.25	4.8	0.44
0.5	5	0

1 2	5 5	0 0

Table 8-1 shows that as the concentration of pesticide increased more larvae died. As the concentration was increased past 0.5 g/L all of the larvae were found to be dead

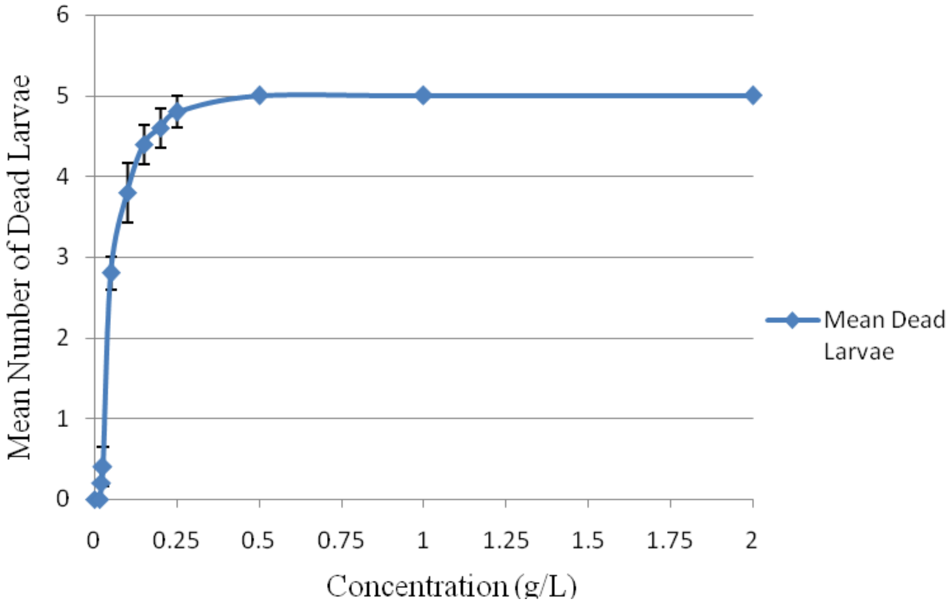

Figure 8-1 Dose response curve showing the effect of concentration on survival rate after 48 hours

The dose response curve shown in Figure 8-1 clearly displays the death rate increasing as the concentration of pesticide is increased. The curve produced from the data taken after 48 hours was used to find the LD50 (lethal dose for 50% of larvae). The data points at either end of the graph had standard deviations equaling 0.

Table 8-2 Table of Probit values calculated using SPSS used to produce a probit regression curve

Concentration	Probit
0.015	-2
0.025	-1.25
0.05	-1
0.1	-0.3
0.15	0
0.2	0.8
0.25	1

Table 8-2 only includes concentrations up to and including 0.25 g/L, because after this the curve flattened out and the probit analysis of these data points would be not only irrelevant but inaccurate.

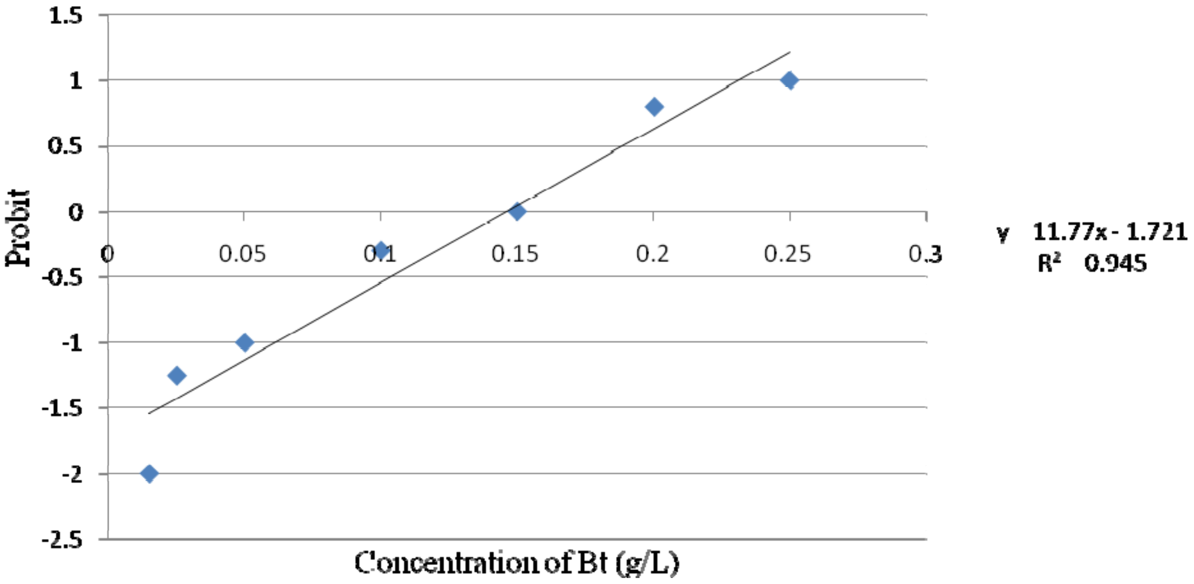

Figure 8-2 Probit regression of mean values found using SPSS, where 50% death occurred at 0.15 g/L

The data were transformed by using a probit regression, and fitting a linear trendline as shown in Figure 8-2. A probit regression involves each mean value being converted into a probit value and generally forms a straight line. Table 8-2 shows the probit values and associated concentrations used to produce the probit regression curve. In this case the line wasn't entirely straight and so a trendline was fitted. The equation of the trendline was used to find the concentration at which 50% of the larvae died. The equation was calculated as follows:

$y = 11.772x - 1.7214$ $1.7214 = 11.772x$
$x = 1.7214 / 11.772$ $x = 0.146$ $x \approx 0.15$ g/L

UV Degradation of *Bacillus thuringiensis*

Table 8-3 Data for the degradation of *Bacillus thuringiensis* over time with means and standard deviations.

time	means	stdev
0	3	1.58
20	3.2	1.30
40	3.2	1.30
60	3.6	1.14
80	3.2	1.64
100	3.75	0.95
120	3.2	0.83
140	3.5	1.29
160	3.5	1.29
180	3.8	1.30
200	3.25	2.21
300	3.4	1.51
350	1	0.70
400	0.8	0.44
450	0.6	0.89
500	0.8	0.83
800	1	0.70

The values in Table 8-3 reflect the number of larvae that were killed at each time interval and the standard deviation of the mean.

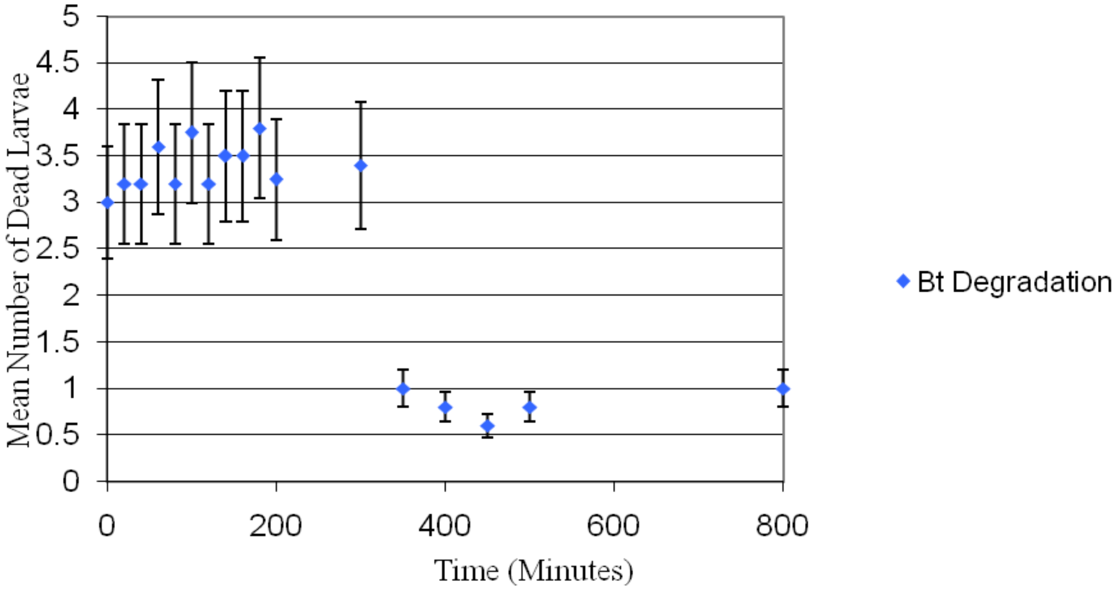

Figure 8-3 Graph showing degradation of *Bacillus thuringiensis* as UV exposure is extended

From Figure 8-3 it is clear that UV degradation does take many hours to occur. Only after 300-350 minutes did degradation begin to occur, and the pesticide became less effective. From 0-300 minutes the mean number of dead larvae remained between 3 and 4, however at 350 minutes the mean number of dead larvae was recorded as 1, and never rose above 1 for the remainder of the experiment.

Although the standard deviations are quite large at the lower x values, the difference between high pesticide efficacy and low pesticide efficacy is still obvious.

Effect of UV Exposure on Cabbage and Survival of Plutella

Table 8-4 Data for the mean number of dead larvae observed after being fed cabbage that had been exposed to UV for 0-800 minutes.

time	means	stdev
0	0	0
20	0	0
40	0	0
60	0	0
80	0	0
100	0	0
120	0	0
140	0	0
160	0	0
180	0	0
200	0	0
300	0	0
350	0	0
400	0	0
450	0.4	0.54
500	0.8	0.44
800	1.4	0.54

From Table 8-4 it is clear that the larvae remain unaffected by cabbage that had been exposed to UV for 400 minutes. However, after 450 minutes, some larvae weren’t surviving after being fed UV exposed cabbage. The cabbage was exposed for a maximum of 800 minutes (13 hours and 20 minutes) which is obviously an unrealistic amount of strong UV radiation that a cabbage crop would be exposed to under field conditions. The length of daylight in Australia varies from 8 to 14 hours depending on the time of year, and the UV irradiated during this time varies in strength, unlike the consistent UV light used in this experiment. 800 minutes was used as a maximum merely to observe the long-term effects of UV on the nutritional integrity of the feeding medium.

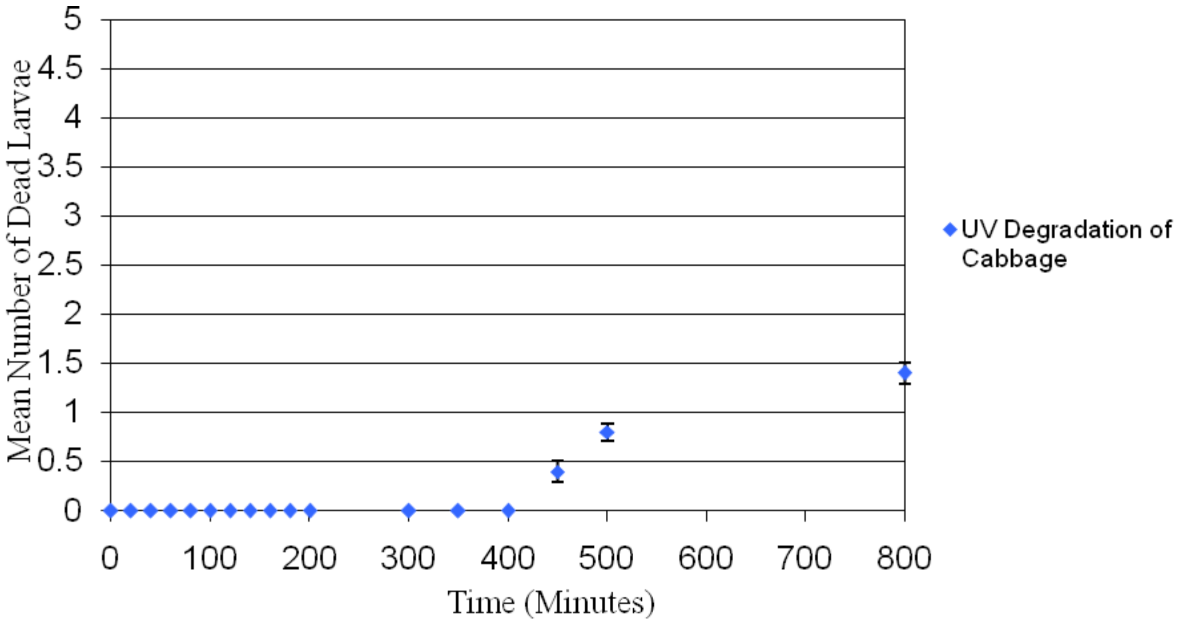

Figure 8-4 Graph showing the effect that UV light has on small segments of cabbage.

From Figure 8-4 it is shown that survival of larvae was reduced after 450 minutes of UV exposure. These results are significant and depict the effect that extended UV exposure alone has on the survival of *Plutella xylostella* larvae. From the trend of the graph it is assumed that the negative effect that UV has on the survival of the larvae would plateau shortly after 800 minutes, and would be unlikely to cause more than a mean number of 2 dead larvae. It is assumed only the weaker individuals can't survive on the dried cabbage.

UV Degradation of *Bacillus thuringiensis* with Nufilm P®

Table 8-5 The number of larvae killed by the pesticide after increasing the time exposed to UV with the UV protectant Nufilm P®

Time	means	stdev
0	3	1.58
20	3.6	1.14
40	3.2	1.30
60	3.2	1.30
80	3.6	1.14
100	3.2	1.64
120	3	0.70
140	4	0.81
160	4	0.81
180	3	0.70
200	3.2	1.64
300	4	1.00
350	4	1.00
400	3	1.00
450	3.2	0.83
500	1.6	0.54
800	1.4	0.54

Table 85 shows the degradation of Bt as UV exposure is extended when the UV protectant Nufilm P® is used. It is clear from these results that the mean number of dead larvae drops at UV exposure of 500 minutes. The decrease in mean number is not as obvious as those observed in Table 8.6, but there is still a significant difference between non-degraded and degraded pesticide.

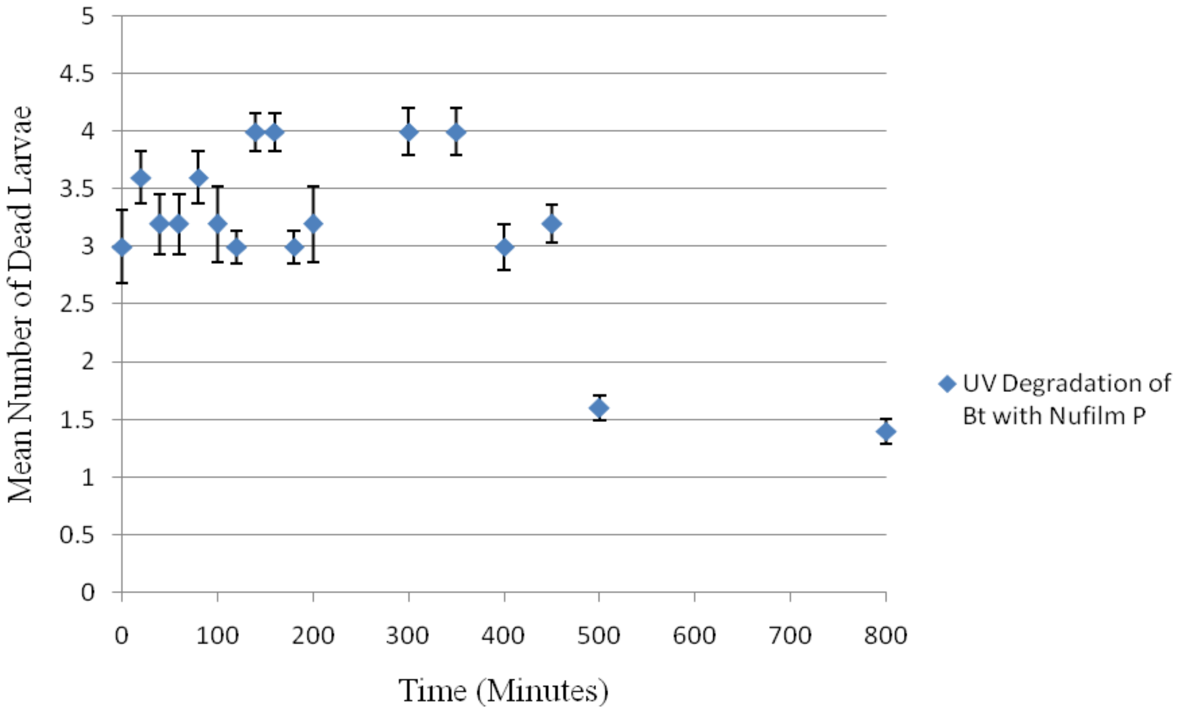

Figure 8-5 Graph showing the mean number of dead larvae observed when UV exposure is increased.

Figure 8-5 shows that the decrease observed between 450 and 500 minutes is not a large difference. As for Tables 8-4 and 8-6 the mean number of dead larvae remained between 3 and 4 until degradation occurred, when the mean number dropped by more than 1. A small number of larvae continued to die even after 500 minutes, which is consistent with those results displayed in Figures 8-4 and 8-6.

UV Degradation of *Bacillus thuringiensis* with Nufilm 17®

Table 8-6 The number of larvae killed by the pesticide after increasing the time exposed to UV using the UV protectant Nufilm 17®.

Time	means	stdev
0	3.2	1.30
20	3	1.58
40	3.6	1.14
60	3.2	1.30
80	4	1.00
100	3.2	1.64
120	3	1.00
140	3.25	1.25
160	3.5	1.00
180	3.6	1.14
200	3.8	1.30
300	3.6	1.14
350	3.2	1.30
400	3	0.70
450	0.6	0.54
500	1	0.44
800	1.2	0.44

Table 8-6 shows the degradation of Bt as UV exposure is extended when the UV protectant Nufilm 17® is used. In these results the lower mean values have a lower standard deviation.

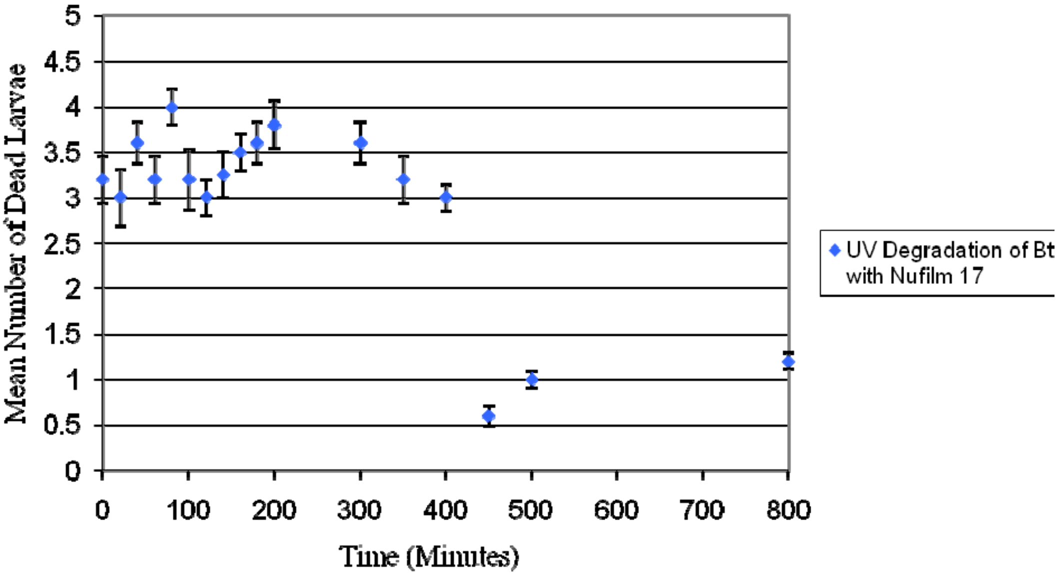

Figure 8-6 Graph showing the mean number of dead larvae observed when UV exposure is increased.

As seen in Figure 8-6 the protected Bt remained effective for 450 minutes, unlike the unprotected pesticide which was less effective after 350 minutes. Nufilm 17® showed a delay in degradation of 100 minutes compared with the unprotected Bt pesticide. Following 450 minutes, the death of larvae still occurred, as can be seen in Figures 8-5 and 8-4.

Discussion

The LD50 of *Bacillus thruingiensis* was found to be 0.15 g/L. Results indicate that the Bt insecticide was deactivated by UV light after 300–350 minutes (5 hours to 5 hours 50 minutes). Two UV protectants were used to test the potential to extend the efficacy of *Bacillus thuringiensis* -based products when exposed to UV lights. Nufilm 17® extended allowable UV exposure to 400–450 minutes (6 hours 40 minutes – 7 hours 30 minutes). Nufilm P® extended allowable UV exposure to 450–500 minutes (7 hours 30 minutes – 8 hours 20 minutes). These results were found using 2nd and 3rd instar *Plutella xylostella* larvae housed at temperatures of 20-25 ºC and fed treated green cabbage for 48 hours.

These results were obtained in the laboratory using UV lights at a set height over the treated cabbage. It is not known how the exposure times that caused degradation of Bt relate to field conditions. However, if normal degradation occurs over 12 or more hours in the field then the 5 hours in the test chamber here could be approximated to one days field exposure. Therefore the proportion of time that the 2 Nufilm formulations extended efficacy could well be significant in the field and could allow growers to spray hours earlier than Bt's sprayed without sunscreen. This needs to be tested in the field, but the results of this study suggest that such research is worth considering.

9. Effect of short-term exposure to imidacloprid on the predatory ladybird, *Hippodamia variegata*

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Introduction

Imidacloprid (Confidor®) is widely used by Australian lettuce growers to control currant lettuce aphid, *Nasonovia ribisnigri* Mosley. Compared to foliar insecticides such as Chess® (pymetrozine) and Pirimor® (pirimicarb), imidacloprid gives long-term protection. A single application can last the life of a lettuce crop (5-16 weeks after transplanting; McDougall *et al.* 2005), and as imidacloprid is systemic (Sur & Stork 2004) it can penetrate into the lettuce heart where *N. ribisnigri* colonies establish. A survey of commercial growers (Bechaz 2006) suggested that 93% of lettuce growers use imidacloprid as a prophylactic treatment.

Imidacloprid is regarded to be IPM-compatible, as pests are only exposed when they directly consume the plant tissue or sap, and non-target insects do not come into direct contact with it (Mizell & Sconyers, 1992; Bayer CropScience, 2007). However, several studies suggest that imidacloprid affects non-target insects via indirect exposure routes. Since imidacloprid is systemic it is translocated to the flowers, affecting nectar and pollen feeding insects such as bees (Yang *et al.* 2008) and lacewings (Rogers *et al.* 2007). Beneficials can also be exposed to imidacloprid when they consume prey that have fed on imidacloprid-treated plants (Grafton-Cardwell & Gu 2003, Papachristos & Milonas 2008, Cole & Horne 2006, Walker *et al.* 2007). This exposure can affect their survival, behaviour, development and fecundity.

Hippodamia variegata (Goeze) (spotted amber ladybird) is native to Central Europe. *H. variegata* was first discovered in southeast Queensland in 2000 (Franzmann, 2002) and is now established throughout Australia. It is frequently found in lettuce in Tasmania, NSW and WA (McDougall *et al.* 2008), where it is thought to prey on aphids. A previous study (Wyber 2008) examined the effect of *H. variegata* larvae and adults fed for 21 days on imidacloprid intoxicated aphids at doses representing half the recommended field rate, field rate, and twice the recommended field rate. The aim of this study was to examine the effect of a shorter exposure period on development and survival of *H. variegata* larvae, adults and adult fecundity. A shorter exposure period was considered to be more likely to occur in the field where ladybirds are likely to feed on imidacloprid-treated aphids for only a short time.

Materials and methods

Aphids

Aphid colonies were reared in separate Plexiglass aphid proof cages (350 mm deep, 400 mm high and 300 mm wide) in a glasshouse at the Western Australian Department of Agriculture and Food, South Perth. Species reared included green peach (*M. persicae*), currant lettuce (*Nasonovia ribisnigri* (Mosley)) and potato aphid (*Macrosiphum euphorbiae* (Thomas)). All aphid species are found on lettuce in Australia. The *N. ribisnigri* colony was initiated from individuals collected from a commercial lettuce grower in Gingin (*Lactuca sativa* L) in January 2009. Green peach and potato aphids were collected from lettuce in glasshouses at South Perth in October-November 2008. Colonies were reared on untreated lettuce (var *Levistro*). Lettuce was replaced every 3 days, or when plants became unthrifty.

Ladybirds

Hippodamia variegata colonies were initiated from eggs supplied by IPM Technologies, Victoria in 2006. The colony was supplemented with adults collected from *Hibiscus* in autumn (March-May) each year. Ladybirds were reared in controlled temperature and light cabinets (12 hours light 12 hours dark, 25°C). At 25°C, the pre-adult development time for *H. variegata* is 18.1 days, and adults live for approximately 36.9 days when reared on Hawthorn carrot aphid (*Dysaphis crataegi* Kaltenbach) (Lanzoni *et al.* 2004). Adults (~10 adults/cage) were housed in transparent 850mL plastic cages (110 mm high, 83 mm base diameter, 110 mm upper diameter, Genfac Plastics). The cage lid was fitted with muslin for ventilation and humidity control. Adults were given an ad libitum supply of live green peach (*Myzus persicae* (Sulzer) and corn aphids (*Rhopalosiphum maidis* (Fitch)). Since *H. variegata* prefers to lay eggs on a plant surface (Kontodimas & Stathas 2005), 5 cm lengths of corn leaves (*Zea mays* L.) were provided as an oviposition substrate. Cages were checked daily for eggs. If present, eggs were removed and placed into transparent containers (60 mm high, 55 mm base diameter, 70 mm upper diameter, Genfac Plastics) for larval rearing. Within 24 hours of 1st instar eclosion, larvae were removed from the cage with a fine paintbrush and placed into separate transparent plastic cages (37 mm high, 28 mm base diameter, 42 mm upper diameter, Huhtamaki, New Zealand). The lid of the cage was fitted with a 5 mm x 5 mm square of muslin for ventilation and to reduce humidity.

Insecticide application

Iceberg lettuce seedlings (var. *Levistro*) were placed in four separate rows on a conventional seedling tray, with 10 plants per treatment. Seedlings were treated with imidacloprid (Confidor® 200SL) (treatments) or water (control) (Table 9-1). The water volume for all treatments was 5 L/1000 seedlings, and treatments were applied by injecting into the soil core with a 5 mL syringe. Seedlings were kept in the trays for 24 hours after treatment, then transplanted into 90mm square pots (Premium Plastics) containing potting mix (Baileys Fertilisers, Rockingham, WA). Lettuce was used 7–21 days after treatment. No pesticides were used prior to the experimental applications.

Table 9-1 Treatments

Treatment	**Rate**
Control	Water only
Half recommended rate (1/2 RR)	27.5 mL (5.5 g.a.i) per 1000 seedlings
Recommended rate (RR)	55 mL (11 g.a.i) per 1000 seedlings
Twice recommended rate (2RR)	110 mL (22 g.a.i) per 1000 seedlings

Bioassay

The study was conducted as a completely randomized design repeated over time, with 20 individual larvae per treatment. Larvae were placed in controlled temperature and light cabinets (12 hours light 12 hours dark, 25°C), and removed briefly each day for feeding. Six plants treated at different times (7–21 days) were used for each treatment. Lettuce was placed in plexiglass aphid proof cages (350 mm deep, 400 mm high and 300 mm wide) and equal proportions of each aphid species were collected from aphid rearing cages and released onto treated plants. Aphids were allowed to feed on lettuce for 24 hours, before being removed with a fine paintbrush and placed into cages containing first instar *H. variegata* as described above. Larvae were fed with treated aphids for 48 hours: approximately 10 fresh aphids were added every 24 hours. Thereafter, larvae were fed untreated aphids *ad libitum*.

Larval survival and development

Larvae were checked at the same time each day from treatment through to adult emergence. Larvae and adults were classified ‘live’ if they moved when stimulated with a fine hair brush. Larvae classified ‘dead’ were maintained and monitored for possible recovery until the end of the experiment. Instars were classified by the presence of a shed exoskeleton skin. Pupal survival was based on the ability to moult to the next stage. If an adult did not emerge within 10 days, the pupa was considered dead. Adults were weighed within 24 hours after emergence.

Oviposition

Newly emerged adults were held in communal plastic cages (110 mm high, 83 mm base diameter, 110 mm upper diameter, Genfac Plastics), one cage per treatment, and provided with aphids as previously described. Mating pairs were removed from the communal cage and placed into individual transparent containers (60 mm high, 55 mm base diameter, 70 mm upper diameter, Genfac Plastics). Cages and plants were checked daily for adult survival and eggs for 26 days once oviposition had commenced. If eggs were present, adults were removed and placed into a new cage. The number of egg clutches and the number of eggs was recorded (fecundity). Eggs were observed daily and the incubation time and number of larvae hatched (fertility) were recorded.

Statistical analysis

The differences in pupal and adult survival amongst treatments were analysed using the Chi-square test (Papachristos & Milonas 2008). The effects of treatment on the duration of larval and pupal stages, total development time (1^{st} instar – adult), preoviposition period, number of egg laying days and adult weight were evaluated with separate ANOVAs. Data were transformed using log10 (x + 1) prior to analysis where appropriate, and untransformed means and SEMS are shown in tables. Significantly different means were separated by LSD (5%).

The total number of eggs laid per female were transformed using log10(x+1) prior to analysis with ANOVA. The percentage of eggs hatched were transformed using angular transformation for percentages (arcsine sqrt), followed by an ANOVA. Significantly different means were separated by LSD (5%). Genstat for Windows 12th edition (http: www.genstat.com) was used for all statistical analyses.

Results

Larval and adult survival

There was no relationship between treatment and survival of larvae and pupae (Figure 9-1). Larvae in all treatment groups survived to adulthood, with 75% of larvae at the recommended rate (RR) and 80% at twice recommended rate (2 RR) (Table 9-2). There were no significant differences in the percentage of larvae surviving to pupate (chi-square=2.05, P>0.05), nor the number of adults that successfully emerged (chi-square = 2.3, P>0.05).

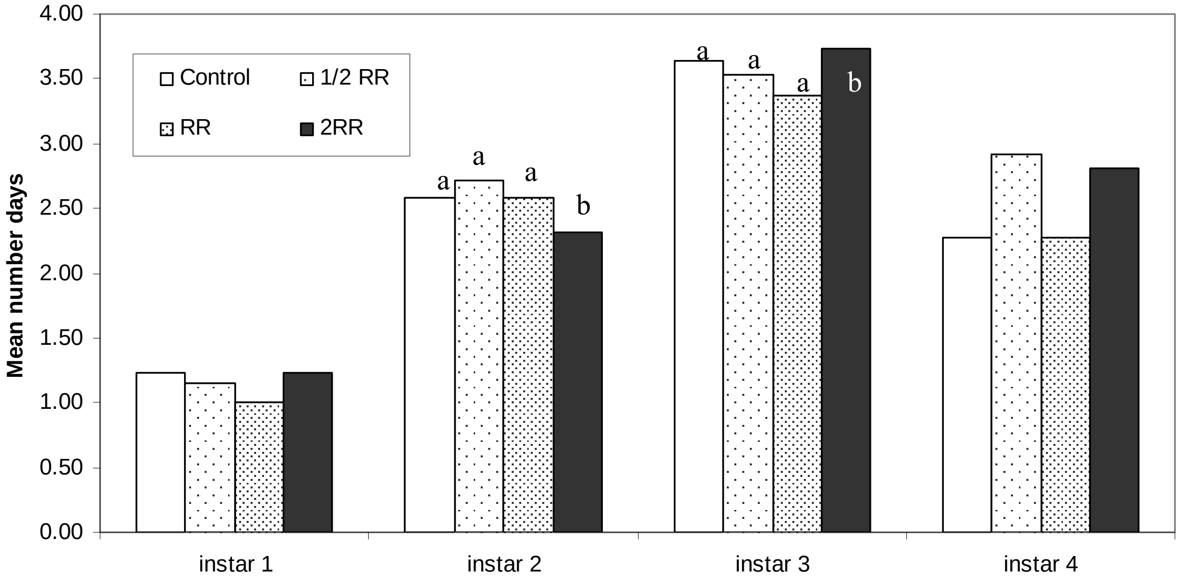
Table 9-2 Percentage survival for *H. variegata* fed on aphids reared on imidacloprid-treated or untreated lettuce at different treatment rates.

Treatment	**instar 1**	**instar 2**	**instar 3**	**Instar 4**	**Pupa**	**Adult**
Control	100 (n=20)	95 (n=19)	95 (n=19)	95 (n =19)	95 (n=19)	90 (n=18)
1/2 RR	95 (n=19)	90 (n=18)	90 (n=18)	90 (n=18)	90 (n=18)	90 (n=18)
RR	90 (n=18)	90 (n=18)	90 (n=18)	90 (n=18)	90 (n=18)	75 (n =15)
2 RR	100 (n=20)	100 (n=20)	90 (n=18)	90 (n=18)	91 (n=18)	80 (n=16)

Developmental time

The effect of imidacloprid on larval and developmental time and adult weight is presented in Figure 9-1 and Table 9-3. There were significant differences between developmental time and treatment for instars 2 and 3. Larvae treated at twice the recommended rate took significantly longer to develop from instar 2 to 3 (*F*=2.87, *P*=0.04, 3 df). Control larvae took significantly less time (2.30 days) to develop from third to fourth instars compared to larvae treated at twice the recommended rate (2.83 days; Figure 1, *F*=7.72, *P*<0.001). Control adults were also heavier than treated adults, ranging from 8.8 mg (control) to 8.1 mg (recommended rate), though this difference was not statistically significant (*P*>0.1).

Figure 9-1 Larval developmental time (backtransformed means)*



*Within a group, means followed by the same letter are not significantly different (LSD = 0.05).

Table 9-3 Total development time (larvae-adult) and adult weight (Mean ± SEM)

Treatment	Total development time from first instar to adult (days)	Adult weight (mg)
Control	24.2 ± 0.5a	8.8 ± 0.3a
1/2 RR	24.3 ± 0.5a	8.3 ± 0.4a
RR	23.9 ± 0.6a	8.1 ± 0.4a
2 RR	24.5 ± 0.5a	8.4 ± 0.4a

*Means in the same column followed by the same letter are not significantly different (LSD = 0.05)

Fecundity

Adults in the control treatment had the shortest pre-ovipositional period at 6.6 days, compared to 9.2 to 11.6 days for treated adults (Table 9-4). However, these differences were not significantly different due to high individual variation within and between treatments (F = 0.85, P = 0.48, df = 3). Eggs took 3-4 days to hatch, with no differences between treatments (F = 1.02, P = 0.4, df = 3). Females in the control group laid eggs for 4-18 days, 2-3 days longer than treated adults with the number of egg laying days declining with imidacloprid rate (Table 9.3; F = 2.52, P = 0.08, df = 3). This trend was also reflected in the percentage of days that eggs were laid (F = 2.40, P = 0.09, df = 3). Three females treated at the recommended and twice recommended rate laid eggs once during the experimental period and of these, the eggs of two females at the 2RR failed to hatch (n=24 eggs). One female in the half RR treatment laid eggs only once. All females in the control group laid eggs more than once during the 26 day experimental period.

Table 9-4 Pre-ovipositional period, number of egg laying days and percentage of days on which eggs were laid (mean ± SEM)

Treatment	n	Pre-ovipositional period (days)	Egg duration (days)	# days eggs laid	Percentage of days eggs laid
Control	7	6.6 ± 0.5a	3.9 ± 0.2a	7.8 ± 1.2a	36.7 ± 5.5a
1/2 RR	9	9.2 ± 1.5a	4.1 ± 0.2a	6.7 ± 1.3a	32.6 ± 6.3a
RR	9	9.2 ± 2.1a	3.9 ± 0.3a	4.2 ± 1.1b	20.5 ± 5.4b
2 RR	5	11.6 ± 3.8a	4.0 ± 0.6a	3.6 ± 1.7b	16.5 ± 7.5b

*Means in the same column followed by the same letter are not significantly different (LSD = 0.05)

The total numbers of eggs laid per female, hatched eggs per female and percentage egg hatch are shown in Table 9-5. Females in the control and half RR treatments produced 50% more eggs than females in the twice RR treatment, and 35% more eggs than females at RR (Table 9-5) though the result was not significantly different at P=0.05. Similarly, females in the control and half RR treatments produced more larvae than the other treatment groups. Interestingly, treatment did not appear to affect egg hatch, with more eggs hatching at the higher treatment rates (Table 9-5).

Table 9-5 The total number of eggs laid per female, egg hatch per female and percentage egg hatch (mean ± SE)

	n	Total eggs/female	Total egg hatch/female	Percentage egg hatch
Control	7	106.9 ± 30.3a	37.9 ± 14.6a	35.8 ± 7.4a
1/2 RR	9	116.0 ± 29.5a	35.7 ± 8.1a	34.4 ± 6.1a
RR	9	70.4 ± 19.8a	26.9 ± 6.3a	45.2 ± 9.4a
2 RR	5	55.0 ± 27.3a	15.0 ± 7.5a	42.0 ± 15.9a

*Means in the same column followed by the same letter are not significantly different (LSD = 0.1)

Discussion

For biological control of *N. ribisnigri* to be successful, Australian growers need to conserve predators such as ladybirds (transverse ladybird, *Coccinella transversalis* Fabricius, *H. variegata*), syrphids (*Melangyna* sp.), and lacewings (Tasman's lacewing, *Micromus tasmaniae* (Walker)) that occur naturally in lettuce. Our results and those of Cole & Horne (2006), Walker *et al.* (2007), and Wyber (2008) suggest that soil-drenching lettuce with imidacloprid is not compatible with conservation of natural enemies, nor IPM. Cole & Horne (2006) found that 85% of *M. tasmaniae* larvae died when fed imidacloprid intoxicated aphids at the recommended field rate (Australia: Confidor® 200SC, 55 mL per 1000 seedlings). Walker *et al.* (2007) recorded 93% mortality of *M. tasmaniae* larvae after they were fed aphids treated at the recommended field rate (New Zealand: 30 mL per 1000 seedlings) and half-field rate (15 mL per 1000 seedlings) over a 2-3 day exposure period.

Few studies have examined the long-term effect of imidacloprid on survival and fecundity. Wyber (2008) found that imidacloprid reduced survival and growth of *H. variegata* adults and larvae, and the number of aphids consumed decreased with increasing rate. Only three adults in the lowest dose treatment (27.5 mL per 1000 seedlings) survived the 21 day trial period; adults in all other treatment groups (55-110 mL per 1000 seedlings) died after 13–14 days. Fourth instar larvae also took longer to develop into pupae, with delayed development increasing with increasing imidacloprid rate. Papachristos & Milonas (2008) studied the effect of imidacloprid on larval survival, adult longevity and fecundity of the ladybird *Hippodamia undecimnotata*. First instar larvae were fed aphids (*Aphis fabae* Scolpoli) that had been feeding on beans (*Vicia faba* L.) treated with a single rate of imidacloprid (0.0206 mg ai/pot). Larvae were fed imidacloprid treated aphids until they pupated. They found that larval and pupal survival was adversely affected by imidacloprid, but not total larval duration or adult weight.

This study found no apparent effect of imidacloprid on survival of *H. variegata* larvae. Compared to Wyber (2008) and Papachristos & Milonas (2008) however, we fed larvae imidacloprid treated aphids for 48 hours. Though the duration of the 2nd instar was significantly longer for larvae treated at twice the recommended rate (110 mL/1000 seedlings), and the duration of the third instar was significantly shorter for control larvae in our study, there was no effect on larval developmental time. Slightly fewer larvae developed through to adults at the higher treated rates and weighed less than the other treatment groups, but this difference was not significant.

Adults from all treatment groups survived for at least 26 days post-emergence (the trial period), though fecundity appeared to be reduced by indirect exposure to imidacloprid. Females in the control treatment had the shortest pre-ovipositional period at 6.6 days, compared to 9.2 to 11.6 days for imidacloprid treated adults. Imidacloprid also reduced egg lay, with control females laying eggs for 4-18 days, 2-3 days longer than treated adults. The number of females that laid eggs only once during the trial was highest in the recommended and twice recommended treatments (n=3), and of these, the eggs of two females (twice the recommended rate) failed to hatch. One female in the half recommended rate treatment (27.5 mL per 1000 seedlings) laid eggs only once, whilst all females in the control group laid eggs on more than one occasion. Females in the control group and females exposed to the lowest dose of imidacloprid (27.5 mL per 1000 seedlings) also produced 50% more eggs than females in the twice recommended rate treatment, and 35% more eggs than females at the recommended rate. The hatching rate was unaffected, with a higher hatch rate recorded for the higher treatment rates than the control and lower tested rates.

Papachristos & Milonas (2008) similarly found that imidacloprid increased the pre-oviposition period, with imidacloprid-treated adults taking 2 days longer than the control. Fecundity was also lower, with control adults laying 30% more eggs. There was no statistically significant difference in egg hatchability between control and imidacloprid-treated females, though more of the control eggs hatched (70.2%) compared to imidacloprid-treated (58.2%). The main problem with the study undertaken and reported here was the low number of females for fecundity measurements. Due to high individual variation within treatments there were no statistically significant differences (P>0.1) between treatments. A minimum of 9 females/treatment would be required to show significance at P=10%. Unfortunately, the trial could not be repeated due to the loss of the *N. risbisnigri* colony. Whatever the outcome of further trials, imidacloprid drenches are not a sustainable management tool since aphids develop insecticide resistance. Some populations of *M. persicae* in the United Kingdom for example are resistant to pyrethroid, organophosphorus and carbamate insecticides (Foster *et al.* 1998). Insecticide resistance has also been identified in populations of *N. ribisnigri* to pirimicarb, pyrethroids and organophosphates, but show no significant differences in response to imidacloprid (Barber *et al.*, 1999; Rufingier *et al.* 1997).

10. Cereals as benefical insectaries

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Aim

To identify the most suitable cereals for hosting aphid populations and their predators or parasitoids, and then to test whether planting these cereals next to lettuce reduces aphid numbers in lettuce during the winter months.

Introduction

Lettuce crops are infested by a number of different aphid species. Until the arrival of the currant lettuce aphid (*Nasonovia ribis-nigri* CLA*)*, the aphid species attacking lettuce tended to colonize the outer wrapper leaves and generally only during short windows in autumn and in spring. Brown sowthistle aphids (*Uroleucon sonchi)*, and green peach aphid (*Myzus persicae)* are the most common aphids to attack lettuce and are usually easily controlled by either relying on endemic beneficial insects or aphicide sprays. CLA, however, prefers to disperse and reproduce within the lettuce head making it difficult to reach with contact sprays. This has been observed in lettuce in all seasons in the areas where CLA is found. Current control methods include the use of insecticides, such as imidacloprid (Confidor®), pymetrozine (Chess®) and pirimicarb (Pirimor®), and the planting of *Nas*-resistant lettuce varieties. CLA has already developed resistance to a number of insecticides and because it tends to infest the inner leaves of the lettuce, control with chemical sprays is particularly difficult in head-forming varieties such as Iceberg (Barber *et al.* 1999, Stufkens & Wallace 2004). In Europe, a new strain of CLA has also overcome the resistance in the *Nas*-resistant varieties (Rijk Zwaan). Apart from resistance issues, the continual use of insecticides also affects the populations of beneficial insects, that are an integral part of integrated pest management (IPM) programs.

In 2007, an IPM trial/demonstration in Sydney found that CLA numbers increased towards the end of autumn and persisted on the lettuce through winter. Conversely, the numbers of beneficial insects decreased through autumn, were low through winter and only increased in spring. By mid-spring the beneficial insects were effectively managing CLA numbers in infested lettuce however the winter harvested lettuce was severely infested. Cereal crops host a number of aphid species not found on lettuce and these can support aphid predators and parasitoids. It was hypothesised that cereals planted next to lettuce would increase aphid predation in lettuce.

To use cereals as insectary crops involves planting cereals earlier than they are normally planted and potentially in areas they are not generally grown. In the first year of this trial, small plots of a variety of cereals, planted at three different dates, were screened for aphid and beneficial numbers at three week intervals in two locations. In the second year, the most promising cereal in each location was planted next to lettuce and compared to lettuce plots with no bordering cereal.

I. Cereal Screening trial

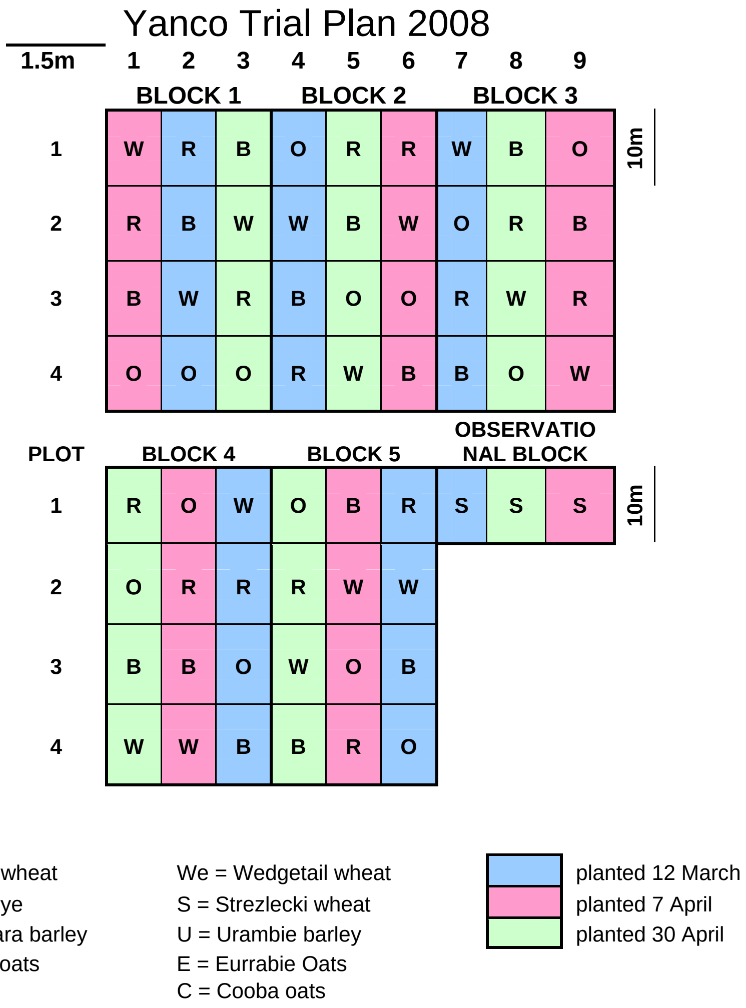
Materials and methods

In 2008, wheat (var. *Ventura*), barley (var. *Tantangara*), rye (var. *Ryesun*) and oats (var. *Echidna*) were grown in small plots (1.5 m x 10 m) replicated 5 times, and planted at 3 planting dates in March and April at both Sommersby and Yanco. Observational plantings of *Stezlecki* wheat, *Cooba* oats, *Eurrabie* oats, *Urambie* barley and *Wedgetail* wheat were planted in single observational plots at Sommersby.

Varieties were selected based on recommendations by Peter Martin (Research Agronomist, NSW DPI) for good vegetative growth, potential to host high aphid populations and slowness to seed. Seed numbers were calculated for a high stand density (200 plants/m^2) and 80% germination rate.

At Yanco, the first planting was on 12th March, the second on 7th April, and the third on 30th April 2008 (Figure 10-1). Seed were planted with a single bed cone seeder, planting 8 rows per bed. Sommersby plots were planted by hand in 8 rows per bed with the first planting on 12th March, the second on 7th April, and the third on 30th April 2008 (Figure 10-2).

Figure 10-1 Yanco Trial Plan 2008



Yanco Trial Plan 2008

1.5m	1	2	3	4	5	6	7	8	9	
	BLOCK 1			BLOCK 2			BLOCK 3			
1	W	R	B	O	R	R	W	B	O	10m
2	R	B	W	W	B	W	O	R	B	
3	B	W	R	B	O	O	R	W	R	
4	O	O	O	R	W	B	B	O	W	

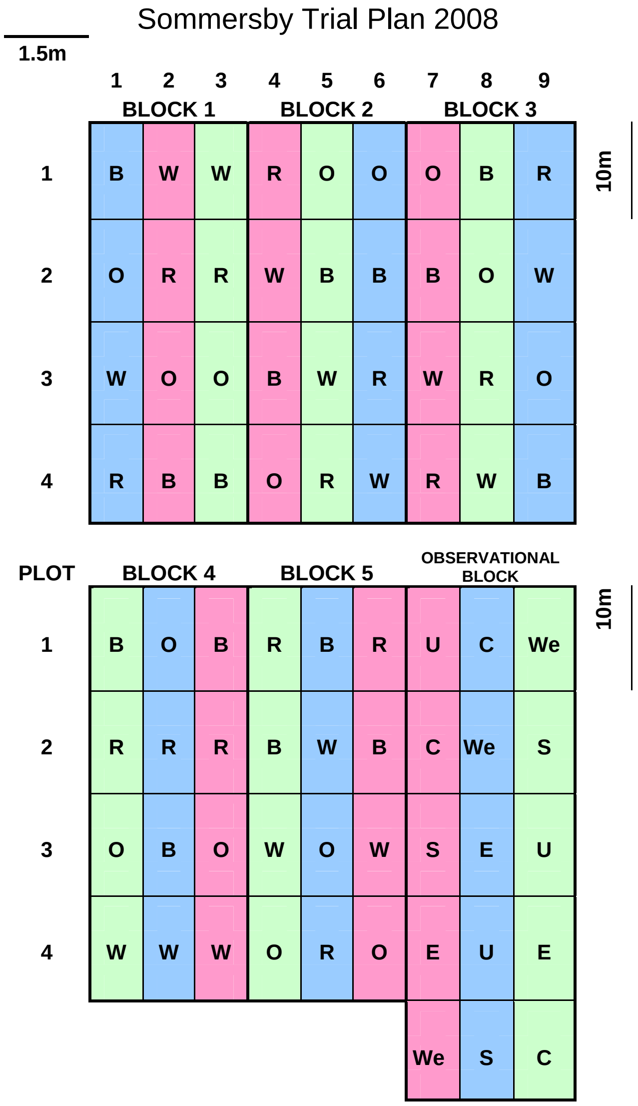
PLOT	BLOCK 4			BLOCK 5			OBSERVATIONAL BLOCK			
1	R	O	W	O	B	R	S	S	S	10m
2	O	R	R	R	W	W				
3	B	B	O	W	O	B				
4	W	W	B	B	R	O				

W = Ventura wheat
R = Ryesun rye
B = Tantangara barley
O = Echidna oats

We = Wedgetail wheat
S = Strezlecki wheat
U = Urambie barley
E = Eurrabie Oats
C = Cooba oats

🟦 planted 12 March
🟥 planted 7 April
🟩 planted 30 April

Figure 10-2 Somersby Trial Plan 2008



	1	2	3	4	5	6	7	8	9
	BLOCK 1			BLOCK 2			BLOCK 3		
1	B	W	W	R	O	O	O	B	R
2	O	R	R	W	B	B	B	O	W
3	W	O	O	B	W	R	W	R	O
4	R	B	B	O	R	W	R	W	B

PLOT	BLOCK 4			BLOCK 5			OBSERVATIONAL BLOCK		
1	B	O	B	R	B	R	U	C	We
2	R	R	R	B	W	B	C	We	S
3	O	B	O	W	O	W	S	E	U
4	W	W	W	O	R	O	E	U	E
							We	S	C

Monitoring

Approximately every three weeks (Table 10-1), a 50cm² quadrat of each plot was vacuum sampled, samples were placed into labelled ziplock bags, chilled, and kept in a freezer until samples could be sorted and counted. The growth stage of each plot was recorded.

Table 10-1 Sampling dates

Yanco

Julian days		133	155	175	210	231	253
Planting		12/5	3/6	23/6	28/7	19/8	9/9
12/03/2008		🟨	🟨	🟨	🟨	Plots slashed due to rust levels	
7/04/2008		🟨	🟨	🟨	🟨	Plots slashed due to rust levels	
30/04/2008			🟨	🟨	🟨	🟨	🟨

Somersby

Julian days	122	143	164	179	185	214	234	255	276	305
Planting	1/5	22/5	12/6	27/6	3/7	1/8	21/8	11/9	2/10	31/10
12/03/2008	🟨	🟨	🟨		🟨	🟨	🟨	🟨		
7/04/2008	🟨	🟨		🟨	🟨	🟨	🟨	🟨	🟨	
30/04/2008			🟨		🟨	🟨	🟨	🟨	🟨	🟨

coloured blocks indicate that planting was sampled

Samples were sorted into: winged and wingless aphids, pest thrips, caterpillars, pest bugs, pest beetles, grasshoppers, flies, predator thrips, lacewings, predatory bugs, spiders, hoverflies, ladybeetles, parasitoids, predatory mites, ants, and other.

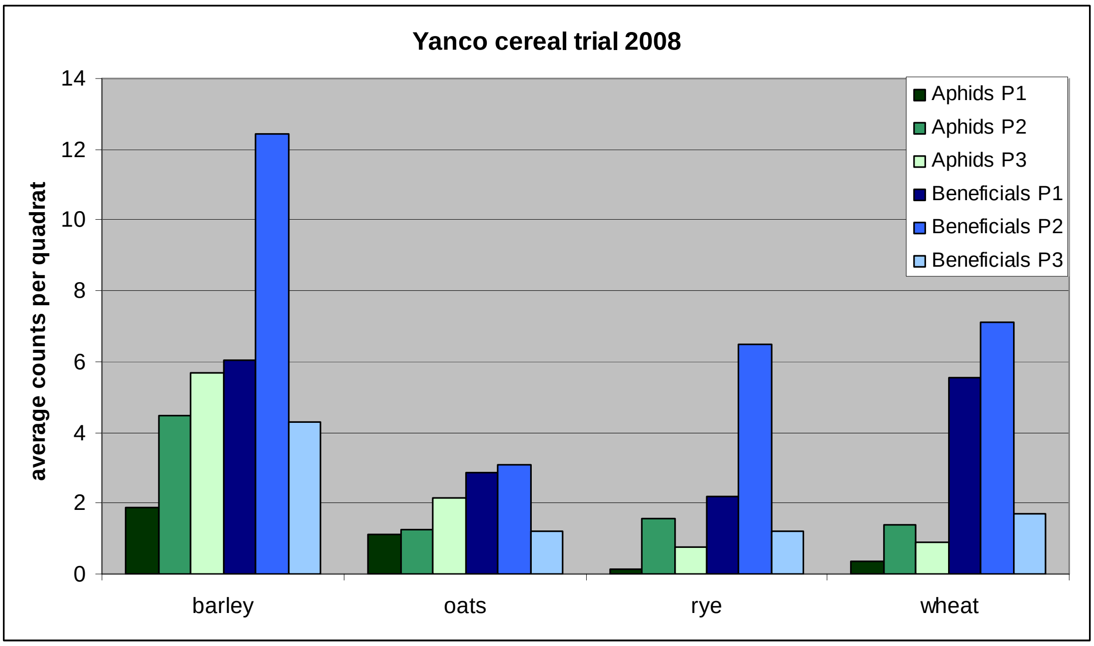
Data collected from Somersby and Yanco was analysed separately. The insect count data was square root transformed prior to analysis to satisfy the homogeneity of variance assumptions. GenStat was used to fit a mixed linear model to the count data. Correlation between sampling times was assumed to be zero. For analysis, data were combined into total aphids, total pests (not including aphids), and total beneficials.

Results

Total numbers of beneficials (Yanco: F=1.64 ddf=184.8 F pr=0.066; Somersby: Wald statistic 47.86 df=33 chi pr=0.046) and aphids (Yanco: F= 1.86 ddf=186.6 F pr=0.029, Somersby: Wald statistic 56.83 df=33 chi pr=0.006) were both significant for planting x sample date x variety at both Yanco and Somersby (see Appendix 10-1).

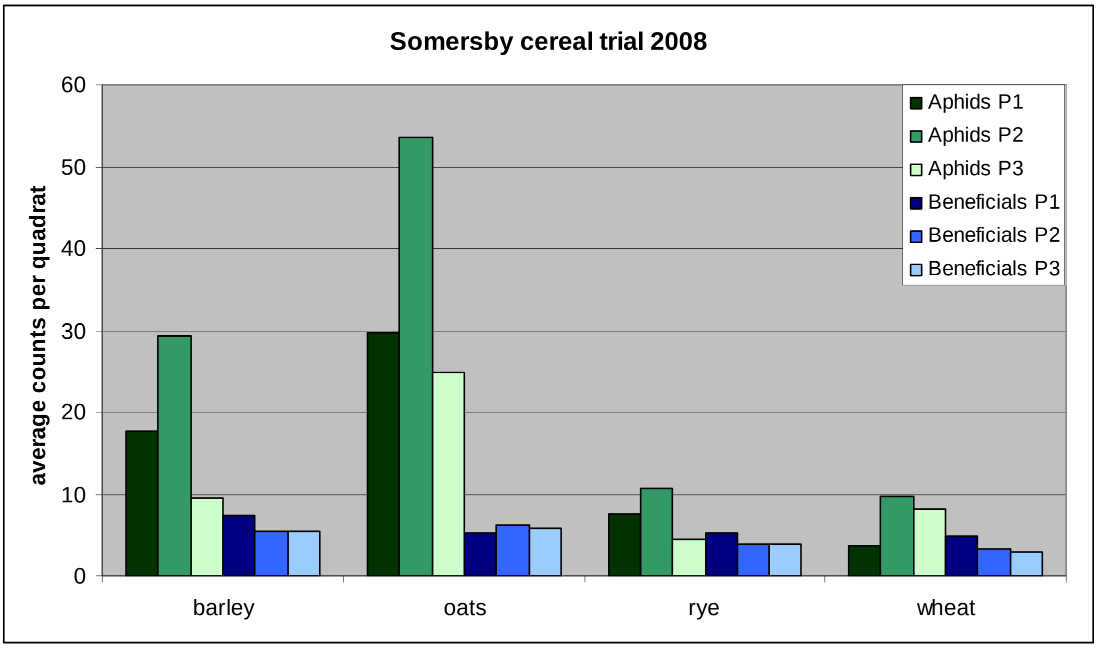
Aphid numbers were very low at Yanco, and beneficial counts were usually higher than aphid counts (Figure 10-3). Both aphid and beneficial averages per quadrat were higher in the barley plots for all three plantings with relatively more beneficials than aphids and numbers increasing from planting 1 to 3. Wheat and rye also had higher numbers of beneficials than aphids in the quadrant samples, and numbers increased from the first to the third planting. Oats had the lowest total number of insects.

Figure 10-3 Average aphid and beneficial counts per quadrat for three cereal plantings at Yanco



Somersby had much higher numbers of aphids collected with oats consistently having higher numbers than the other cereals at all planting dates. Barley was the second highest in average aphid numbers (Figure 10-4). Average beneficial numbers were slightly higher in the oats and barley relative to rye and wheat for all three plantings.

Figure 10-4 Average aphid and beneficial counts per quadrat for three cereal plantings at Somersby



II. Lettuce- Cereal trial

Materials and methods

In 2009, two trials were conducted, one each at Yanco (Figure 10-5) and Somersby (Figure 10-6) to assess the potential impact of a cereal planted adjacent to lettuce on aphid and beneficial insect populations. Based on the 2008 cereal screening trials, the cereal used at Yanco was the barley variety *Tantangara,* and at Somersby the oat variety *Echidna*. In both cases the seed were planted on 27th April 2009, at Yanco using a single bed 8 row cone seeder, and at Somersby by hand. Lettuce seedlings, *Deltona* leafy-oak variety, were purchased from Leppington Speedy Seedlings in Sydney and planted on 13th May 2009. Fertilizer, herbicides and irrigation were as per a commercial lettuce crop. The raised beds had 1.5 m centres with a 10 m buffer between plots and blocks. Buffers were kept plant free with cultivation and herbicides. Over-head irrigation was used.

Monitoring

The cereal and lettuce plants in beds 1 and 5 were monitored with a bugvac sampler and 15 lettuce per plot in bed 3 were visually monitored 3, 6, and 9 weeks after planting. A 50 cm^2 quadrat of cereal and four lettuce per bed were suction sampled, with samples placed into labelled ziplock bags, cooled, and kept in the freezer until the samples were sorted and counted. At harvest eight lettuce per plot were collected into a labelled polybag and stored in a coolroom. In the laboratory, the leaves were stripped leaf by leaf and any insects found recorded.

Data collected from Somersby and Yanco were analysed separately. The insect count data were square root transformed prior to analysis to satisfy the homogeneity of variance assumptions. For analysis, data were combined into total aphids, total pests (not including aphids), total insects, and total beneficials. The data was analyzed by ANOVA.

Figure 10-5 Yanco trial plan 2009

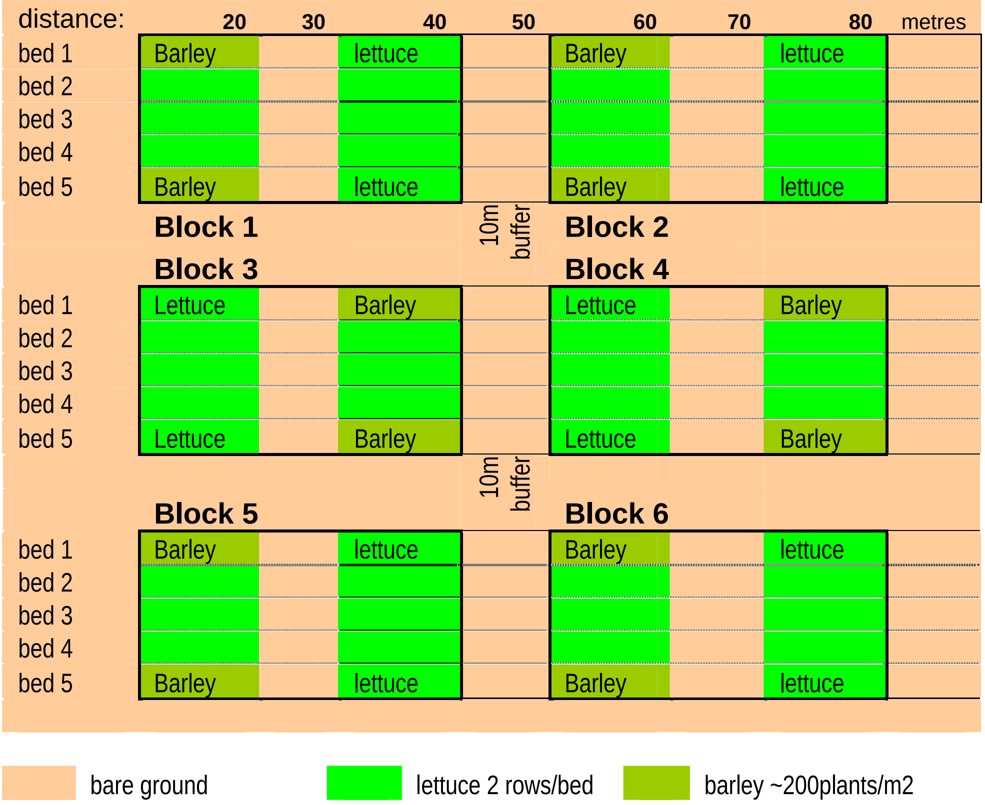
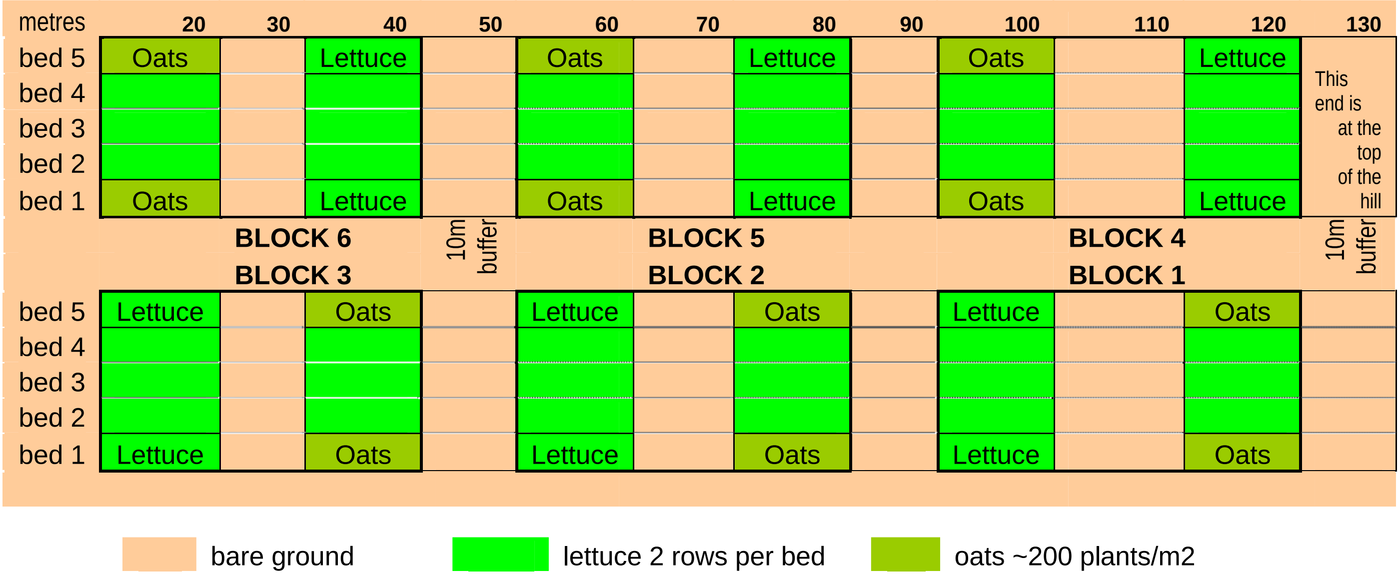


Figure 10-6 Somersby trial plan 2009



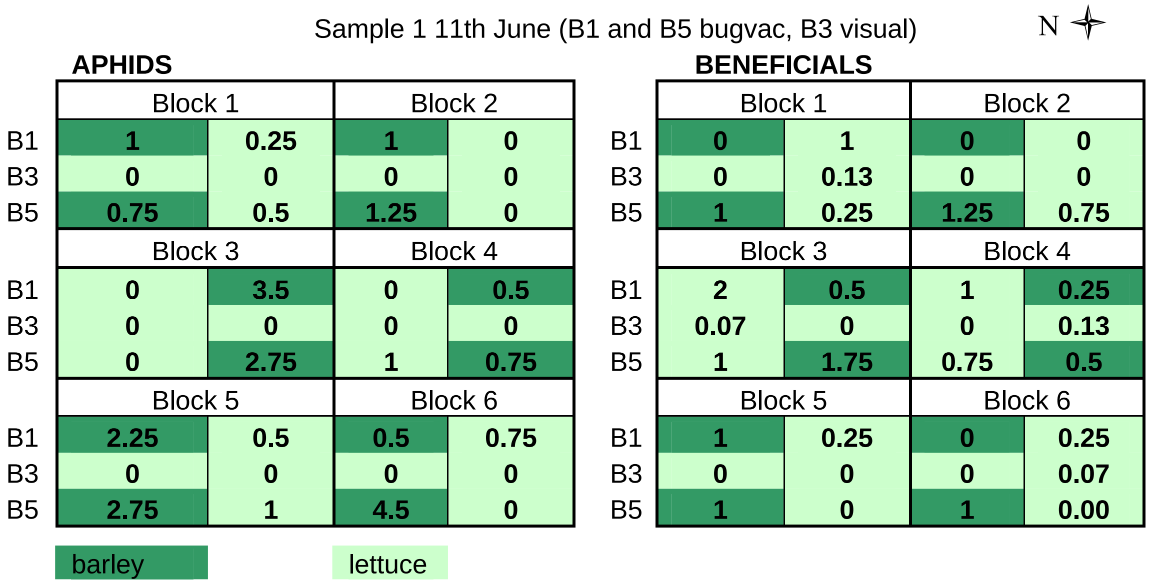
Results

Yanco

The Yanco treatment effects were mostly non-significant, but some of the vacuum samples were significant (see Appendix 10-2). Trends were evident, but not consistent.

When comparing average numbers of aphids or beneficials per lettuce or ¼ of 50 m^2 quadrat of barley vacuumed with a bugvac in beds 1 and 5 and visually sampled in bed 3 (lettuce) on 11th June, 6 weeks after transplanting, aphid numbers were higher in the barley beds than the lettuce beds (f=0.02) (Table 10.2).

Table 10-2 Yanco Sample 1 results



Sample 1 11th June (B1 and B5 bugvac, B3 visual) N

APHIDS

	Block 1		Block 2	
B1	**1**	**0.25**	**1**	**0**
B3	**0**	**0**	**0**	**0**
B5	**0.75**	**0.5**	**1.25**	**0**
	Block 3		Block 4	
B1	**0**	**3.5**	**0**	**0.5**
B3	**0**	**0**	**0**	**0**
B5	**0**	**2.75**	**1**	**0.75**
	Block 5		Block 6	
B1	**2.25**	**0.5**	**0.5**	**0.75**
B3	**0**	**0**	**0**	**0**
B5	**2.75**	**1**	**4.5**	**0**

BENEFICIALS

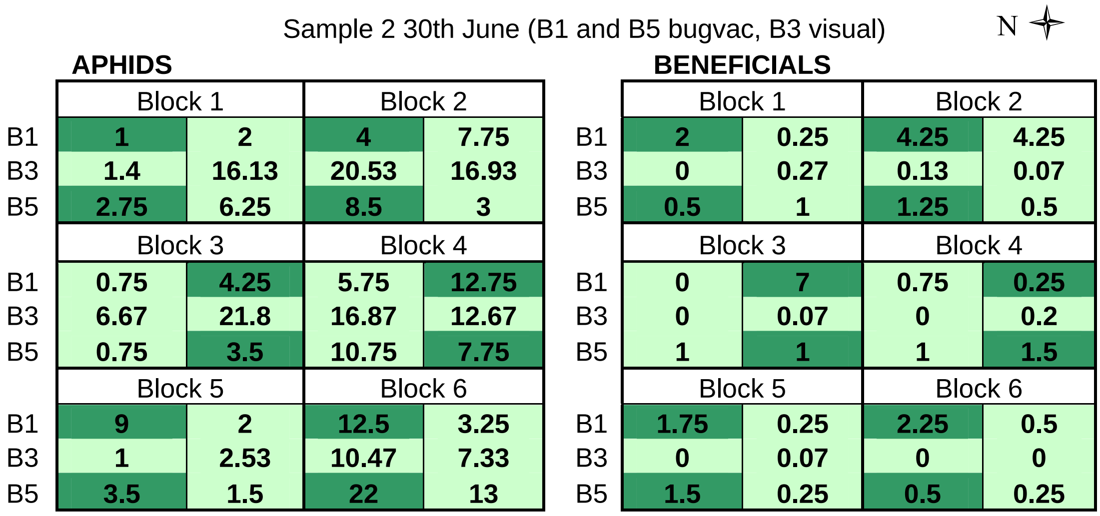
	Block 1		Block 2	
B1	**0**	**1**	**0**	**0**
B3	**0**	**0.13**	**0**	**0**
B5	**1**	**0.25**	**1.25**	**0.75**
	Block 3		Block 4	
B1	**2**	**0.5**	**1**	**0.25**
B3	**0.07**	**0**	**0**	**0.13**
B5	**1**	**1.75**	**0.75**	**0.5**
	Block 5		Block 6	
B1	**1**	**0.25**	**0**	**0.25**
B3	**0**	**0**	**0**	**0.07**
B5	**1**	**0**	**1**	**0.00**

barley

lettuce

The second sample was made at 9 weeks after transplanting. Aphid numbers increased in this sample with relatively higher numbers in lettuce in bed 3 relative to the lettuce in beds 1 and 5 (Table 10-3). Beneficials similarly increased compared to the first sample. Significantly higher numbers of beneficials were found in the barley beds than in the lettuce beds (f=0.036).

Table 10-3 Yanco Sample 2 results



Sample 2 30th June (B1 and B5 bugvac, B3 visual) N

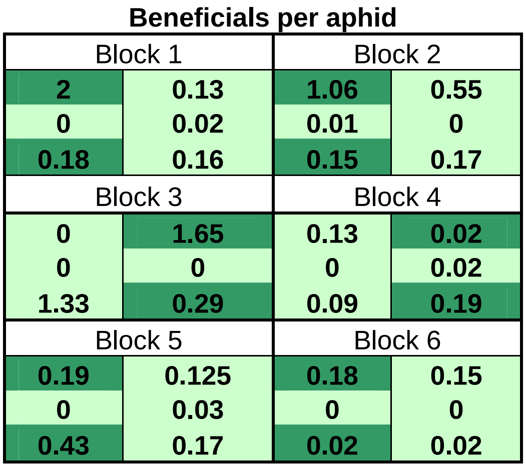
APHIDS

	Block 1		Block 2	
B1	**1**	**2**	**4**	**7.75**
B3	**1.4**	**16.13**	**20.53**	**16.93**
B5	**2.75**	**6.25**	**8.5**	**3**
	Block 3		Block 4	
B1	**0.75**	**4.25**	**5.75**	**12.75**
B3	**6.67**	**21.8**	**16.87**	**12.67**
B5	**0.75**	**3.5**	**10.75**	**7.75**
	Block 5		Block 6	
B1	**9**	**2**	**12.5**	**3.25**
B3	**1**	**2.53**	**10.47**	**7.33**
B5	**3.5**	**1.5**	**22**	**13**

BENEFICIALS

	Block 1		Block 2	
B1	**2**	**0.25**	**4.25**	**4.25**
B3	**0**	**0.27**	**0.13**	**0.07**
B5	**0.5**	**1**	**1.25**	**0.5**
	Block 3		Block 4	
B1	**0**	**7**	**0.75**	**0.25**
B3	**0**	**0.07**	**0**	**0.2**
B5	**1**	**1**	**1**	**1.5**
	Block 5		Block 6	
B1	**1.75**	**0.25**	**2.25**	**0.5**
B3	**0**	**0.07**	**0**	**0**
B5	**1.5**	**0.25**	**0.5**	**0.25**

Table 10-4 Yanco Sample 2 Beneficials per aphid



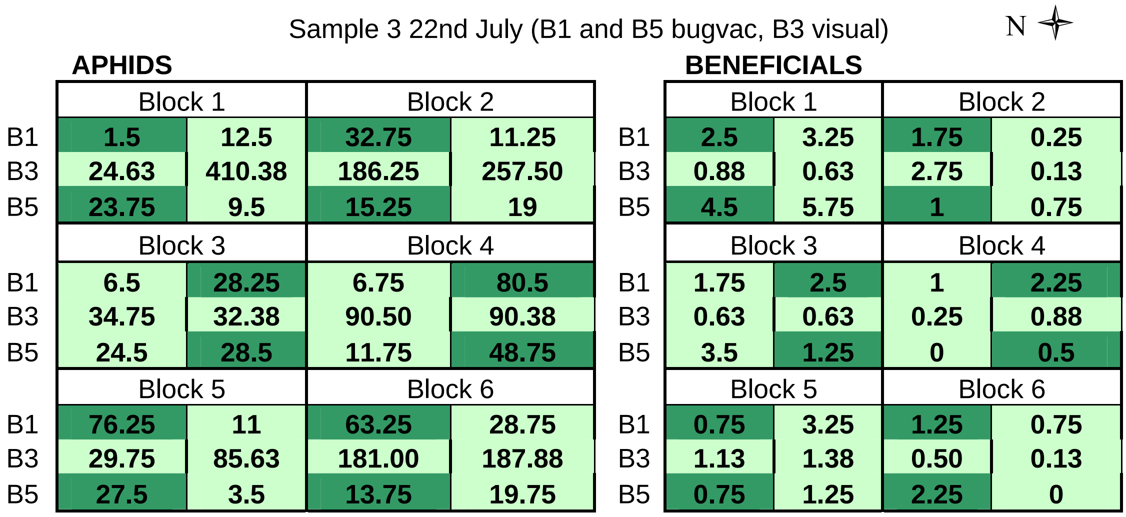
Beneficials per aphid

Block 1		Block 2	
2	0.13	1.06	0.55
0	0.02	0.01	0
0.18	0.16	0.15	0.17
Block 3		**Block 4**	
0	1.65	0.13	0.02
0	0	0	0.02
1.33	0.29	0.09	0.19
Block 5		**Block 6**	
0.19	0.125	0.18	0.15
0	0.03	0	0
0.43	0.17	0.02	0.02

When comparing average numbers of beneficials per aphid the barley plots tended towards higher numbers but it was not consistent across the plots, nor statistically significant (Table 10-4).

Both aphid and beneficials numbers increased again in the third sample, with significantly higher numbers in the barley plots relative to the lettuce (f=0.037) (Table 10-5). There tended to be lower numbers of aphids and higher numbers of beneficials in bed 3 in the barley plots relative to the lettuce plots.

Table 10-5 Yamco Sample 3 results



Sample 3 22nd July (B1 and B5 bugvac, B3 visual)

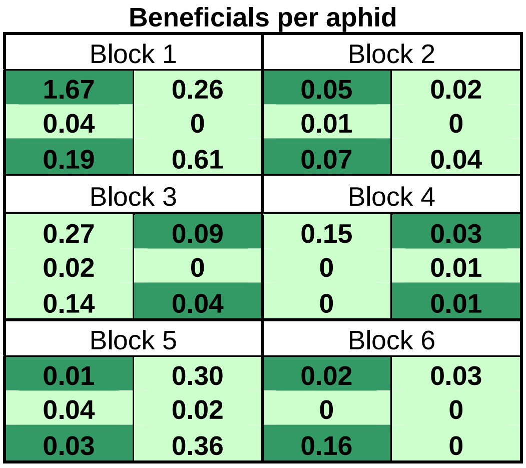
APHIDS

	Block 1		Block 2	
B1	1.5	12.5	32.75	11.25
B3	24.63	410.38	186.25	257.50
B5	23.75	9.5	15.25	19
	Block 3		**Block 4**	
B1	6.5	28.25	6.75	80.5
B3	34.75	32.38	90.50	90.38
B5	24.5	28.5	11.75	48.75
	Block 5		**Block 6**	
B1	76.25	11	63.25	28.75
B3	29.75	85.63	181.00	187.88
B5	27.5	3.5	13.75	19.75

BENEFICIALS

	Block 1		Block 2	
B1	2.5	3.25	1.75	0.25
B3	0.88	0.63	2.75	0.13
B5	4.5	5.75	1	0.75
	Block 3		**Block 4**	
B1	1.75	2.5	1	2.25
B3	0.63	0.63	0.25	0.88
B5	3.5	1.25	0	0.5
	Block 5		**Block 6**	
B1	0.75	3.25	1.25	0.75
B3	1.13	1.38	0.50	0.13
B5	0.75	1.25	2.25	0

Table 10-6 Yanco Sample 3 Beneficials per aphid



Beneficials per aphid

Block 1		Block 2	
1.67	0.26	0.05	0.02
0.04	0	0.01	0
0.19	0.61	0.07	0.04
Block 3		**Block 4**	
0.27	0.09	0.15	0.03
0.02	0	0	0.01
0.14	0.04	0	0.01
Block 5		**Block 6**	
0.01	0.30	0.02	0.03
0.04	0.02	0	0
0.03	0.36	0.16	0

Again average beneficials per aphid tend towards being higher in the barley plots, including the lettuce in bed 3 within the barley blocks (Table 10-6).

When comparing the total numbers of aphids between the barley and lettuce in beds 1 and 5, the aphid numbers increased at a greater rate in the barley (Figure 10-7).

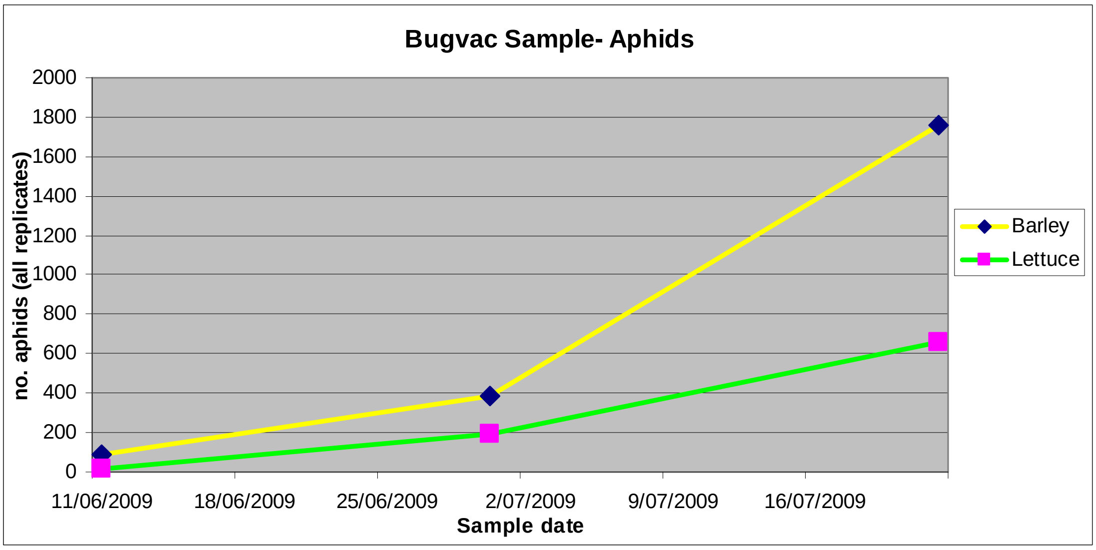


Figure 10-7 Yanco bugvac sampled aphids in barley versus lettuce

However, the total numbers of beneficials initially increased more quickly in the barley, but at harvest, the total numbers of beneficals were the same in the lettuce and barley (Figure 10-8).

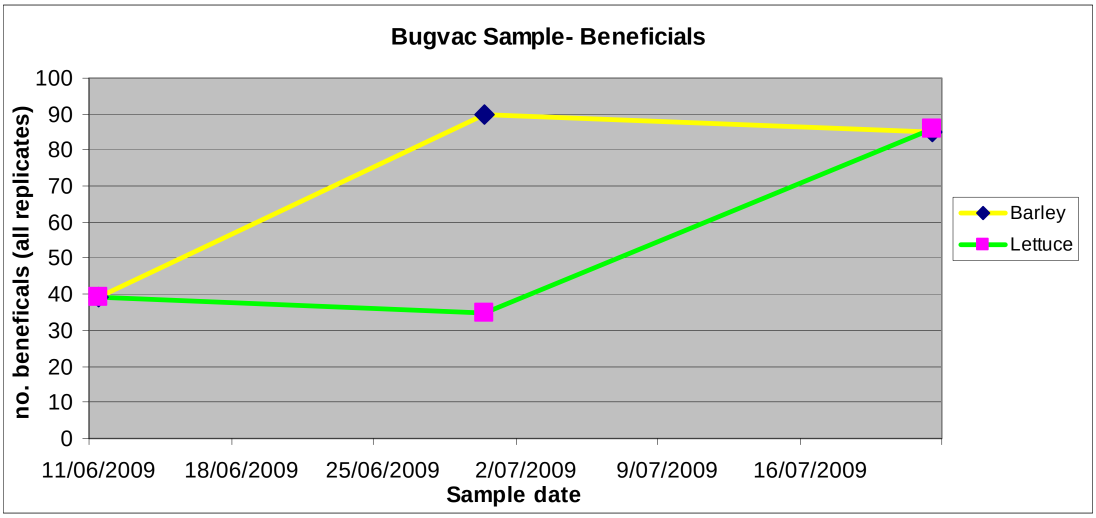


Figure 10-8 Yanco bugvac sampled beneficials in barley versus lettuce

When comparing the visual samples of lettuce in the central bed (bed 3), total aphid numbers at harvest were higher in the lettuce neighboured by lettuce than lettuce neighboured by barley (Figure 10-9). The total numbers of beneficials were higher in the lettuce in the barley blocks relative to the lettuce blocks (Figure 10-10). These are trends, not significant differences.

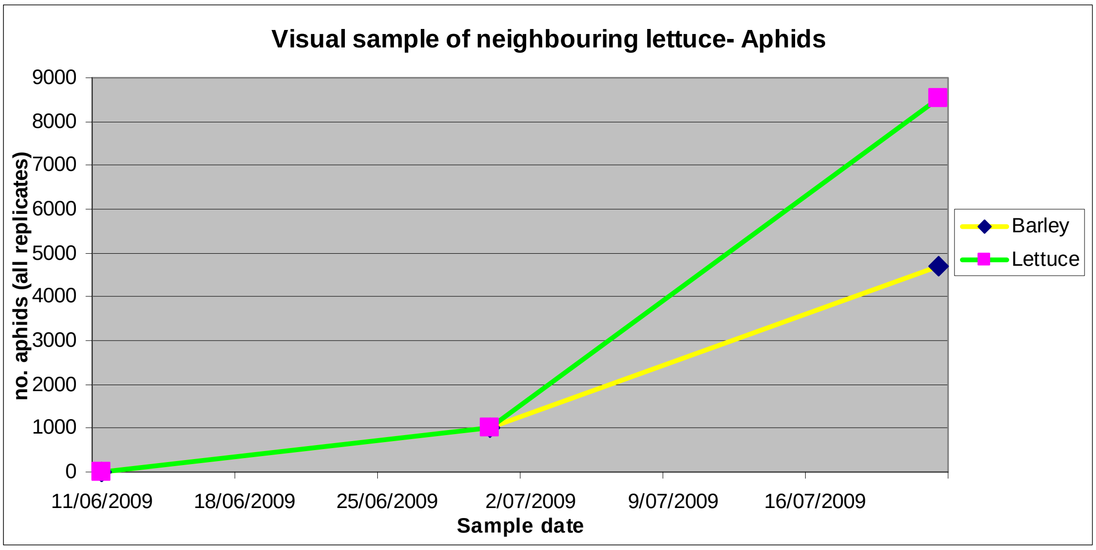


Figure 10-9 Yanco visual aphid sample in lettuce neighbouring barley or lettuce

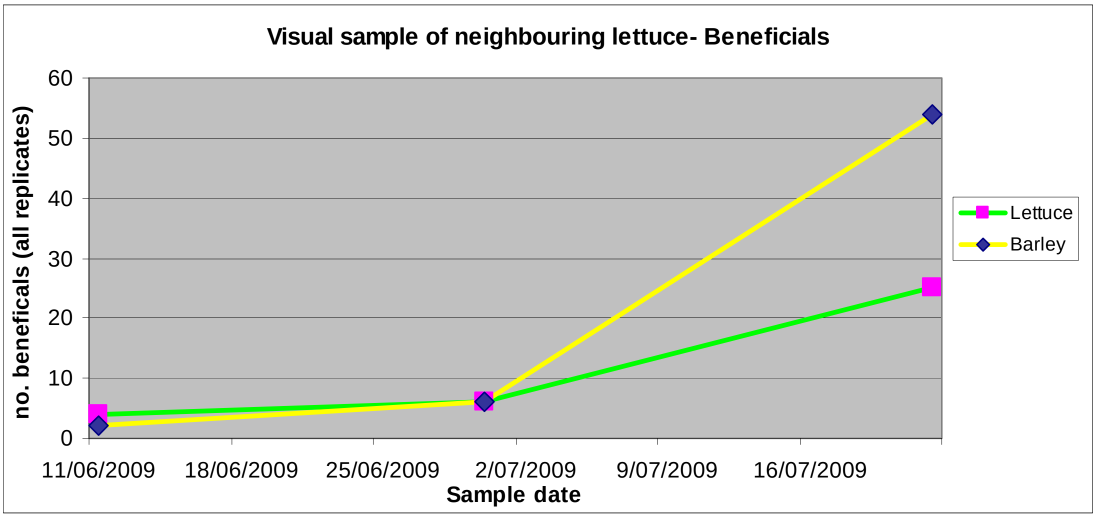
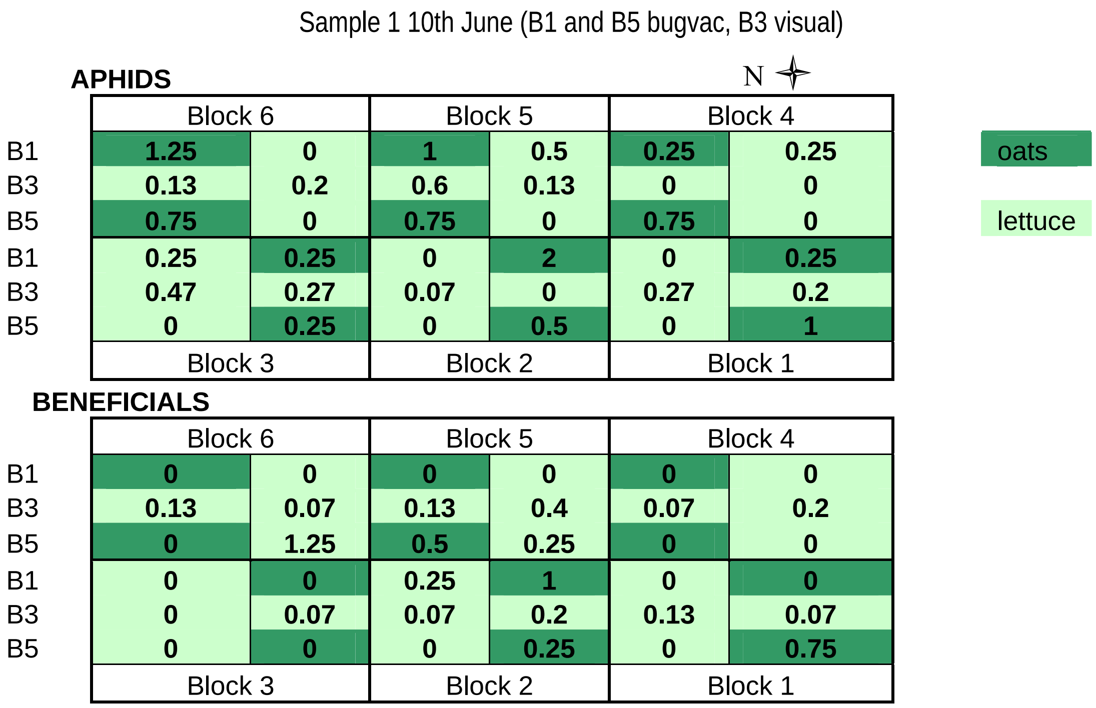


Figure 10-10 Yanco visual beneficial sample in lettuce neighbouring barley or lettuce

Somersby

The analysis of results from Somersby were also largely non-significant (see Appendix 10-2). Some trends were observable. In the first sampling period, taken 6 weeks after transplanting, aphid numbers were significantly higher in the oats than in the lettuce in rows 1 and 5 (f=0.007) but aphid numbers in lettuce in the middle beds (row 3) tended to be lower in neighbouring oats than in those neighbouring lettuce (Table 10-7).

Table 10-7 Somersby Sample 1 results



Sample 1 10th June (B1 and B5 bugvac, B3 visual)

APHIDS

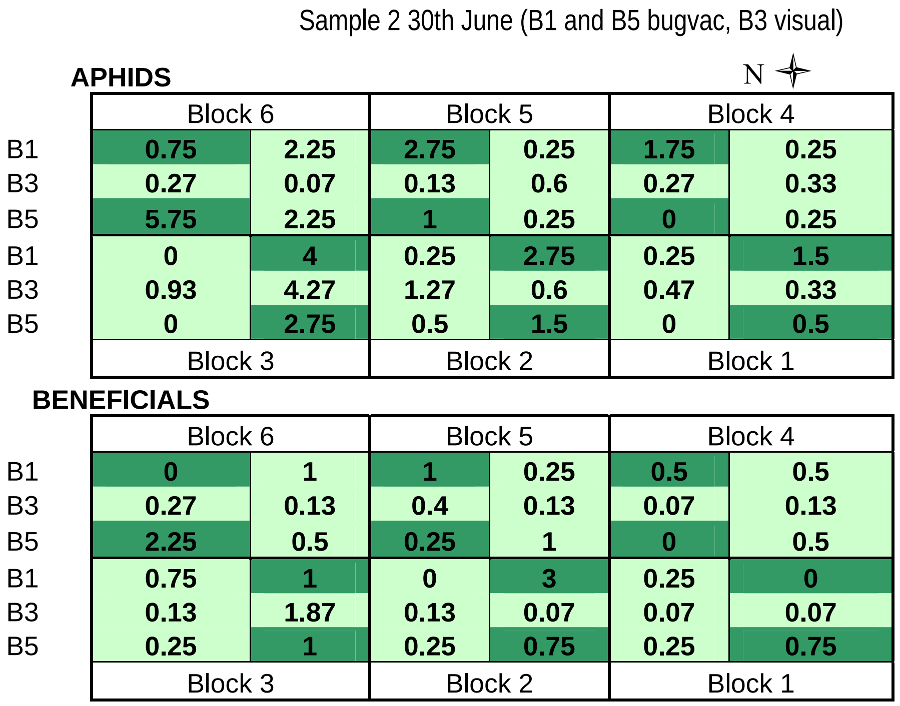
	Block 6		Block 5		Block 4	
B1	1.25	0	1	0.5	0.25	0.25
B3	0.13	0.2	0.6	0.13	0	0
B5	0.75	0	0.75	0	0.75	0
B1	0.25	0.25	0	2	0	0.25
B3	0.47	0.27	0.07	0	0.27	0.2
B5	0	0.25	0	0.5	0	1
	Block 3		Block 2		Block 1	

BENEFICIALS

	Block 6		Block 5		Block 4	
B1	0	0	0	0	0	0
B3	0.13	0.07	0.13	0.4	0.07	0.2
B5	0	1.25	0.5	0.25	0	0
B1	0	0	0.25	1	0	0
B3	0	0.07	0.07	0.2	0.13	0.07
B5	0	0	0	0.25	0	0.75
	Block 3		Block 2		Block 1	

Second sample was taken 9 weeks after transplanting (Table 10-8). Aphid numbers increased by a factor of 3 in this second sample. Aphid numbers continued to be significantly higher in the oat samples (f=0.013), and they also tended to increase in the lettuce neighbouring oats. Beneficials similarly increased by a factor of 3 compared to the first sample. Similarly the trend to higher numbers of beneficials in oats was less obvious in sample 2 relative to sample 1.

Table 10-8 Somersby Sample 2 results



Sample 2 30th June (B1 and B5 bugvac, B3 visual)

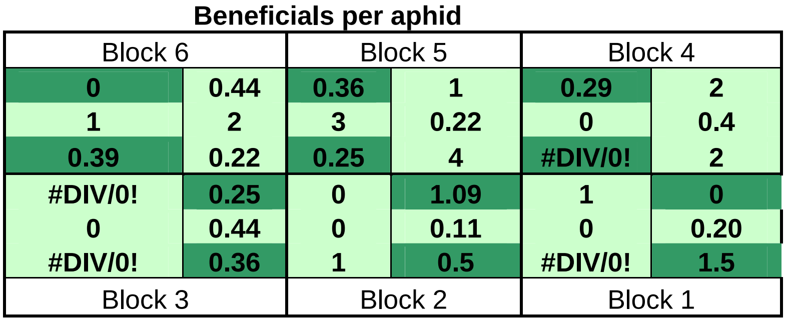
APHIDS

	Block 6		Block 5		Block 4	
B1	0.75	2.25	2.75	0.25	1.75	0.25
B3	0.27	0.07	0.13	0.6	0.27	0.33
B5	5.75	2.25	1	0.25	0	0.25
B1	0	4	0.25	2.75	0.25	1.5
B3	0.93	4.27	1.27	0.6	0.47	0.33
B5	0	2.75	0.5	1.5	0	0.5
	Block 3		Block 2		Block 1	

BENEFICIALS

	Block 6		Block 5		Block 4	
B1	0	1	1	0.25	0.5	0.5
B3	0.27	0.13	0.4	0.13	0.07	0.13
B5	2.25	0.5	0.25	1	0	0.5
B1	0.75	1	0	3	0.25	0
B3	0.13	1.87	0.13	0.07	0.07	0.07
B5	0.25	1	0.25	0.75	0.25	0.75
	Block 3		Block 2		Block 1	

Table 10-9 Somersby Sample 2 beneficials per aphid



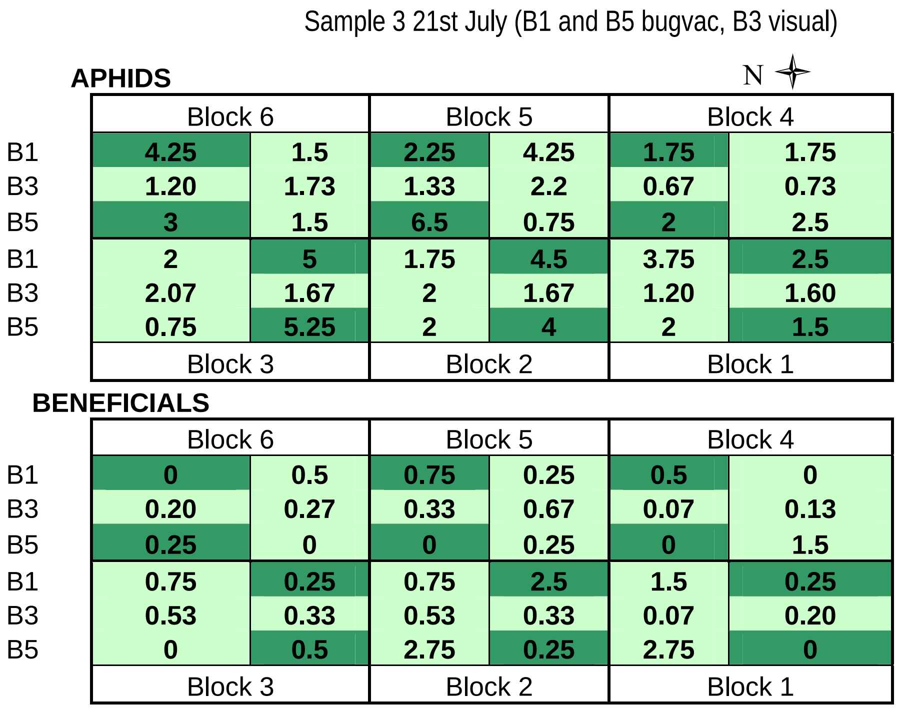
Beneficials per aphid

Block 6		Block 5		Block 4	
0	0.44	0.36	1	0.29	2
1	2	3	0.22	0	0.4
0.39	0.22	0.25	4	#DIV/0!	2
#DIV/0!	0.25	0	1.09	1	0
0	0.44	0	0.11	0	0.20
#DIV/0!	0.36	1	0.5	#DIV/0!	1.5
Block 3		Block 2		Block 1	

When comparing average numbers of beneficials per aphid, the oats tended to have lower numbers of beneficals per aphid than lettuce in the same bed, and no consistent to trend could be seen in the lettuce in bed 3 (Table 10-9).

Aphid numbers increased by a factor of 2 in the third sample compared to the second sample, with a continuing trend towards higher numbers in the oat plots relative to the lettuce (Table 10-10). In the central bed of lettuce the lettuce bordering the oats tended to have lower aphid numbers.

Table 10-10 Somersby Sample 3 results



Sample 3 21st July (B1 and B5 bugvac, B3 visual)

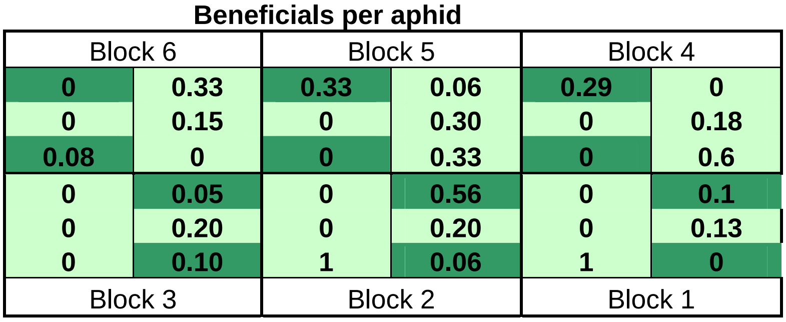
APHIDS

	Block 6		Block 5		Block 4	
B1	4.25	1.5	2.25	4.25	1.75	1.75
B3	1.20	1.73	1.33	2.2	0.67	0.73
B5	3	1.5	6.5	0.75	2	2.5
B1	2	5	1.75	4.5	3.75	2.5
B3	2.07	1.67	2	1.67	1.20	1.60
B5	0.75	5.25	2	4	2	1.5
	Block 3		Block 2		Block 1	

BENEFICIALS

	Block 6		Block 5		Block 4	
B1	0	0.5	0.75	0.25	0.5	0
B3	0.20	0.27	0.33	0.67	0.07	0.13
B5	0.25	0	0	0.25	0	1.5
B1	0.75	0.25	0.75	2.5	1.5	0.25
B3	0.53	0.33	0.53	0.33	0.07	0.20
B5	0	0.5	2.75	0.25	2.75	0
	Block 3		Block 2		Block 1	

Table 10-11 Somersby Sample 3 beneficials per aphid



Beneficials per aphid

Block 6		Block 5		Block 4	
0	0.33	0.33	0.06	0.29	0
0	0.15	0	0.30	0	0.18
0.08	0	0	0.33	0	0.6
0	0.05	0	0.56	0	0.1
0	0.20	0	0.20	0	0.13
0	0.10	1	0.06	1	0
Block 3		Block 2		Block 1	

No consistent trend can be seen in average numbers of beneficials per aphid (Table 10-11).

The Somersby harvest assessment of lettuce in bed 3 was taken ten days after sample 3, using mature lettuce (Table 10-12). The lettuce neighbouring oats (Table 10-12 numbers in green) had a small trend to have higher numbers of aphids but no consistent trend in beneficial numbers.

Table 10-12 Somersby harvest sample

Harvest Sample 31st July (B3 visual)

APHIDS

	Block 6		Block 5		Block 4	
B3	7.13	7.40	14.27	6.4	8.40	7.47
B3	17.60	25.20	15.53	27.4	14.53	10
	Block 3		Block 2		Block 1	

BENEFICIALS

	Block 6		Block 5		Block 4	
B3	1.80	1.93	1.27	2.27	2.13	1
B3	2.27	3.33	1.20	3.73	1.47	0.73
	Block 3		Block 2		Block 1	

Table 10-13 Somersby harvest sample beneficials per aphid

Beneficials per aphid

Block 6		Block 5		Block 4	
0.25	0.26	0.09	0.35	0.25	0.13
0.13	0.13	0.08	0.14	0.10	0.07
Block 3		Block 2		Block 1	

When comparing the average number of beneficials per aphid, there was no consistent trend (Table 10-13). However, when comparing the total numbers of aphids between the oats and lettuce in beds 1 and 5, the aphid numbers were consistently higher in the oats (Figure 10-11).

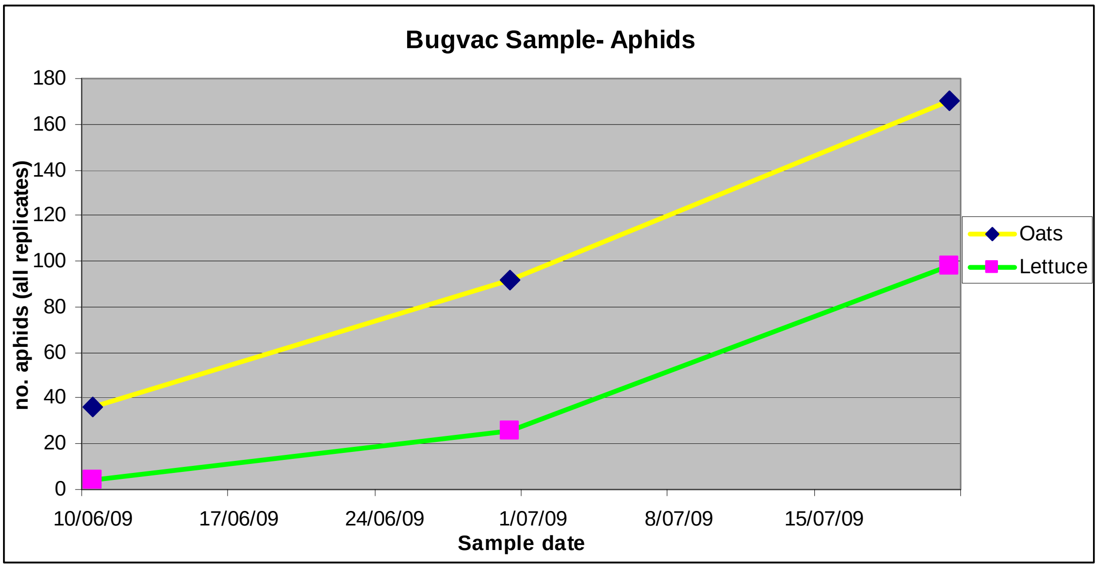


Figure 10-11 Somersby bugvac sampled aphids in oats versus lettuce

When comparing the total number of beneficials across the treatments, the oats had higher numbers at the second sample and lower numbers at the third sample (Figure 10-12).

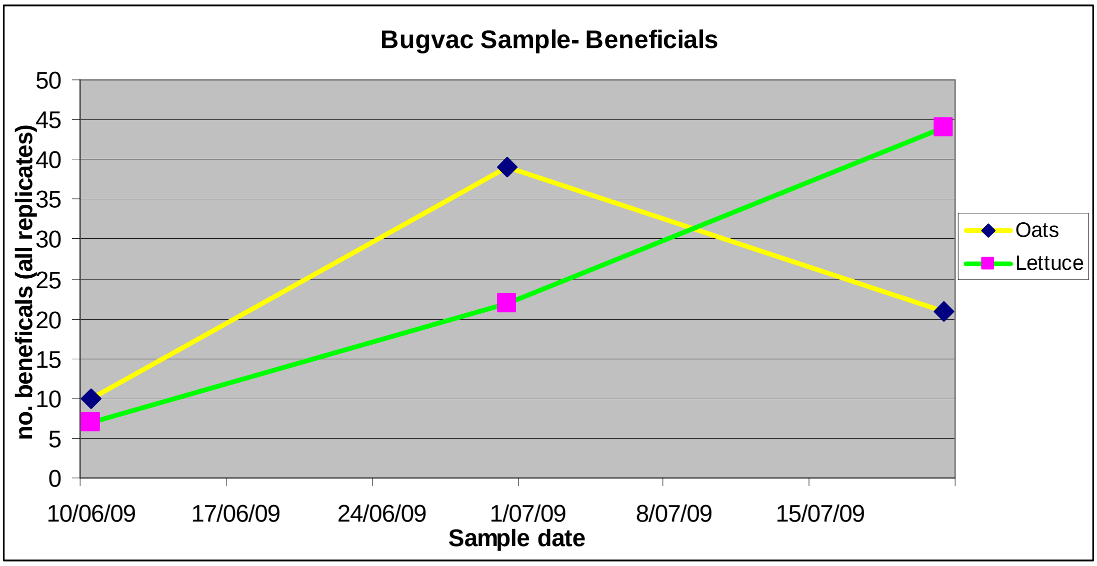


Figure 10-12 Somersby bugvac sampled beneficials in oats versus lettuce

The visual samples in the field contained fewer aphids than in the destructive harvest assessment that stripped lettuce leaf by leaf. The lettuce bordered by oats had a higher total aphid count than lettuce bordered by lettuce (Figure 10-13).

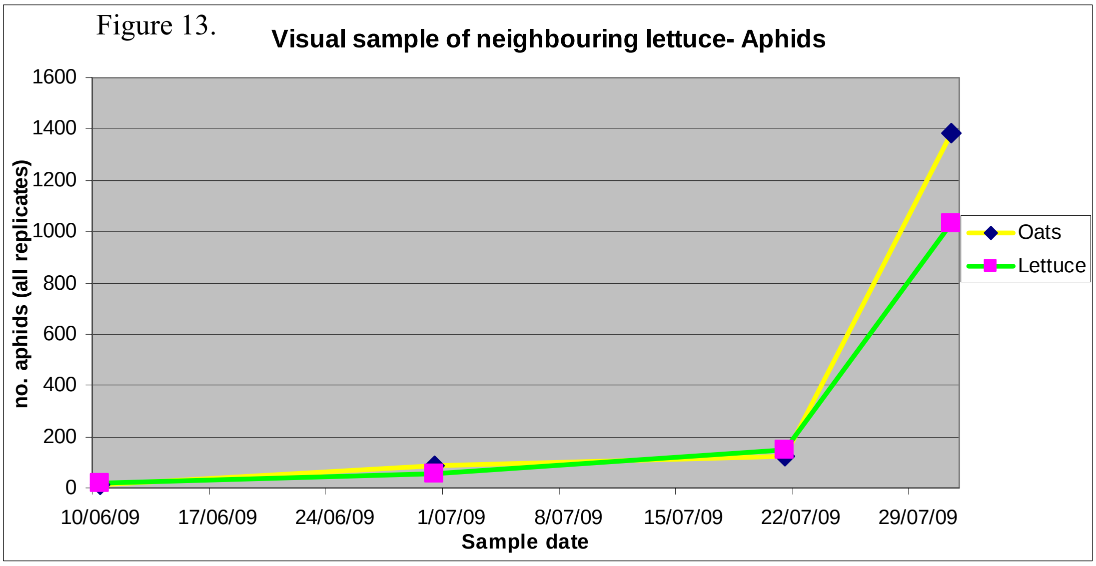


Figure 10-13 Somersby visual sample of aphids in lettuce neighbouring oats or lettuce

Total beneficial numbers similarly were much higher in the destructive sample versus the field visual samples, and the total numbers of beneficials were similarly higher in the lettuce bordered by oats at harvest (Figure 10-14).

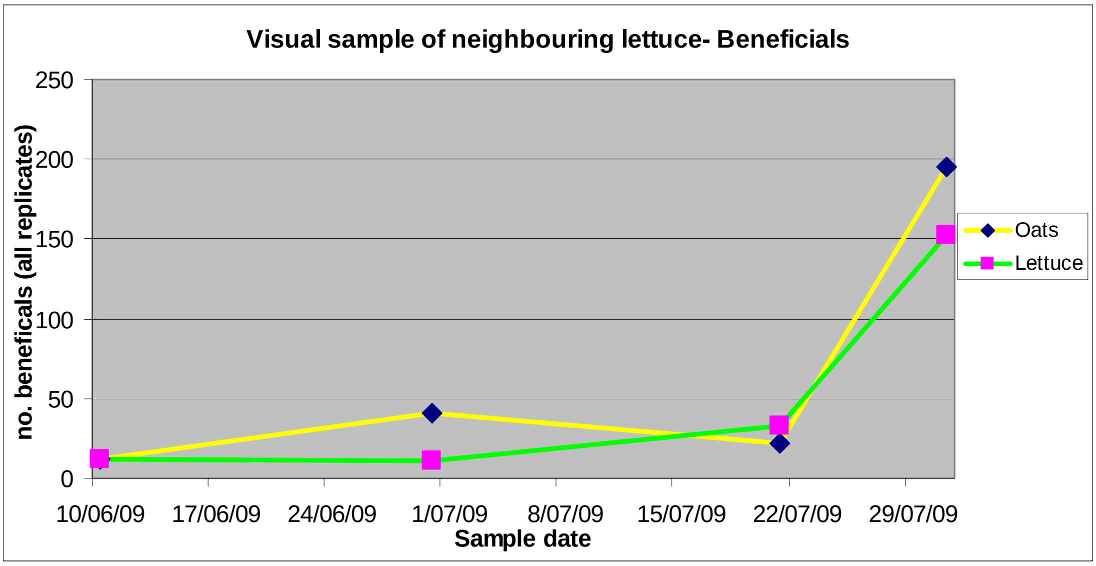


Figure 10-14 Somersby visual sample of beneficials in lettuce neighbouring oats or lettuce

Discussion

Ecologically, it would be expected to see cereal crops supporting cereal aphids and their natural enemies, and that the adults of those natural enemies being largely winged would readily colonise neighbouring lettuce once aphids had started colonising the lettuce. A lag would be expected but the natural enemies would respond to increasing aphid numbers and readily control the aphids in the lettuce.

The application of the expected ecological process is not quite as straight forward, and this trial did not unequivocally support the planting of a cereal next to lettuce. The trials illustrated the variability in aphid numbers between regions and seasons, probably reflecting the different prevailing weather conditions at the time of the trials. In 2008, Yanco saw relatively few aphids compared to Sommersby, but in 2009, the situation was reversed.

The different cereals were variable in their attractiveness to aphids but both the oats and the barley were colonised more readily than wheat or rye. The rye in particular was relatively quick to go to seed and hence loose attractiveness for aphids. Barley, on the other hand, was the slowest to set seed, but at Sommersby it had relatively poor germination and hence had a more patchy stand, and hosted more weeds than oats.

To be able to say that a treatment is effective it is important to test it in a replicated trial with a suitable untreated control. To work within available resources requires trade offs between size of the treatment plots and the number of replicates and a design that is not necessarily optimal statistically. The 2009 trials to test whether the planting of cereals near lettuce would improve control of aphids found much greater variability between the rows and blocks of the lettuce than between the treatments. This re-inforces the importance of replicates in that if only a single treated planting was compared with a single untreated planting, quite different results would have been recorded depending on treatment placement relative to each other, and not necessarily the treatment itself.

However, cereal aphids and aphid natural enemies were observed to colonise the cereals in higher numbers than in the lettuce. The important result was that at Yanco, there was an impact on aphid and beneficial numbers in lettuce 2 beds away from the cereals. This trial design did not allow for testing the effect at a greater distance from the source. However, the numbers of aphids were extreme, and although the lettuce near the cereals had generally fewer aphids, the numbers were not acceptable for market. Sommersby had much lower numbers of aphids and they were similar in the lettuce whether near the oats or not and again the aphid numbers at harvest would not be acceptable for the market.

Clearly growing lettuce with adjacent cereals is not a practice that could be recommended to growers on its own without further investigation. It is currently being practiced by some IPM growers in Victoria (P. Horne pers. comm.), but those growers would have used selective aphidicides to reduce the aphid population with minimal effect on the beneficials. Thus, aphid management services from both the aphicides and the beneficials can improve overall management of aphids when compared to using aphicides on their own.

This trial did succeed in showing that cereals were supporting both aphids and their natural enemies and thereby could be a nursery for neighbouring lettuce.

11. Bion® and Movento® efficacy trials

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Introduction

Tomato spotted wilt virus (TSWV) is transmitted by a number of thrips species. Tomato thrips (*Franklienella schultzei*), onion thrips (*Thrips tobaci*) and western flower thrips (*Franklienella occidentalis* WFT) are the most common TSWV vectors in lettuce. WFT develops resistance to insecticides quickly and there are very few insecticide options for growers to use to manage this pest, with only one registered or permitted insecticide for use in hydroponic lettuce – spinosad (Success®). WFT resistance to spinosad was first detected in 2002 (Herron *et al.* 2004) and in 2005 a single strain found in the Sydney basin had resistance levels of around 97% (Herron & Broughton 2006).

Both WFT and TSWV have very broad host ranges (Persley *et al.* 2006) and have been found on most annual weeds in and around crop production areas (McDougall *et al.* 2008). Not all species infected with TSWV will show visible symptoms. For a thrips to become a vector of TSWV it must develop on a plant with TSWV. This means that eggs must be laid on an infected plant, the larvae hatch and feed on the infected plant, and ingest the TSWV. Once the larvae mature and pupate, it is the emerging winged adult that is mobile enough to move to other plants and infect them with TSWV. Therefore, weed management is an essential method for effectively managing TSWV incidence. However, there will be times when thrips move from neighbouring areas, and other management options would be helpful.

Any chemical option needs to be managed to avoid pesticide resistance build-up to retain efficacy for future strategic use. Ideally any new chemistry should be compatible with use of biological control agents in the system. These chemistries are called “biorational” pesticides.

A biorational pesticide is generally derived from biological sources such as bacteria, viruses, fungi and protozoa, as well as chemical analogues of naturally occurring biochemicals. Biorational pesticides are often considerably different to conventional, broad-spectrum products in the sense that they are typically highly target-specific and have little to no impact on non-target organisms. This trait is particularly important in order to protect beneficial insects. Two potential options are Bion® and Movento®.

Bion® - *benzothiadiazole* is a commercial salicylic acid mimic that can stimulate the plant to produce defence compounds against diseases – commonly called Systemic Acquired Resistance (SAR). Some research indicates that it can reduce TSWV infection.

Movento® (Bayer) – *spirotetramat* is a chemical with a new mode of action which is an inhibitor of lipid biosynthesis (Bruck *et al.* 2009). It is active by ingestion against immature insects feeding on treated plants. In addition some studies have shown significant impact on exposed female adults by reducing fecundity and survival of offspring, providing more effective overall reduction in pest pressure (Bruck *et al.* 2009). It needs to be applied with an adjuvant that allows penetration of the plant and then it moves systemically through the plant in both the xylem and phloem. Movento® has low toxicity to key beneficials making it suitable to use in an IPM system (Schnorbach *et al.* 2008, Horne *et al.* 2009). The only published studies on Movento® are by the manufacturers of the chemical. Additional testing is needed to determine the practical applications of this chemical in a crop environment.

Hasten® (Victoria Chemicals) is a spray adjuvant based on ethylated corn, canola, soybean oils and a blend of non-ionic surfactants which acts as a spreader-penetrator. It aids in translocation of pesticides through the waxy plant cuticle.

Two trials were conducted to test the potential efficacy of Bion® and Movento® with Hasten®.

Aim

To evaluate the potential of Bion® and Movento® to reduce Tomato Spotted Wilt Virus (TSWV) incidence in hydroponic lettuce in a period of high thrips and TSWV pressure.

Materials and methods

Trial 1 – Commercial Hydroponic lettuce

A commercial hydroponic farm in the Sydney basin which had been experiencing high levels of TSWV was selected as the trial site in March 2009. Commercially reared seedlings were treated as per the trial protocol, then transplanted into “seedling” channels for the first three weeks and retransplanted into “maturing” channels for the remainder of the trial. The nutrient solution was as per the usual grower practice.

Each treatment consisted of 30 green oak lettuce seedlings (var: *Deltona*) that had not been previously treated with insecticides, each treated with one of seven treatments:

Treatment	Treatment name	Treatment /100 ml water	Volumne of solution on 120 seedlings (ml)
1	Water control	100 ml	45
2	Bion® low	7.8 µL	50
3	Bion® medium	68 µL	45
4	Bion® high	136 µL	40
5	Movento®	16 µL	40
6	Movento® + Hasten®	40 µL + 10ml	45
7	Hasten®	10 ml	45

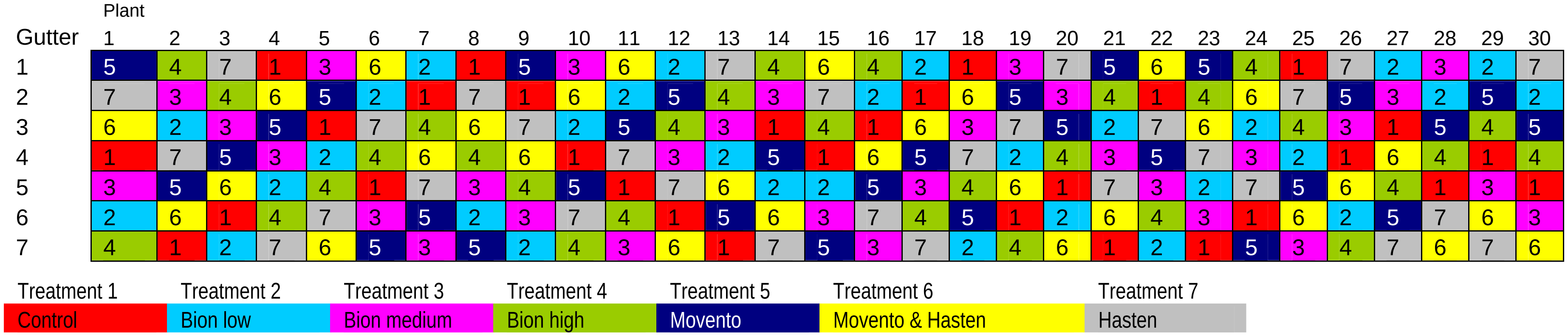
Note Bion® is 50% ai acibenzolar-S-methyl and Movento® is 240 gai/L of spirotetramat

Application

The recommended rate of Bion® was 1g ai/7000 plants and the recommended application rate for WFT of Movento® was 400 ml/ha with 0.5 -1% Hasten® as an adjuvant. This converts to 40 ml per 100 L assuming a 1000 L water rate/ha or 40 µL/100 ml. Hasten® was used at 1%. One hundred ml of each chemical or combination of chemicals was made up in 500ml spray bottle. Trays of 120 previously untreated seedlings were sprayed to run-off and the actual volume was recorded.

The seedlings were collected from a commercial nursery, and chemical applications were made at EMAI, Menangle, before going either to the growers farm or Gosford Research Station (Trial 2). After seedlings were treated, they were transported to the grower’s farm

Figure 11-1 Trial 1 Commercial hydroponic lettuce: ‘nursery tables’ 5th March – 26th March 2009

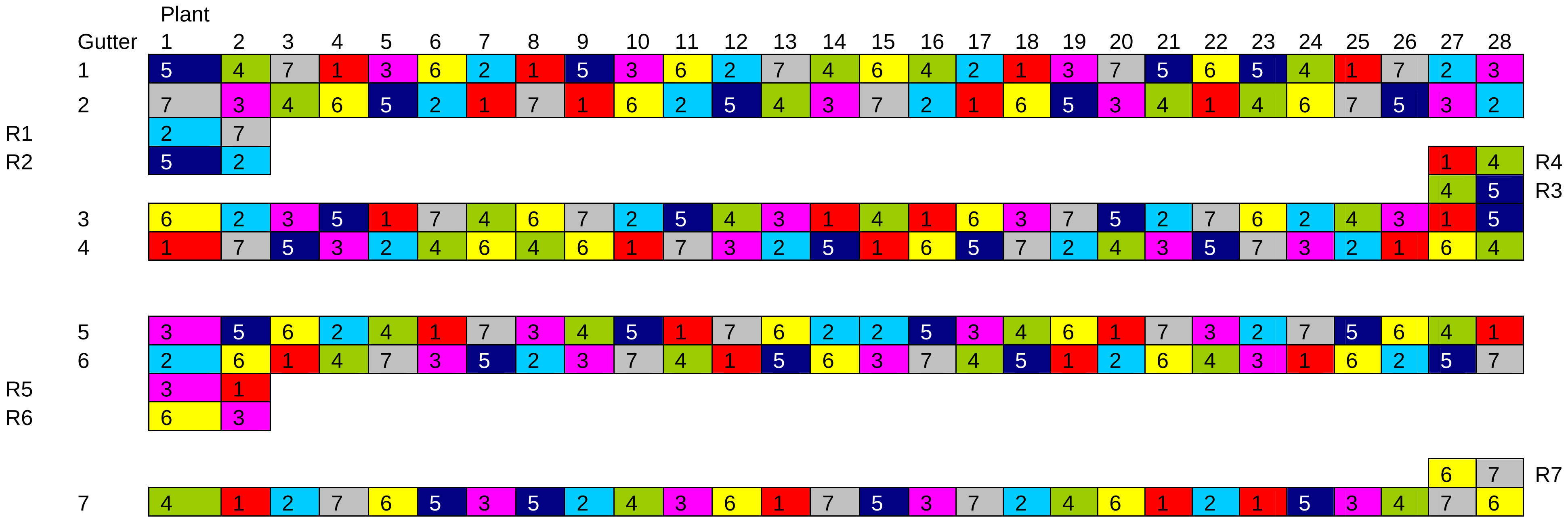


Plant

Gutter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	5	4	7	1	3	6	2	1	5	3	6	2	7	4	6	4	2	1	3	7	5	6	5	4	1	7	2	3	2	7
2	7	3	4	6	5	2	1	7	1	6	2	5	4	3	7	2	1	6	5	3	4	1	4	6	7	5	3	2	5	2
3	6	2	3	5	1	7	4	6	7	2	5	4	3	1	4	1	6	3	7	5	2	7	6	2	4	3	1	5	4	5
4	1	7	5	3	2	4	6	4	6	1	7	3	2	5	1	6	5	7	2	4	3	5	7	3	2	1	6	4	1	4
5	3	5	6	2	4	1	7	3	4	5	1	7	6	2	2	5	3	4	6	1	7	3	2	7	5	6	4	1	3	1
6	2	6	1	4	7	3	5	2	3	7	4	1	5	6	3	7	4	5	1	2	6	4	3	1	6	2	5	7	6	3
7	4	1	2	7	6	5	3	5	2	4	3	6	1	7	5	3	7	2	4	6	1	2	1	5	3	4	7	6	7	6

Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7
Control	Bion low	Bion medium	Bion high	Movento	Movento & Hasten	Hasten

Figure 11-2 Trial 1 Commercial hydroponic lettuce: 26th March - 21st April 2009



Plant

	Gutter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
	1	5	4	7	1	3	6	2	1	5	3	6	2	7	4	6	4	2	1	3	7	5	6	5	4	1	7	2	3	
	2	7	3	4	6	5	2	1	7	1	6	2	5	4	3	7	2	1	6	5	3	4	1	4	6	7	5	3	2	
R1		2	7																											
R2		5	2																									1	4	R4
																												4	5	R3
	3	6	2	3	5	1	7	4	6	7	2	5	4	3	1	4	1	6	3	7	5	2	7	6	2	4	3	1	5	
	4	1	7	5	3	2	4	6	4	6	1	7	3	2	5	1	6	5	7	2	4	3	5	7	3	2	1	6	4	
	5	3	5	6	2	4	1	7	3	4	5	1	7	6	2	2	5	3	4	6	1	7	3	2	7	5	6	4	1	
	6	2	6	1	4	7	3	5	2	3	7	4	1	5	6	3	7	4	5	1	2	6	4	3	1	6	2	5	7	
R5		3	1																											
R6		6	3																											
																												6	7	R7
	7	4	1	2	7	6	5	3	5	2	4	3	6	1	7	5	3	7	2	4	6	1	2	1	5	3	4	7	6	

and arranged as per the trial plan (Figure 11-1) within hydroponic ‘seedling’ channels with 12 cm spacings between holes. Each channel hole was labelled (1-30) and each channel labelled (1-7) to ensure correct data collection but anonymity of treatment when monitoring. Once the seedlings had grown too large for the seedling channels they were carefully moved to channels with larger holes spaced 24 cm apart and again labelled. Unfortunately the larger channels only had room for 28 plants and it was not possible to monitor across three channels so the plants were arranged as per Figure 11-2 once they outgrew the nursery channels.

Trial 2 – Greenhouse Hydroponic lettuce (Gosford Research Station)

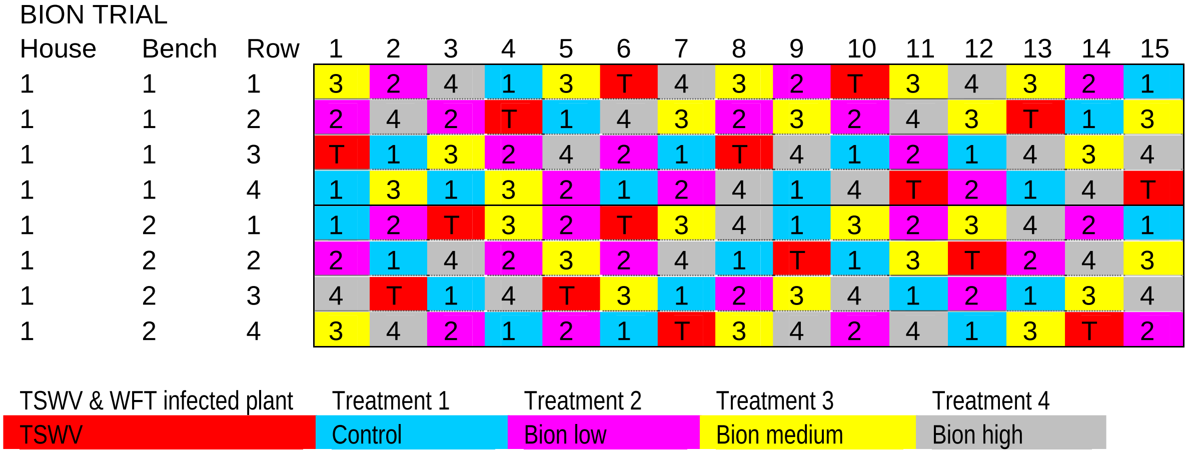
This trial was conducted using lettuce from the same nursery and treated at the same time as Trial 1 with the same treatment batches. The lettuce was transported to Gosford and left in a polyhouse overnight. The following day it was laid out in two small polyhouses. Each house had 4 hydroponic channels per bench, each channel supporting 15 plants and there were 2 benches per house. Given the trial could not be housed in the one greenhouse the Bion® treatments plus a water control were in one greenhouse (Figure 11-3), and the Movento and Hasten® treatments plus a water control were in the second greenhouse (Figure 11-4).

The Gosford channels were at the larger spacings and so initially three seedlings of the same treatment were put into each hole to prevent the seedlings from falling into the channel solution. As the seedlings grew, first one and then a second seedling was removed. Since the greenhouses were screened from thrips field collected lettuce showing signs of TSWV and presence of WFT were introduced into the greenhouses. The infested plants were arranged three per channel as per the trial design (Figures 11-3 and 11-4).

Monitoring

The plants in trial 1 and 2 were managed as per the grower’s commercial hydroponic lettuce crop except that no insecticides were applied. The trials were monitored weekly for nymph and adult thrips and signs of TSWV. Other insect pests or beneficials were also noted. Plants showing signs of TSWV were tested using immuno test strips to confirm diagnosis. At harvest, TSWV was assessed on a scale of 0-3: where 0=absence, 1= necrotic spots present but plant saleable, 2= necrotic lesions significant, unsaleable, and 3= plant dead.

Figure 11-3 Trial 2a Gosford Research Station 6th March – 8th April 2009

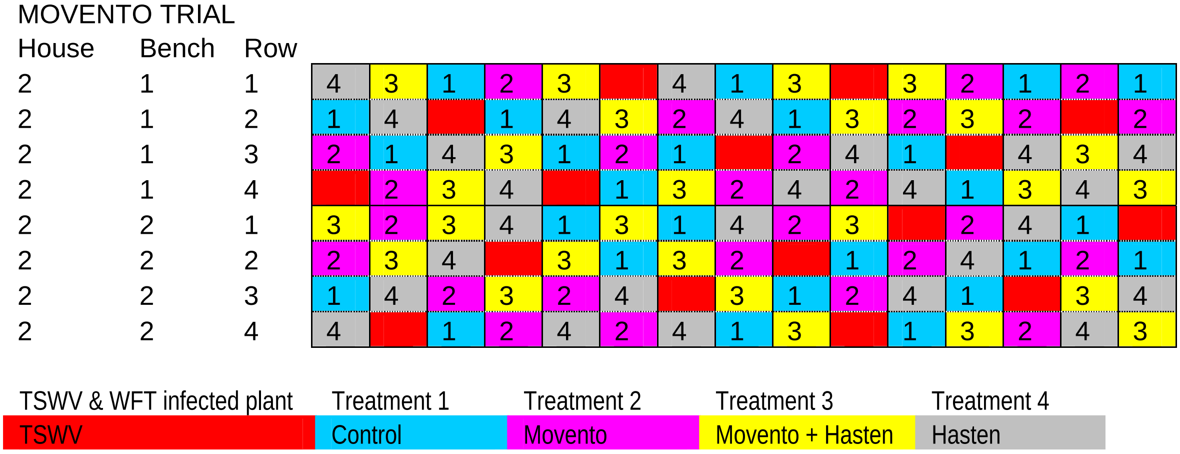


BION TRIAL

House	Bench	Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	3	2	4	1	3	T	4	3	2	T	3	4	3	2	1
1	1	2	2	4	2	T	1	4	3	2	3	2	4	3	T	1	3
1	1	3	T	1	3	2	4	2	1	T	4	1	2	1	4	3	4
1	1	4	1	3	1	3	2	1	2	4	1	4	T	2	1	4	T
1	2	1	1	2	T	3	2	T	3	4	1	3	2	3	4	2	1
1	2	2	2	1	4	2	3	2	4	1	T	1	3	T	2	4	3
1	2	3	4	T	1	4	T	3	1	2	3	4	1	2	1	3	4
1	2	4	3	4	2	1	2	1	T	3	4	2	4	1	3	T	2

TSWV & WFT infected plant	Treatment 1	Treatment 2	Treatment 3	Treatment 4
TSWV	Control	Bion low	Bion medium	Bion high

Figure 11-4 Trial 2b Gosford Research Station 6th March – 8th April 2009



MOVENTO TRIAL

House	Bench	Row															
2	1	1	4	3	1	2	3	🟥	4	1	3	🟥	3	2	1	2	1
2	1	2	1	4	🟥	1	4	3	2	4	1	3	2	3	2	🟥	2
2	1	3	2	1	4	3	1	2	1	🟥	2	4	1	🟥	4	3	4
2	1	4	🟥	2	3	4	🟥	1	3	2	4	2	4	1	3	4	3
2	2	1	3	2	3	4	1	3	1	4	2	3	🟥	2	4	1	🟥
2	2	2	2	3	4	🟥	3	1	3	2	🟥	1	2	4	1	2	1
2	2	3	1	4	2	3	2	4	🟥	3	1	2	4	1	🟥	3	4
2	2	4	4	🟥	1	2	4	2	4	1	3	🟥	1	3	2	4	3

TSWV & WFT infected plant	Treatment 1	Treatment 2	Treatment 3	Treatment 4
TSWV	Control	Movento	Movento + Hasten	Hasten

Results

Trial 1

In trial 1, located at the commercial growers farm, the first visual monitoring took place a week after placing the seedlings into the hydroponic channels. A small number of adult Western flower thrips (WFT) colonized the lettuce in the first week, with nymphs being observed in the second week, peaking in numbers in the 4th week (3rd April), and tomato spotted wilt virus (TSWV) was first observed three weeks after transplanting (Table 11-1 a&b). After the lettuce was moved to the channels with larger holes some of the lettuce fell into the solution and was flushed out of the system; this occurred with 1 lettuce of Treatment 1 (control), 1 of Treatment 6 (Movento® + Hasten®), and 2 of Treatment 7 (Hasten®). At harvest (9th April) between 10-30% of the lettuce were showing signs of TSWV. On 21st April a further assessment was made with 30-50% showing signs of TSWV.

Table 11-1a Trial 1 Monitoring results for WFT nymphs and adults and incidence of TSWV in first 3 weeks after transplanting.

Plant # at transplant	Treatment	12/03/2009 WFT nymphs	adults	TSWV	19/03/2009 WFT nymphs	adults	TSWV	26/03/2009 WFT nymphs	adults	TSWV
30	Bion low	0.00	0.03	0	0.03	0.73	0	0	1.27	1
30	Bion medium	0.03	0.03	0	0.07	0.43	0	0.13	1.33	2
30	Bion high	0.00	0.03	0	0.00	0.70	0	0	1.3	0
30	Control	0.00	0.07	0	0.03	0.50	0	0.03	1.2	2
30	Movento	0.00	0.10	0	0.00	0.43	0	0.10	1.57	0
30	Movento & Hasten	0.00	0.07	0	0.03	0.61	0	0.07	1.52	1
30	Hasten	0.00	0.03	0	0.00	0.57	0	0.07	1.43	2

Table 11-1b Trial 1 Monitoring results for WFT nymphs and adults and incidence of TSWV weeks 4, 5 and 6.5

Plant # at Harvest	Treatment	3/04/2009 WFT			9/04/2009 WFT			Post Harvest SCORE 21/04/2009			Saleable
		nymphs	adults	TSWV	nymphs	adults	TSWV	1	2	3	0
30	Bion low	0.93	1.21	3	0.66	1.48	8	1	0	8	21
30	Bion medium	0.53	1.03	1	0.63	1.57	7	0	1	8	21
30	Bion high	0.50	0.53	0	0.33	1.07	4	1	3	6	20
29	Control	0.93	0.69	3	0.28	1.31	3	2	1	7	19
30	Movento	0.79	0.54	0	0.57	1.21	3	1	0	10	17
29	Movento & Hasten	0.48	0.52	3	0.34	0.86	5	1	2	5	21
28	Hasten	0.70	0.70	6	0.53	0.80	10	0	2	14	14

Statistical analysis did not show any significant differences between treatments. WFT nymph (Figures 11-5a) and adult (Figure 11-5b) numbers followed a similar pattern for all treatments.

Figure 11-5a Trial 1 visual monitoring for WFT nymphs

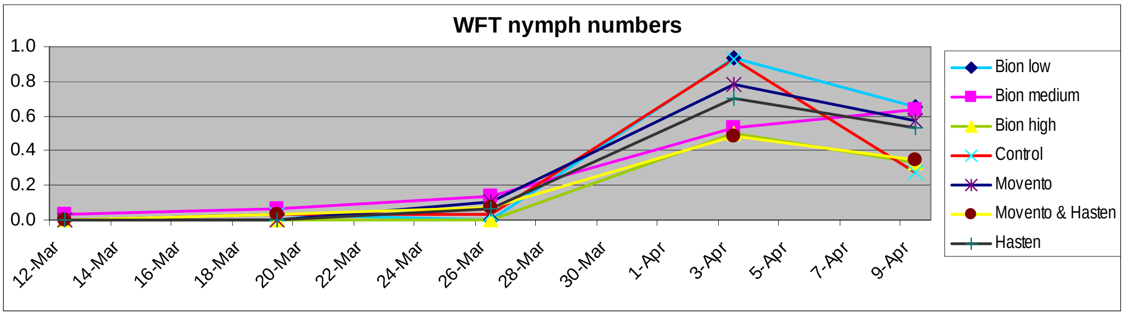
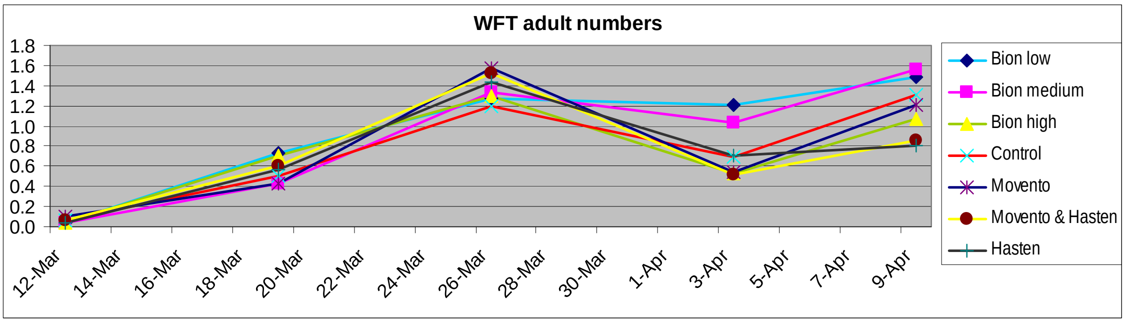
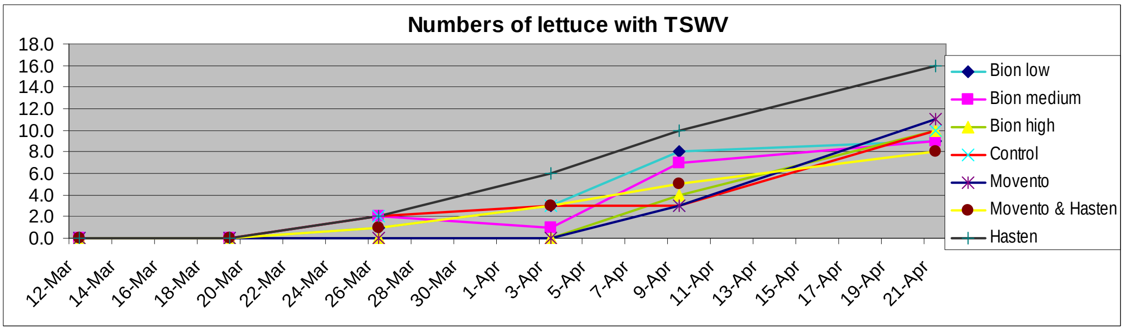


Figure 11-5b Trial 1 visual monitoring for WFT adults



The TSWV data (Figure 11-5c) show an increase in incidence over time with a trend for the Hasten® only treatment to have higher numbers of TSWV.

Figure 11-5c Trial 1 Lettuce showing TSWV symptoms at weekly monitoring



Trial 2

In Trial 2, using a greenhouse hydroponic setup and infected sentinel plants as part of the design, the numbers of thrips and incidence of virus was much higher than in the open hydroponic system used in Trial 1. In the first week after transplant, all treatments already had WFT nymphs as well as adults present (Table 11-2a). TSWV symptoms were first observed in week 3 and increased dramatically in week 4, and by week 5, virtually all plants were showing symptoms (Table 11-2b).

Table 11-2a Trial 2 Monitoring results for WFT nymphs and adults and incidence of TSWV in first three weeks after transplant

# Plants	Treatment	12/03/2009 WFT nymphs	adults	TSWV	19/03/2009 WFT nymphs	adults	TSWV	26/03/2009 WFT nymphs	adults	TSWV
26	Bion low	0.19	0.46	0	5.50	3.12	0	9.19	2.96	5
26	Bion medium	0.23	0.62	0	6.46	4.27	0	10.04	3.85	3
26	Bion high	0.35	0.77	0	4.73	4.54	0	8.04	3.50	5
26	Control	0.35	0.35	0	3.31	1.92	0	5.96	2.50	4
26	Control	0.50	0.27	0	2.88	4.15	0	7.12	5.58	2
26	Hasten	0.35	0.08	0	3.19	7.00	0	15.50	5.19	2
26	M&H	0.15	0.27	0	5.46	9.54	0	12.42	6.08	3
26	Movento	0.23	0.46	0	6.35	8.62	0	12.65	5.42	5

Table 11-2b Trial 2 Monitoring results for WFT nymphs and adults and incidence of TSWV in forth and fifth weeks after transplant

		2/04/2009 WFT			**Harvest** **8/04/2009** WFT			Score			saleable
# Plants	Treatment	nymphs	adults	TSWV	nymphs	adults	TSWV	**1**	**2**	**3**	**0**
26	Bion low	3.27	1.08	21	7.68	5.09	25	2	18	4	2
26	Bion medium	2.92	2.42	11	7.25	8.38	20	3	15	2	6
29	Bion high	1.85	1.42	13	6.75	7.25	20	4	14	2	6
52	Control	2.69	1.88	13	5.83	9.42	20	4	14	2	6
26	Control	5.85	5.62	8	11.69	17.88	26	11	15		0
26	Hasten	7.58	2.92	11	12.73	12.23	25	3	18	4	1
25	M&H	9.77	2.92	14	18.58	10.88	26	2	24		0
20	Movento®	7.62	2.54	19	13.36	8.40	25	1	24	1	0

Statistical analysis did not show any significant differences between treatments. WFT nymph (Figures 11-6a&b) and adult (Figure 11-6c&d) numbers followed a similar pattern for all treatments. In both greenhouse trials the control plants in all but one of the monitoring periods had lower numbers of nymphs than in any of the treatments (Figure 11-6a&b), although this trend was not seen with WFT adult numbers.

Figure 11-6a Trial 2 visual monitoring for WFT nymphs in Greenhouse 1 (Bion® treatments)

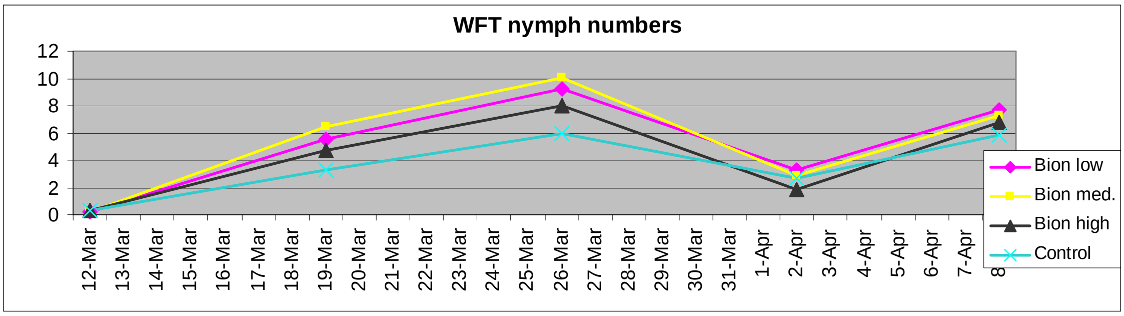


Figure 11-6b Trial 2 visual monitoring for WFT nymphs in Greenhouse 2 (Movento® treatments)

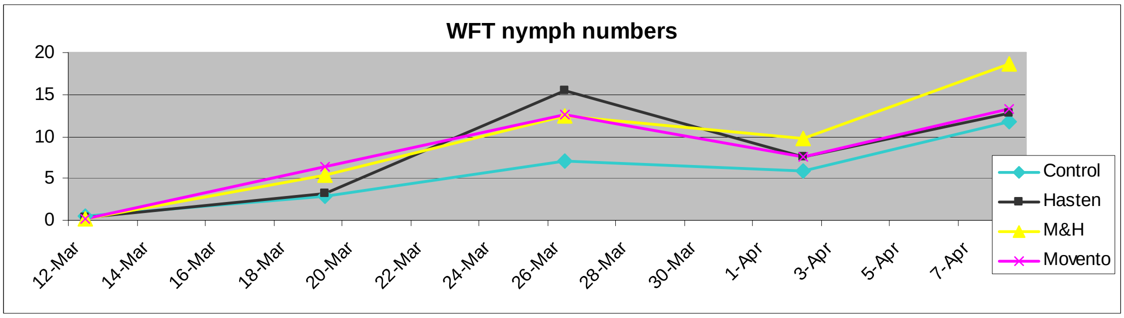


Figure 11-6c Trial 2 visual monitoring for WFT adults in Greenhouse 1 (Bion® treatments)

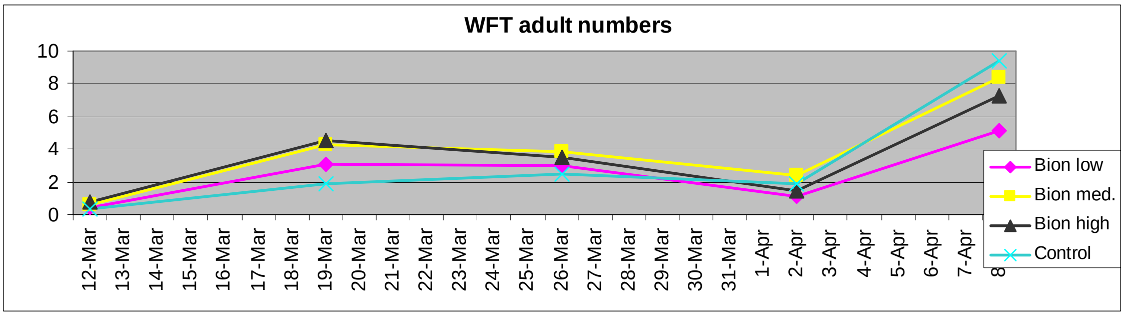
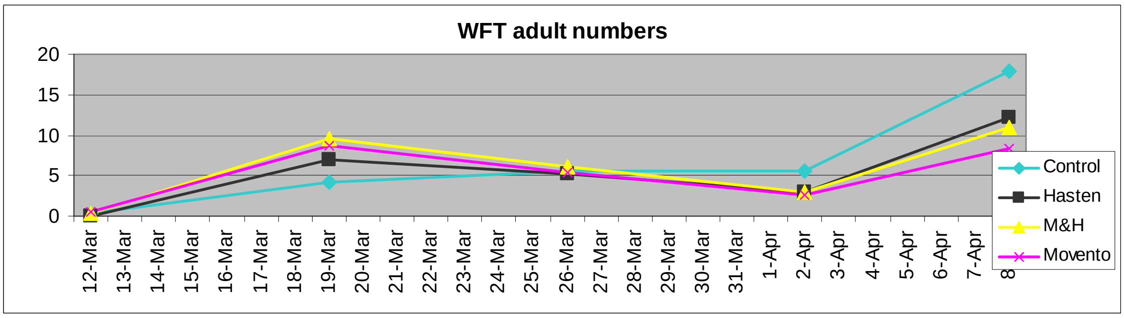


Figure 11-6d Trial 2 visual monitoring for WFT adults in Greenhouse 2 (Movento® treatments)



The levels of TSWV increased over the trial period with a trend towards the low rate of Bion® and the Movento® only treatments having slightly higher rates of virus infection (Figure 11-6 e&f).

Figure 11-6e Trial 2 Lettuce showing TSWV symptoms at weekly monitoring in Greenhouse 1 (Bion® treatments)

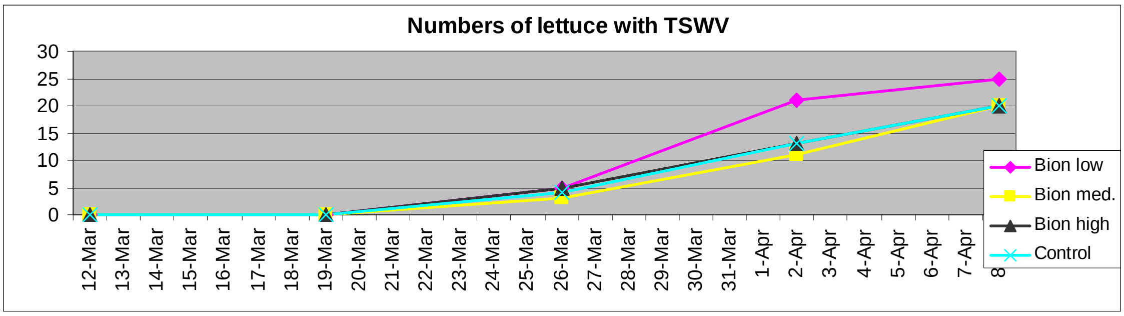
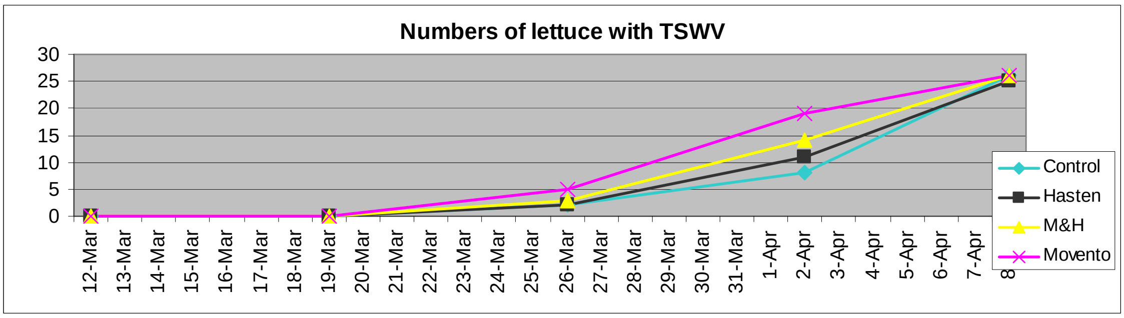


Figure 11-6f Trial 2 Lettuce showing TSWV symptoms at weekly monitoring Greenhouse 2 (Movento® treatments)



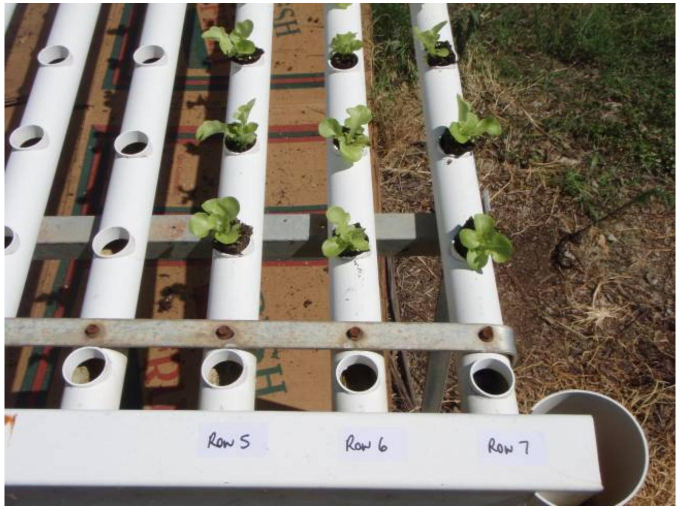
Discussion

Bion® acts to stimulate the plant to resist disease. Hence, we would not expect it to influence the numbers of thrips found on treated plants, but we would expect to see a reduction in levels of TSWV transmitted by the thrips. This was not evident in either of these trials. Movento® on the other hand, acts against WFT nymphs and reduces fecundity of female WFT, so we would expect to see lower numbers of nymphs on the Movento® treated lettuce but not reduced transmission of TSWV if an infected adult flew onto the lettuce. Using Hasten® as an adjuvant with Movento® should improve the penetration of Movento® into the lettuce and potentially improve the activity of Movento®. In trial 1 the Movento® plus Hasten® treatment generally had lower numbers of both nymphs and, less obviously, adults and had a lower incidence of TSWV although in no case was it statistically significant. In trial 2 under the higher thrips and TSWV environment there was no such trend toward lower nymph or adult numbers nor of a lower incidence of TSWV.

Anecdotally, two applications of Movento® on new plantings of lettuce produced a significant reduction in the incidence of TSWV at harvest (<10%) on one farm where the previous plantings had greater than 75% TSWV infected lettuce. Andy Ryland (Beneficial Bug Company) was the crop consultant visiting the farm and he noted much lower numbers of nymphs than he had been seeing on other untreated lettuce after the first application. Both Trial 1&2 were designed to test this, but they did not succeed in replicating the positive results. However, each plant was treated as a replicate to maximise replication and hence statistical power however this meant independence of the replicates was necessarily traded off. Adult thrips can fly and will move around between plants which would have certainly confounded the adult numbers and increased TSWV pressure compared with what would have been experienced if large areas were treated as a single treatment.

The results were not promising but the trial should be repeated with larger plot sizes or for testing the Movento® treated plants. The addition of nymphs onto treated lettuce, and more frequent monitoring of those nymphs could give a greater indication of the efficacy of Movento® or Movento® plus Hasten®.

Pictorial view of Bion®-Movento® Trials



Trial 1 Commercial hydroponic layout in nursery gutters

Trial 2 Greenhouse trial layout – note larger plants are TSWV infected and WFT infested plants.

Bion® trial just prior to harvest

Harvest Assessment

Harvest assessment category 0= saleable no TSWV symptoms

Harvest assessment category 1= saleable but some necrotic spots

Harvest assessment category 2 = unsaleable significant TSWV

Harvest assessment category 3 = unsaleable/dead from TSWV

12. Evaluation of the suitability of currant lettuce aphid resistant iceberg lettuce varieties for an early sowing timeslot at Hay, NSW

Tony Napier[1] and Jorian Millyard[2]

[1] NSW Department of Primary Industries Yanco Agricultural Institute. [2]MIA Rural.

Summary

It was demonstrated that there are currant lettuce aphid (*Nasonovia ribisnigri* CLA) resistant lettuce varieties suitable for an early season sowing at Hay, NSW. The performance of all the individual varieties evaluated is presented in a summary table.

Introduction

CLA is now a major pest of lettuce and is endemic across all of Australia. This aphid is different to other aphid pests of lettuce because it prefers to colonize the centre of the lettuce, making it very difficult to control with foliar insecticides. Since CLA has become endemic across Australia, the most popular form of control has been the use of the insecticide imidacloprid. Imidacloprid can be applied as a drench for seedlings or as a soil drench for direct seeded crops. CLA-resistant lettuce varieties are a preferred alternative to prevent CLA lettuce aphid infestation. However, the inclusion of CLA resistance into head lettuce is still relatively new and many of the earlier varieties did not perform as well as hoped.

Many of the seed companies are developing and releasing new lettuce varieties resistant to the *Nasonovia* lettuce aphid. All lettuce varieties are adapted to specific planting periods, and planting them out of their timeslot will result in a less than desirable product. Planting a cool season crisphead variety out of its timeslot (too warm) can result in bolting, puffiness or non-hearting. Planting a warm season crisphead variety out of its time slot (too cold) can result in small, undersized hearts. The most difficult periods for selecting varieties are when the seasons are changing. This is the situation faced by Hay lettuce growers when the season first starts at the end of January. Variety selection will change quickly as day length shortens and average maximum temperatures drop from 33°C in mid January to 15°C in mid July.

The aim of the trial is to determine the most appropriate sowing window for the majority of the CLA-resistant iceberg lettuce varieties now available.

Materials and methods

Ten variety trials were conducted on a commercial vegetable farm at Hay, NSW. The trials were sequentially sown on a weekly schedule with the first trial sown on 25 January 2008. The last of the trials were sown nine weeks later on 27 March 2008. Harvest commenced on 20 March 2008 and continued through to 01 July 2008 when the final trial was harvested.

Six different seed companies supplied 16 varieties for evaluation (Table 12-1). Twelve varieties were supplied to the trial by the seed company with a suggested sowing window. These varieties were sown every week within the recommended time slot. Some were also sown one or two weeks either side of their recommended sowing time. Four varieties were supplied without a suggested sowing period and they were sown, on average, every second week throughout the trial period.

Table 12-1 List of *Nasonovia* resistant iceberg lettuce varieties evaluated in the 2008 trial

	Variety	**Company**	**Recommended sowing window for Hay trial**	**Harvest slot and other characteristics**
1	LEC 7687	Lefroy Valley	Week 1 to week 5	Summer to early autumn
2	LEC 7862	Lefroy Valley	None given	Summer to early winter. Intermediate resistance to Lettuce Mosaic Virus
3	Dover	Nunhems	None given	Cooler - late spring, summer and early autumn. Warm - autumn and spring
4	NUN 0126	Nunhems	None given	
5	Kestrel	Terranova	Week 7 to week 10	Spring and autumn
6	Albanas	Rijk Zwaan	Week 3 to week 7	Shoulder season - Lettuce Mosaic Virus resistance
7	Argentinas	Rijk Zwaan	Week 1 to week 4	Cooler - late spring, summer and early autumn. Warm -autumn and early spring. Lettuce Mosaic Virus resistance
8	Cartagenas	Rijk Zwaan	Week 1 to week 4	Cooler - late spring, summer and early autumn. Warm - late autumn and early spring. Tip-burn tolerant
9	Gitanas	Rijk Zwaan	Week 7 to week 10	Cooler - late autumn to early spring. Warm - mid winter. Corky root resistance
10	Ribenas	Rijk Zwaan	Week 2 to week 4	Cooler - late spring, summer and early autumn. Warm - late autumn and early spring
11	Alpinas (45-30)	Rijk Zwaan	Week 4 to week 10	Large framed variety for harvesting during cooler periods
12	2302	Seminis	None given	Late spring, summer and early autumn
13	Constanza	Seminis	Week 5 to week 10	Spring and autumn
14	Foxtrot	SPS	Week 1 to week 3	Cooler - summer
15	Kong	SPS	Week 3 to week 8	Spring and autumn
16	Lily	SPS	Week 7 to week 10	Spring and autumn

Trial design and analysis

Plot size for each variety was a single plant line 20 m long. All trials and the commercial crop were direct seeded onto 1.5 m beds with two plant lines per bed and were furrow irrigated. Each trial consisted of the selected varieties (ranging from 4 to 16 cultivars) and a control variety selected by the grower. The trials were treated as part of the commercial crop through until harvest.

As these were not replicated trials, no statistical analysis was conducted on the data. Results and conclusions have been made from the harvest measurements and visual assessments.

Assessments

For each trial, a harvest assessment was conducted plus or minus one day of the grower harvesting the surrounding commercial crop. The harvest assessment included both subjective and objective assessments. The subjective measurement involved a visual assessment of the entire plot of each variety for its suitability in that timeslot. The objective measurements involved harvesting four plants from each plot and measuring head weight, head diameter and core length. Average plants for each plot were selected for objective measurements.

Head diameter (mm)

Heads were cut into two equal halves by cutting from the top of the heart through to the centre of the base of the plant. The measurement was taken at the widest point of the heart. The measurement given in the results is an average of the four cut lettuces.

Core length (mm)

After the head was cut into two equal halves, the core length was also measured. The core length was measured from the base of the plant to the tip of the core. The measurement given in the results is an average of the four cut lettuces.

Untrimmed head weight (kg)

The untrimmed head weight was the weight of each head with the majority of all wrapper leaves still attached. This represented the weight of the head if being sold on the fresh market. The measurement given in the results is an average of the four cut lettuces.

Visual assessments

At the time of harvest the entire 20 m plots were visually assessed for marketability. The plots were checked for general health, plot uniformity and heart firmness. Results of these observations are recorded as “comments” and “suitability for timeslot” in the results section.

The main criteria of this evaluation for determining if a variety was suitable are the objective measurements of bolting and head size. Visual assessments of plot uniformity and heart firmness were also considered. There are many other traits that lettuce plants must exhibit to produce a marketable product which were not considered in the evaluation. These traits include disease resistance, rib discolouration, tip burn resistance, shape, colour and other cosmetic defects.

Results

Trial One

This trial was sown on 25 January 2008 with Raider selected as the control variety. The grower harvest was on the 20 March 2008, which resulted in a growing season of 55 days from sowing to harvest (Table 12-2).

Table 12-2 Harvest results of Trial One

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comments	Suitable for timeslot
Control	**145**	**88**	**1.03**	Looked OK, but a bit small	Yes
Foxtrot	**170**	**165**	**1.26**	Bolting	No
Cartagenas	**163**	**110**	**1.29**	Starting to bolt	Maybe
Argentinas	**168**	**78**	**1.51**	Looked good. Large size	Yes
Dover	**170**	**198**	**1.05**	Bolting	No
NUN 0120	**168**	**200**	**1.06**	Bolting	No
LEC 7687	**160**	**200**	**1.13**	Bolting	No

Trial Two

This trial was sown on 01 February 2008 with Raider selected as the control variety. The grower harvest was on the 31 March 2008, which resulted in a growing season of 59 days from sowing to harvest (Table 12-3).

Table 12-3 Harvest results of Trial Two

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comment	Suitable for timeslot
Control	**156**	**95**	**1.20**	OK	Yes
Foxtrot	**198**	**180**	**1.46**	Bolting	No
Kong	**178**	**200**	**1.23**	Bolting	No
Cartagenas	**170**	**96**	**1.39**	OK	Yes
Argentinas	**158**	**158**	**1.33**	Bolting	No
Ribenas	**173**	**178**	**1.13**	Bolting	No
LEC 7687	**153**	**93**	**1.19**	OK	Yes

Trial Three

This trial was sown on 08 February 2008 with Target selected as the control variety. The grower harvest was on 14 April 2008, which resulted in a growing season of 66 days from sowing to harvest (Table 12-4).

Table 12-4 Harvest results of Trial Three

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comment	Suitable for timeslot
Control	**141**	**136**	**1.39**	Good size, but close to bolting	Maybe
Foxtrot	**145**	**125**	**1.36**	Good size, but close to bolting	Maybe
Kong	**140**	**120**	**1.06**	Close to bolting and a bit small	No
Cartagenas	**163**	**103**	**1.34**	Good size, but early signs of bolting	Yes
Argentinas	**158**	**85**	**1.21**	OK	Yes
Ribenas	**160**	**98**	**1.47**	OK and good size	Yes
Albanas	**195**	**183**	**1.18**	Bolting	No
Dover	**150**	**120**	**1.17**	Starting to bolt	Maybe
NUN 0120	**150**	**153**	**1.14**	Bolting	No
LEC 7687	**160**	**88**	**1.19**	OK	Yes

Trial Four

This trial was sown on 15 February 2008 with Target selected as the control variety. The grower harvest was on 23 April 2008, which resulted in a growing season of 68 days from sowing to harvest (Table 12-5).

Table 12-5 Harvest results of Trial Four

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comment	Suitable for timeslot
Control	**210**	**200**	**1.61**	Bolted	No
Foxtrot	**228**	**200**	**1.73**	Bolted	No
Kong	**205**	**150**	**1.79**	Bolted	No
Cartagenas	**178**	**90**	**1.64**	OK	Yes
Argentinas	**178**	**135**	**1.71**	Starting to bolt	Maybe
Ribenas	**175**	**90**	**1.63**	OK	Yes
Albanas	**203**	**148**	**1.62**	Bolted	No
45-30	**178**	**143**	**1.96**	Bolted	No
Kestrel	**190**	**118**	**1.45**	Starting to bolt and looked variable	Maybe
LEC 7687	**185**	**140**	**1.69**	Bolted	No

Trial Five

This trial was sown on 22 February 2008 with Target selected as the control variety. The grower harvest was on the 01 May 2008, which resulted in 69 days from sowing to harvest (Table 12-6).

Table 12-6 Harvest results of Trial Five

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comment	Suitable for timeslot
Control	**168**	**123**	**1.56**	Variable – some look good and some bolted	No
Foxtrot	**178**	**70**	**1.47**	OK	Yes
Kong	**175**	**130**	**1.38**	Starting to bolt	Maybe
Lily	**190**	**200**	**1.00**	Bolted, nice colour	No
Cartagenas	**173**	**55**	**1.50**	Looked good	Yes
Argentinas	**145**	**65**	**1.46**	Looked good	Yes
Ribenas	**160**	**70**	**1.52**	Looked OK	Yes
Albanas	**120**	**70**	**0.93**	Too small	No
45-30	**193**	**200**	**1.67**	Bolted	No
Gitanas	**193**	**200**	**1.46**	Bolted	No
Kestrel	**150**	**95**	**1.10**	Ok but too small	No
LEC 7687	**160**	**98**	**1.60**	Looked good	Yes
LEC 7862	**160**	**48**	**1.10**	Ok but too small	No
Dover	**160**	**133**	**1.43**	Variable– some looked good and some bolted	Maybe
NUN 0120	**178**	**200**	**1.39**	Bolted	No
2302	**173**	**135**	**1.45**	Variable– Some looked good and some bolted	No
Constanza	**175**	**83**	**1.46**	OK	Yes

Trial Six

This trial was sown on 27 February 2008 with Magnum selected as the control variety. The grower harvest was on the 12 May 2008, which resulted in 75 days from sowing to harvest (Table 12-7).

Table 12-7 Harvest results of Trial Six

Variety	Head width (mm)	Core length (mm)	Head weight (kg)	Comment	Suitable for timeslot
Control	**183**	**48**	**1.58**	Looked very good	Yes
Kong	**178**	**68**	**1.68**	Looked good, but some with slightly loose hearts	Yes
Lily	**193**	**158**	**1.28**	Bolted	No
Albanas	**160**	**60**	**1.29**	Looked good, but some with slightly loose hearts	Yes
45-30	**173**	**168**	**1.84**	Bolted	No
Kestrel	**145**	**45**	**1.77**	Looked very good – large size	Yes
NUN 0120	**153**	**123**	**1.78**	Variable - half looked good and half bolted	No
LEC 7862	**180**	**55**	**1.51**	OK but looked a bit uneven and variable	Maybe
Constanza	**165**	**53**	**1.58**	Looked good	Yes

Trial Seven

This trial was sown on 06 March 2008 with Magnum selected as the control variety. The grower harvest was on 22 May 2008, which resulted in a growing season of 77 days from sowing to harvest (Table 12-8).

Table 12-8 Harvest results of Trial Seven

Variety	**Head width (mm)**	**Core length (mm)**	**Head weight (kg)**	**Comment**	**Suitable for timeslot**
Control	**153**	**45**	**1.40**	Looked good	Yes
Kong	**153**	**43**	**1.45**	Looked good, but some with slightly loose hearts	Yes
Lily	**165**	**73**	**1.44**	Looked good, but some with slightly loose hearts	Yes
Albanas	**148**	**80**	**1.54**	OK	Yes
45-30	**180**	**48**	**1.72**	Looked very good – large size	Yes
Gitanas	**163**	**130**	**1.58**	Variable - half looked good and half bolted	No
Kestrel	**163**	**43**	**1.49**	Looked very good	Yes
Dover	**168**	**43**	**1.62**	Looked very good	Yes
2302	**150**	**43**	**1.40**	OK	Yes
Constanza	**153**	**45**	**1.40**	Looked good	Yes

Trial Eight

This trial was sown on 12 March 2008 with Sentry selected as the control variety. The grower harvest was on 04 June 2008, which resulted in a growing season of 84 days from sowing to harvest (Table 12-9).

Table 12-9 Harvest results of Trial Eight

Variety	**Head width (mm)**	**Core length (mm)**	**Head weight (kg)**	**Comment**	**Suitable for timeslot**
Control	**165**	**58**	**1.68**	Looked good	Yes
Kong	**175**	**65**	**1.52**	Looked good	Yes
Lily	**168**	**200**	**1.50**	Bolted	No
45-30	**170**	**200**	**1.73**	Bolted	No
Gitanas	**160**	**128**	**1.56**	Variable - half looked good and half bolted	No
Kestrel	**143**	**48**	**1.57**	Looked very good	Yes
NUN 0120	**155**	**53**	**1.58**	Looked very good	Yes
LEC 7862	**150**	**100**	**1.46**	OK but a bit loose and variable	Maybe
Constanza	**153**	**95**	**1.31**	Looked good	Yes

Trial Nine

This trial was sown on 19 March 2008 with Sentry selected as the control variety. The grower harvest was on the 17 June 2008, which resulted in a growing season of 90 days from sowing to harvest (Table 12-10).

Table 12-10 Harvest results of Trial Nine

Variety	**Head width (mm)**	**Core length (mm)**	**Head weight (kg)**	**Comment**	**Suitable for timeslot**
Control	**125**	**38**	**1.21**	Looked good	Yes
Kong	**158**	**43**	**1.30**	Looked very good	Yes
Lily	**153**	**45**	**1.36**	Looked very good	Yes
45-30	**173**	**45**	**1.33**	Looked good	Yes
Gitanas	**168**	**60**	**1.22**	OK, but has a large loose heart	Maybe
Kestrel	**163**	**40**	**1.44**	Looked very good	Yes
Dover	**143**	**40**	**1.40**	Looked good	Yes
2302	**143**	**40**	**1.22**	OK, but a bit loose	Maybe
Constanza	**135**	**48**	**1.08**	OK, but a bit small	No

Trial Ten

This trial was sown on 27 March 2008 with Sentry selected as the control variety. The grower harvest was on the 01 July 2008, which resulted in a growing season of 96 days from sowing to harvest (Table 12-11).

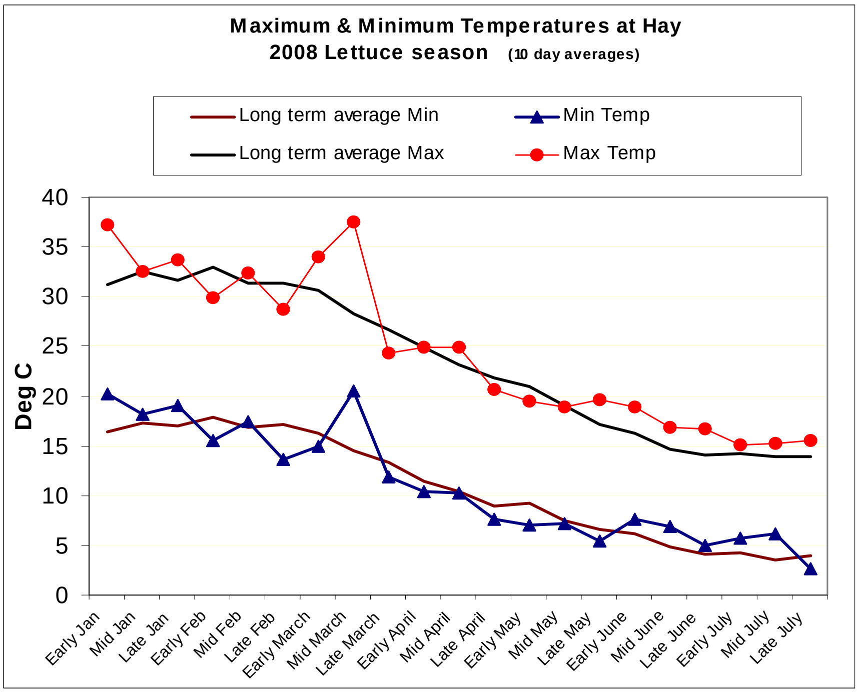
Table 12-11 Harvest results of Trial Ten

Variety	**Head width (mm)**	**Core length (mm)**	**Head weight (kg)**	**Comment**	**Suitable for Harvest**
Control	150	**35**	**1.52**	Looked good	Yes
Kong	160	**40**	**1.11**	Looked good, but small with loose heart	Maybe
Lily	160	**50**	**1.26**	Looked very good	Yes
45-30	140	**48**	**1.22**	OK	Yes
Gitanas	138	**53**	**1.29**	OK, but has a large loose heart	Maybe
Kestrel	133	**38**	**1.14**	OK, but a bit small	Maybe
NUN 0120	145	**33**	**1.14**	Looked very good, but a bit small	Maybe
LEC 7862	153	**38**	**1.01**	OK, but too small	No
Constanza	128	**38**	**1.01**	OK, but too small	No

Weather conditions

Lettuce is a cool season crop with optimal growing temperatures from 23°C during the day to around 7°C at night. The temperature experienced throughout the growing period has a large influence on how a variety performs. Figure 12.1 shows the long term maximum and minimum temperatures and temperatures recorded during the growing period of the 2008 trial at Hay.

Figure 12-1 Maximum and minimum temperatures recorded at Hay 2008



The temperature at the beginning of the growing season normally starts very hot then slowly cools as it moves into autumn and then onto winter. The 2008 season had an unseasonably hot period during the middle of March. During this time the maximum temperature averaged 38.6ºC for ten days. The extreme hot temperatures experienced during this time may have affected the performance of the varieties under evaluation at that time. The lettuce plant can handle the higher temperatures quite well when vegetative, however when the plant gets closer to maturity, environmental stresses have a greater influence on the plant. The unseasonably high temperatures during March probably had the most impact on Trials Three, Four and Five when Target was used as the standard variety. Target is commonly sown at Hay during February and it was unusual to see it bolt as it did during this trial.

For each trial, the harvest assessment was conducted as close as possible to when the control variety was ready for harvest. The CLA-resistant varieties may have had a shorter or longer maturity time thus affecting the results. Extended harvest assessments for each trial may have given more accurate results, but time constraints did not allow this. For most assessments it could be seen if a variety bolted before it made a firm heart or if it did not make marketable size.

Control

The variety used as the control changed over time according to the following program used:

Raider:	Weeks 1 to 2
Target:	Weeks 3 to 5
Magnum:	Weeks 6 to 7
Sentry:	Weeks 8 to 10

The control varieties sown in this program are commonly used at Hay and normally give good results. However Target struggled in the hot weather conditions, and was either close to bolting or fully bolted at harvest (Figure 12-3).

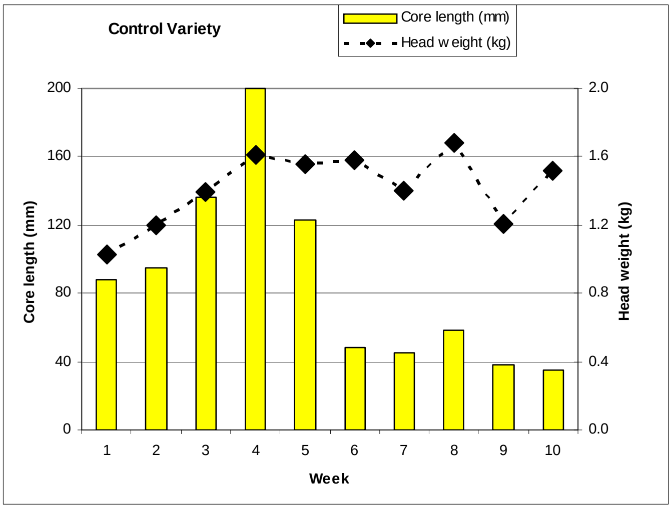


Figure 12-2 Control lettuce core length and head weight

LEC 7687

The variety bolted in the first and fourth weeks but produced marketable heads during the other times. The unseasonably hot temperatures during March possibly contributed to the variety bolting in week four.

The trials indicate the variety is suitable for direct seeding from 1 February to 8 February (Figure 12-4). Further evaluation up to 22 February is recommended.

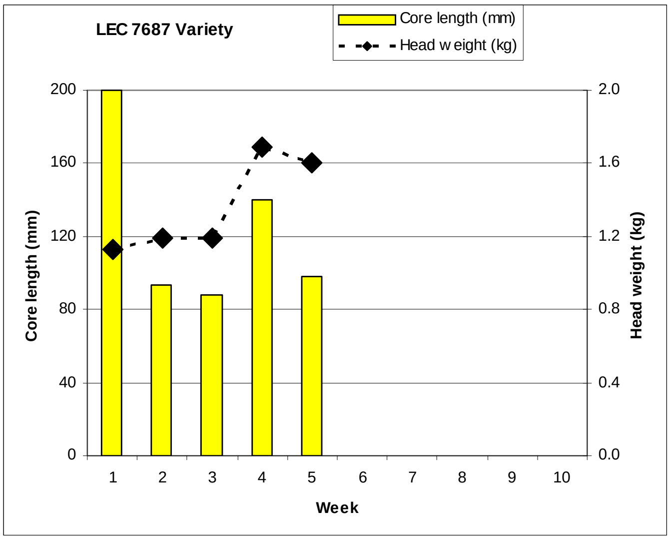


Figure 12-3 LEC 7687 lettuce core length and head weight

LEC 7862

This variety was smaller than average for week five and ten (Figure 12-5). The size was acceptable for week six and eight, but the whole plots looked a bit uneven with some plants still quite loose at harvest.

Results suggest the variety needs further evaluation to establish a sowing window.

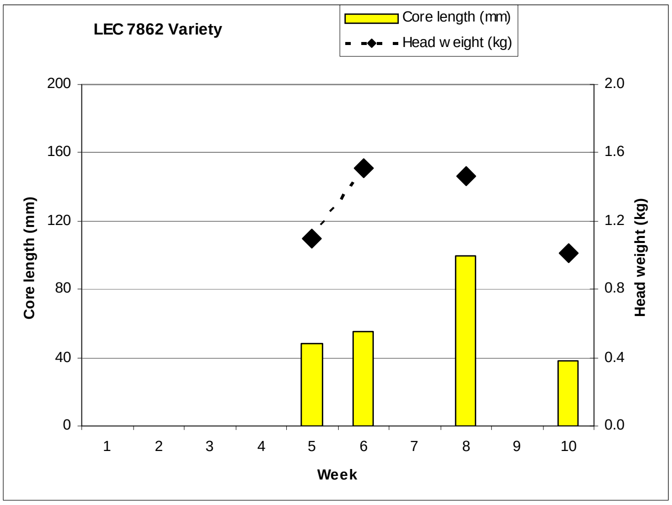


Figure 12-4 LEC 862 lettuce core length and head weight

Dover

This variety bolted or showed signs of bolting through to week five (Figure 12-6). The variety looked very good in weeks seven and nine.

The trials indicate the variety is suitable for direct seeding from 6 March to 19 March. Further evaluation may show a wider sowing window.

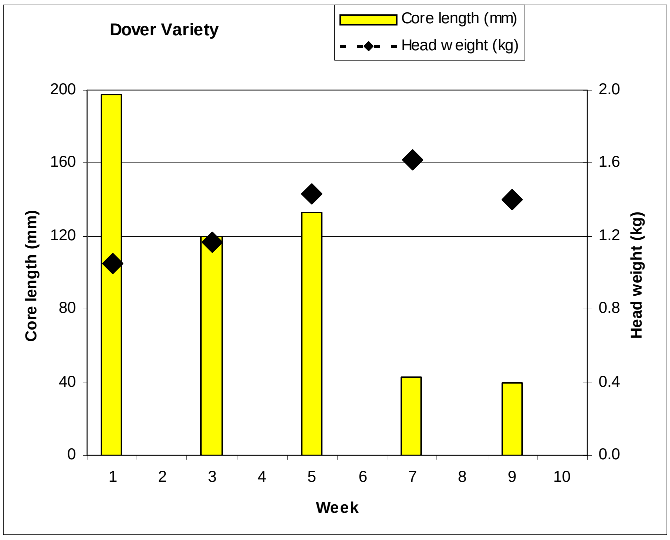


Figure 12-5 Dover lettuce core length and head weight

NUN 0120

This variety bolted or showed signs of bolting through to week six (Figure 12-7). The variety looked very good in weeks eight and ten.

The trials indicate the variety is suitable for direct seeding from 12 March to 27 March. Further evaluation may show a wider sowing window.

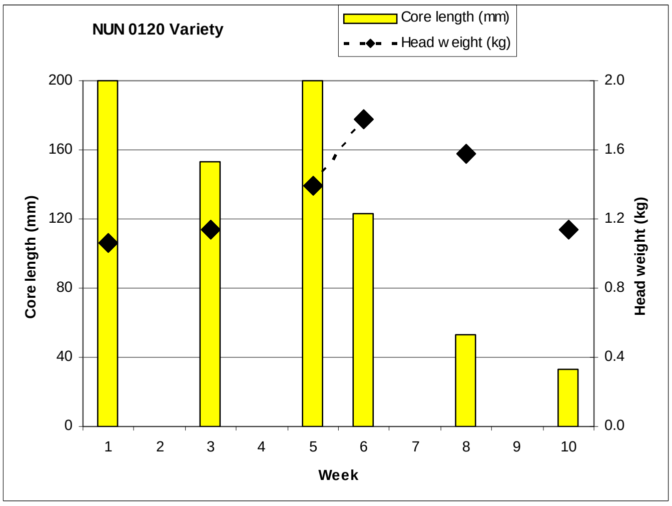


Figure 12-6 NUN 0120 lettuce core length and head weight

Kestrel

The variety looked very good from week six through to week nine (Figure 12-8). It showed some signs of bolting in week four and was struggling for size during week five and ten.

The trials indicate the variety is suitable for direct seeding from 27 February to 19 March. Further evaluation is recommended.

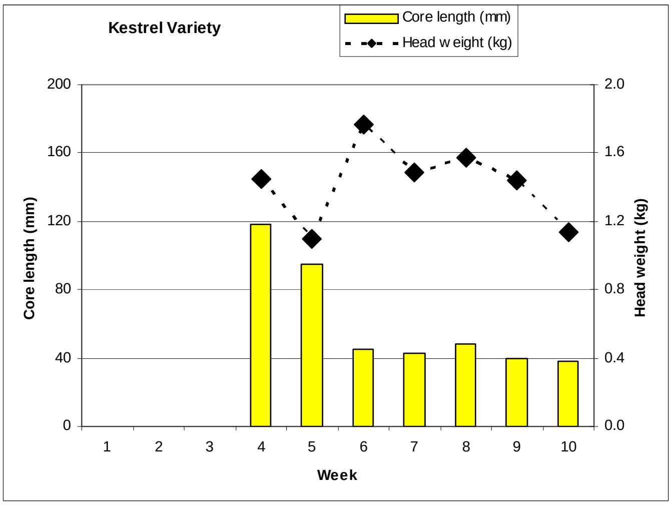


Figure 12-7 Kestrel lettuce core length and head weight

Albanas

This variety bolted during week three and four and was too small during week five (Figure 12-9). The variety looked acceptable during week six and seven.

The trials indicate the variety is suitable for direct seeding from 27 February to 6 March. Further evaluation may show a longer sowing window.

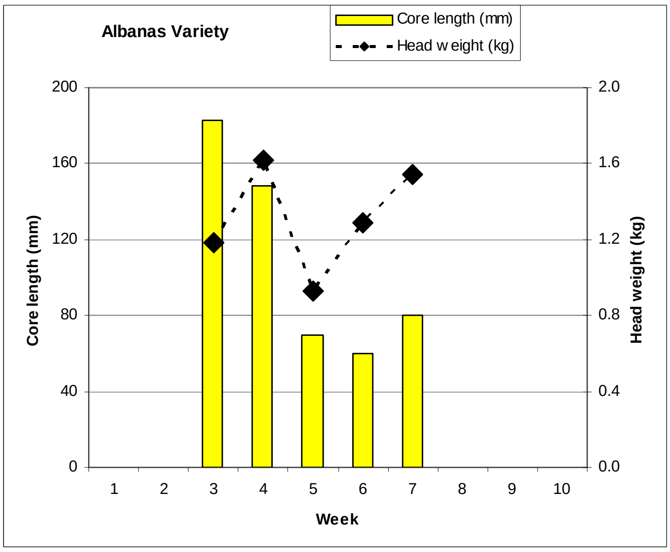


Figure 12-8 Albanas lettuce core length and head weight

Argentinas

This variety had variable results, bolting in weeks two and four but producing a good heart in weeks one, three and five (Figure 12-10).

Results suggest the variety needs further evaluation to establish a sowing window.

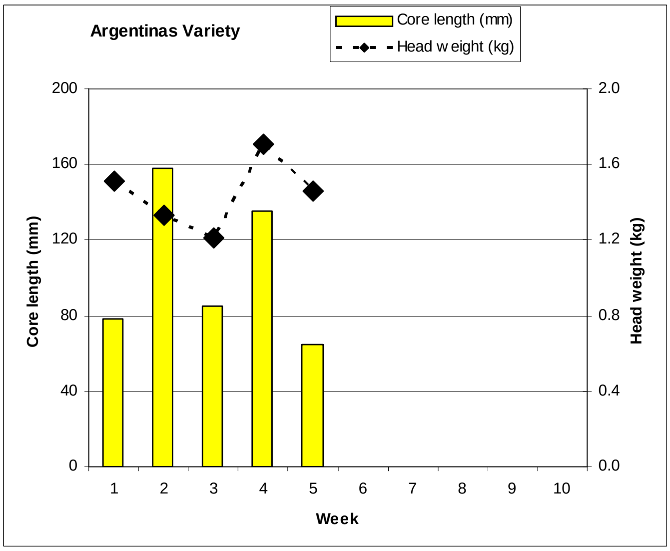


Figure 12-9 Argentinas lettuce core length and head weight

Cartagenas

Showed resistance to bolting early in the season but showed early signs of bolting in weeks one and three (Figure 12-11).

The trials indicate the variety is suitable for direct seeding from 25 January to 22 February. Further evaluation may show a longer sowing window.

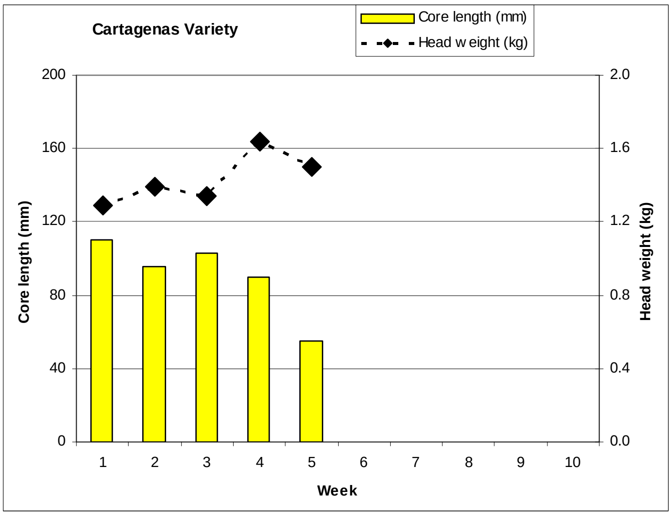


Figure 12-10 Cartagenas lettuce core length and head weight

Gitanas

This variety bolted in weeks five, seven and eight (Figure 12-12). Size was acceptable in weeks nine and ten but the hearts were a bit loose.

Results suggest the variety needs further evaluation to establish a sowing window.

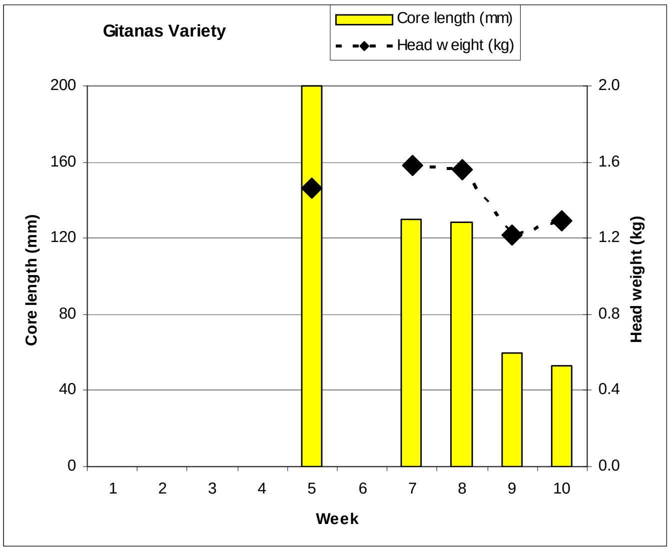


Figure 12-11 Gitanas lettuce core length and head weight

Ribenas

This variety bolted in week two but produced acceptable hearts in weeks three, four and five (Figure 12-13).

The trials indicate the variety is suitable for direct seeding from 8 February to 22 February. Further evaluation may show a longer sowing window.

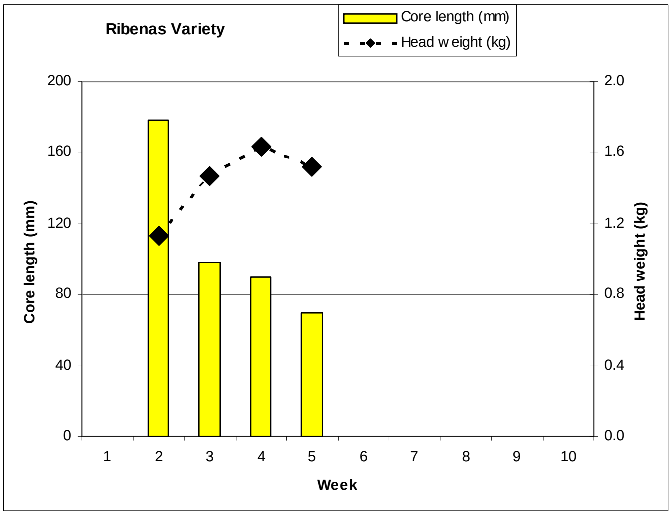


Figure 12-12 Ribenas lettuce core length and head weight

Alpinas (45-30)

This variety bolted from week three through to week eight, except in week seven where it produced large firm hearts (Figure 12-14). The variety looked good during week nine and ten.

The trials indicate the variety is suitable for direct seeding from 19 March to 27 March. Further evaluation may show a wider sowing window.

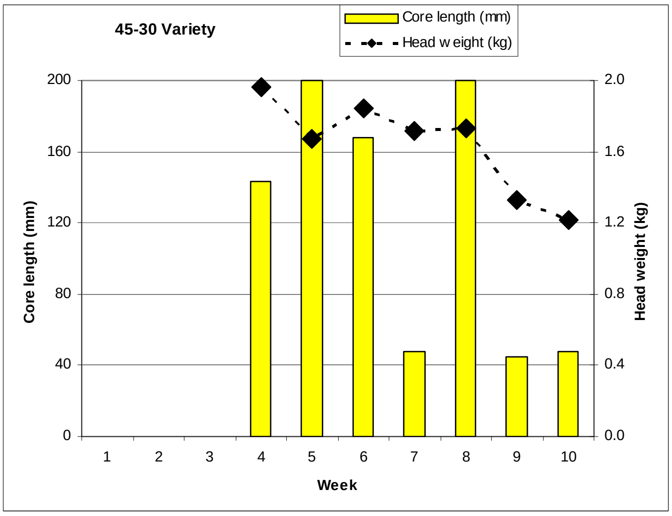


Figure 12-13 Alpinas lettuce core length and head weight

Foxtrot

This variety bolted or was close to bolting, for the first four weeks of the trial (Figure 12-15). The variety produced a good heart in week five.

Results suggest the variety needs further evaluation to establish a sowing window.

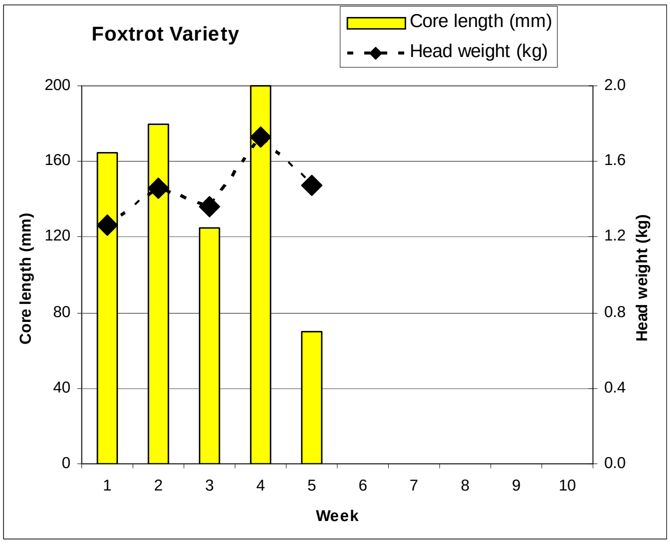


Figure 12-14 Foxtrot lettuce core length and head weight

Kong

This variety bolted or showed signs of bolting through to week five (Figure 12-16). From week six to ten it produced marketable heads although it struggled for size during week ten.

The trials indicate the variety is suitable for direct seeding from 27 February to 19 March. Further evaluation is recommended.

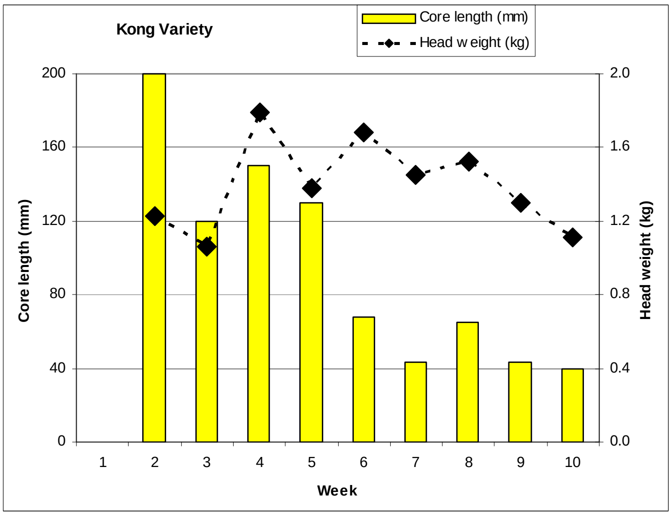


Figure 12-15 Kong lettuce core length and head weight

Lily

This variety bolted or showed signs of bolting through to week eight (Figure 12-17). In weeks nine and ten it produced very good marketable hearts.

The trials indicate the variety is suitable for direct seeding from 19 March to 27 March. Further evaluation may show a wider sowing window.

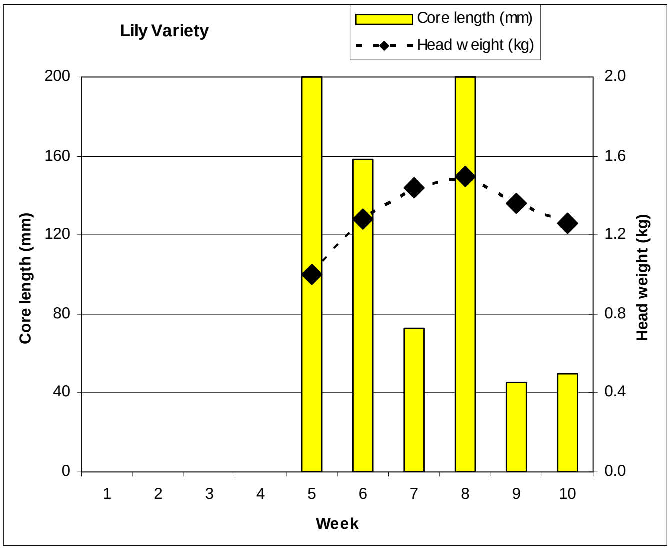


Figure 12-16 Lily lettuce core length and head weight

2302

This variety bolted in week five but produced acceptable hearts in weeks seven and nine (Figure 12-18).

The trials indicate the variety is suitable for direct seeding from 6 February to 19 March. Further evaluation is recommended.

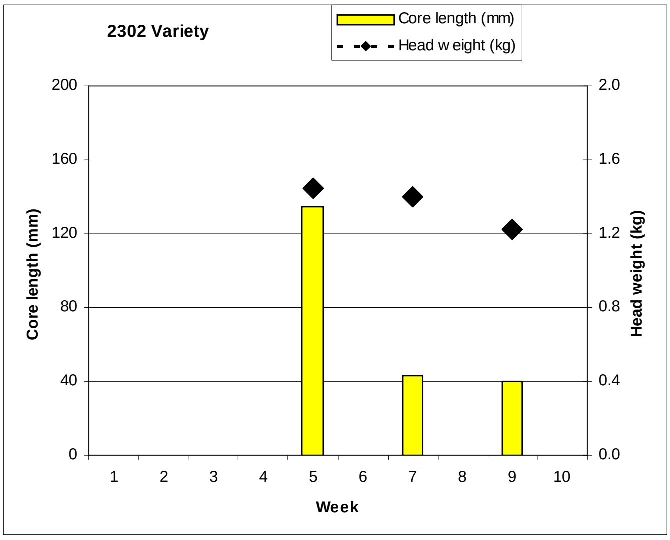


Figure 12-17 3202 lettuce core length and head weight

Constanza

This variety produced acceptable to very good hearts from week five to week eight (Figure 12-19). The hearts produced in weeks nine and ten struggled for size.

The trials indicate the variety is suitable for direct seeding from 22 February to 12 March. Further evaluation may show a wider sowing window.

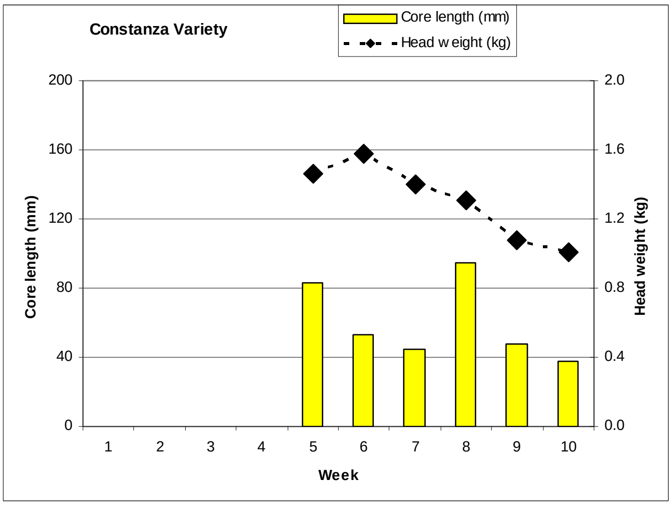


Figure 12-18 Constanza lettuce core length and head weight

Discussion

It was demonstrated that there are CLA-resistant lettuce varieties suitable for early season direct seeding at Hay. The table below summarises the performances of all the varieties evaluated (Table 12-12). The shaded area indicates the timeslot where each variety is best suited. The suggested timeslot for each variety was made if the variety performed well, or was close to producing a marketable heart for two successive evaluations.

Table 12-12 Summary of 2008 CLA resistant lettuce variety trials at Hay

Week	1	2	3	4	5	6	7	8	9	10
Date of sowing	25 Jan	01 Feb	08 Feb	15 Feb	22 Feb	27 Feb	06 Mar	12 Mar	19 Mar	27 Mar
Raider	■	■								
Cartagenas	?	✓	✓	✓	✓					
LEC 7687	X	✓	✓	X	✓					
Target			■	■	■					
Argentinas	✓	X	✓	?	✓					
Ribenas		X	✓	✓	✓					
Dover	X		?		?		✓		✓	
Kong		X	X	X	?	✓	✓	✓	✓	?
Costanza					✓	✓	✓	✓	X	X
Magnum						■	■			
Albanas			X	X	X	✓	✓			
LEC 7862					X	?		?		X
Kestral				?	X	✓	✓	✓	✓	?
2302					X		✓		?	
Centry								■	■	■
NUM 0120	X		X		X	X		✓		?
Alpinas (45-30)				X	X	X	✓	X	✓	✓
Lily					X	X	✓	X	✓	✓
Gitanas					X		X	X	?	?
Foxtrot	X	X	?	X	✓					

KEY

■	Control variety	X	Did not produce a marketable heart
✓	Performed well in this time slot		Not evaluated in this time slot
?	Close to producing a marketable heart		

13. IPM and the Markets

Sandra McDougall (NSW Department of Primary Industries,Yanco Agricultural Insitute)

Background

In July 2006, 79 growers responded to a telephone survey on Lettuce IPM and lettuce projects (see VG05044 Further developing integrated pest management for lettuce Final Report). Within the survey, growers were asked about barriers to IPM adoption. Responses that related to market issues included:

- ⇨ *Market, consumer, retailer acceptance of IPM product*
- ⇨ *Consumer awareness of IPM principles important (i.e. "education")*
- ⇨ *Lettuce conference organised well, however need to educate consumers and retailers, not the growers*
- ⇨ *Need premiums for practising IPM*
- ⇨ *"Zero Tolerance" - clean lettuces wanted by QA people (i.e. no beneficials present either)*
- ⇨ *Qld - processors accepting IPM products (i.e. with wildlife in lettuce)*
- ⇨ *Qld - processors have banned the use of Bt because of a perceived "health risk" (i.e. education needed)*
- ⇨ *Lack of awareness by consumer/retailer about IPM - "zero tolerance", beneficial contamination - "education"*
- ⇨ *No premiums paid for use of IPM*

Again at the end of VG05044 growers were consulted at meetings in South Australia, Western Australia, Queensland and NSW, and via individual discussions in Victoria. The meetings were poorly attended, and in total 25 growers responded to the survey questions. Within this survey (Appendix 16-1) 9 work areas were listed, and growers were asked to rate them from 1 (low priority) to 5 (high priority), or "shouldn't fund". The component addressing the market issues proposed for VG07076 was defined as: *Improving attitudes of Processors & Supermarkets towards IPM – having discussions and forum with processors and supermarkets to see what their attitudes are to IPM and whether there is potential to work together*. Thus defined the growers rated:

Please give priority rating	low 1	2	3	4	high 5	shouldn't fund
Supermarkets & processors	2	3	4	2	10	3

Comments

maybe they are not interested (don't fund);
don't understand (no response);
more education for general public.
IPM lettuce a disadvantage because Confidor lettuce is very clean. (5);
need educating (5);
growers need to understand IPM better first (3),
changing consumer & markets attitudes towards bugs in lettuce critical (5);
always learn from those intouch with consumers (3)
Numbers in brackets are numbers of growers making comment

Method

It was understood that issues of chemical use, insect contamination, and specific processes or procedures to manage them may be commercially sensitive. The approach taken was to endeavour to initially have informal conversations with processors, providors and supermarket buyers who deal with lettuce about their attitudes to IPM. Jonathan Eccles approached a number of such people at the PMA meeting in April 2009 and was essentially given the response that zero tolerance for insect contamination was not negotiable.

Particularly in light of the response from one grower in Queensland (that processors had banned the use of Bt) it was important to make specific contact with the processors to understand whether this was true and on what basis. Two Queensland-based lettuce processors were contacted initially by phone and after a contact name was given an email giving background to the project and why they were being contacted was sent (Appendix 13-1). An exchange of emails, telephone calls and in one case a personal visit, was made.

Approaches to a major supermarket resulted in a meeting being organised with three levels within the lettuce procurement chain, but only the lower level was actually available on the day of the meeting.

To open the discussion about the potential for the "Market" to exert a pull on IPM rather than be an obstacle, a session was planned for the Australian Vegetable Industry Conference in Melbourne in May 2009. Fifty minutes was allocated and speakers were approached to contribute. One large lettuce processor, one grower/processor, an IPM grower, an IPM consultant, and a market consultant, were prepared to speak. The market consultant couldn't make the session on the day. A summary of the speeches was published in the Lettuce Leaf issue 36. The IPM growers talk was later recorded and a version prepared for loading onto the AUSVEG website.

A final approach in this project was to test consumers' attitudes to IPM and insect contamination through focus groups and a national consumer on-line survey. This component was conducted by Dr Jenny Ekman, a post-harvest expert, and is written up in next two chapters (Chapter 14 and 15).

Results

Informal discussions that Mr Eccles had with lettuce buyers at the PMA conference suggested that IPM was a low priority issue and that minimising the potential for insect contamination was a very high priority. Email discussions with two lettuce processors reiterated this line and that contamination of lettuce with beneficial insects was as much of a concern as pest insects (see Appendix 13.3 for email responses). Insects are *foreign matter* and they collect data on the estimated percentage of lettuce contaminated, that the *foreign matter* is insects but not what the insects are. Customer complaints are recorded and insects are "as serious as glass or other foreign material in the product". Although they "do not ask growers to use any specific insecticides…..the imidacloprid drench will be a necessary precaution for us to ensure our incoming produce is pest free". Pesticide residues were a concern and they request their growers to provide annual residue test results. One of the processors also conducted "MRL validation" testing.

One processor said they actively encourage growers to adopt IPM and were developing a "comprehensive policy to deal with Food Safety and Environmental Sustainability".

After the initial email responses, followup emails and phone calls were not responded to with any more detail.

Visit to Processor on 2 March 2009

- Summer 08/09 found high levels of insect contamination, conducted detailed monitoring of the levels of infestation and washout
- Needed to have increased numbers of people looking at product before washing.
- Do 2x double wash at times but they suffer with shelf life
- Moths cause more consumer angst than thrips or Ladybeetles
- They sell a 'ready-to-eat' product so people have a higher expectation that it is just that
- Showed data that the numbers of insects at receival has been increasing each year over the last 5 years
- Reject loads with presence of "dangerous insects"
- Insects small insects <5 mm – max 5 per crate, no more than 10% of crates affected

  - Large insects >5 mm max 1 per crate, no more than 10% of crates
- If expecting to exceed levels then growers must inform them prior to delivery. In case where everyone is suffering similar problems then they will change specs and modify process
- Looking at better management options with major growers

Meeting with Supermarket national lettuce buyer

- Customers complain about insects in produce and as the lettuce buyer they need to personally deal with any complaints related to lettuce.
  - Dealing with customer complaints is a very unpleasant and time consuming activity
- Specifications don't allow for insects in produce although at times the specifications are changed, i.e. when widespread problem with particular insects
- Therefore any practice that may increase levels of insect contamination would not be encouraged
- QA checks at receival look for contamination, records kept but not on type of insect
  - Need to talk to QA about records – access unlikely
- Residues are not an issue
  - QA do random residue testing 1/month, lettuce is sampled some months maybe 2-3 times in a year
  - QA requires growers to do own testing at least once per year and have spray diaries audited
  - If residues detected they work with growers individually to resolve – not often a problem
- Supermarket has a sustainability officer who looks at issues of packaging etc.

Discussion

The market end of the chain did respond to initial contact, but clearly, the topic was not one they were particularly enthusiastic to pursue. There are relatively few processors or major supermarkets, hence a reluctance to be particularly open in discussions for fear of competitors using the information to their detriment is understandable. The mantra that *Customers are King and have no tolerance for insect contamination* was the standard first response, and in some cases, the only response. Insect contamination was a problem in fresh produce no matter how it is produced but believed to be more of a problem with produce from IPM growers.

Larger insects were more of a problem than smaller insects and although washing of the processed product removed some insects, there can still be contamination problems. Therefore having fewer insects in the incoming load was highly desirable. Chemical residues were not considered a problem, i.e. they rarely detect MRL breaches. It was stated that an increased use in pesticides was more desirable than an increase in insect contamination, as long as the pesticides were used as per the label or permit.

Attempts to follow-up initial conversations or email exchanges was not met with enthusiasm and rather than being too persistent, it was thought that another approach needed to be found and that it was probably better to work more closely with a market chain specialist.

Recommendations for a study on insect contamination

From the conversations had with processors and buyers it is not clear how big a problem insect contamination really is. Because the information is commercially sensitive it could not be effectively addressed within this project. It is recommended that a project be negotiated, potentially with voluntary contributions and pre-negotiated confidentiality agreements to quantify this problem and identify possible solutions.

How big a problem is it?

- Study of actual insect load in consignments, variability between source and time of year by management practices.
- Frequency of rejections due to insect contamination
- Study of actual insect load at point of sale
- Collate customer complaints
    - What proportion of complaints are insect contaminant related?
    - Which insects are complained about?
- What are consumer attitudes to insect contamination, to chemical residues, to potential trade off between the two and do different categories of consumers vary in their attitudes?

Processors

- Trial with processors to follow insect load from receival through washing (sump wash-out) and bagging. At multiple points in year. If possible run a trial with a heavily infested load.
- Options to use additives to the wash water to increase insect removal or to modify the agitation action of the washers.

Supermarkets

- Study of actual insect load in consignments, variability between source and time of year by management practices.

Growers

Potential of non-chemical means to reduce insect contamination at harvest:

- Use of attractants or repellants to move insects e.g. Magnet® to move *Helicoverpa spp.* moths
- Light sources on the harvest aids
- Blower/vacuum on harvest aid

14. Focus groups report: Consumer attitudes to insect contamination of fresh vegetables

Jenny Ekman

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Background

Over the last 10 years, HAL and the Australian vegetable industry have invested $43 million on plant health related projects. The underlying approach of many of these projects has been based on Integrated Pest Management (IPM). Despite this, adoption of IPM by Australian vegetable growers has been slow to occur and limited in scope.

One of the main barriers to adoption of IPM practices is the perception, real or otherwise, that consumers will not tolerate any insects in the vegetables. Both processors and retailers have previously rejected lettuce consignments which contained live insects. However, it is not clear whether this concern is truly justified.

However, it is not known:

⇨ How consumers REALLY react to finding an insect
⇨ Whether this reaction is different if the insect is inside a bag of mixed salad vs on a whole head lettuce
⇨ How reactions vary depending on the type of insect found
⇨ Consumer understanding of and response to the IPM concept and growing practice
⇨ Whether marketing IPM grown lettuce with an “Eco” label makes consumers more tolerant of finding an insect.

This report represents the first part of a two part study – a series of six focus groups in two locations. The second part of the study will involve an online survey of at least 1,000 main grocery buyers. The quantitative survey will be used to validate the qualitative observations reported here.

Aim

To investigate consumer reactions to insect contamination in bagged salad and whole head lettuces and examine the potential market for IPM (Eco?) labelled products.

Method

A series of 6 focus groups were conducted. Three were located in Crows Nest and involved upper / middle class participants (location A). The remaining groups were held in Harris Park and targeted middle / lower class participants (location B). All participants had nominated as the main grocery buyer for their household. Each of the three groups / location had involved specific selection criteria:

Women with school age children (<12 years)

Women aged 45 – 60, grown up children, most with partners

Women aged 25 – 35, most with partners

After completing a short questionnaire on shopping habits, the participants were lead through a structured discussion on fruit and vegetable shopping. This narrowed to focus particularly on purchase and use patterns relating to lettuce (including fresh cut). They were shown samples of hydroponic (green oakleaf) and iceberg lettuce and asked to discuss what they thought about these.

Participants were then presented with sealed bags of lettuce mix. These were labelled either "Aussie Grown" or given an "Eco" branding, including a claim that the samples were "Grown sustainably for a better environment" (Appendix 13-1). The lettuce mix was purchased from Sydney Markets on the morning of the focus groups and was the best quality available. A number of the bags for each group had been deliberately contaminated beforehand with ladybugs, lacewings, a spider, or a green vegetable bug.

The group members were told to tip the contents of each bag onto the plastic plate provided and fill in a second questionnaire which included evaluation of product quality, appearance and their interest in purchasing such a product. The purpose of this was to stimulate close examination of the product. The observers could note reactions to finding an insect, if this occurred.

The discussion then turned to the issue of insect contamination – what does it mean and what would the consumer do if it occurred. The participants were shown 12 x A4 size pictures of insects as well as actual insects in vials. Insects were chosen so as to potentially range from least disgusting (ladybeetle) to most disgusting (caterpillar, slug). Participants were asked how they felt about each. They were questioned to see how much they understood about control of insects during vegetable production and in the supply chain. Organics was also discussed to explore attitudes and understanding of this production method.

The facilitator then explained some basic elements of Integrated Pest Management – the use of beneficial insects, applying pesticides only as a last resort, and using targeted chemicals instead of broad spectrum ones. Participants were quizzed regarding their acceptance of this method if quality was similar to conventionally grown product and asked how much extra they might be willing to pay for product grown this way.

Finally they were shown samples of dirty products – leeks, parsley, beetroot – and asked if that was an issue. They were also shown some red-tipped "eco-bananas" and asked whether they had seen them and/or knew what they were. The discussions then closed, having usually lasted for approximately 75 minutes.

Results

Where do you usually shop for your fruit and vegetables?

Around half of the participants said they purchased most of their fruit and vegetables from the supermarket. However, many said that they used both supermarkets and fruit and vegetable shops, according to what was better / cheaper / more convenient at the time.

Previous focus groups had found a strong negative attitude to supermarkets – that although consumers were 'forced' to shop there for convenience they considered their produce overpriced and the quality often poor. This was not expressed as strongly in the current study. Although fruit and vegetable shops were generally still regarded as having the best quality and variety, some participants were quite satisfied with produce from the supermarket;

"I thought it wasn't very good but... (friends) got all this produce from Woolworths Crows Nest and it was beautiful, I was surprised at the quality"

"I used to shop at Harris Farm but now I find the prices are really expensive. Since having children I just go to Woolworths it's cheaper"

What is most important? What are turn-offs?

Quality and freshness were consistently the most important factors in fruit and vegetable purchases. Price was secondary, although also still very important, and often expressed as "*value for money*". Variety, convenience and "*what is in season*" were also seen as important. While some were reasonably confident about seasonality in fruit (e.g. mangos, cherries and apples) they were less sure about vegetables.

The biggest turn-off was, unsurprisingly, lack of freshness. This was expressed by words like "*limp, soggy, old*". Participants also mentioned quality factors such as rots, bruising, internal browning in fruit and poor texture. High prices were also a major turn-off. Although most examples given were fruit such as avocados and berries, salad mix was also cited. Over-packaging was mentioned as another turn-off, but it was not clear whether this was usually because of environmental concerns or because it meant the consumer could not pick and choose individual items. There is still a perception that poor quality fruit and vegetables are hidden inside packaged products in order to deceive consumers.

Several groups mentioned the presence of insects as being a turn-off. In most cases the culprits were described as fruit flies (vinegar flies - *Drosophila sp.*), which are attracted to displays of ripe or damaged fruit. The presence of these flies not only discouraged purchase of the specific items on display, but also reflected badly on the retail outlet as a whole. Flies (including *Drosophila*) are seen as 'dirty' and indicating poor hygiene. Bugs in vegetables (in fact, specifically in lettuce), were mentioned as a turn-off by a member of group B3;

"I've bought lettuce in Woolworths and there've been, like, bugs and stuff and rotten on the inside"

None of the groups mentioned pesticides, although several participants (especially group A2) said they regularly purchased organic produce.

Let's talk about lettuce – what do you look for?

The majority of the participants in all groups said they ate salad vegetables daily (67%) or at least several times a week (31%) during summer. Despite this, a number of participants stated they did not buy lettuce. Also, although 41 out of 45 focus group participants had bought a salad mix at some stage, half also said they purchased such products only infrequently (<weekly). The high levels of reported salad eating did not appear to be fully reflected in purchases of lettuce and lettuce mixes, suggesting perhaps that salads are eaten away from the home.

Loose leaf lettuces were regarded as good value, being cheap and often in good condition. Some talked enthusiastically about cos lettuce, especially for making Caesar salad. Although many agreed that iceberg lettuce could last a long time, the size was a problem for some, particularly singles and couples without children;

"They're the biggest rip-off around, because you hardly ever get through a whole lettuce".

Iceberg was most frequently purchased by those whose children wouldn't eat other types of lettuce, and by younger women. Women in group A3 regarded iceberg as "everyday" lettuce, while loose leaf lettuces and mixes were for entertaining. Those in B3 talked about buying iceberg for san choy bow and tacos, while "fancy" lettuce was for BBQs with friends.

When asked what they looked for in lettuce, most talked about freshness, crispness and no wilting or browning. Iceberg lettuces should be heavy, others should be full and fluffy. At this point several participants mentioned finding insects in lettuce;

"It shouldn't have any little bugs crawling out of it"

"You get it home and there's a snail or a slug or something"

"I pull the top leaves off when I'm at the supermarket, because they're always hiding in there"

However, the way people reacted to discovering an insect or other contaminant varied according to what it was;

"Certain ones matter, a snail or a slug is awful, but I've had a tiny frog in a lettuce and that was alright I didn't mind"

It was already becoming clear that attitudes varied between the groups and locations. The women in the group 2s (older ladies) appeared to be the most tolerant in each location. Participants in Crows Nest (location A) were generally more tolerant than those from Harris Park (location B). Group B3 was far less tolerant than any other. Whereas insect contamination of lettuce was a minor issue to other groups, to B3 it was a major factor influencing their purchasing patterns;

"I just salvage what I can, wash it and that's OK" (A1)

"It comes from the ground, it's natural to have an insect" (A2)

"It's funny how it's acceptable (to have a grub) in a lettuce but it's not acceptable in an apple" (B2)

"In the end I just gave up (buying lettuce at Woolworths) as they were just disgusting, with insects, worms…" (B3)

"If I found one bug in my lettuce I'd chuck the whole thing out...there would probably be more in there" (B3)

The groups were asked what they did with a lettuce when they got it home. Some said that they washed everything so that it was ready to use. Iceberg lettuces were sometimes cored and/or split up into leaves and washed before storing in special lettuce keepers. Others said that they put lettuces straight into the crisper and washed them just before use. Regardless of when it happened, most took it for granted that lettuce had to be washed;

"It's important to wash it before you use it get rid of any bugs and dirt, and you don't know how many hands have been on that lettuce…" (B1)

Lettuce mixes were rather different – while some re-washed, others didn't, perhaps depending on their level of trust in the product. Either way, most participants were less tolerant of finding an insect in a bagged product than in whole lettuce. There was a clear expectation that bagged lettuce had already been cleaned and checked. It is more expensive than whole lettuce and this is part of what they are paying for;

"It's being sold as already washed and prepared, you shouldn't need to go home and do it yourself"

"I like buying the lettuce in the ready prepared bags because of the number of times I've bought a whole lettuce and when I've been pulling it to pieces there've been little worms in it… I figure the stuff in bags has been washed already so I don't need to do anything"

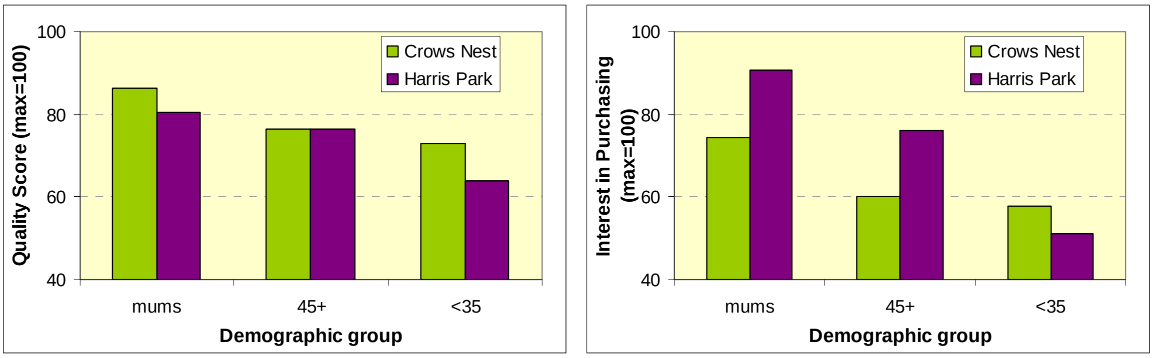
"I wouldn't trust it, I'd re-wash it anyway"

Evaluating the whole and bagged lettuce (with insects)

The comments about the whole lettuces indicated that many participants, particularly in location B, had limited understanding of how the lettuces were grown. Several commented that the slightly yellowed leaves at the base of the oakleaf lettuce showed that it was old and harvested up to a week ago. Many had no idea why the roots were still attached to the hydroponic lettuce. Others recognised that this showed it had been grown in water, but the presence of "dirt" at the base of the plant confused them – how could this be so?

The participants had been asked to examine and score bags of fresh lettuce mix. Scores varied considerably between the different demographics, even though the mix was the same in all cases. Mothers with young children (group 1's) scored quality highest, while younger women (group 3's) scored it lowest. Although quality tended to be graded slightly lower by the groups in Harris Park, their interest in purchasing the product was higher than those from Crows Nest (Figure 13-1).

Figure 14-1 Mean quality scores and interest in purchasing lettuce mix as recorded by 3 demographic groups in 2 locations



In four of the six focus groups conducted, none of the participants noticed any insects in the lettuce samples. In the two cases where insects were noticed spontaneously, it was because a ladybeetle fell out of the general pile onto the white examination plate;

"Hey I found a ladybug!! How cute, maybe I should take it outside" (A3)

The groups were then told that the bags had been deliberately contaminated with various kinds of 'bug', stimulating more intense searching. However, in many cases the focus group members still couldn't find the insects. Only one green lacewing was found (despite 2 being placed in each of several bags per group), and then only because it had stuck to the plastic bag when the lettuce was tipped out. Even large green vegetable bugs often escaped detection. Juvenile ladybeetles were also difficult to spot, although the adults were found more easily due to their contrasting colour and regular shape.

Although there was a general feeling that 'bugs' didn't belong in packaged salad, most participants did not appear unduly shocked or repulsed by finding insects in the samples. Several commented that it would have been far more disgusting if they had found a cockroach or a fly. In general, insects that were found on lettuce while it was growing in the field were regarded as 'natural', whereas contamination that occurred during packing, transport or retail were less acceptable;

"I've got a big green grasshoppery thing! I don't know that I'd buy this salad…but, it means it's fresh" (A1)

"I would have more of a problem with it (insects) in bags than in the loose stuff, but it's still part of the natural process…if it was a cockroach that would be a completely different story" (A2)

"I bought a pre-packaged Caesar salad kit, and I opened it up and found two dead flies in it, it turned me right off it and I haven't bought it since" (B2)

In general, the Crows Nest participants appeared less concerned about insect contamination than those from Harris Park. Several even commented that perhaps it meant there were less pesticides used on the product, and that that was a good thing;

"You don't want pesticides on them, so you can't really have it all" (A1)

"Presumably the bugs mean it hasn't been sprayed" (A3)

The only group that was not tolerant of insects in the bagged lettuce was group B3. These young women differed from all other groups in their absolute rejection of insect contamination. Two of the group were particularly vocal on this topic, which may have influenced the responses of other group members. Nevertheless, it was clearly an important issue to them;

"Having found my little black ladybug, I would throw the whole bag out, even if it cost me four bucks. It's contaminated. The bug may have disease" (B3)

"I'd chuck it (the lettuce), the bug might have laid eggs or something" (B3)

Who is responsible for keeping bugs out of lettuce?

There was a general agreement that, while the farmer would try to minimise insect infestation, it was not realistic to expect them to ensure there were none in fresh produce. Responsibility mainly fell to the middle man – the processor, produce buyer or greengrocer. They were expected to check the vegetables for bugs and remove them if necessary. Some felt that they - as consumers - were also partly responsible, having chosen the item in the shop.

The participants were asked whether they thought it was reasonable for supermarkets to have a "Zero Tolerance" for insects. The answer to this was overwhelmingly no, that this was not realistic. Members of groups A2 and A3 commented that this would just force farmers to use more chemicals, which they didn't want;

> *"I just think they'd have to spray it with more pesticide to uphold their end of the bargain, so I specifically wouldn't buy from that supermarket" (A3)*

When questioned about how farmers controlled pests, the focus group participants agreed that farmers had to use pesticides to protect their crops. Although none of the groups could say exactly who was responsible for controlling pesticides, there was a general feeling that the Government, or perhaps the farmers organisations, made sure that pesticide use was kept within safe limits. Despite several mentions of the recent 60 Minutes program on endosulfan and carbendazim, most participants trusted that fresh produce was safe to eat.

Participants who had already self nominated as organic produce buyers were exceptions – they weren't sure how good the standards / regulations were and suspected they benefitted growers rather than consumers.

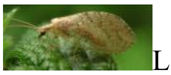
Differences between types of insect

The groups were shown pictures of insects as well as samples and asked to indicate whether they would tolerate finding the particular insect in a lettuce. One complicating factor was that they were necessarily shown pictures taken with major magnification. Even after it was explained how small the creature was, it may have been difficult for them to visualise what it would look like.

This was supported by the observation that, even though many groups rejected ladybeetle and lacewing larvae (Table 13-1), they were unable to find these insects when mature instars were placed in the samples of bagged lettuce. This suggests that, although they were considered unacceptable in fresh produce by some, in actuality they may not even be noticed.

The groups were also shown a picture of a tiny green mirid (~1.5 mm long) on a raspberry. This created some concern due to its superficial resemblance to a cockroach – even though the mirid was far smaller than a normal roach. Again, participants may have found it difficult to visualise the actual size of the insect.

Table 14-1 Acceptability of some insects in lettuce as generally agreed by each focus group; ✓ = OK, easily washed off; ~ maybe OK, so long as only 1; ✗ = not OK, would result in product rejection

	Groups at Crows Nest			Groups at Harris Park		
	A1	A2	A3	B1	B2	B3
 Ladybeetle (adult)	✓	✓	✓	✓	✓	~
 Lacewing (adult)	✓	✓	✓	✓	✓	✗
 Praying mantis	✓	✓	✓	✓	✓	✗
 Rutherglen bug	✓	✓	✓	✓	✓	✗
 Whitefly	✓	✓	✓	✓	✓	✗
 Lacewing (larvae)	✗	✓	~	✗	~	✗
 Ladybeetle (larvae)	✗	✓	~	✗	~	✗
 Caterpillar	✗	✗	✗	✗	✗	✗
 Slug	✗	✗	✗	✗	✗	✗

Eco-labelling and IPM

Most participants did not look at the bag labels at all when they were examining the mixed lettuce. They were therefore asked to look at the label and discuss whether it meant anything to them. Some saw the "EcoFresh – Grown sustainably for a better environment" as purely a marketing ploy that was fairly meaningless;

"You expect that vegetables will be fresh and fairly ecologically good anyway, I don't think this makes any difference"

"I'm pretty cynical so I'd probably just dismiss it"

Some in groups A1 and A2 thought that there could be some benefits;

"Because it says grown sustainably I would be hoping that it is grown so as to look after the farming land better" (A2)

There was clear scepticism regarding labelling symbols. Even the Heart Foundation tick did not go unquestioned;

P1 - "*That doesn't mean so much anymore… just means they've paid for that tick*",
P2 – "*… they do have to meet some standards, I'm sure…*"

The basic concept of Integrated Pest Management was then explained to the participants. It was presented as an option in between conventional and organic farming, where beneficial insects were used to control pests where possible and insecticides were used only when there was no alternative. This meant that there might be more insects in the product, but also less pesticides.

Many of the group participants in A1 – A3 appeared engaged and curious during this discussion;

"I'd like to know more about it first, but it sounds like a step in the right direction" (A2)

However, interest in purchasing an IPM branded product varied. Those who had said they purchased organics were not convinced, given that the product could still have been sprayed with pesticides. Others said they were happy with the current situation, that they believed vegetables were safe to eat anyway and saw no need to change. The remaining participants expressed a willingness to pay 10–20% extra for IPM grown product, so long as they were convinced it was properly certified.

There was less enthusiasm in groups B1 and B2. In this case the explanation of IPM was met with caution and immediate questions regarding how much more it would cost. Some said they would be willing to pay 10% extra and only a few volunteered up to 20% additional.

In the case of group B3, there was a negative reaction to the IPM labelling concept. Several participants clearly didn't like the idea of having "*bugs crawling*" on vegetables they were going to eat. They were concerned that there would be more "bugs" on the product than before, and didn't think there was any problem with current pesticide use in any case;

> *"I'm OK with them spraying pesticides, so long as there aren't too many chemicals on it (the lettuce). I wash mine in antibacterial wash anyway" B3*

The groups were shown some dirty vegetables (leeks, beetroot) to see whether the presence of dirt stimulated more or less negative reaction than insects. In general it was similar – dirt was seen as part of the natural process of growing vegetables, and simply washed off before use. Again, members in group B3 were slightly less accepting, one saying that she did not purchase leeks because they were dirty.

Finally, each group was shown red-tipped EcoBananas to see if they knew what they were. Guesses included that they were organic, that they were a different variety or that the wax had been put on to make them ripen more slowly / store better. Apart from knowing they cost more than regular bananas, most had no idea what was different about them (i.e. grown using IPM and avoiding fertiliser runoff onto the Barrier Reef).

Key Points

- ⇨ Focus groups were conducted in Crows Nest (A) and Harris Park (B) with three demographic groups; 1. Mothers of young children, 2. Women aged 45–60, 3. Women aged 25–35.
- ⇨ Asked what turned them off fresh produce most consumers talked about issues with quality and price. These mainly related to fruit rather than vegetables. Insects (other than vinegar flies in the stores) was mentioned only once and pesticides were not raised at all
- ⇨ Although most participants ate salads regularly during summer, purchases of salad mixes were infrequent. Younger women tended to purchase iceberg lettuce for everyday use whereas older women purchased several different types of lettuce.
- ⇨ Asked what they looked for in lettuce, some participants mentioned that they had found bugs and worms in the past. On finding a bug, nearly all participants said they would simply remove it and wash the affected leaves. The exception was group B3, where some said they would throw out the entire lettuce.
- ⇨ Asked to closely examine bags of lettuce mix, most participants did not notice the insects which had been placed inside. Even when told insects were there, stimulating further examination, many participants could not find them.
- ⇨ Ladybeetles were found the most frequently. Lacewings (adult and larvae), whiteflies and even green vegetable bugs generally escaped detection.
- ⇨ Shown pictures of several types of insect, five of the six focus groups were extremely tolerant of the idea of finding a ladybeetle or other small insect in lettuce. However they would not tolerate caterpillars or slugs, or contamination occurring post-farm such as cockroaches or flies.

- ⇨ Members of group B3 were intolerant of finding any insect, even a ladybeetle, in a head of lettuce. However, this group was also most critical of the samples shown and least interested in purchasing such products.
- ⇨ Bagged lettuce was generally expected to be free from insects as it had already been through washing and processing.
- ⇨ While there was good interest in IPM as a concept, interest in purchasing IPM branded product was more limited; a few thought it didn't go far enough, some were happy with the status quo, others were interested and possibly willing to pay a small premium. Some members of B3 were repelled by IPM as it potentially increased the number of bugs in contact with produce.
- ⇨ None of the participants knew what an EcoBanana was.
- ⇨ Most participants in the focus groups had very limited understanding of how fresh vegetables are grown and distributed. However, they accepted that insects (and dirt) are a natural part of growing vegetables and did not expect 100% removal.
- ⇨ In general, participants from location A (North Shore) were more aware of farming practices, less concerned about insects and more interested in IPM (including willingness to pay extra) than participants from location B (Western suburbs). It is this group, particularly consumers >35, who would likely be the best target market for IPM branded products.

15. National on-line consumer survey of attitudes to insects in fresh fruit and vegetables.

Jenny Ekman

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Method

A national online survey was conducted to evaluate what main grocery shoppers think about farmers, the environment, lettuce and the issue of insect contamination in fresh fruit and vegetables.

The panel

The survey was conducted by Research Now, a Sydney based company which specialises in on-line consumer research. Suitable respondents were recruited from their National database and were rewarded for successfully completing the survey with credits towards retail vouchers. Since respondents were not randomly selected, results are applicable only to those surveyed, not to the general population.

Only main or joint household grocery buyers between the ages of 18 and 64 were surveyed. Approximately 71% of respondents were female and 29% male, reflecting what is widely believed to be the gender bias of grocery shoppers within the population (AC Nielsen).

Respondents were further selected so as to reflect National population data as closely as possible in terms of age and location. Although the number of respondents from each state closely reflected National averages (Table 14-1), there was an inherent bias of up to 6% towards people located in major population centres. This may reflect the better Internet / Broadband access available in cities.

Table 15-1 Age and location demographics of survey respondents compared to those in the general population.

Age bracket	Australian population %	Survey respondents % (n)
18-24	16.3	14.3 (154)
25-34	22.4	20.9 (225)
35-44	22.4	23.4 (252)
45-54	21.3	22.4 (242)
55-64	17.6	19.1 (206)

Home state	Australian population %	Survey respondents % (n)
Qld	20.2	19.2 (207)
NSW	32.5	33.1 (358)
Vic	24.8	25.7 (277)
Tas	2.3	3.1 (34)
SA	7.4	8.6 (93)
WA	10.2	9.1 (98)
NT	1.0	0.9 (10)
ACT	1.6	0.2 (2)

A total of 1120 people completed the survey over a two week period in May 2010. Most were completed in the first few days, the extended time being necessary to include more respondents in the higher and lower age brackets and regional locations. Since the participants were not randomly selected, there could be additional biases in the data not noted here and inference to the whole population is necessarily speculative.

The questions

The questionnaire was designed to be as wide ranging as possible while still easily completed in less than 10 minutes. It was hypothesised that factors such as experience with growing vegetables at home, interest in environmental issues, purchasing of organics and vegetarianism could affect acceptance of Integrated Pest Management. Questions on these factors were therefore included.

There was an assumption that the presence of insects would be closely related to the emotion of disgust. Six questions from the Disgust Scale (Haidt *et al.*, 1994) were included, and a scale was developed to measure individual differences in sensitivity to disgust. The questions chosen were those that assessed core disgust – the fear of contamination of the body. Core disgust includes the reaction to eating something generally regarded as disgusting, such as a cockroach or faeces. The Revised Disgust Scale (DS-R) records responses to hypothetical scenarios against a 5 point scale, ranging from strongly agree (4) to strongly disagree (0). These points are added (after reversing questions asked in the negative) and averaged to gain a total disgust sensitivity score.

In this study, we additionally calculated an "Insect Intolerance" Score (IIS) and an "Environmental Activism" Score (EAS). The IIS was calculated similarly to the disgust scale, using 7 questions on reactions to the presence of insects in food. In the case of the EAS, 6 questions focussed on the respondents concern about the environment generally and their level of trust in farmers and Government with regard to environmental issues.

In both cases, questions were chosen so as to attempt divide the respondents around an average response. For example, insect intolerance scenarios ranged from experiences expected to be only very slightly irritating (e.g. finding a ladybeetle on some herbs) to those thought likely to be unpleasant to the majority of the population (e.g. finding a cockroach in a bag of salad).

In calculating the IIS, EAS and DS-R, a response of "Don't know" was allocated a score of 2, indicating a neutral position, neither agreeing nor disagreeing with the statement.
As respondents were rewarded to complete the survey, it was expected that some might not take the time to answer the questions accurately, but just input random responses. The second question in the survey asked respondents to "*Please think about what matters most to you when buying fresh fruit and vegetables and rank the following in order of importance from 1 to 10*". The 10 factors (appearance, price, dirt free, etc.) were presented in a randomised order. However, it was clear that some respondents had simply numbered the factors from 1-10. Several of these respondents had also completed the survey very quickly (less than 5 minutes). It seemed likely that those ranking the answers in this way were not taking the time to think and answer questions seriously and truthfully. Survey respondents were therefore culled if they had ranked the factors in order 1-10, or in order but with a single change. This resulted in 36 deletions from the total pool of respondents.

A test question "*I would rather eat a piece of paper than a piece of fruit*" had also been included to check how carefully people were reading the questions. A total of 36 of the original group of respondents had agreed with this statement. However, on examining these respondents, many were otherwise consistent in their answers. It seemed possible that at least some of those who agreed with this statement had done so accidentally. A number of tests were therefore constructed to check the basic consistency in response.
These were:

1. They would rather eat a piece of paper than a piece of fruit (Q5/21 > 2)
2. They are bothered by a ladybeetle but would eat lettuce which had a caterpillar on it (Q4/9 – Q4/11 < -2)
3. Although they wouldn't eat a salad if they had seen a bug on it, they also wouldn't throw it away (Q3/10 – Q4/12 > 2)
4. They are bothered by seeing a cockroach in someone else's house but would not throw away bagged salad that had a cockroach in it (Q5/16 + Q4/14 < 5)

Respondents who failed two or more of these tests were culled. Only three respondents were culled by this method. This left a total of 1079 survey respondents.

Of this final group of respondents, 3.3% remained who had agreed that they would rather eat a piece of paper than a piece of fruit. It therefore seems reasonable to assume an error rate of at least 3% for any question, these being people who accidentally answered incorrectly due to misreading the question or mistakenly checking the wrong box when answering.
A copy of the full questionnaire is included in this report as Appendix 14-1.

Data analysis

The responses to each question were summarised as percentages of respondents in each category. Association between the characteristics, likes and dislikes of people who were or weren’t gardeners, purchasers of organic products, those interested in IPM or regular buyers of lettuce were examined by forming cross tabulations. Chi-square goodness of fit tests were then used to test the associations between these factors. In addition, the correlation between IIS, EAS and disgust scores with other attributes was also calculated.

In question 2 respondents were required to forcibly rank purchasing characteristics in order of importance from 1 to 10 where 1=most important to 10=least important. A table of the 10 purchasing characteristics and 10 ranks was formed with the number of respondents in each cell tabulated. Since this type of data is ordinal, a generalized linear model (GLM) with multinomial error distribution and logit link function was used to test the effect of purchasing characteristics on the proportion of respondents selecting each rank. GenStat statistical analysis software (v14.1, VSN International Ltd.) was used to analyse the data and least significant differences between characteristics were determined on the logit scale although, for ease of presentation, mean ranks are supplied. Similar analyses were conducted to test differences between factors such as age bracket and organics choice on importance rank. ANOVA was used to test differences between factors on core disgust sensitivity scores.

For questions where the response was ‘level of agreement with a statement’ (e.g. question 3) an ordinal scale (Likert) was employed where: 0=don’t know, 1=strongly disagree, 2=mildly disagree, 3=neither agree nor disagree, 4=mildly agree and 5=strongly agree. The effect of various factors on the proportion of respondents in each category was modeled using a GLM with logit link and multinomial errors.

Results

What is important when buying fruit and vegetables?

Freshness was by far the most important characteristic when purchasing fruit and vegetables, followed by freedom from rots and bruises, taste / aroma and appearance. Price and freedom from insects both ranked 3rd in importance with pesticide free, locally grown, in-season and clean all equally unimportant. This indicates that factors relating to fruit and vegetable quality are the most important, with price ranking significantly lower (Table 14-2).

Table 15-2 What is important when purchasing fruit and vegetables?

Importance	Purchasing factor	Mean rank		Order of presentation in survey
1	Freshness	2.8	a	3
2	No rots or bruises	4.7	b	6
2	Taste / Aroma	4.8	b	10
2	Appearance	5.0	b	1
3	Price	5.5	c	9
3	No insects	5.8	c	7
4	Pesticide free	6.5	d	8
4	Locally grown	6.5	d	5
4	In season	6.6	d	4
4	Clean / dirt free	6.6	d	2

Different letters indicate factors that were ranked significantly differently on the logit scale ($p<0.001$).

More than 40% of respondents considered freshness the most important factor when purchasing fruit and vegetables, compared to only 2.5% who ranked “dirt free” or “in season” as their top priority. In all, 74% of survey respondents ranked “freshness” within their top 3, compared to 20% who included “insect free” and 15% who included “pesticide free” (Figure 14-1).

There are some individuals (~20%) who consider issues such as freedom from insects, dirt or pesticides to be very important when choosing fresh fruit and vegetables. However, the majority of consumers are far more concerned about product quality attributes – freshness, taste, freedom from rots and bruises - than they are about contamination issues or how product is grown.

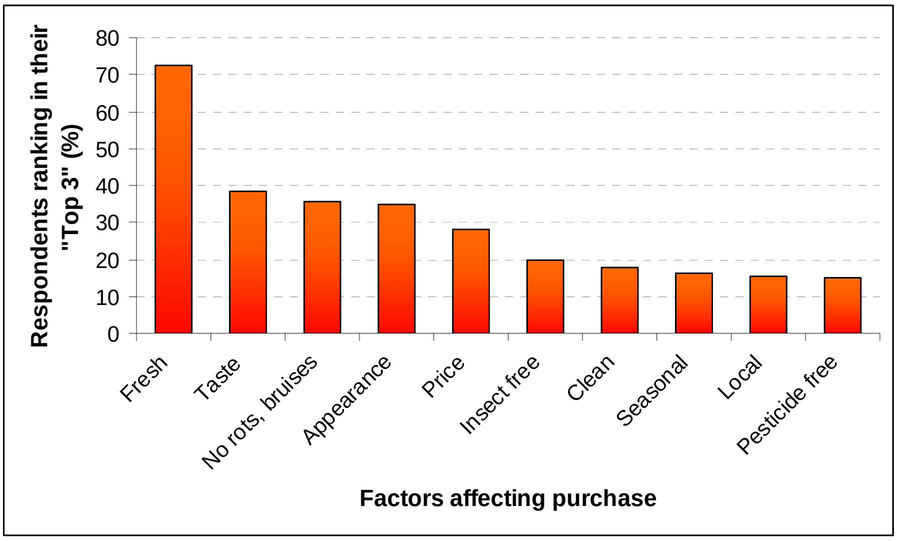


Figure 15-1 The "Top 3" priorities when buying fruit and vegetables, as ranked by the survey respondents.

There were significant differences between the age groups in how they ranked the different factors (Table 14-3). In particular, those aged <35 were different to older respondents. This was particularly evident in the importance given to "no insects" and "dirt free", both of which were considered much less important by older respondents than younger ones (Figure 14-2). In contrast, whereas "taste / aroma" was second in importance only to "freshness" for those aged 35+, this factor fell to 4th or 5th priority among younger consumers.

Table 15-3 Differences between age brackets of the importance of different factors when purchasing fruit and vegetables.

Age bracket (years)	Importance when purchasing fruit and vegetables							
	Clean, dirt free		Freshness quality		Taste aroma		No insects	
18-24	5.8	a	3.7	b	5.5	c	5.0	a
25-34	6.1	a	2.8	a	5.0	bc	5.3	a
35-44	7.2	b	2.7	a	4.4	a	6.1	b
45-54	6.9	b	2.7	a	4.7	ab	6.1	b
55-64	6.7	b	2.6	a	4.7	ab	6.5	b

For each column, different letters indicate age brackets that were ranked significantly differently on the logit scale ($p<0.05$). The smaller the rank, the more important the factor

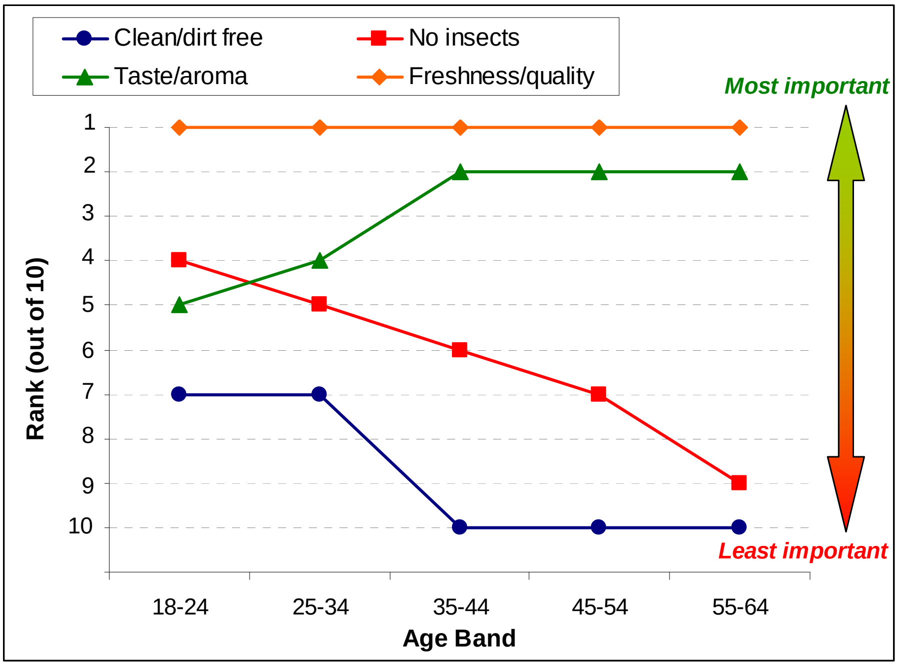


Figure 15-2 Importance of various factors when choosing fresh fruit and vegetables, expressed as mean ranking out of 10, by different age groups.
NB. Raw data has been used to determine rank out of 10, in some cases values were not significantly different.

Key Results

- ⇨ Freshness / quality parameters were consistently ranked the most important factor when buying fruit and vegetables for all age groups.
- ⇨ Price, contamination and environmental issues were generally less important than product quality – but not to everyone.
- ⇨ Taste and aroma were ranked second by respondents aged 35+, but were less important to younger groups.
- ⇨ Insect free and dirt free were more important to younger respondents (<35 year olds) than older respondents.

Are the environmental impacts of fruit and vegetable production a concern?

These questions aimed to find out how much respondents knew about and trusted in government regulations for managing fruit and vegetable production practices and their concern about the environmental impacts of farming. Respondents were asked whether they agreed, disagreed or were neutral / did not know with regard to a series of statements. Two of the statements were negative about the environmental impacts, three were positive, and two simply assessed whether people thought environmental issues were important.

Regardless of how the questions were asked, more respondents agreed with the statements than disagreed with them. Moreover, a large percentage of respondents did not have an opinion either way or simply did not know. On average, 36% of respondents were neutral regarding the five statements (Figure 14-3). This compares with only 13% of respondents providing neutral / don't know responses to the questions relating to insects in food.

It would be useful for future studies to reverse all questions half way through the survey so as to neutralise any bias towards positive answers.

Control of Pesticides

Nearly half of the respondents (47%) did not know whether the Government controls pesticide use in Australia. A further 14% thought that pesticide use was <u>not</u> controlled by the Government. It is also notable that 31% of respondents agreed that many farmers are not responsible in their use of pesticides. Such a high level of agreement may reflect coverage by the popular press promoting this view.

The previous focus groups indicated that most people understood that farmers sometimes use pesticides to protect their crops. However, it seems that most people are unaware that pesticide use in Australia is controlled by State and Federal Government regulations as well as subject to food safety audits and fruit and vegetable chemical residue testing. Perhaps this is an area where the industry could be more pro-active, as many consumers have poor understanding of chemical use and regulation.

Despite this, the majority of respondents agreed that fruit and vegetables grown in Australia are safe to eat. Only 7% disagreed with this statement, including 1.6% who strongly disagreed. Given an error rate of at least 3% (see methods) it seems possible that up to 96% of respondents consider Australian fruit and vegetables to be safe to eat.

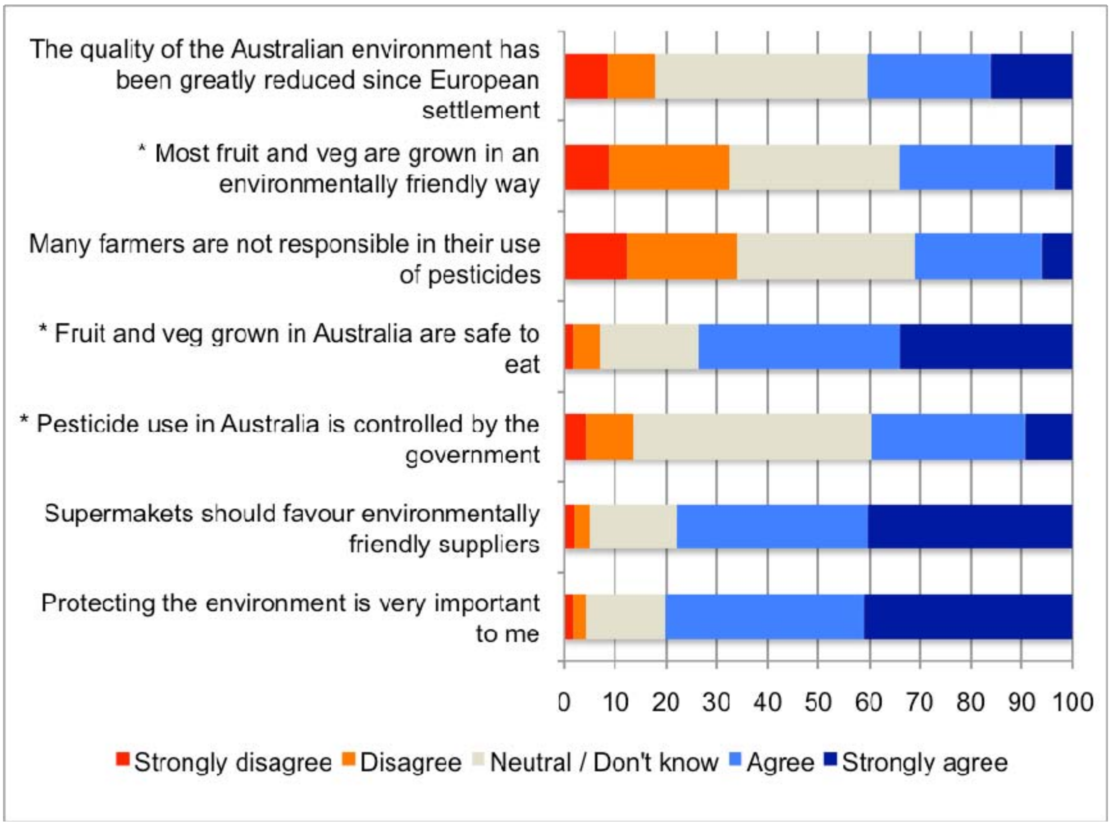


Figure 15-3 Percentage of respondents agreeing, disagreeing or remaining neutral on statements regarding environmental issues.

* marks questions where the answer was reversed when calculating the EAS.

Caring for the environment

The final statement from this section; “protecting the environment is very important to me” was supported by more than 80% of respondents with only 16% undecided. This was not surprising; not many people would openly admit to not caring about the environment. However, it is more suprising that the previous statement; “supermarkets should favour suppliers who can show they use environmentally friendly production methods” received almost the same level of support (78%). Having the supermarket select suppliers on the basis of their environmental credentials represents an easy option for consumers, who can effectively outsource environmental responsibility to a third party. This helps them shop guilt free, without having to weigh the ‘pros and cons’ of each purchase.

Favouring environmentally responsible suppliers also represents an opportunity for supermarkets to create a clear point of difference with other retailers. The results suggest that any such program is likely to be supported by many consumers. Some UK supermarket chains (e.g. Tesco Greener Living, Marks and Spencer “Plan A”) have used this strategy succesfully in the past. However, consumers must have a high level of trust in the supermarket for such schemes to be effective.

Calculating the EAS

The Environmental Activism Score (EAS) was calculated from the combined scores of the questions shown in Figure 14-3, with the exception of the fifth question relating to whether pesticide use was government controlled. This was omitted due to the large numbers of respondents who didn’t know (20%) or were neutral (27%) on the issue.

The EAS proved to have a normal, although somewhat narrow distribution. Scores ranged from 0 to 4 with a mean value of 2.25. More than 70% of respondents scored between 1.7 – 2.8, so they could be considered to have a moderate level of concern about these issues. Only 5.6% scored >3, indicating a high level of concern and, perhaps, mistrust in the environmental responsibility of farmers and Governments.

The EAS was slightly higher among women than men ($p=0.008$) and higher among vegetarians / mostly vegetarians and vegans compared to non-vegetarians ($p<0.001$). EAS was highest among singles with children and lowest among couples with children. Overall, the EAS was unaffected by age, location, education, job or income.

Key Results

- ⇨ A large proportion of respondents was either neutral or did not know when questioned about environmental issues relating to fruit and vegetables.
- ⇨ Although most respondents agreed that fruit and vegetables are safe to eat, understanding of pesticide use and regulation was low.
- ⇨ Most people who took part in the survey agreed that they cared about the environment.
- ⇨ There was strong support (78%) amongst respondents for supermarkets favoring environmentally responsible suppliers - potentially outsourcing responsibility for environmental issues and offering a “point of difference” for retailers.
- ⇨ An EAS (environmental activism score) was calculated for each respondent from their combined scores. This had a normal distribution and could be used as an indicator of concern regarding environmental issues.

How much do people tolerate insects in food?

This section examined how much people would tolerate insect contamination in vegetables. As previously, respondents were asked whether they agreed, disagreed or were neutral / did not know regarding a series of statements. In this case five questions were negative about insects and two were positive.

As previously noted, there appeared to be a trend to people agreeing with a given statement, regardless of what the statement is. It would be interesting to reverse the statements on this issue and redo the survey. As positive answers favored non-tolerance of insects (5 questions compared to 2 asked the opposite way), neutralizing any bias in this way could hypothetically "increase" insect tolerance.

Despite this effect, it was clear that the respondents had much more definite opinions about what they would do faced with an insect than they did about environmental issues. Not only were there fewer neutral / don't know responses, but also much greater polarization of respondents. For example, while 15% strongly agreed that they would use fly spray to kill an insect in the home, 26% strongly disagreed with the same statement, with only 12% unsure.

Finding a bug

Although the majority of respondents were tolerant of a ladybeetle on herbs (73%), they were far less tolerant of a "bug", particularly if it was in bagged salad (Figure 14-4). For example, only 22% of respondents still wouldn't eat a salad if they had seen a bug in it, even if the bug was removed and the salad washed. However, nearly double as many (39%) said that they would throw away a bag of salad mix if they saw a bug in it, with approximately the same number saying they would complain to the store.

Given these results, it is surprising that nearly 78% of respondents agreed that if they found a caterpillar in a lettuce, they would remove the damaged leaves and wash and eat the remainder. It might be expected that people would be less tolerant of a caterpillar than a bug, but the results appear to indicate the opposite. This result could indicate a degree of acceptance that a whole lettuce, grown in a field, might have insects or grubs in it and that these would be hard to find and remove before sale. People might have found such creatures in the past, especially if they are a home gardener, and therefore accept them as part of the natural process of growing food.

Salad mix, on the other hand, is meant to be ready to eat. It should have been thoroughly washed and checked already by somebody in the supply chain, so finding anything here is a lot less acceptable. Moreover, salad mix is more expensive than whole head lettuce, raising expectations of quality and cleanliness. Only 45% of respondents said they would still eat the "contaminated" salad mix, compared to 78% who would eat the lettuce. This therefore suggests that the context of finding an insect may sometimes be more important than what type of creature it is.

The exception is likely to be a cockroach, strongly associated with dirt and disease. Unsurprisingly, only 12% of respondents disagreed or were undecided about throwing away salad which had been in contact with a cockroach. Most (88%) agreed they would not eat this product.

These results are consistent with previous observations from the focus groups – although many people will tolerate an insect which is a "natural" part of the production system, acceptance declines rapidly as the product becomes more processed, while post farm gate contamination (e.g. a cockroach or fly) is totally unacceptable.

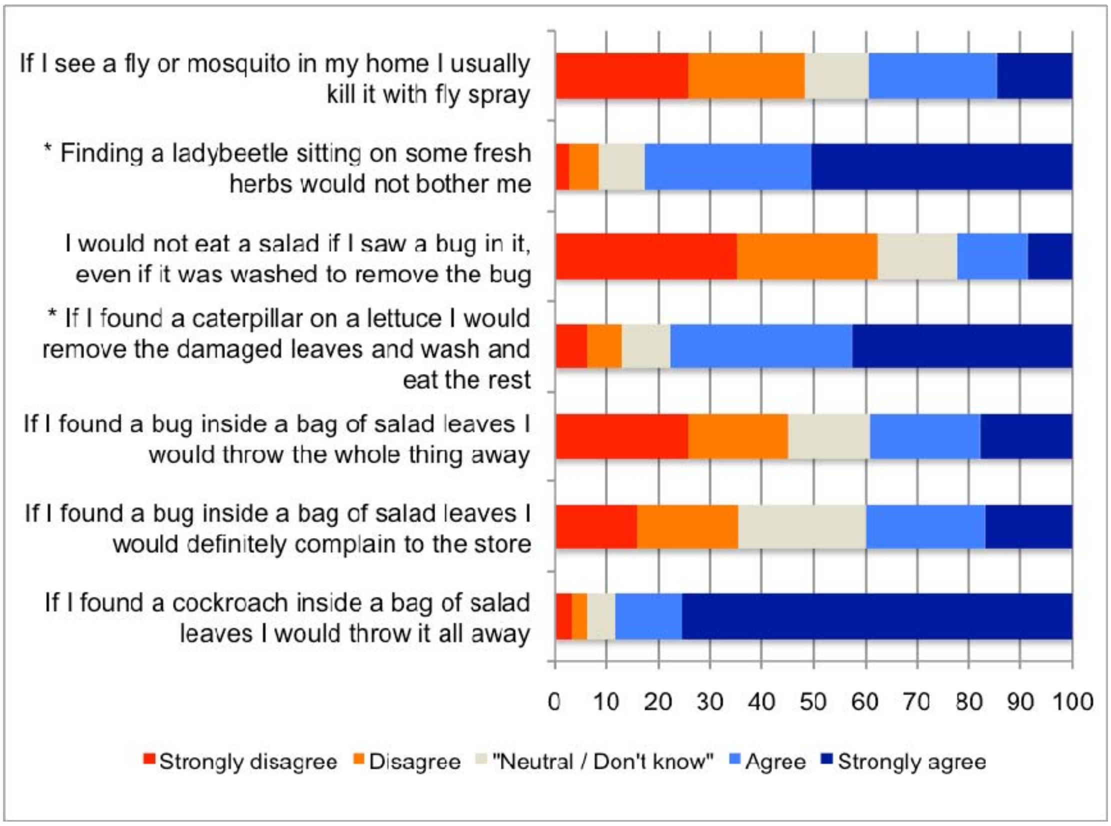


Figure 15-4 Percentage of respondents agreeing, disagreeing or remaining neutral on statements describing reactions to insect contamination of fresh vegetables.
* marks questions where the answer was reversed when calculating the IIS.

Calculating the IIS

Insect Intolerance Scores (IIS) were calculated by combining each respondent's scores for the 7 insect contamination related questions. A high IIS indicated respondents were very intolerant of insects with 49 people scoring >3, while 150 scored less than 1 (very tolerant of insects). The scores were approximately normally distributed wth a slight bias towards tolerance (<2), (Figure 14-5). Scores ranged from 0 to 4 with a mean of 1.77 and standard error of 0.02.

The IIS was the same for respondents in regional areas as in cities and did not vary significantly between states. It was also independent of living arrangement, education, household income and vegetarianism. However, the IIS values did indicate that men were less tolerant of insects than women (male IIS = 2.0; female IIS = 1.7; p<0.001) and that respondents aged <35 were less tolerant compared to those who were older (<35 IIS = 1.9; 35+ IIS = 1.6; p<0.001). Mean IIS values for each group are shown below (letters indicate values that are significantly different; p<0.001).

	Men	Women
< 35 years	2.2 a	1.8 b
> 35 years	1.8 b	1.6 c

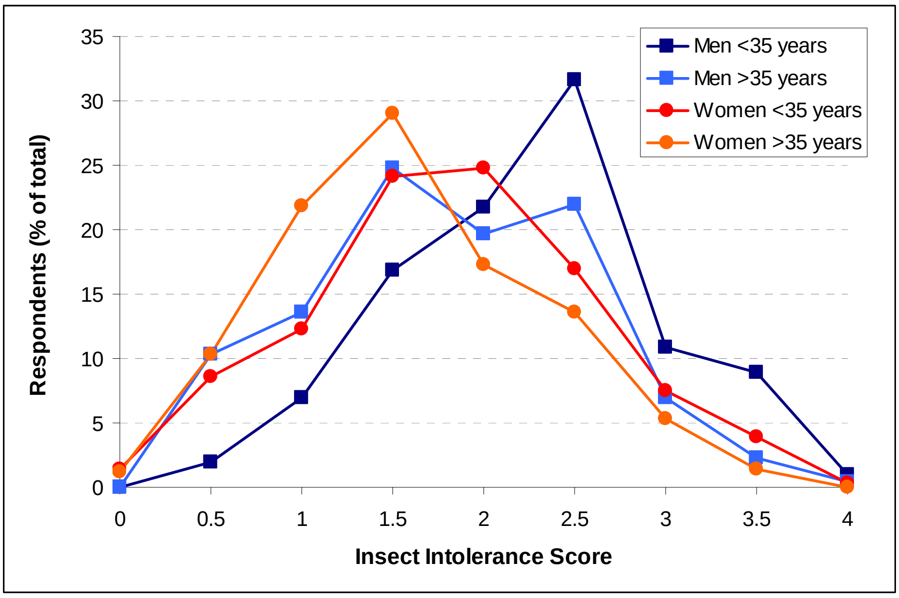


Figure 15-5 Distribution of Insect Intolerance scores among survey respondents, divided by age and gender. High II scores indicate intolerance of insects.

There was a very slight negative correlation (r=-0.14, P<0.001) between the IIS and the importance given to "no insects" when purchasing fresh fruit and vegetables (Figure 14-6). This confirms, to some extent, that survey respondents were consistent in their responses on this issue.

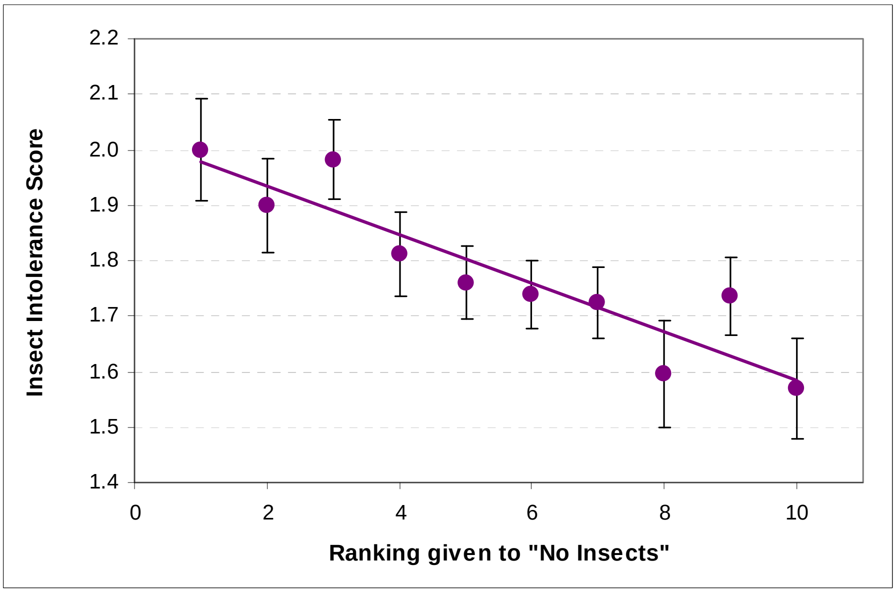


Figure 15-6 Mean insect intolerance scores (IIS) plotted against the importance allocated to "no insects" when choosing fruit and vegetables. People who had high IIS's commonly tended to rank "no insects" as more important than did those with lower IIS values.
Bars indicate the standard error of each mean value.

Key Results

- ⇨ Respondents had more definite opinions about insects in food than about environmental issues.
- ⇨ Most respondents (73%) said they would tolerate finding a ladybeetle on herbs and would still eat a lettuce even if they found a caterpillar on it (78%).
- ⇨ Fewer would eat a salad which had had a bug on it (62%), and this figure fell further the bug was found in a pre-prepared salad mix (46%).
- ⇨ Many respondents (40%) said they would complain to the store if they found a bug in a packet of salad.
- ⇨ Although many respondents were relatively tolerant of a "bug", most (88%) were strongly repulsed by a cockroach – perceived as not a "natural" contaminant from the farm.
- ⇨ An IIS (insect intolerance score) was calculated for each participant from their combined scores. IIS values were higher for men than women and for respondents <35 years compared to older consumers, indicating that these groups were less likely to tolerate finding insects on fresh vegetables.

How easily disgusted were the survey respondents?

As previously noted, there appeared to be a tendency for respondents to agree with statements rather than disagree (Figure 14-7). There were also quite high numbers of neutral answers. For example, 27% of repondents were neutral regarding whether they would still go to their favorite restaurant if the chef had a cold. The exception was the first question regarding eating monkey meat – only 5% were neutral on this issue, although an additional 3% didn't know.

The limited space available had permitted inclusion of only 6 questions from the DS-R scale instead of the full 25, making it potentially less sensitive to individual differences between respondents. This may be why the test resulted in relatively high mean core disgust score of 2.6 (Table 14-4), where someone extremely easily disgusted would score 4 and someone insensitive to disgust would score 0. A website offering the DS-R quiz online notes a mean core disgust score of 1.9 from over 47,000 visitors (www.yourmorals.org), although this may also represent a biased sample relative to the general population.

Disgust sensitivity and insects

It had been expected that core disgust sensitivity would correlate closely with the responses to insects in food, given that both sets of questions were assessing fear of contamination of the body. Although the correlation between these factors was significant ($p<0.001$), it was rather poor, particularly for the middle values. Disgust sensitivity scores were significantly higher for those who strongly agreed with the insect intolerance questions and significantly lower for those who strongly disagreed with them ($p<0.001$, Table 14-4). Disgust sensitivity had much less of a relationship with answers between those extremes. Disgust sensitivity was also a poorer indicator of response when the questions were asked the other way i.e. "strongly agree" indicated a high level of tolerance for insects.

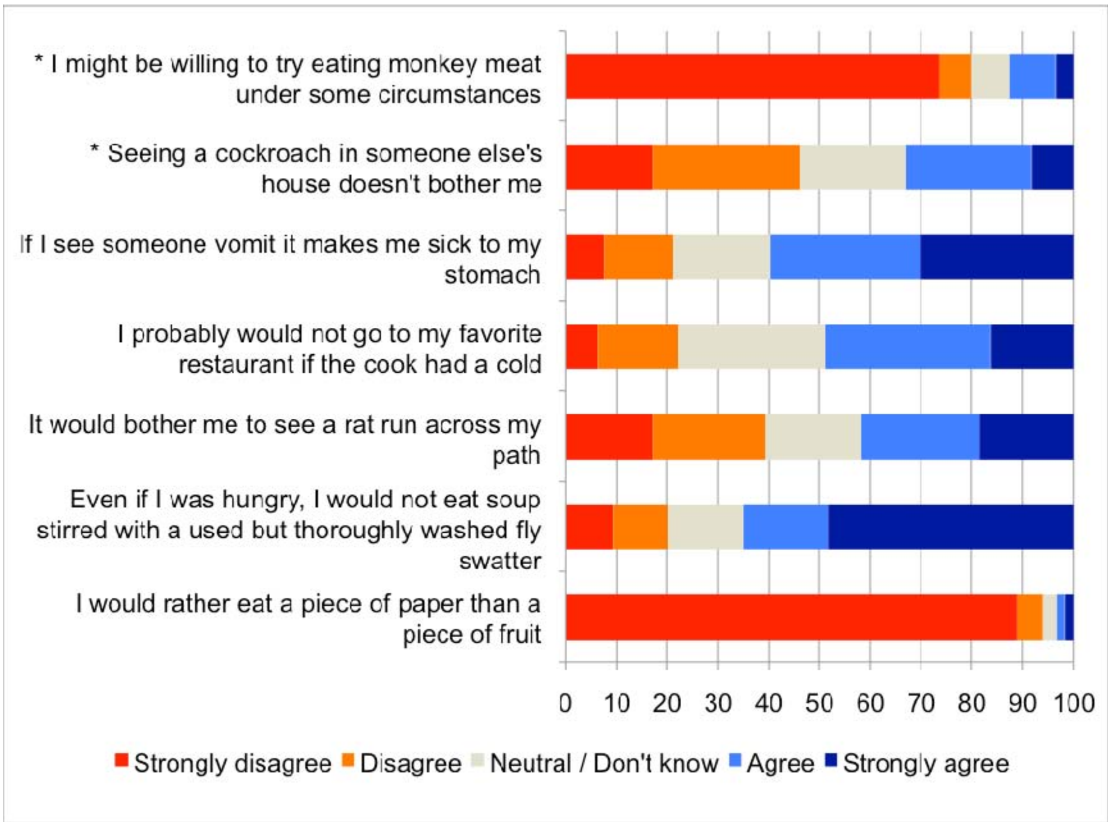


Figure 15-7 Percentage of respondents agreeing, disagreeing or remaining neutral on statements evaluating sensitivity to disgust.

* marks questions where the answer was reversed when calculating sensitivity to core disgust.

Table 15-4 Mean core disgust sensitivity scores divided by responses to questions about tolerance for insects in food.

	Core disgust sensitivity scores					
	Q4_10 *I would not eat salad if I had seen a bug in it*		Q4_12 *If I found a bug inside a packet of salad I would throw it away*		Q4_13 *If I found a bag in a bag of salad I would complain to the store*	
V. agree	2.9	c	2.8	c	2.8	c
Agree	2.8	c	2.6	b	2.6	b
Neutral	2.6	b	2.6	b	2.6	b
Disagree	2.6	b	2.6	b	2.5	b
V. disagree	2.4	a	2.3	a	2.3	a

Letters indicate mean values which are significantly different within each column.

Variability in senstivity to disgust

As with the other scales, there may be a natural inclination to agree with statements, distorting the result. This could easily be tested in the future by reversing the statements for half of the survey respondents. Disgust sensitivity followed an approximately normal distribution, with a tendency to higher scores ie greater sensitivity. For example, only 18% of respondents scored <2, whereas 31% scored >3.

While women were significantly more easily disgusted than men (p<0.001), sensitivity to disgust did not vary significantly by any of the other demographic dividers used (age, location, income etc.).

Key Results

- ⇨ Disgust sensitivity scores of respondents were approximately normally distributed with a tendency to higher values.
- ⇨ Sensitivity to disgust was somewhat correlated with IIS values, but the relationship was not as strong as expected.
- ⇨ Disgust sensitivity could predict responses to insect intolerance questions only when the respondent had strong views; more moderate opinions were not reflected in disgust sensitivity scores.
- ⇨ While female respondents were slightly more easily disgusted than males, disgust sensitivity did not vary among other demographic dividers (age, location etc.).

What's special about people who like gardening?

One of the hypotheses in this study was that people who had experience with growing vegetables would be more interested in the idea of IPM. It was thought that their own experiences trying to control insects could have increased their understanding of the issue and interest in improving sustainability. Question 1 in the survey therefore asked respondents which statement best described themselves and had the following results:

		% responses
A.	*I am a keen gardener and grow as many vegetables as I can*	7.6
B.	*I occasionally grow a few vegetables for my own use*	38.2
C.	*Although not growing any now, I have grown vegetables in the past*	35.7
D.	*I can't OR I'm not interested in growing vegetables*	18.5

A series of analyses were conducted to determine how peoples experience with or interest in gardening affected their attitudes to food, insects and IPM.

Demographics of the gardener

Interest – or disinterest – in gardening was very evenly spread across most demographic dividers. There was no difference between respondents in regional areas compared to cities or between states and no significant effect of education, occupation or income. Interest was also spread very evenly across all age brackets, with the exception of <25 year olds; 24% of this age group said they had no interest in growing vegetables (response D) compared to 17% of respondents aged 35+. Despite this, the number of keen gardeners (response A) among this group was similar to that of other age groups. Gardening interest also tended to be lower among singles, particularly those with children, but higher for couples with children at home.

What is important to gardeners when buying vegetables?

When buying fresh fruit and vegetables, respondents who identified as keen gardeners had different priorities to those respondents who couldn't or didn't want to grow vegetables (non-gardeners, response D). Both keen and occasional gardeners (responses A and B) ranked "In season" and "Locally grown" as significantly higher priorities than did non-gardeners (Table 14-5). Keen gardeners also ranked "no rots or bruises" slightly lower. Perhaps surprisingly, however, gardening did not significantly affect the rankings given to "clean/dirt free" or "no insects", or any of the other suggested factors.

Table 15-5 Differences between respondents' interest in growing vegetables and herbs on what they consider important when purchasing fruit and vegetables (ranked 1-10); the larger the number, the less important the factor.

Interest in growing vegetables and herbs	Importance when purchasing fruit and vegetables									
	Clean, dirt free		*In season*		*Locally grown*		*No rots or bruises*		*No insects*	
Keen	6.9	b	5.8	a	5.5	a	5.4	b	6.3	b
Occasionally do	6.8	b	6.4	b	6.3	b	4.7	a	5.8	b
Previously have	6.5	b	6.8	b	6.7	b	4.7	a	5.9	b
No interest / can't	6.0	a	7.1	c	7.1	c	4.3	a	5.6	a

Different letters indicate gardening interest levels that were significantly different on the logit scale in each column (p<0.05).

Gardeners and insects

Despite ranking "no insects" as of similar importance to non-gardeners, both keen and occasional gardeners who were surveyed were significantly more tolerant of insects in general (i.e. had lower IIS) then non-gardeners (p<0.001). They were not, however, less sensitive to disgust than other survey respondents, perhaps confirming the tenuous connection between disgust as a general emotion and specific attitudes to insects on food.

The effect of gardening on IIS values was strongest in those respondents who had no experience in growing their own vegetables and herbs. Respondents who were non gardeners (response D) were more likely to be bothered by finding a ladybeetle on fresh herbs (p=0.004), less likely to eat a lettuce after removing leaves damaged by a caterpillar (p=0.003) and more likely to throw away a bag of salad which had had a bug in it (p=0.001) compared to respondents who were keen or occasional gardeners. Respondents who had previously grown vegetables tended to give intermediate responses.

These results are not unexpected. People who have grown vegetables and herbs will inevitably have had to deal with insects, whether in controlling them before harvest, picking them off afterwards or, most likely, both. Having invested time and effort in growing a lettuce, it would be surprising if they then threw it away because of a bug or grub. Interacting with the natural world may therefore be one of the best ways to increase tolerance to insects in fresh fruit and vegetables.

Gardeners and the environment

Keen gardener respondents did not have stronger opinions about whether or not fruit and vegetables are grown in an environmentally friendly way (p=0.228), or whether farmers are irresponsible with pesticides (p=0.9). However, they were slightly less convinced than non-gardeners about whether most fruit and vegetables grown in Australia are safe to eat (p=0.01).

Again, however, it was the non-gardener respondents who stood out most from other groups. The EAS values of this group were significantly lower (p<0.001) than those who had at any time tried growing their own vegetables. They were also less likely to strongly agree that "*protecting the environment is very important to me*" (p=0.011).

Unsurprisingly, the non-gardener respondents were also significantly less interested in IPM as a concept or in purchasing IPM grown products (p<0.001). They were more likely to buy the cheapest product available and significantly less likely to be willing to pay extra for an IPM labelled product (p<0.001). Again, it is interesting that any previous experience growing vegetables or herbs increased interest in IPM (Table 14-6).

Table 15-6 Differences between surveyed gardeners and non-gardeners in their attitudes to insect contamination and interest in IPM. Statements / scores have been reversed where appropriate so that a high score (5) indicates strong agreement with the statement while a low score (1) indicates disagreement.

	Agreement score							
Interest in growing vegetables & herbs	*Would eat a salad even if it had had a bug in it*		*Would eat lettuce chewed by a caterpillar*		*Interested in IPM?*		*Pay more for IPM?*	
Keen	3.8	b	4.2	c	3.2	c	2.2	b
Occasionally do	3.8	b	4.2	c	3.1	c	2.4	b
Previously have	3.6	ab	3.9	b	3.0	b	2.3	b
No interest / can't	3.4	a	3.8	a	2.7	a	2.0	a

Different letters indicate mean values that are significantly different on the logit scale within each column ($p<0.05$)

Gardeners and lettuce

There was no difference between respondents who were gardeners and non-gardeners in terms of likelihood of washing lettuce or mixed salad before use, and little difference in lettuce purchasing frequency. While iceberg was the most frequently purchased lettuce variety overall, keen gardener respondents were more likely to most often purchase cos or loose leaf lettuces, while non-gardener respondents favoured pre-prepared lettuce mixes (Table 14-7).

Table 15-7 Lettuce choice of keen gardeners (response a) compared to the choices of those not interested in gardening (response d).

	% of responses	
Lettuce type purchased most often	Keen gardener	Non gardener
Iceberg	46%	58%
Cos	24%	10%
Loose leaf / hydroponic	20%	10%
Lettuce mix	10%	22%

Key Results

- ⇨ Families were more likely to be interested in growing vegetables and herbs than single respondents. Respondents aged <25 were more likely to be non gardeners than those aged 35+. Interest was otherwise widely distributed across all other demographic dividers.
- ⇨ Respondents who were keen gardeners or occasionally grew vegetables and herbs considered "locally grown" and "in season" more important than respondents who were non-gardeners.
- ⇨ Although keen gardener respondents did not rank "insect free" as less important than other respondents, they were generally more tolerant of insects (lower IIS)
- ⇨ Any experience growing vegetables increased tolerance of insects; many non-gardener respondents would not put up with insects on lettuce or salad.
- ⇨ Respondents who were non gardeners were less interested in environmental issues and unlikely to be purchase IPM grown products (especially if they cost more) compared to those with any experience of growing their own vegetables.
- ⇨ While iceberg was the favourite lettuce overall, keen gardener respondents were more likely to purchase cos or loose leaf types, while non gardeners respondents favoured lettuce mixes.

What's special about people who are interested in organics?

It seemed possible that current purchasers of organic foods could be a key market for IPM grown products. It was hypothesised that organic purchasers would be concerned about use of chemicals on fresh fruit and vegetables and interested in issues relating to sustainability, both of which factors could translate into sales for an IPM branded product range. According to the 2010 Australian Organic Market Report (AOMR), 61% of consumers who purchase organics spend 10% or less of their total food budget on these items. Price is the biggest barrier to increased purchases of organic products, although product quality and convenience are also issues. IPM branded products could potentially appeal to these consumers.

Respondents were therefore asked about their purchases of organic products, the results of which are summarised below:

"I choose organic products...

	% responses
Always / often	6.1
Occasionally	44.0
Rarely	38.6
Never / don't know	11.3

The AOMR found that 61% of households had purchased at least one organic product in the last 12 months. As the current survey did not specify exactly what was meant by "occasionally" or "rarely" it is difficult to compare the data. However, our figure of 50.1% purchasing organics "always" to "occasionally" appears a consistent result.

Demographics of the organic purchaser

There is a common perception that purchasers of organics are most likely to be high income city residents. However, the organic industry has long claimed that its products are not "*just for rich people*". Supporting this, a recent survey by Freshlogic asked whether respondents agreed with the statement *"I try to buy organics where I can"*. There was no difference between singles on high or low incomes (39-40% agreed with the statement respectively) or between established and budgeting families (29-31% respectively).

This survey would also appear to confirm this view. There was no relationship between income and interest in purchasing organic products for the surveyed group. Respondents' education level had minimal effect, as did whether the participant lived in a city or a regional area. Interest in organics was slightly lower in respondents from Queensland and higher in Tasmania than might be expected by chance, but otherwise there were no differences in respondents based on location.

There were, however, major differences between respondents with different living arrangements. Perhaps surprisingly, given likely budget constraints, single parent respondents with children were significantly more likely to be keen or occasional purchasers of organics and less likely to be rare or never purchasers than expected on average (Figure 14-8). Conversely, respondent couples with children were less likely to always or occasionally choose organic products. This result, being the opposite of what is instinctively expected, is worth further examination.

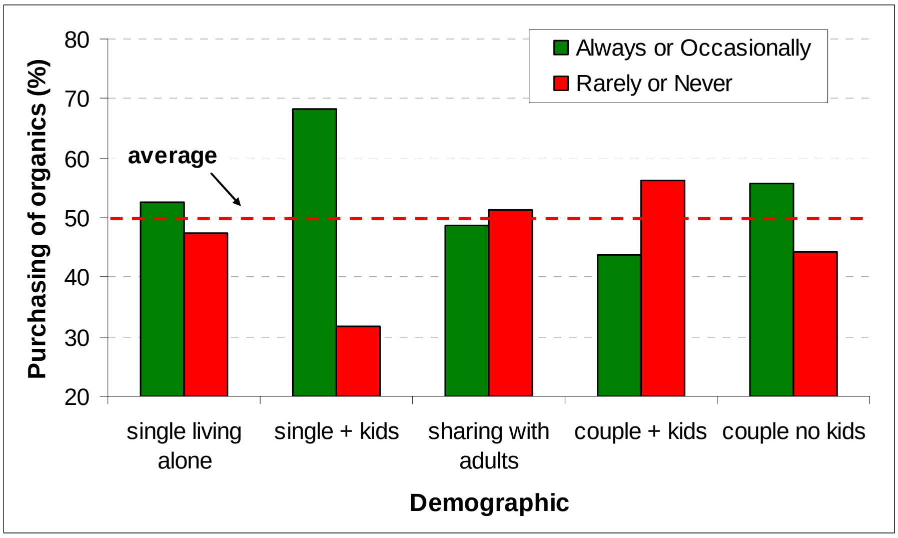


Figure 15-8 Percentages of respondents from different demographics who choose organic products always / occasionally or rarely / never (original 4 categories have been simplified into 2 for ease of presentation). Line indicates overall mean value for each response type.

The results also suggest that for the surveyed group a significant portion of the market for organic products is among younger consumers. More than half (54%) of those who stated they "always or often" purchased organics were aged <35 (Figure 14-9). In contrast, the Freshlogic survey found that the group most interested in organics were the "Empty nesters" aged over 60. Again, this warrants further investigation, particularly as the factors that motivate a younger person to purchase organic products may be different to what motivates an older person.

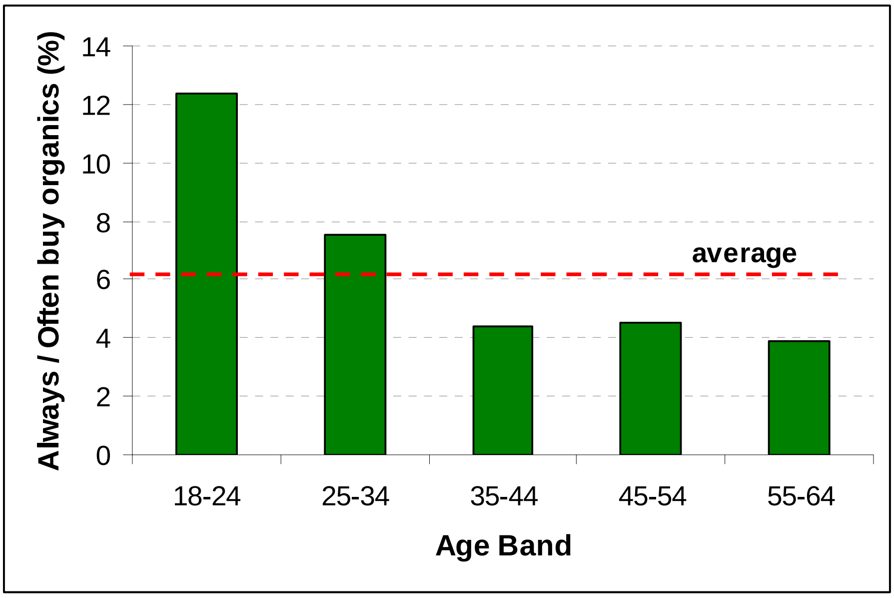


Figure 15-9 Percentage of respondents who choose organic products always / often, divided by age bracket. Line indicates overall mean value.

Those respondents who purchased organics were also more likely to be vegetarian / mostly vegetarian or vegan; 74% of this group purchased organics always / often or occasionally, compared to 48% of non vegetarian respondents.

What is important to organic purchasers when buying vegetables?

Respondents who were keen purchasers of organics also differed from others in how they ranked the factors which are important when buying fruit and vegetables. Respondents who always or often purchased organics ranked "Locally grown" and "Pesticide free" higher and "Dirt free" lower than respondents who purchased these products rarely or never. Interestingly, perhaps, there was no difference in the importance given to “No insects” or “In season” despite both issues also being potentially linked with sustainability, commonly thought to be a driver for purchases of organics.

However, on closer examination it becomes clear that younger and older surveyed consumers consider different things important (Table 14-8). For those aged <35, differences between those who say they often choose organic products and those who never choose these products are relatively small – only the ranking given to “pesticide free” is obviously different. In contrast, among respondents aged 35+, there are distinct differences between organics purchasers and others. For example, respondents who often bought organic products considered “dirt free” unimportant and “locally grown” important compared to those who never bought organic products. There was also a trend to “insect free” being ranked lower by respondents who were keen purchasers of organics, although differences were still not significant.

Table 15-8 Differences between organics purchaser respondents and others, aged <35 or 35+ in terms of what they consider important when purchasing fruit and vegetables (ranked 1-10); the larger the number, the less important the factor.

a)

“I choose organic products….”	Importance of factor when buying fruit and vegetables				
	Clean / Dirt free	In Season	Locally Grown	No Insects	Pesticide Free
Under 35 year olds					
Always / Often	6.2 a	6.6 a	6.2 a	5.2 a	5.1 a
Occasionally	5.9 a	6.8 a	6.9 a	5.2 a	6.3 b
Rarely	6.2 a	7.2 a	7.1 ab	5.2 a	6.8 b
Never / don’t know	5.4 a	7.1 a	7.9 b	4.9 a	7.6 c
35 years and over					
Always / Often	8.3 c	5.4 a	4.2 a	7.0 a	4.8 a
Occasionally	7.2 bc	6.4 a	6.1 b	6.4 a	6.0 b
Rarely	6.5 a	6.5 a	6.5 bc	6.2 a	7.2 c
Never / don’t know	6.7 ab	6.4 a	6.9 c	6.0 a	6.8 bc

Different letters indicate organics purchasing frequency on the logit scale that is significantly different within each age group and column ($p<0.05$).

Organics purchasers and insects

Similarly to respondents’ purchase priorities, interest in organics only appeared to relate to other attitudes in respondents aged 35+. Under 35 year old respondents who always / often bought organics effectively answered all of the questions about insects the same way as others in their age group. They were just as likely to use fly spray to kill a mosquito in the home or be bothered by finding a ladybeetle on fresh herbs as those who never bought these products.

In contrast, there were large differences among those respondents aged 35+. For example, those respondents who always or even occasionally purchased organics were less likely to use fly spray in the home, more likely to eat salad which had had a bug in it and more likely to use a lettuce previously nibbled by a caterpillar compared to those who rarely or never purchased organic products.

As a result, IIS values for those respondents aged <35 were effectively the same regardless of interest or otherwise in organics. However, among older survey respondents there was a strong effect. Those who were interested in organics were relatively tolerant of insects in food, whereas those who never purchased organics were just as intolerant as the <35 year olds in the sample (Figure 14-10).

Respondents in the 35+ age group appeared to understand that there is a trade-off between freedom from insects and freedom from pesticides whilst <35's expected organic products to meet the same high standards as conventionally grown fruit and vegetables.

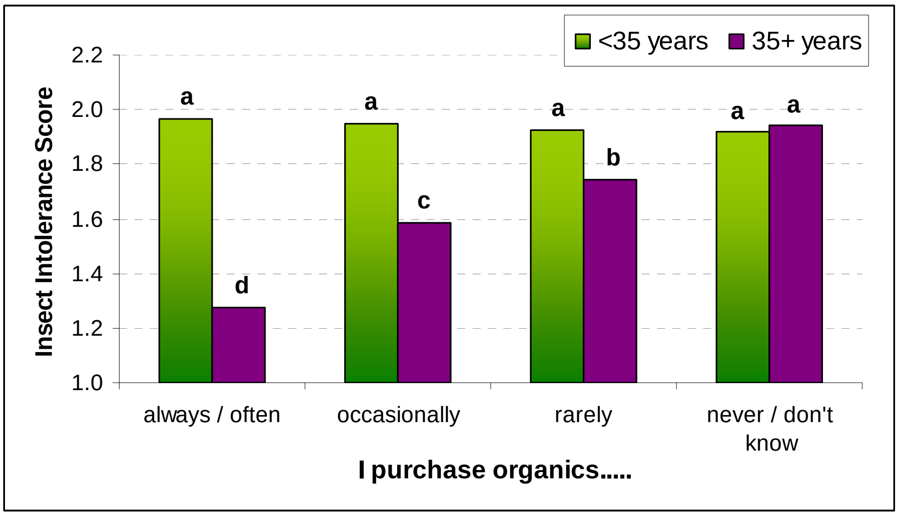


Figure 15-10 Insect intolerance scores (IIS) of respondents aged <35 and 35+, identified by whether they purchase organic products always / often, occasionally, rarely or never.
Letters indicate mean values that are significantly different by age group ($p<0.05$).

Organics purchasers and the environment

Interest in organics appeared to relate closely to some attitudes to environmental issues, regardless of age group of respondents. People surveyed who always or often purchased organics were more likely to agree that the Australian environment had suffered since European settlement, that supermarkets should favour environmentally friendly suppliers, and that protecting the environment was important. They was also a strong correlation between respondents' interest in organics and agreement that Australian fruit and vegetables are safe to eat. Despite this, organics purchasers surveyed were not significantly more likely to agree that fruit and vegetables are not grown in an environmentally friendly way or that farmers are not responsible with pesticides.

As a result, there were significant differences in respondents' EAS values across all age groups, although the effect was slightly stronger among those 35+ who always / often purchased organics. (Figure 14-11). This suggests that concern about environmental issues is an important driver for purchase of organic products.

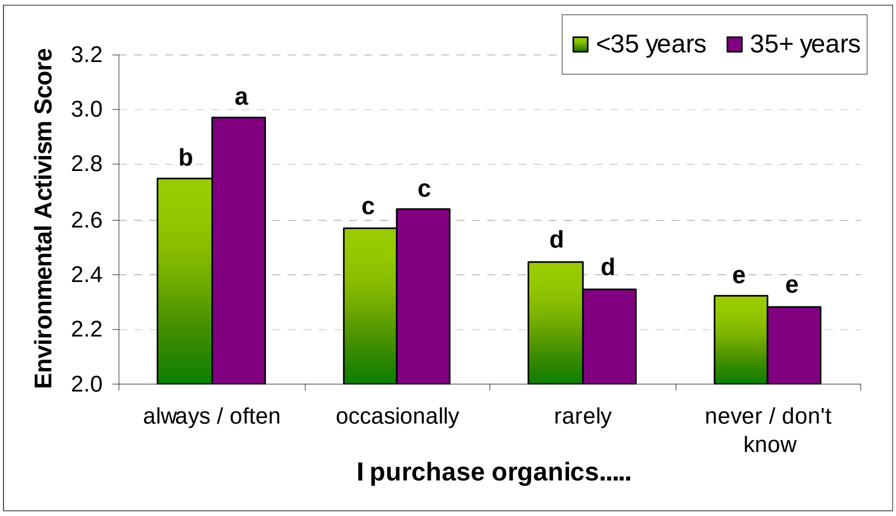


Figure 15-11 Environmental Activism Scores (EAS) of respondents aged <35 and 35+, classified by whether they purchase organic products always / often, occasionally, rarely or never.

Letters indicate mean values that are significantly different by age group ($p<0.05$).

As hypothesized, many of the organics purchasers surveyed were positive regarding IPM, although some felt that IPM did not go far enough. Those respondents who always or occasionally purchased organics were significantly more interested in buying IPM grown products than those who never bought organics ($p<0.001$). There was also a significant positive relationship between respondents' willingness to pay extra for IPM grown products and purchase of organics ($p<0.001$). This will be discussed further in the following section.

Organic purchasers and lettuce

The main differences in lettuce purchasing were among those respondents who declared that they never purchased organic products. This group bought salad mix and lettuce less often than other survey respondents. If they did purchase lettuce, it was most likely to be an iceberg type (61%) and unlikely to be a cos or loose leaf lettuce (10% and 8% respectively). While those respondents who always purchased organics were also most likely to buy an iceberg lettuce (42%), they were more likely to choose alternatives such as loose leaf (23%) or a pre-made salad mix (18%) than those who never purchased organic products.

The conflicting requirements of organics purchasers

People may be interested in purchasing organics for many different reasons. When focus group consumers were asked what they thought organics meant, they invariably answered "not sprayed", "no chemicals" or similar. It might therefore be assumed that most people purchase organics because they don't want to eat products treated with artificial pesticides. This is supported by the data in the AOMR, which reported that "chemical free" and "additive free" were the top perceived benefits of purchasing organic products. "Environmentally friendly", "more nutritious" and "better taste" also rated highly. The results from this study would appear to confirm that there is a strong positive association between organic production and environmental sustainability.

From a grower's point of view, there are inevitable trade-offs in growing fruit and vegetables without chemical pesticides or fertilisers. Products may be delivered to market with minor insect damage, or even with insects still attached. Achieving zero insects is likely to be difficult or impossible within an organic system, especially if the product is sold without washing. This may explain why 76% of the surveyed group who always or often purchased organics said they had recently (in the last 6 months) found insects on fresh vegetables, compared to 43% of those who never purchased organic products.

Purchasers of organics in the surveyed group who are aged 35+ appear to recognize the limitations inherent in growing vegetables without chemicals and, to some extent, accept them. They understand that produce may still have dirt attached, or have insects on it. To them, this is less important than the product being free of pesticides and produced in an environmentally friendly way. If they find a bug they will most likely just wash it off and eat the product anyway. In this, they conform to expectations about the typical purchaser of organic products.

What is less clear is why so many of the respondents aged <35 always/often or occasionally buy organic products. Concern for the environment may be an important factor, although even in this their views are not as strong as those of older survey respondents. Unlike those 35+, they expect organic products to be clean and insect free as well as pesticide free. To growers this may seem a contradiction; certainly it suggests a lack of understanding about how food is grown.

Organics has had much media attention in recent times, including frequent mentions on popular cooking shows. It would be interesting to repeat this work in several years time to assess whether the current strong interest in organics by younger consumers is sustained.

Key Results

Most demographic dividers (income, education, location etc.) did not affect respondents' interest in purchasing organic products. However, organics purchasing was more frequent among respondents who were single with children, those with mostly vegetarian to vegan diets and to some extent among those aged <35.

Although overall interest in organics was not significantly affected by age, there were major differences between respondents aged <35 and 35+ in terms of other attitudes associated with organics purchasing:

- ⇨ Tolerance of insects on vegetables was similarly low in all respondents aged <35, regardless of their interest in organics.
- ⇨ There was a strong, positive association between insect tolerance and interest in organics among those respondents 35+.
- ⇨ There was a positive association between interest in environmental issues and purchase of organics for all age groups, although this effect was slightly stronger in the 35+ age groups.
- ⇨ For those respondents aged 35+, frequent purchase of organics could indicate attitudes about wider issues relating to food. For those aged <35 such associations were less clear.
- ⇨ Respondents who were purchasers of organics (especially occasional purchasers) had strong interest in IPM and were more willing to pay a premium for IPM grown products than those who never purchased organics.

Who cares about IPM?

Ecobananas – an IPM product

Having collected information about the interests, priorities and likes / dislikes of the survey respondents, the topic of IPM was introduced. In the first of these questions, respondents were shown a picture of red tipped bananas. These were chosen as they are a product grown using IPM methods and differentiated in the marketplace as an "eco" label. They are also commonly available in supermarkets and independent retailers.

Respondents were asked the following questions with results shown.
"*These bananas are different because…*"

	% responses
They have been treated to make them ripen more slowly	5.7
They have been treated to prevent disease	3.7
They are a sweeter variety	13.7
They are grown with care for the environment	5.2
They are organic	35.7
Don't know / never seen before	36.0

These responses were chosen from discussions with the grower and the reaction to these fruit during the earlier focus groups. All are based on earlier statements by consumers.

It was previously stated that an error rate of at least 3% needs to be assumed for each question. As the most correct answer was "d: *they are grown with care for the environment*" this suggests that as little as 2% of respondents recognised these bananas as an eco-labeled product. Some might also consider "c: *they are a sweeter variety*" correct, as these bananas have been marketed as having better flavour than conventionally grown bananas. Although they are not organic (some chemical fertilizers and other non-organic inputs are used), the fruit is described as "ecoganic" by the grower group that produces them.

The main conclusion from these results is that the messages about how these fruit are grown (i.e. reduced chemicals, environmentally sustainable, reef friendly etc) are not reaching consumers. Although clearly differentiated from other bananas by their red tips, most consumers really have no idea why this is.

Attitudes to IPM

Following this question, the survey included a short explanation of IPM:
"*Vegetable farmers often have to use pesticides on their crops at some stage during growing to control pests and diseases. In contrast, organic farmers don't use any synthetic chemical fertilisers or pesticides. Between these two is a third option known as "integrated pest management" (IPM).*

Farmers who grow with IPM use predatory insects and cultural methods to control pests. At times they also use pesticides, but wherever possible these are "soft" pesticides that specifically target the pest and minimise impact on the environment. The result is that IPM grown vegetables may have less pesticides but more insects (such as ladybeetles) on them compared to conventional vegetables."

The respondents were then questioned regarding this statement (results shown).

Which of these statements best reflects your feelings about growing vegetables with IPM?

	% responses
It doesn't go far enough as farmers can still use pesticides	7.0
It sounds like an improvement on the way farmers currently grow vegetables	69.8
I am happy with the way farmers normally grow vegetables, there's no need to change	14.6
I don't want more insects on the vegetables I buy	8.7

Would you be interested in purchasing vegetables grown using IPM?

	% responses
Very interested	22.7
Possibly interested	55.1
Neither interested nor not interested	20.5
Definitely not interested / turned off	1.7

Given a choice between vegetables grown normally or a similar quality product grown using IPM I would…

	% responses
Buy the cheapest one	29.2
Buy the normal vegetables because that's what I usually buy	19.9
Buy the IPM vegetables so long as the price wasn't >10% above that of the normal product	47.9
Buy the IPM vegetables even if they cost 20 – 30% more than the normal product	3.0

These results appear very promising in terms of marketing an IPM grown product, with around 70% of respondents positively engaged and interested and around half even willing to pay a small premium for an IPM grown product.

Demographics of interest in IPM

Age significantly influenced whether a person was likely to be interested in IPM (Figure 14-12). Respondents aged <35 were significantly less likely to be interested in IPM products than older respondents (p<0.001). Women were slightly more willing to pay extra for IPM grown products than men, while other demographic differences were not significant.

Survey respondents who did not grow any of their own vegetables or herbs were significantly less likely to be interested in IPM, even compared to ex-gardeners ($p<0.001$). Interest in gardening and IPM were positively correlated ($p<0.001$).

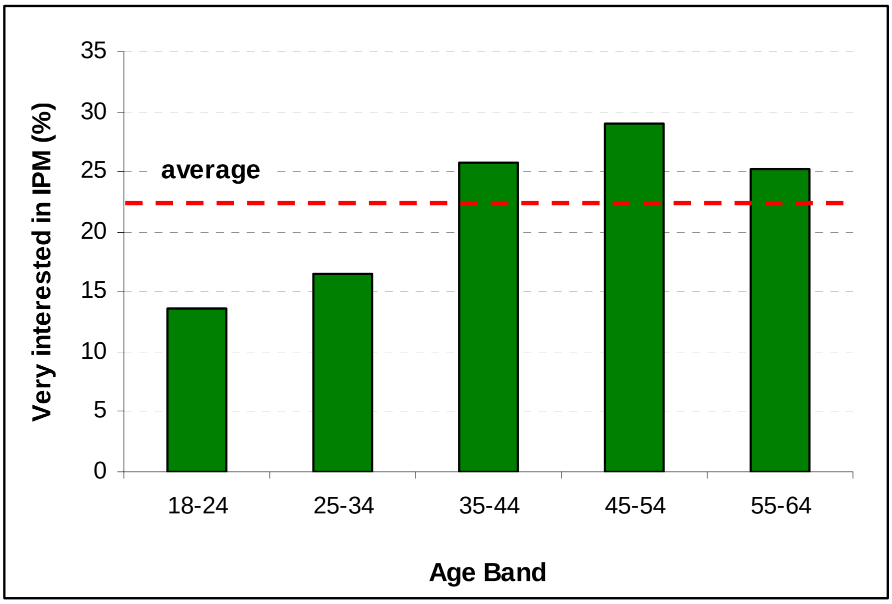


Figure 15-12 Percentage of respondents from each age group who were very interested in purchasing IPM grown products. Line indicates mean of all respondents

The link between IPM and organics

There was a strong positive association between purchasing organics and interest in IPM, with those respondents who never purchased organic products also significantly less likely to be interested in IPM ($p<0.001$). For example, only 55% of respondents who never purchased organic products were interested in IPM, compared to 80% of those who said they always or often purchased organic products (Figure 14-13).

Despite this, interest in purchasing IPM grown products was certainly not confined to those who were already purchasing organics, with many of the surveyed group who had no interest in organics still professing some interest in an IPM label. Moreover, 26% of those respondents who always / often purchased organic products felt that IPM did not go far enough, with the result that 19% of this group were not interested in purchasing IPM products, compared to 12% of those who occasionally purchased organics (Figure 14-13).

However, once the issue of cost was introduced, larger differences were observed. Those respondents who always or occasionally purchased organic products were much less cost sensitive than those who rarely or never purchased these products (Figure 14-14). Most of those who said they never purchased organic products would simply buy the cheapest vegetable available despite any stated interest in IPM.

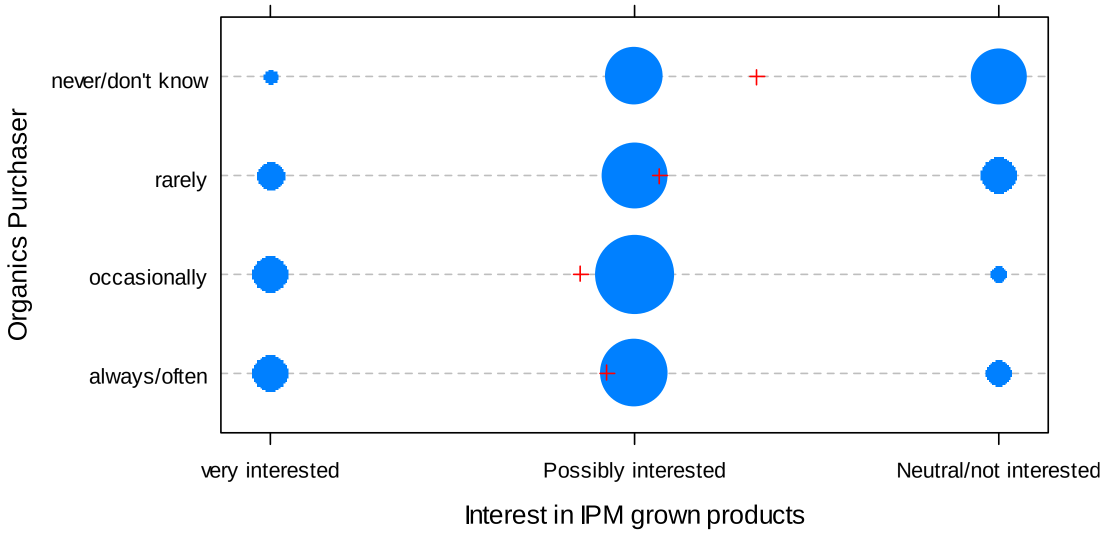
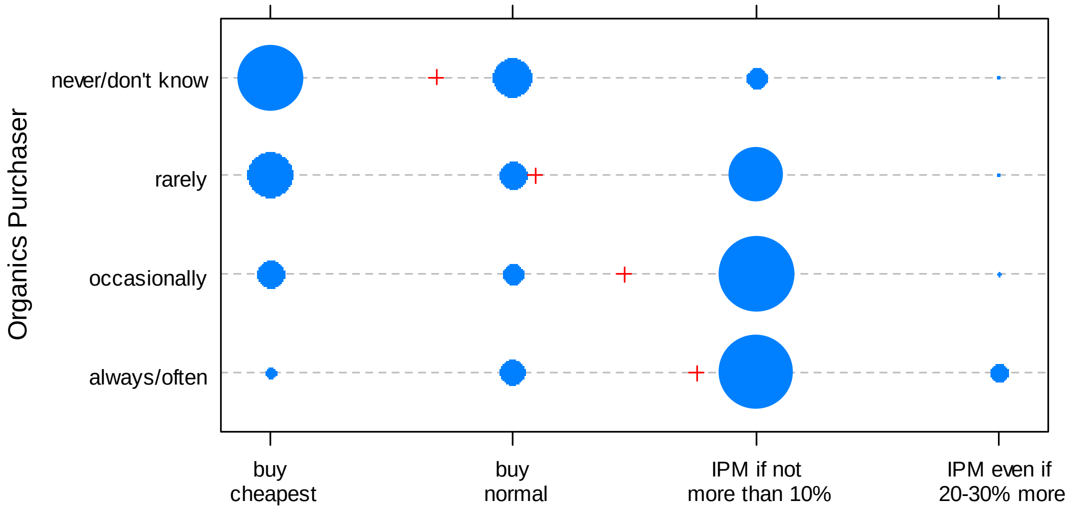


Figure 15-13 Interest in purchasing IPM grown vegetables, classified by respondents previously stated purchases of organic products (always/often, occasionally, rarely, never/don't know).
The size of the bubble indicates the number of responses.



"If choosing between IPM grown and regular vegetables I would…."

Figure 15-14 Differences between often, occasional, rare and non-purchasers of organic products when asked under what conditions respondents would choose an IPM grown product.
The size of the bubble indicates the number of responses.

IPM and insects

It was previously noted that the IIS was a good predictor of interest in organics in respondents 35+ but did not vary among those <35. In this case, the IIS was closely related to both interest in IPM and price tolerance for all respondents. Respondents with high II scores were significantly more likely to not want more insects on vegetables, have no interest in IPM and continue to buy the products they normally would if presented with an IPM grown option, compared to those with lower IIS's. Conversely, a low IIS was associated with strong interest in IPM and willingness to pay extra, even if the IPM grown product was 20-30% more expensive.

At the beginning of this section of questions it was explained that use of IPM could potentially increase insect contamination. This may explain the observed close relationship between insect tolerance and IPM acceptance. On the other hand, it seems possible that some respondents did not make such a connection with organically grown fruit and vegetables.

This result suggests that an IPM grown product is likely to appeal to those who are tolerant of finding a bug in fresh products. This would mean that insect contamination is a non-issue for an appropriately labeled IPM grown product.

Sensitivity to disgust had no relationship to respondents' interest in IPM.

IPM and the environment

It was expected that people who were concerned about environmental issues would be more likely to be also interested in IPM. This proved correct, with those respondents who thought IPM was an improvement over current practices or, that IPM didn't go far enough, having higher EAS's than those who saw no need to change. Respondents who were interested in IPM and willing to pay more for IPM grown products consistently scored significantly higher on the EA scale.

The group of respondents who stated that "*IPM doesn't go far enough…*" had particularly strong opinions about environmental issues in general. They were therefore more likely to strongly agree or disagree with the environmental statements given. For example, only 24% of this group remained neutral on whether most farmers were irresponsible with pesticides compared to 42% of those who had no interest in IPM. This group was also significantly more likely to agree that pesticide use is not controlled by the government compared to other groups.

Surprisingly perhaps, 26% of the respondents who said they "*don't want more insects on vegetables*" (i.e. not interested in IPM) agreed with the statement that "*farmers are not responsible in their use of pesticides*". Possibly this group don't consider pesticides on food to be a major issue.

Key Results

- ⇨ Only 5% of respondents recognised "eco bananas" as an environmental label.
- ⇨ Respondents responded very positively to an explanation of IPM, 70% agreeing that it sounded like an improvement on current practices and 78% expressing interest in purchasing these products.
- ⇨ While 48% of respondents said they would buy IPM products if they were a similar price to conventionally grown vegetables, this fell to 3% if the price differential increased to 20% or more.
- ⇨ IPM grown products appealed most strongly to those respondents aged 35+, especially if they had some experience with growing their own vegetables.
- ⇨ There was a strong positive association between respondents' purchase of organics and interest in IPM, particularly among those who were occasional buyers of organics.
- ⇨ Respondents who were purchasers of organics were more likely to potentially pay extra for IPM grown products.
- ⇨ Interest in IPM was also strongly associated with respondents' tolerance of insects on vegetables. Unlike the correlation between IIS and organics, which was only true for those aged 35+, the IIS was a good indicator of interest in IPM for all age groups.
- ⇨ Survey respondents with who were interested in IPM also scored higher EAS values, indicating increased concern regarding environmental issues associated with farming.

Who eats lettuce?

The final part of the questionnaire contained a series of questions about lettuce. The answers were as follows:

"*Before using pre-prepared loose leaves in a salad I would…*"

	% responses
Always / usually wash them	60.4
Occasionally wash them	19.1
Rarely or never wash them	14.9
I never use these products	5.6

"*In summer, I buy lettuce*

	% responses
Weekly	57.3
Fortnightly	27.1
Occasionally	14.1
Never	1.6

"*I most frequently buy*"

	% responses
Iceberg lettuce	53.8
Cos lettuce	13.0
Loose leaf types	13.7
Prepared lettuce mix (loose or bagged)	19.5

"*Before I use whole lettuce leaves in a salad I would*"

	% responses
Always wash them	71.5
Usually wash them	17.6
Occasionally wash them	9.5
Rarely or never wash them	1.4

While it might be expected that most people would wash whole lettuce leaves before using them (89%), it was surprising that the majority of respondents said they usually or always washed bagged salad leaves before use (80%). These products have been triple washed before packing and may be sold as "ready to eat". They don't necessarily require washing again. However, this does suggest an extra level of "security" against any potential insect contamination of the product.

Very few survey respondents did not buy lettuce, confirming its wide appeal to many demographic groups. While iceberg was still the dominant variety chosen, it is interesting to note that nearly 20% of respondents bought pre-prepared products most frequently.

Demographics of the lettuce buyer

There were some significant differences in purchasing behavior between the different demographic groups. Respondents aged <25 years purchased lettuce less frequently on average than other groups, as did those on very low incomes (<$20,000 annually). Singles living alone tended to buy lettuce fortnightly or only occasionally, whereas most other groups of respondents bought it weekly, at least during summer. Vegans also bought lettuce significantly less frequently than others ($p=0.04$), although the sample size was very small ($n=8$). Couples with children were the most frequent purchasers.

Iceberg lettuces tended to be purchased by young respondents and couples with children, whereas leaf mixes were more likely to be purchased by respondents who were singles living alone and couples without children at home. Keen gardener respondents were also more likely to purchase iceberg or lettuce mixes than loose leaf types – perhaps this is because these are harder to grow in the home garden than loose leaf types.

Lettuce and other beliefs and attitudes

It was expected that people who were more concerned about hygiene and less tolerant of insects would be more likely to wash products before use. This proved to be the case, as respondents who said they always washed lettuce before use had significantly higher IIS values and disgust sensitivity scores than those who washed the products less frequently ($p<0.001$). Those respondents who always washed salad mix were also more sensitive to disgust ($p<0.001$), although they did not differ significantly in their IIS ($p=0.045$).

Of the attitudes to foods tested in this survey, washing of lettuce and salad mix is the first to show some correlation with disgust scores. As previously noted, it seems likely that the issue of insects in food does not tap directly into the basic emotion of core disgust, but is a specific issue for each person. In contrast, washing products before use relates to a broader set of hygiene issues – the vegetables might have been handled by other people, be dirty, have pesticides on it, or a host of other reasons why it needs to be cleaned before consumption. These are the types of "fear of contamination of the core" which are tested by the disgust scale.

Key Results

- ⇨ Most respondents said that they wash both lettuce and pre-prepared salad products before use.
- ⇨ Iceberg lettuce was chosen most frequently by respondents (54%), followed by bagged products (20%).
- ⇨ During summer most people surveyed bought these products weekly, although singles tended to buy lettuce fortnightly or less often.
- ⇨ Families were regular purchasers of iceberg lettuces in the surveyed group.
- ⇨ Couples without children at home and singles were more likely to choose pre-prepared salad mixes than other respondents.
- ⇨ Washing of lettuce and salad mix was positively correlated in the surveyed group with disgust sensitivity but showed less relationship with IIS values.

Discussion and Conclusions

The difference between respondents from different age groups is one of the most interesting aspects to come from this work. It appears that younger people have different priorities when purchasing fruit and vegetables compared to those from older generations. Despite their avowed interest in environmental issues and purchasing organics, those aged <35 were more likely to value extrinsic factors such as appearance, cleanliness and freedom from insects. Older consumers tended to be more interested in the intrinsic values of the products, such as freshness, taste and aroma. Women aged 35+ were the least likely to be offended by insects on vegetables, especially if they had grown vegetables or herbs themselves, while men aged <35 were the most likely to react negatively to contamination by insects.

One of the central aims of this study was to find out whether consumers cared about finding a bug of some kind on a vegetable. The results show that many do, and that a significant number are likely to complain to a retailer if they do find something, even if it is only a ladybeetle. However, it was noted in the focus groups that many of the participants were unable to find insects in bags of lettuce even when they were told they were there. In this survey 90% of respondents said they always / usually washed whole lettuce leaves before use, with nearly 80% always / usually washing fresh cut salad mix. This suggests that small insects, such as predatory mites or even lacewings, would be easily missed and probably removed before serving anyway.

Another positive result is that a large majority of respondents did express some level of care regarding environmental issues, even though knowledge of specific farming practices and regulation was quite low. It was encouraging that ~80% of respondents thought that retailers should favour environmentally friendly suppliers. However, the extent to which people are prepared to change their own behaviour to minimize their impact on the environment is unclear. For example, the current widespread opposition to the carbon tax suggests that many consumers are unwilling to make personal sacrifices for a “global good”.

This is borne out by attitudes to IPM. Although 78% of consumers expressed some interest in purchasing vegetables grown using IPM, this support disappeared if prices were significantly higher than those of conventionally grown products. Nevertheless, as the main issue for IPM grown vegetables is not necessarily that they are more expensive to produce, but rather that presence of insects can exclude them from the marketplace, this may not be a major problem.

The results of this survey suggest that there would be consumer support for IPM grown and labeled vegetables if this issue is linked with environmental sustainability, with reduced pesticides as a secondary selling point. Such products would need to be clearly explained, believable and priced within 10% of conventionally grown vegetables. The consumers most likely to be attracted to these products are women aged 35+ who are concerned about environmental issues. They are likely to have grown vegetables or herbs for themselves at some stage and may already be occasional purchasers of organic products, although even consumers with little interest in organics could potentially be persuaded by IPM.

It is probably not realistic to develop an IPM brand without support from at least one of the major retailers. For them, this offers an opportunity to demonstrate good corporate citizenship and care for the environment. Despite the current emphasis on price, for most consumers this is not the most important factor when choosing fruit and vegetables. A retailer who can satisfy their customers that they are demanding a high environmental standard from their suppliers - thus saving the consumer the trouble of worrying about this issue – is likely to be rewarded with increased customer loyalty and sales.

Another necessary component is an independently audited certification scheme. This could be run similarly to existing food safety programs. Schemes which include elements of IPM include LEAF, “Red Tractor” and “Good Natured” from the UK, and “Freshcare Environmental” in Australia. Certification is important, given the high level of cynicism among many consumers regarding environmental claims. The “Eco” label used in the focus groups met with universal indifference, which is perhaps unsurprising given the huge range of products, from cleaning fluid to cheese, which already have poorly explained or justified “environmental” labels. Again, the support of a major retailer could be key in developing a credible label.

In conclusion, the results of this study provide some support for IPM branded consumer products. While explaining IPM is challenging given existing sensitivities about pesticides on vegetables, for some consumers and retailers this could be an appealing point of difference. Further research could test methods of explaining IPM to consumers and develop actual products to test in suitable marketplaces.

16. Grower Benchmarking and Evaluation

Introduction

In 2006 lettuce growers were surveyed as part of VG05044 to gauge attitudes to IPM, levels of adoption as well as some information on specific insect pest and disease management practices. In 2010 a one year Vegetable IPM Coordination project (VG09191) considered options for benchmarking IPM adoption in the vegetable industry. One of the options was a standardised grower benchmarking survey that could be used to collect survey data that could be used to monitor changes in crop protection practices. The questions were an amalgam of previous survey questions used in vegetable IPM projects and expanded to cover the suite of pests. Although the number of questions was large the feedback from stakeholders was that they were all useful questions.

This survey uses a modified version of the Vegetable Grower Benchmarking IPM survey to only include lettuce and not other crops, and include some project specific qualitative evaluation questions.

To get a true evaluation of a project or a proper benchmark of adoption of IPM practices it was important to try to survey a broad cross-section of lettuce growers, from those who engaged with the project to those who did not. To do this however, requires a comprehensive database of lettuce contacts. Each State grower association and Department of Primary Industry holds a list of growers in their state with varying degrees of information about what crops they grow. Due to Privacy legislation this contact information cannot be shared readily and each state was handled differently.

Materials and methods

An electronic survey was constructed in SurveyMonkey [http://www.surveymonkey.net] (see Appendix 16.3 for survey questions). The survey was divided into three parts including a short project evaluation (five questions), a set of 33 standardised tick-box questions on pest management practices, and another 8 questions that involved estimating levels of pest damage over the previous year and changes in practices and costs over the previous 5 years. A concluding section allowed for suggestions or comments about future research or any other related issue.

The survey link was publicised in the Lettuce Leaf newsletter issue 40, in the Vegetable Industry Development Program (VIDP) electronic newsletter and again on the cover letter that went out with the Lettuce Crop Protection Toolkit. Growers could complete the survey themselves on-line, request a printed version to fill in or answer over the phone.

Initially InnoVeg, the extension team of the VIDP, was contacted about the survey, they then passed the request onto the State grower associations. The State grower associations were then subsequently contacted directly by the project leader to see if they were prepared to conduct the survey of their state's lettuce growers or whether they were prepared to contact growers on our behalf. The interstate collaborators on this project were subsequently contacted as to whether they could contact lettuce growers to facilitate the completion of the survey. Although it was seen as preferable to have someone independent from the project conduct the survey there was the difficulty of accessing contact information. Through this and previous projects we had some contact information but had largely relied on interstate colleagues or the Vegetable Industry Development Officers for distribution of project related information in each state.

In Queensland David Carey, Extension Horticulturist from DEEDI contacted growers for the survey and in most cases visited them to do the survey face to face. Alison Anderson, the previous Vegetable Industry Development Officer for NSW (Sydney Basin) and the coordinator of the Lettuce Think tank (VG09057) was contracted to contact lettuce growers in NSW (Sydney basin), Victoria, NT and SA. She was seen as someone with trust and respect of lettuce growers but without direct involvement in this project. She contacted growers initially by telephone and then either did the survey over the phone or emailed them the link for them to do on-line. Similarly Bronwyn Walsh, a PhD student who has previous experience running IPM projects in Queensland, contacted WA lettuce growers to do the survey. David Troldahl, NSW DPI District Horticulturist contacted Tasmanian lettuce growers to encourage them to do the on-line version of the survey. Tony Napier, NSW DPI District Horticulturist visited the Hay lettuce growers and did the survey face to face.

All surveys were entered into SurveyMonkey and a results file downloaded for review and analysis.

Results

For the full results see Appendix 16.2. A summary is included here.

This survey is not necessarily reflective of a broad cross-section of lettuce growers. It does cover at least 1620 ha of lettuce production including growers from each State and all production types. Of the 42 grower respondents, 32 or 76% answered more than 75% of the questions in the survey. These growers are engaged with RDE levy funded projects with over 80% having attended field days or workshops in the last three years.

The picture of the average grower from this survey indicates that they have attended field days or a workshop in the past three years, have completed a previous survey and probably have hosted a trial on their farm. They rate the Lettuce Leaf newsletter as ‘satisfactory’ to ‘good’, but the average grower has not seen the IPM demonstrations nor the DVD. Of those who have seen the IPM demonstrations they rated them as ‘good’ to ‘excellent’ and the Crop Protection Toolkit DVD was rated ‘good’. Lettuce IPM information resources are referred to ‘sometimes’ with the field identification guide and posters referred to most frequently, followed by the information guide and past newsletters. The past conference proceedings are ‘never’ referred to. The average grower in this survey felt that the Vegetable levy investment into lettuce IPM over the past 12 years produced some useful results and information, and as a result they had adopted some new practices.

In terms of producing lettuce the average grower from this survey primarily grows iceberg lettuce and has a small planting of cos lettuce grown in field for the domestic fresh market. They are most likely to purchase seedlings from a commercial nursery and use a boom sprayer. They identify as using a ‘Medium IPM’ crop protection strategy which they are happy with. To them this means monitoring their crops themselves at least weekly and probably by a crop consultant as well. They monitor for insects, diseases, weeds, nutritional issues, soil moisture and beneficials, and are likely to keep records of monitoring results. They use a wide range of sanitation or pest prevention practices, with the most important being: crop rotations, a Quality Assurance program, weed management, cultivating crops in straight after harvest, using resistant varieties, using soil amendments, modifying soil pH and changing irrigation timing to reduce insect or disease problems. The growers hold a chemical user certificate although they are not clear on the AQF level, they calibrate their spray equipment at least once a year, probably at least every 6 months, they rely on leaf wetness for checking spray coverage and use an annual standard lab residue test. They manage insecticide resistant insects primarily *Helicoverpa armigera* to which they rotate chemical groups. They are unlikely to manage a fungicide resistant disease but if they do it is either sclerotinia or downy mildew. Fungicides are applied preventatively and are modified primarily based on weather and crop monitoring. Herbicide resistant weeds are not a problem for the average lettuce grower. Synthetic pyrethroids and organophosphate insecticides are rarely if ever used, and choice of pesticide is informed by their impact on beneficials. Biological insecticides are at least sometimes used, and they are familiar with ladybird beetles as a common beneficial. The average grower is likely to review crop monitoring records at least occasionally, chemical records seasonally, and harvest records weekly. They are likely to have had a crop rejected by the markets in the past three years, and it was probably for insect contamination, possibly for disease symptoms or size. In the last year they are not aware of any damage due to nematodes and are likely to have experienced some damage by insects all year, with highest levels in summer (7%) and lowest in winter (2%); their greatest potential losses were due to diseases in autumn (13%) and winter (10%), but had still significant losses in spring (8%) and summer (6%). Vertebrate pest damage was high in summer (10%) but was a possibility all year around. Low levels of crop loss due to weeds, was experienced all year round but somewhat higher in summer (7%). The average grower in the last year estimates to have lost $3,370 /ha to pest damage, had pesticide costs of $1,189 /ha and non-chemical pest management costs of $476 /ha. The average grower estimates that damage levels have dropped by 14% in the last five years but that pesticide costs have gone up by 26%, whereas non-chemical costs have stayed the same. The average lettuce grower is concerned about the oversupplied domestic lettuce market, would like to see consumers eat more lettuce and supermarkets pay more to them for their lettuce. They wish for more RDE project work on disease management.

Discussion

In comparison with the 2006 survey of lettuce growers proportionally the same number of lettuce growers from NSW were surveyed which is also similar to the proportions of NSW growers growing lettuce in Australia (Table 16.1). Western Australia growers are more highly represented in the 2012 survey compared to 2006 and are overestimated relative to numbers of growers growing lettuce in Australia. Queensland and Victorian lettuce growers are under-represented and Tasmanian growers are overrepresented in the 2012 survey.

This survey is not necessarily reflective of a broad cross-section of lettuce growers. It does cover at least 1620 ha of lettuce production including growers from each State and all production types. Of the 42 grower respondents, 32 or 76% answered more than 75% of the questions in the survey. These growers are engaged with RDE levy funded projects with over 80% having attended field days or workshops in the last three years.

Table 16.1. Percentage of lettuce growers by state, percentage completing lettuce survey in 2006 and 2012

State	ABS 2008	2006 Survey	2012 Survey
NSW	33.4%	36.7	35.7%
QLD	26.2%	7.6	14.3%
SA	4.2%	11.4	7.1%
Tas	1.7%	15.2	4.8%
Vic	24.2%	21.5	11.9%
WA	9.9%	7.6	23.8%
NT	0.03%	0	2.4%

The first part of this survey gave a wide range of ratings to this lettuce project and of the usefulness of the previous information resources. Distribution of these resources were highlighted with the most recent distribution of the Lettuce Crop Protection Toolkit DVD having not been seen by 28 of the 40 respondents when over 700 were mailed directly or indirectly via the Grower Associations two to three weeks prior to the growers being surveyed. Some growers stated that they had received the DVD but not had the time to watch, others said they were unsure of whether they had received it because they have little time to devote to opening mail. However, one grower reported that he had already watch the DVD 4 times and it was very useful. The Lettuce Leaf newsletter was seen by almost all growers which is not surprising given 40 issues have been distributed over 13 years. Similarly it is not surprising that most growers have not seen one of the IPM demonstrations given in this project there was one demonstration in Stanthorpe and one in the Sydney basin, with comparative data collected from Victoria and an IPM casestudy done in WA. In the previous project there was an IPM demonstration in the Sydney Basin and Victoria as well as detailed data collected from IPM trials/demonstrations in Victoria and in Hay NSW.

Of the previously produced and distributed information resources the Lettuce Field Identification Guide [Pests, Beneficials, Diseases and Disorders Field Identification Guide for Lettuce] and the Common Pests or Diseases of Lettuce Posters were the most frequently referred to. The field identification guide, the Lettuce IPM Information Guide and the Lettuce Leaf newsletters were all directly mailed to the known lettuce growers at the time of publication and available to new growers as we became aware of them. The Lettuce Conference proceedings were available to growers at the conferences and by request to others. The Common Pests or Diseases of Lettuce posters have been available at field days or by request, but not mailed to all known lettuce growers.

Half the growers agreed with the statement that the investment in lettuce IPM has produced some useful results and they have adopted some new practices as a result of the projects. A number of growers were very scathing and agreed with the statement that the projects were a waste of money and they hadn't changed a single practice. In at least three of these cases I know that the growers have changed practices but they are expressing a general dis-satisfaction with the levy and that they have not had much face to face contact within this current project. Lettuce prices were poor at the time of the survey and that does affect grower's general outlook. Poor prices was mentioned by those collecting survey results as a common discussion topic.

If we compare the questions that have a direct comparison from the 2006 lettuce grower survey then we see that the numbers of growers self identifying as IPM growers has increased from 61% to 79% and conversely the numbers identifying as 'calendar sprayers' has reduced from 39% to 21% (Table 16.2). The numbers of growers monitoring crops is similar although the number of consultants being used to monitor crops has increased from 28% to 46%. It is therefore likely that many growers who are using crop consultants but have stated they have not benefited from the lettuce projects are doing so indirectly via their consultant. There has been an increase in the numbers of growers monitoring for invertebrate beneficials from 38% to 55% and the use of biological insecticides has increased from 43% to 76%. Use of older chemistry is similar in numbers of growers nominating they use it sometimes or regularly. The satisfaction rating of the Lettuce Leaf newsletter dropped from 4.2 to 3.5 out of a scale of 1-5.

Table 16.2 Comparison between 2006 & 2012 lettuce grower surveys. Only including data where there is a direct comparison.

Comparative Questions	**2006 Survey**	**2012 Survey**
Growers surveyed	79	42
Self identified as IPM grower	61%	**79%**
Self identified as 'calendar sprayer'	39%	21%
Monitor crops	91%	97%
Monitor crops self	74%	70%
Consultant monitors crops	28%	**46%**
Monitors for beneficials	38%	**55%**
Beneficial insect releases	10%	5%
Use biological insecticides	43%	**76%** (sometimes or regularly)
Use SPs and OP insecticides	23%	27% (sometimes or regularly)
Use conventional boom sprayer	62%	69%
Use boom with droppers	4%	4%
Use air- assist sprayer	19%	25%
Rating of Lettuce Leaf newsletter	4.20	3.5

Conducting this survey has highlighted that communicating with growers has become increasingly difficult, with no easily available or consistent communication channel. Mail-outs are the easiest and can be facilitated by some of the State Grower Associations, although their contact lists are of variable quality. It is also difficult to ascertain the timeliness of delivery of project outcomes when mailouts are facilitated by an Association. One State Association felt their contact lists were inadequate to mail information out to just lettuce growers, so were unable to send out the Lettuce Leaf newsletters or the DVD. Even the states where there was a willingness to assist it is evident from the numbers of growers who had 'Not Seen' the DVD that it is possible that lists are poor or the DVDs had not gone out at the time of the survey. In some cases growers reported that they probably had received the DVD but they have little time to sort through mail or they rely on someone else in the family who opens the mail to pass on relevant information. Others said they had received it but had not watched it yet.

The benchmarking component of this survey will be most useful if subsequent surveys use these questions as a standardised set of questions. It was evident that there is some confusion with the wording, particularly in the quantitative section and that should be improved before using again.

17. Overall Discussion

The delivery of IPM for the lettuce industry has delivered two IPM demonstrations, both written and video casestudies of IPM growers and a range of specific trials aimed at overcoming barriers to IPM or to evaluate the potential of new crop protection tools. And finally tieing up all the past extension outputs from previous lettuce IPM and crop protection projects into an electronic library and distributed to all known lettuce growers.

When the previous Lettuce IPM project (VG05044) was completed currant lettuce aphid, *Nasonovia ribis nigri* (CLA) had been found in all major lettuce production areas. Three lettuce growers in Victoria chose not to use imidacloprid seedling drenches and worked with Paul Horne to monitor CLA and other invertebrate pests and their beneficials. The data collected demonstrated that CLA could be managed with beneficials and if needed, some foliar aphicides. A demonstration in Sydney in 2006 starting in mid-winter and into late spring suggested that beneficials will not manage CLA over the winter period if they are not already in the system prior to the cooler winter months, but will colonise in spring. Hence the need to reconduct a trial/demonstration in Sydney in 2009 over a similar period but after CLA had established in the system for three years. With almost the entire NSW lettuce crop being treated with imidacloprid it was difficult to monitor populations in CLA. Untreated *Nas*-susceptible lettuce was planted in Sydney and Hay to assist in identifying whether CLA was still in the system and likely to colonise untreated lettuce. In Stanthorpe a demonstration/trial similarly allowed monitoring for CLA, beneficials and invertebrate pest management using soft chemistries.

In all three locations - Hay, Sydney and Stanthorpe - where significant area of lettuce was untreated with imidacloprid and *Nas*-susceptible lettuce was grown, CLA was not detected for almost the entire monitoring periods. In Sydney only in June and July 2008 was any CLA observed. CLA continued to be observed in Victorian untreated and susceptible lettuce. The demonstrations in Sydney and Stanthorpe allowed other local growers to have confidence that they need not treat all their lettuce with imidacloprid. Other growers in Victoria who had pre-CLA managed their crops using IPM but who had had to use seedling drenches to maintain their interstate or processing markets had noted that they were struggling to manage their lepidopteran pests. Data collected on an IPM and a number of non-IPM treated crops showed that invertebrate beneficial numbers were reduced and the numbers of WFT increased in the crops with where seedlings were treated with a systemic insecticide compared to the crops without treatment

CLA resistant varieties are an excellent IPM compatible method for managing CLA. In 2004 when CLA arrived in Australia there was only one experimental line of headlettuce that was *Nas*-resistant and it was only suitable for use in the shoulder production windows in Victoria and to some extent in other areas. Each production area grows particular sequences of varieties that produce marketable heads within their local climatic conditions. Unusal weather or varieties grown in the wrong area or time-slot lead to unmarketable heads: bolting, too small, too loose, or not hearting. The sensitivity of lettuce varieties makes it difficult for them to gauge how varieties will grow in their area from trials in other regions. Hence *Nas*-resistant varieties were screened at Hay and also in conjunction with the Stanthorpe IPM demonstration.

It was intended at the beginning of this project to have IPM demonstrations in hydroponic lettuce in Sydney, field demonstrations in South Australia and in Western Australia. *Nas*-resistant varieties are very widely used in hydroponics and the growers contacted that had some *Nas*-susceptible lettuce were not seeing any CLA and none of the growers initially contacted were comfortable to have a block of hydroponic lettuce managed without regular Western flower thrips, *Frankliniella occidentalis* insecticide sprays. As Spinosad is the only chemical registered for control of WFT in hydroponic lettuce the main difference between how non-IPM and IPM growers manage WFT in hydroponics is in sanitation practices, and weed management to reduce alternative hosts to breeding WFT populations.

One hydroponic grower did eventually take the advice to improve santitation practices and weed managagement and got excellent reduction in WFT numbers. We were not collecting data during the transition to include in this report although we did capture the grower and his IPM consultant in one of the video casestudies. In South Australia we had intended to monitor lettuce with neighbouring plantings of native vegetation that was established in the previous project however the grower sold their property and it was ploughed under by the new owner. In Western Australia the only IPM crop consultant was working with vegetable growers within another funded project and did not have the time to take on the lettuce growers who were keen to host an IPM demonstration/trial. Instead one of the lettuce growers working with the crop consultant was written up as a case study in the Lettuce Leaf newsletter issue 38, June 2010 and a version was also published in the Good Fruit and Vegetables magazine.

In the grower survey at the commencement of this project (Appendix 16.1), IPM growers in Victoria were keen for some research into UV screens that could be added to *Bacillus thuringiensis* (Bt) that would provide similar efficacy to day applications with the sunscreen as they see when they spray the biopesticide out at night by itself. Day applications would suit their farm management and cause less stress with their family. It would also reduce a barrier to other growers who choose not to use Bt because it is either less effective because they apply it during the day, or they are not prepared to apply at night. The laboratory based trial, using diamondback moth, *Plutella xylostella* as the model caterpillar, found that Bt was deactivated by UV light after 300-350 minutes and deactivation was increased with both of the UV screens tested to 400-450 and 450-500 minutes respectively. This addition of up to 2.5 hours in the laboratory under UV lights should equate to longer times in the field given Bt normally degrades over 12 daylight hours. Field trials were not conducted within this project and are recommended before growers are encouraged to use the UV screens with Bt.

Another targeted trial was to evaluate the impact of short-term exposure to imidacloprid on the ubiquitous predatory ladybird beetle *Hippodamia variegata* because: almost the entire lettuce industry adopted the use of imidacloprid as a preventative measure in managing CLA and that imidacloprid had been shown previously to have a negative impact on *H. variegata* when larvae and adults fed for 21 days on imidacloprid intoxicated aphids (Wyber 2008). This extended period is probably more than is likely to be seen in field lettuce conditions hence this trial wanted to evaluate the impact of short exposure periods. Cole and Horne (2006) had also shown field rates of imidacloprid killed 85% of brown lacewings *Micromus tasmaniae* larvae and relatively short exposure of low rates of imidacloprid impacted on reproduction. Feeding *H. variegata* larvae for 48 hours with imidacloprid intoxicated aphids at equivalent to field rates did not adversely impact survival of the larvae, however it did impact on the fecundity of adult females and reduced their egglay period and lifetime fertility by 35% compared to the control group. This supports efforts to demonstrate alternative methods for managing CLA in lettuce other than using seedling drenches of imidacloprid. Another reason is that CLA has developed resistance to a range of aphicides and therefore it is risky to depend so heavily upon a single mode of action for managing this pest.

A third area of directed activity was at following up on previous screening trials for alternative cereal hosts for aphid predators that would be compatible as an intercrop or bridging crop to ensure a ready supply of aphid predators in a production system when there are lettuce production breaks. A previous trial had identified barley as a suitable host of cereal aphids in inland NSW (Yanco) and oats for the mid north coastal region of NSW (Sommersby). Trials comparing lettuce planted next to oats or barley compared to lettuce next to lettuce illustrated trends towards higher numbers of beneficals and lower aphid numbers in lettuce next to cereals but the results were not consistently significant at either location. In theory this should work well and a number of growers in Victoria are using cereals along sprinkler lines as insectary crops for aphid predators already, however this inconclusive data suggests that it can not be relied upon to give a reduction in aphid numbers. Nevertheless if it can easily be incorporated into an existing system and cereal aphids colonise the cereal, aphid predators are likely to follow and be a source of predators for neighbouring lettuce.

As mentioned above hydroponic lettuce growers currently only have a single registered insecticide to manage WFT. It is therefore not unsurprising that insecticide resistance has already developed to spinosad, and in some WFT populations is already at field–failure levels (Herron & Broughton 2006). Hence finding other options to either reduce WFT populations or reduce the transmission of tomato spotted wilt virus (TSWV) which it transmits, would greatly assist hydroponic lettuce growers, along with targeted extension to improve non-chemical management practices to reduce non-crop sources.

A commercial salicylic acid mimic that can stimulate a plant to produce defence compounds against disease was trialed as well as a new mode of action insecticide that inhibits lipid biosynthesis and which has been tested to have low toxicity to key beneficials. Unfortunately in both lettuce trials, one greenhouse hydroponic and one open hydroponic, found neither a reduction in WFT numbers nor a reduction in transmission of TSWV. In both cases the trials were under high WFT and TSWV pressure and plots were individual lettuce. Having plots with multiple lettuce would be better although logistically difficult. At this point emphasis on sanitation and weed management to reduce non-crop habours for both WFT and TSWV is key in an integrated management strategy for WFT in hydroponic lettuce.

The RDE area that is new and novel to this project in comparison to previous lettuce IPM projects is the attempts to address the issue that lettuce growers have repeatedly raised that the "market' is a barrier to their adoption of IPM. Ideally the market chain works collaboratively or at least complementary to deliver quality 'safe' product to consumers. Growers don't like to use pesticides but they will use them if it allows them to manage pests and produce marketable lettuce. There is a strong perception that regular use of pesticides is essential to produce marketable lettuce, and vested interests maintain that perception. Whether it is changing consumer perceptions to having pesticide residues on their produce, or the fact that our 'key' pests are key pests because they have biology that assists them in developing pesticide resisistance rendering some, or in some cases, all pesticides as ineffective in their management, is reason alone to endeavour to find other pest management options. Integrated pest management is internationally accepted as the most effective long-term strategy for managing pests however if growers are getting contrary information from their markets they are not likely to try to even adopt something that they perceive as being risky. If on the other hand the markets send a signal that they see IPM as being desirable then adoption is likely to increase dramatically.

Three approaches were taken in this project to look at where the 'common ground' is with IPM and the market end of the production chain, and with consumers. Conversations were initiated with lettuce processors and supermarket lettuce buyers on their attitudes to crop protection practices of lettuce growers and what information they were feeding back to their growers on how they wanted them to manage pests. Getting engagement with the processors and lettuce buyers was difficult and the response can be summed up as "IPM = greater risk of insect contamination = unhappy consumers". Hence the project then looked at consumer attitudes to insect contamination.

The first approach was via focus groups, one in a relatively affluent area and one in a low socio-economic area. At the focus groups discussions indicated that the younger "generation Y" lettuce buyer was the most adverse to insect contamination and that the other age groups were not particularly concerned if the insects were not seen as having infested post-farm. It was also illustrated with insect contaminated product that they were not very good at finding the contaminating insects in bagged lettuce. The second approach was using an on-line consumer survey service to survey over 1000 consumers nationally using questions designed to evaluate what main grocery shoppers think about farmers, environment, lettuce and insect contamination of fresh fruit and vegetables. This survey indicated that younger (< 35 years old) consumers are more interested in extrinsic factors such as appearance, cleanliness and freedom from insects despite an avowed interest in environmental issues and purchasing organics. Whereas older consumers (> 35 years old), were more interested in intrinsic values of products, such as freshness, taste and aroma.

The on-line survey has provided more context to the notion that consumers don't like insect contamination hence markets are going to discourage use of any production method that they perceive as having a greater risk of having contaminated product. This re-inforces the need to investigate the levels of complaints received by market sectors, levels of insect contamination at receival and in marketed product, particularly with lettuce processors.

In conclusion this project has demonstrated that using an integrated pest management strategy can effectively manage invertebrate pests in lettuce and produce marketable lettuce. It has produced a range of resources for growers and consultants to assist with using an IPM strategy. The directed research may not have given conclusive results but has brought some clarity to where improvements can be made.

Based on the grower survey there has been an increase in adoption of IPM practices with 18% more growers identifying as IPM growers, a 44% increase in numbers of growers monitoring for beneficials and a 76% increase in the numbers of growers using biological insecticides. The other increase is a 64% increase in numbers of growers using consultants to monitor their crops. A reduction in the use of the older chemistry (synthetic pyrethroids and organo phosphates) was not recorded in the survey. In 2006 the survey did not ask for frequency or areas it was used on so it is possible that growers are using less of it on an area basis but that similar numbers of growers still use them occasionally. For some invertebrate pests, such as Rutherglen bug (*Nysius vinitor)* there are no soft options available to growers. One of the unexpected findings from the benchmarking component of the survey was the level of vertebrate pest damage that growers experience averaged 10% in summer and was estimated as up to 40% by one grower. All known lettuce growers should have or soon have a DVD with an entire collection of electronic information resources.

18. Technology Transfer

A significant component of this project was directed at industry communication or Technology Transfer. Lettuce growers and allied industry people have had 9 issues of the Lettuce Leaf newsletter, a workshop at the national vegetable conference 2009, 4 field days and the Lettuce Crop Protection Toolkit DVD.

Lettuce Leaf Newsletter (Issues 33-40)

The Lettuce Leaf newsletter was first distributed to Australian lettuce growers and allied industry in December 1999 and has continued to be produced 4-6 times per year with updates from the lettuce IPM projects. Every two to three months lettuce researchers and some industry people are canvassed about any research results or industry information relating to lettuce crop protection to be included in the newsletter. Information is compiled and the newsletter produced and 720 paper copies are mailed out. The loss of the Vegetable IDO network has caused many problems with mail outs and particularly in QLD many lettuce growers have not been getting copies of the newsletter. Electronic versions are e-mailed to interested parties and are available from both the NSW DPI and AUSVEG websites.

Lettuce Leaf newsletter (issue 33 June 2008): What to Expect when using IPM in lettuce. Summary of Lettuce IPM grower consultation. Success for IPM in WA. New project – Disease prediction & control. New Zealand lettuce system launched.

Lettuce Leaf newsletter (issue 34 October 2008): Suction traps to understand CLA migration patterns. Lettuce growers "hitting the target" (spray application). Coragen® new insecticide for lettuce. Current permits for leafy vegetables.

Lettuce Leaf newsletter (issue 35 May 2009): Breeding beneficials – cereal, Lettuce aphid & beyond. CLA Permit update. Evaluation of CLA resistant iceberg varieties

Lettuce Leaf – special issue (June 2009)
Getting best out of pesticides. Using Pirimor®, Chess® and Bts. Resistance management.

Lettuce Leaf newsletter (issue 36 August 2009): Lettuce Downy mildew model. Is there a market-pull for IPM? Market is King. IPM acknowledged again. Chemical permit update. New Cucurbit guide.

Lettuce Leaf newsletter (issue 37 Feb 2010) Leafy vegetable think tank. Summaries of current and recent leafy projects. Keep It Clean – new guide for greenhouse growers. All current permits for leafy vegetables. Pesticide impacts on beneficials

Lettuce Leaf newsletter (issue 38 June 2010) Sunscreens for Bt. WA IPM case study. Lettuce insect contamination – what do consumers think? IPM Coordination.

Lettuce Leaf newsletter (issue 39 Mar 2011) Annotated summary of information resources related to lettuce IPM.

Lettuce Leaf newsletter (issue 40 October 2011) Summary of Stanthorpe IPM demonstration and of Consumer on-line survey.

Grower information sessions

In April-May 2008 at the conclusion of the previous lettuce IPM project VG05044, and the start of this project a series of meetings were held to canvass growers about whether the project should continue and if so in what direction given most of the industry were comfortable using imidacloprid as a preventative control of CLA. Meetings were held at Virginia, SA (10 growers); Waneroo, WA (12 growers); Richmond NSW (4 growers); and Gatton, QLD (5 growers & 2 consultants). In addition 6 growers in Victoria were canvassed directly and a survey was sent out with issue 32 of the Lettuce Leaf newsletter for growers to fax back; which none did.

Field days

Sydney

Three field days were planned to follow-through the IPM demonstration with four sequential plantings of susceptible head lettuce at Werombi, Sydney at two week intervals in October and November 2009. The first field day which was to focus on IPM was very disappointing with only 1 consultant attending other than the project team, growers and staff [day after long weekend and first day most growers could get on their fields after rain few days previous].

The second field day in Werombi was held on October 22nd 2009 and attended by 25 growers and consultants, and the third was held on November 5th 2009 and attended by 22 growers and consultants. Sandra McDougall demonstrated in the second field day sampling the lettuce crop for insect presence using the BugVac, a common tool used by IPM consultants to collect insects in order to determine what pest and beneficial insect levels are within the crop. Andy Ryland of *Beneficial Bug Co. (BBC)* in Richmond and Sylvia Jelinek of *NSW DPI* also discussed with the growers and consultants the importance of IPM in a field lettuce production crop. They highlighted the value of protecting natural enemies and maintaining their numbers to assist lettuce growers in keeping insect pest species at bay. This was followed by a refresher demonstration on correct spray application, chemical dilution and spray calibration by Tony Napier, *NSW DPI* Yanco District Horticulturist. A presentation by the *NSW DPI* Nutrient and Water SmartFarms project officers concluded the afternoon.

The third lettuce field day focused on lettuce diseases. This was headed up by Len Tesoriero and Leanne Forsyth, *NSW DPI* resident plant pathologists from Camden. Disease issues were discussed, how to reduce them, and fungicide issues that are of importance to the field lettuce industry. Lettuce breeder Stephen Mitchell, *Enza Zaden*, was a special guest for the day and discussed variety resistance, with a focus on Downy Mildew *Bremia lactucae.* IPM accreditation for growers and IPM consultants was promoted by Leigh Pilkington and Sylvia Jelinek, *NSW DPI,* with an overview by Andy Ryland *BBC* on how the accreditation scheme would work for growers and consultants alike in the Sydney Basin.

Stanthorpe

All local resellers and crop scouts were invited to visit and observe the IPM trial demonstration site on either of the two days a week that the Qld IPM lettuce demonstration team were present throughout the period of the trial (Feb-March 2010). The two local reseller representatives who visited the farm weekly and scouted insects were encouraged to also scout the IPM trial area. These local resellers, interested local growers, farm staff, and contributing seed company representatives were part of a field walk held to highlight trial outcomes when the first variety trial matured (15th Mar 2010). This field walk consisted of people attending the site at a time throughout the day that suited them, allowing them time to examine the site and talk to the IPM lettuce demonstration team on a one to one basis. Seed company representatives were also encouraged to arrange site visits for growers that wished to view the *Nas*-resistant variety trials. Growers and resellers attending the field walk were shown over the demonstration crop and shown all crop scouting and insect monitoring techniques. The use of the FullStop® irrigation monitoring tool was also explained to all attendees as they visited the site. The co-operating farm owners and key farm staff were also walked through the trial area just prior to the final harvest.

Conference Presentations

At the **Australasian Vegetable Conference** in Melbourne May 2009 a 50 minute workshop session was organised entitled: *Is there a market pull for IPM?* The session was organised and introduced by Sandra McDougall. Peter Schreurs from P. Schreurs and Sons gave an inspiring talk about their transition to IPM and the evolution of their farming practices. [A video of the talk is included in the IPM Casestudy DVD, copies were also provided to the Knowledge Management component of the Vegetable Industry Development Program for loading onto the AUSVEG website in November 2010.] Lee Peterson, Technical Director of Houston's Farms spoke of their interest in IPM and how the arrival of CLA halted that plan, and how they were now ready to move towards an IPM strategy (2010-11 they transitioned to IPM). Chris Berge, lettuce buyer for GSF, spoke of the imperative of zero tolerance for contamination of product, particularly for ready-to-eat product. Paul Horne, IPM consultant highlighted that using pesticides didn't necessarily equal zero insects and gave examples of growers who adopted IPM because they couldn't control their pests with pesticides. He also showed examples of IPM logos and the use of IPM as a marketing tool. Summaries of these talks are written up in Issue 36 of Lettuce Leaf newsletter.

Two Lettuce IPM related presentations were given at the **International Tospovirus and Thysanoptera Conference** in September 2009. Dr Paul Horne presented on IPM versus non IPM management of WFT and Dr Sandra McDougall on the approach taken in Australia to manage TSWV in lettuce.

Media coverage

Stanthorpe and Lockyer Valley Times newspapers

August 2010 Good Fruit & Vegetables reprinted the WA IPM Casestudy (Lettuce leaf issue 38).

October 2011 Agriculture Today covered the Lettuce Crop Protection Toolkit DVD

January 2012 WA Grower magazine published articles on the Stanthorpe Demonstraion, the consumer on-line survey and the Lettuce Crop Protection Toolkit DVD

Press Release from NSW Minister for Primary Industries Katrina Hogkingson launches Lettuce Crop Protection Toolkit DVD

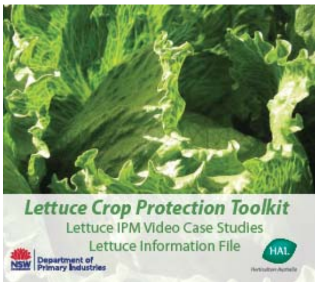
Sydney and Regional radio mentions

Article in Irrigator newspaper (local Leeton newspaper) and Area News (local Griffith newspaper)

March 2012 Good Fruit & Vegetables

Air March 2012 On-Target in Agriculture radio segment on local ABC radio covering Lettuce Crop Protection Toolkit DVD

Video IPM Case studies



Grower's own voices and experience are often more powerful than the words of a researcher or extension agent. IPM lettuce growers from five production regions and covering a range of different production methods were interviewed about IPM in their businesses to capture both the diversity and similarities in their application of IPM.

Method

Each grower was asked whether they would like to participate in a video casestudy and given a series of questions that we would be covering in the video. We also asked if the person who monitors their crops could also be present at the filming and as much as possible if we could film components of their integrated pest management system.

Initial questions growers were given to consider for the casestudy:

1. What is IPM?
2. Why did I adopt IPM?
3. What are the benefits?
4. What have been the greatest challenges?
5. What advice would you give growers thinking of adopting IPM?
6. IPM on my farm involves…
7. Weed management involves:
8. Disease management involves:
9. Insect pest management involves:

A dummy script was given to the grower as guidance prior to filming.

1. Hi I'm _________ I grow ______________ in ____________
2. On our place IPM looks like___
3. I think IPM is____
4. We adopted IPM because _____
5. My greatest challenge with IPM is____
6. My recommendation to a grower looking to adopt IPM is____

On the day of filming the growers and their consultants or crop scouts were asked a question and asked to include the question in their answer. The script questions were asked, with some additional questions depending on earlier answers and which management strategies they considered the important ones on their farm.

The filming was done by the David Troldahl, NSW DPI District Horticulturist (field vegetables) with assistance from Rick Woolley, Vision 21. Editing was principally done by Rick Woolley. After the first cut of the video each grower and consultant was sent a copy or Utube link to their casestudy for review and approval.

An additional overview of lettuce IPM video was scripted using parts of the grower casestudies and introduction with Sandra McDougall; growers and consultants were similarly asked to approve their inclusion in a draft cut prior to finalising.

The formatted Lettuce IPM DVD includes the individual video casestudies, the overview of lettuce IPM and previous short lettuce IPM videos that were produced in VG05044 or earlier in this project, along with a collection of lettuce IPM resources.

Lettuce IPM Resources

As much as possible, all information resources that had been produced as part of previous lettuce crop protection projects were collected to load onto a DVD for use as a one-stop shop resource library. Ultimately the resources should be available from a grower-friendly website, however relatively few growers are regularly accessing the AUSVEG website and given there was space remaining on the Lettuce IPM Casestudy DVD it was seen as a good opportunity to ensure all lettuce growers had an electronic copy of as many resources as possible.

The 215 resources available as PDFs have been divided into five major sections (see Menu pages and submenus below):

1. Factsheets, posters & books and includes 31 items including newly created Pest Calendars for each major production region.
2. Newsletters which includes the 40 issues of the Lettuce Leaf newsletter and the 10 issues of the NSW IPM newsletter.
3. Training talks & quizzes includes 7 presentations covering: IPM basics, how pesticide resistance develops, introduction to crop monitoring, introduction to beneficials, management of key insects and diseases, currant lettuce aphid basics, and managing WFT and TSWV in

lettuce. Three quizzes are included covering aphids, thrips and lettuce IPM basics. All reformatted to be self explanatory for viewer.

4. Lettuce conference proceedings from the three lettuce conferences (Hay 2001, Gatton 2002, and Werribee 2005). Full proceedings are available for the Hay and Gatton conferences, as well as 53 individual presentations and/or papers from all three conferences.
5. HAL funded lettuce project section includes a summary of all HAL funded lettuce projects, copies of most of the final reports (68) of these projects and copies of the individual reports (10) that makes up this final report.

New information resources produced in this project and included on DVD:

1. Getting best out of insecticides factsheet.
2. Pest calendars for Melbourne, Nth Adelaide Plains, Perth, Riverina, Stanthorpe, Sydney and Tasmania
3. Farm sanitation workbook for field lettuce
4. Lettuce invertebrate pest and disease summary tables.

KASA- Knowledge, aspirations, skills and attitudes

The knowledge of IPM has increased since the 2006 grower survey, with a greater knowledge of key invertebrate beneficials, the potential negative impact of pesticides on beneficials and importance of monitoring. Even many 'calender sprayers' are now routinely monitoring their crops for invertebrate pests.

The final evaluation and benchmarking survey indicated that for the most part growers were happy with their crop protection practices. Of the 42 growers who completed the survey all but six growers indicated that they would be using the same crop protection practices they are currently using in five years time. Two indicated they were leaving the lettuce industry, three aspired to move from 'medium IPM' to 'biointensive IPM' and one aspired to move from 'low IPM' to 'medium IPM'.

Growers are increasingly using crop consultants to assist with crop monitoring and presumably making pest management decisions. Although not assessed as part of this project the increase in growers using crop consultants may increase the transfer of knowledge and project outcomes as it could be assumed that most crop consultants keep up-to-date with R&D outcomes. A number of growers indicated in the survey that they would like to use a 'biointensive IPM' strategy but that the supermarkets have no tolerance for insect contamination. 68% growers have had lettuce rejected in the last 3 years, 48% have had lettuce rejected for insect contamination, including contamination by beneficial organisms.

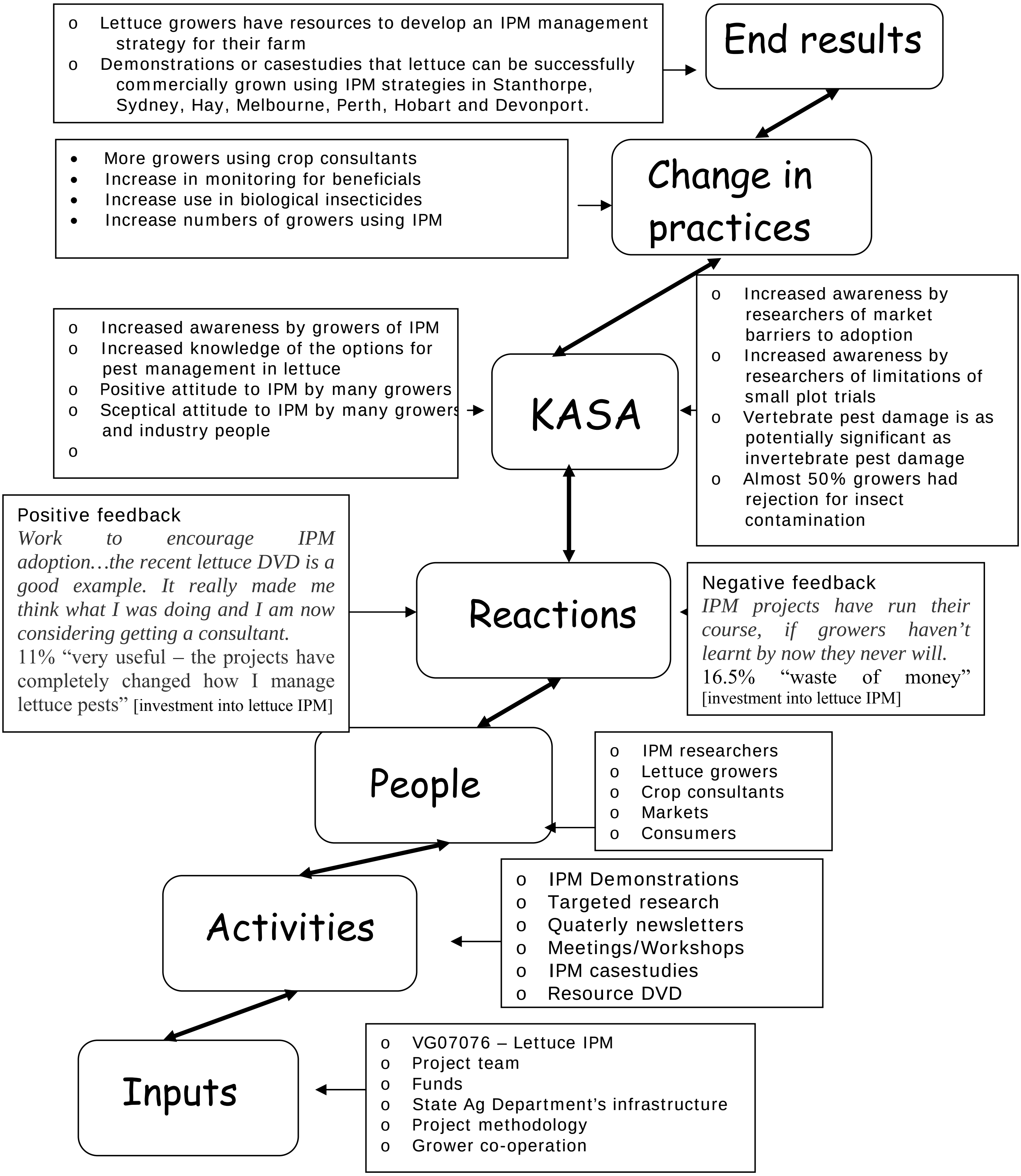
Changes in practice

- 46% growers using crop consultants to monitor lettuce (64% increase since 2006)
- 55% growers monitoring for beneficials (44% increase since 2006)
- 76% of growers using biological pesticides (76% increase since 2006)
- 79% of growers identifying as using an IPM strategy (30% increase since 2006)

End results

This project has demonstrated that using an integrated pest management strategy can effectively manage invertebrate pests in lettuce, including Currant lettuce aphid, *Nasonovia ribis nigri*, and produce marketable lettuce. It has produced a range of resources for growers and consultants to assist with using an IPM strategy. The directed research may not have given conclusive results but has brought some clarity to where improvements can be made. All known lettuce growers should have electronic copies of the information resources produced from the NSW DPI led lettuce IPM projects and some resources from other projects, as well as most lettuce related final reports from HAL funded projects.

Figure 18-1 Bennett's hierarchy for "improving lettuce pest management"



- Lettuce growers have resources to develop an IPM management strategy for their farm
- Demonstrations or casestudies that lettuce can be successfully commercially grown using IPM strategies in Stanthorpe, Sydney, Hay, Melbourne, Perth, Hobart and Devonport.

- More growers using crop consultants
- Increase in monitoring for beneficials
- Increase use in biological insecticides
- Increase numbers of growers using IPM

- Increased awareness by growers of IPM
- Increased knowledge of the options for pest management in lettuce
- Positive attitude to IPM by many growers
- Sceptical attitude to IPM by many growers and industry people
-

- Increased awareness by researchers of market barriers to adoption
- Increased awareness by researchers of limitations of small plot trials
- Vertebrate pest damage is as potentially significant as invertebrate pest damage
- Almost 50% growers had rejection for insect contamination

Positive feedback

Work to encourage IPM adoption…the recent lettuce DVD is a good example. It really made me think what I was doing and I am now considering getting a consultant.

11% "very useful – the projects have completely changed how I manage lettuce pests" [investment into lettuce IPM]

Negative feedback

IPM projects have run their course, if growers haven't learnt by now they never will.

16.5% "waste of money" [investment into lettuce IPM]

- IPM researchers
- Lettuce growers
- Crop consultants
- Markets
- Consumers

- IPM Demonstrations
- Targeted research
- Quaterly newsletters
- Meetings/Workshops
- IPM casestudies
- Resource DVD

- VG07076 – Lettuce IPM
- Project team
- Funds
- State Ag Department's infrastructure
- Project methodology
- Grower co-operation

19. Overall Project Recommendations

1. Demonstrations are an effective tool for testing regional applicability of crop management recommendations, for improving understanding of the implementation requirements, and for increasing local grower interest in adopting recommended practices. It is recommended that demonstrations are funded periodically in key production regions to bring together recommendations from a range of RD&E projects and that they are a collaboration between researchers, growers and their consultants or agricultural advisors.
2. Further research into the potential for non-crop plants to reduce invertebrate pests or diseases in neighbouring crops/lettuce. Promising native vegetation-WFT-TSWV and cereal-aphid-predator or rocket-generalist predator – invertebrate pest are important combinations to evaluate in lettuce. All have promising results but not yet sufficient to be strongly recommended. Each would also need to be validated across production regions.
3. Research methods for increasing or enhancing beneficial populations within cropping areas and potential for push-pull systems.
4. Further testing of predatory mites releases in open hydroponic or field lettuce where WFT have been a major problem; following on from VG07003 (Development of IPM Strategies and Tools for Western Flower Thrips (*Frankliniella occidentalis*) in Hydroponic Lettuce).
5. Development of effective use of the Helicoverpa lure and an *attract and kill* approach in lettuce and other vegetable cropping systems.
6. Research into IPM options for Rutherglen bug management or disinfestation.
7. Further research into the impact of agricultural chemistry used in lettuce and other crops on beneficials.
8. Production of resource materials on maximising efficacy of biological insecticides, on impact of pesticides on beneficials and residue periods.
9. On-going periodic independent testing of new crop protection products to verify efficacy, assess best-fit in IPM recommendations and identify potential risks.
10. Access to trusted and competent IPM technical support in all major lettuce production areas.
11. Develop IPM training/ professional development options for agronomists and crop consultants, potential for IPM technical support service.
12. High level discussions between vegetable industry, processors, supermarkets and RD&E providers on crop protection issues such as residues, insect contaminants, food safety concerns and quality specifications. Develop lettuce/vegetable contingency plans, realistic quality specifications and identify RD&E needs.
13. Develop a ‘market –pull’ strategy for IPM.
14. Investigate the potential for a study to provide numbers to define the level of the insect contamination problem for processors and fresh market segments. An outline of a project is at the end of Chapter 13 IPM and Markets.
15. Hosting a 4th Australian Lettuce Industry conference with an emphasis on training workshops and interaction along the market chain including RD&E providers.
16. Development of a website that hosts the information resources related to lettuce crop protection in a form that is easy for growers and their advisors as well as RD&E providers to find the current and relevant information on pests, management options, previous RD&E, and future options in a variety of formats.
17. Industry has an agreed strategy for RD&E providers communicating with growers in all States.
18. Grower crop protection benchmarking questions be used, with some modification to improve clarity, as a standardised set of questions for future grower surveys to track changes in practices.

20. Acknowledgements

The Project Team gratefully acknowledges the input of growers, their family and staff, researchers, consultants, seed companies, rural suppliers and other industry stakeholders who contributed to the successful delivery of this project. Their generous assistance is much appreciated.

In particular, projects such as this would not be possible without growers who believe in the objectives of the project, are keen to learn through first-hand experience and are willing to have researchers use their properties for trials and demonstrations.

In Queensland thank you to Taylor Family Produce and their staff based at Stanthrope for hosting the IPM demonstration trial and allowing other growers and resellers access to the trial site. Special thanks to Taylor Family Produce staff members Dean and Mark who looked after the irrigation and the spraying of the IPM block. Thanks are also due to Rae Taylor, and Denise and son Tim Harslett for talking to camera about their experiences of IPM in lettuce.

In NSW we would like to three lettuce growers from Western Sydney in particular: Eddie Galea of Werombi Farm Produce for hosting the IPM demonstration and associated 3 field days, for planting trays of untreated *Nas*-susceptible lettuce each planting for 12 months over 2008/2009, as well as sharing his experiences via a video casestudy; Joe Vacaro of Vineyard for hosting the Bion® and Movento® efficacy trials on open hydroponic lettuce; and Joe D'Anastasi of Glenorie Hydroponics for sharing his experiences of IPM on video.

In Hay NSW we would like to thank John Langley for hosting the *Nas*-resistant lettuce variety trials, and John Mirabelli and Xavier Molloy for planting untreated *Nas*-susceptible for monitoring for CLA.

From Cranbourne we would like to thank Paul Gazzola for his participation in the video casestudies.
In Tasmania we thank Mark Kable and Lydia Rigby from Harvest Moon, and Kate Turner from Houston's Farms for their assistance and participation in the video casestudies.

Thank you to DEEDI staff Kirsten Ellis for assistance with crop scouting and with setting up each weeks trap collection in Stanthorpe and Craig Henderson who provided advice on setting up the FullStops®, soil solute analysis and preparing graphed results Thanks also to CSIRO staff Dr Nancy Schellhorn for loaning the Malaise traps and Ms Anna Marcora for the crash course in Malaise catch sorting. Thank you to Mr Anthony Hawes of Ag Biotech for providing Vivus Max® for use in the Stanthorpe trial.

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Additionally the Project Team would like to thank growers, resellers and other industry stakeholders who made the time to visit trial and demonstration sites to assess the lettuce and ask questions.

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22. Appendices

Appendix 3-1 History of Lettuce IPM RDE in Australia

Lettuce IPM Development

Lettuce production areas in different states share many of the same insect pests. In 1998 the first of a series of lettuce integrated pest management (IPM) projects was funded with support from the newly introduced vegetable industry levy. This project, '*Adapting to change: enhancing change skills through collaboratively developing an integrated pest and disease management strategy*' (VG98048), was a collaboration between NSW Agriculture (now NSW DPI) and QDPI (now DEEDI) with a voluntary contribution from Golden State Foods (GSF). The project included: lettuce crop monitoring; efficacy trials for new generation insecticides and biologicals for the control of caterpillars, particularly heliothis species (*Helicoverpa armigera* and *H. punctigera*); evaluation of the relative effectiveness of spray application equipment; and sclerotinia management options.

At this time DPI Victoria surveyed Victorian lettuce growers about key pest problems. As tipburn was more of an issue than heliothis, they submitted a separate successful proposal on managing tipburn (VG98082 '*Lettuce - Best management production practice to meet market requirements of consistent product quality and shelf life'*). However flights of *H. armigera* into Victoria in 1999 caused major damage, and the Victorian DPI project was modified to include monitoring of heliothis and insecticide efficacy trials. The project team for VG98048 ran some workshops with Victorian lettuce growers on the request of GSF and Costas. At this time, Paul Horne from IPM Technologies, an IPM consultancy company, had begun a celery IPM project in Victoria (VG99070 '*Development of an integrated pest management program in celery*'). Many of the collaborating celery growers were also lettuce growers and the *H. armigera* flights were causing problems in both crops. These became the first lettuce growers to adopt an IPM strategy.

By the end of VG98048, efficacy data had been generated for four new generation insecticides, three biologicals, and a botanical for control of heliothis with registration coming for Success®, Avatar® and Gemstar® and a permit for Bt products (McDougall 2002). Field survey data confirmed that pests and diseases were seasonal, which illustrated the importance of regular crop monitoring and the potential to reduce insecticide and fungicide applications. Beneficial insects were found in low numbers throughout the monitoring, indicating the removal of broad spectrum insecticides could allow them to multiply and assist with pest management.

Communication with the lettuce industry as a whole was important at the outset, with the first issue of the *Lettuce Leaf* newsletter being distributed in December 1999 and the First Australian Lettuce Industry Conference held in Hay, NSW in 2000. Growers and agronomists serving the lettuce industry were without information on what insect pests, diseases or beneficials they may find in their lettuce, so work began on an *Integrated Pest Management in Lettuce: Information Guide* (McDougall *et al.* 2002). A follow-on project from VG98048 was funded (VG01028 '*Improving lettuce insect pest management- NSW and SE Queensland*') with voluntary contributions from South Pacific Seeds and Convenience Foods, but unfortunately, without the disease management or spray application components. This project continued to conduct efficacy trials for heliothis management but started to include efficacy trials for sap suckers which became more important as the project progressed.

By 2002 silverleaf whitefly (*Bemisia tobaci* biotype B) [SLW] had arrived in the lettuce production areas of SE Queensland, causing considerable damage, and the currant-lettuce aphid (*Nasonovia ribis-nigri*) [CLA] was devastating the NZ lettuce industry (Stufkens *et al.* 2002). In addition, Western flower thrips (*Franklienella occidentalis*) [WFT] was expanding its range and moving more into field grown lettuce crops, causing considerable damage by spreading tomato spotted wilt virus [TSWV]. In total, VG01028 screened the efficacy of 23 new generation insecticides and some novel applications of old chemistry against various sap suckers and/or Lepidoptera (McDougall *et al.* 2005). There were some products, particularly the soil or seedling drenches that showed very good control of aphids and leafhoppers. A smaller group reduced whitefly numbers and data was inconclusive or variable on thrips control. There was also some evidence that the insecticides were toxic to some generalist predators.

VG01028 distributed the *Integrated Pest Management in Lettuce: Information Guide* and both produced and distributed the *Pest, Beneficials, Diseases and Disorders in Lettuce: Field Identification Guide* (McDougall & Creek 2003) to all lettuce growers. The *Lettuce Leaf* newsletter continued to keep the industry informed on research advances and industry issues, as did the second and third Australian lettuce conferences held in Gatton (May 2002) and Werribee (May 2004).

The development of an integrated pest management (IPM) strategy that was less reliant on insecticides was imperative for continued successful production of quality lettuce given WFT (Herron and Gullick 2001, Herron and James 2005), *Helicoverpa armigera* (Gunning and Easton 1993; Young *et al.* 2006), SLW (Gunning *et al.* 1995; Young *et al.* 2006) and CLA (Rufingier *et al.* 1997; Barber *et al.* 1999) all developed insecticide resistance. An IPM strategy must have regular crop monitoring of insect pests as well as beneficial insects. All reasonable effort needs to be made to reduce the chances of pests colonizing crops to maximise the chances of beneficials to manage the pests. Important cultural management practices include ensuring seeds and seedlings are insect pest and disease free, and removing sources of insect pests and diseases, including finished crops, infested/infected hosts and weed hosts. If insect pest numbers are high enough to be causing damage, the choice of insecticide should consider the impact on the beneficials present, and, where possible, consider options that complement the beneficials. Ideally, the IPM approach is applied to all crop pests, including management of nematodes, weeds and vertebrate pests.

Currant Lettuce Aphid IPM projects

The currant lettuce aphid (CLA) arrived in 2002 and spread throughout New Zealand within the year. It was probably blown across to Tasmania in late January 2004 (Stufkens *et al.* 2004) as it was detected in lettuce crops in both the north and south east of Tasmania in March of 2004. An emergency project was funded by the vegetable levy and led by Tasmanian DPI member, Lionel Hill (VG04067 '*Integrating lettuce aphid into IPM for lettuce- a commercial trial*'). At the time, the entire New Zealand industry was using imidacloprid seedling treatments but a New Zealand MAFF Sustainable Farming Fund project for development of an IPM strategy for field lettuce had been funded just prior to CLA's arrival, and they immediately began trials for control options for CLA (Walker *et al.* 2005). From the first of these trials in Pukekohe, North Island they found beneficials, particularly the brown lacewing (*Micromus tasmaninae*), could effectively control CLA numbers by spring lettuce harvests. A fungus, *Erynia neoaphidis* contributed to CLA control over winter. It was also known that aphid predators and parasitoids were quite effective in controlling existing aphid species infesting lettuce in Australia. In 1996, Rijk Zwaan released the first *Nasonovia ribis-nigri* resistant lettuce (van der Arend 2003) but most of the commercially available *Nas* –resistant varieties available in Australia were fancy-types and the few head lettuce were not well trialled in the major production areas.

The initial single year project in Tasmania was designed to be a commercial scale trial-demonstration of an IPM approach. Beds of *Nas*- resistant and *Nas*-susceptible lettuce were planted with a small proportion imidacloprid treated at the seedling stage, but most were untreated (Hill *et al.* 2006). The crops were monitored on a weekly basis and management decisions were made in consultation with Paul Horne. Beneficial insects controlled CLA populations well in the spring and summer plantings, however in autumn, CLA numbers were high at harvest. There were a number of possible reasons for the low beneficial numbers in the autumn plantings, but with an unreplicated trial and a change in design from previous plantings, it was difficult to know why. Another component of this project was a 10 week study testing the impact of seedling drenches on brown lacewings (BLW). Imidacloprid applied at a rate of 11mL active ingredient (ai) per 1000 seedlings and thiamethoxam applied at 0.5g ai per 1000 seedlings were highly toxic to BLW larvae that consumed aphids from the seedlings for up to 4 weeks after application (Cole and Horne 2006).

With VG01028 and VG04067 finishing a new national project was commissioned to continue the work of both projects. This project was designed to have a commercial scale IPM trial-demonstration in each of the major production areas. In each region State department entomologists would work with the grower collaborator, their consultant if they have one and Paul Horne would act as an external IPM consultant throughout the trial. At the time we did not know when CLA would colonise the mainland lettuce areas and planned for a 4 year project. The first two years of this project became VG05044.

VG05044 included commercial-scale IPM trials in head lettuce and babyleaf in southern Tasmania, monitoring of lettuce on commercial IPM farms in Werribee south and Cranbourne in Victoria and a winter-spring IPM trial near Camden in Sydney. Monitoring of hydroponic and field lettuce crops and surrounding weeds for lettuce pests and diseases, in particular for currant lettuce aphid (*Nasonovia ribisnigri*) (CLA) was conducted in the Sydney basin, the lettuce production areas north of Perth and to some extent in South Australia. Soil samples from lettuce producing areas of Victoria, Tasmania, NSW and South Australia were screened for predatory mites. A soil amendment trial was conducted to increase predatory mite populations. A small efficacy trial was conducted of the seed treatment formulation of imidacloprid, Gaucho®. Grower and lettuce consultant surveys were undertaken to establish grower crop protection practices and attitudes towards IPM.

In southern Tasmania six autumn growing iceberg plantings were managed using IPM principals and were assessed as commercially viable. The first six of eleven IPM managed 'loose-leaf' lettuce plantings were deemed to meet commercial standards but too many CLA were present in the last five plantings. Intensive data was collected on aphid and predator numbers at three of the large IPM lettuce growers in Victoria which showed the importance of Brown lacewings (*Micromus tasmaniae)* in managing CLA numbers. A winter-spring IPM demonstration/trial in Sydney revealed the difficulty in managing CLA during winter if no aphid predators are present.

A survey of soil predatory mites found a *Pergmasus* species present in lettuce soils in surveys in South Australia, Victoria, Tasmania and NSW. Applying composted greenwaste to the soil greatly increased the numbers of predatory mites.

Given most lettuce growers had moved to using Confidor® (imidicloprid) on their lettuce, not many growers were looking to adopting IPM. A series of consultative meetings were held in each state and growers were asked to respond to a questionnaire regarding this project (see Appendix 16-1). The sentiment expressed by growers was that they wanted to see the project continue because they saw that they would have to adopt IPM in the future even though they were not prepared to adopt it presently.

Appendix 4-1

Pest and Beneficial insects collected in Queensland IPM lettuce demonstration trials.

PEST SPECIES	
Currant Lettuce aphid	*Nasonovia ribis-nigri*
Brown Sowthistle aphid	*Uroleucon sonchi*
Onion thrips	*Thrips tabaci*
Western flower thrips	*Frankliniella occidentalis*
Common brown leafhopper	*Orosius argentatus*
Vegetable leafhopper	*Austroasca viridigrisea*
Rutherglen bug	*Nysius vinitor*
Helicoverpa sp (*Helicoverpa spp.*)	*Helicoverpa punctigera and Helicoverpa armigera*
Mirid	Miridae
BENEFICIAL SPECIES	
Transverse ladybeetle	*Coccinella transversalis*
Spotted amber ladybeetle	*Hippodamia variegata*
Minute 2 spotted ladybeetle	*Diomus notescens*
Damsel bugs	*Nabis kinbergi*
Brown lacewing	*Micromus tasmaniae*
Green lacewing	*Mallada signatus*
Rove beetles	Staphalinids
Hover fly larvae	Syrphidae
Predatory thrips	*Haplothrips* spp.
Parasitoids	Aphilinidae
Predatory mites	
Spiders	Various

Appendix 4-2

Registered products applied to the Queensland lettuce IPM demo and commercial area throughout the trial period.

Date	**IPM blocks**	**Comment on Crop**	Date	**Commercial Area**	**Comment on crop**
8th Feb 2010	Polyram + Kocide Blue	Wind damage to leaf.	9th Feb 2010	Proclaim + Calcium + Copper	Low level mildew present.
15th Feb 2010 *Trichogramma sp* wasp released.	Vivus Max + Pirimor + Ridomil Gold + copper	Low *Helicoverpa* pressure, couple of small larvae present. Moderate aphid present and moderate downy mildew.	15th Feb 2010	Lannate + Avatar + Ridomil Gold + Copper + Calcium	Mildew pressure moderate, no aphid.
22nd Feb 2010 *Trichogramma sp* wasp released.	Vivus Max + Dipel + Pirimor + Copper + Filan	Low to moderate *Helicoverpa sp*, higher than last week and odd small larvae	22nd Feb 2010	Procliam + Copper + Calcium + Molybdenum.	A lot of mildew and sclerotinia present
1st March 2010 *Trichogramma sp* wasp released.	Vivus Max + Dipel + Pirimor + Copper + Filan + Acrobat	Low to moderate *Helicoverpa sp* pressure, one live small larvae, dead larvae present.	3rd March 2010	Avatar + Polyram + Copper + Magnesium	Snails near drain and mildew present.
8th March 2010 *Trichogramma sp* wasp released.	Vivus Max +Dipel + Polyram + Copper Beneficial local wasp and spiders noticeable in crop.	Sclerotinia levels on the rise, after continuous drizzle. Mildew moderate to high levels and perfect mildew conditions.	Commercial crop first blocks just being harvested.	Crop being cut Out	
15th March 2010	Vivus Gold + Dipel	Moderate pressure, one small *Helicoverpa sp* larve. Half block harvested this week.	Commercial crop cut out.		
22nd March 2010	Vivus Max + Copper	Moderate *Helicoverpa sp* pressure. Crop cut out in seven days.			

Appendix 4-3

Weather records for the Queensland IPM Demonstration trial period.

Source: Stanthorpe Bureau of Meteorology station 13 km east of the trial area.

Date	Day	Temps		Rain
		Min	Max	
		°C	°C	mm
January				
29	Fr	16.4	26.2	15.6
30	Sa	18.1	26.9	0
31	Su	18.2	23.9	6.8
February 1	Mo	17.2	21.4	4.9
2	Tu	16	23.5	2.2
3	We	17.3		1.8
4	Th		24.5	0.6
5	Fr	15.1	26.9	0
6	Sa	18.5	25.2	2.8
7	Su	17.9	23.8	3.4
8	Mo	17.4	25	0.8
9	Tu	17	25.6	0
10	We	15.2	26.5	0
11	Th	13.5	27.8	0
12	Fr	14	30.5	0
13	Sa	14.5	29.8	0
14	Su	16.7	33	0
15	Mo	21.2	28	5.3
16	Tu	18.9	24.9	19
17	We	17.1	25	2.5
18	Th	17	24.2	0
19	Fr	15	22.4	0
20	Sa	15.9	24.3	0
21	Su	15.5	27	0
22	Mo	15.5	28.9	0
23	Tu	13.5	31.6	0
24	We	18.5	21.1	2.2
25	Th	16.8	22.1	0
26	Fr	15.2	21.2	1.5
27	Sa	15	24.1	0.2
28	Su	16.7	26.9	0

Date	Day	Temps		Rain
		Min	Max	
		°C	°C	mm
March 1	Mo	18.8	19.8	11.9
2	Tu	15.6	18.5	33.2
3	We	15.3	20.9	8.8
4	Th	16.2	22.3	0.6
5	Fr	16.8	22	0.2
6	Sa	18	21	13.4
7	Su	16.6	23.8	0.5
8	Mo	16.9	22.7	3.4
9	Tu	15.7	27.4	0.4
10	We	10.4	28	0
11	Th	16.9	23.9	0
12	Fr	14.7	21.1	0
13	Sa	14	21.7	0.4
14	Su	14.4	20.6	0.2
15	Mo	14	22.8	0.6
16	Tu	14.4	23.2	0
17	We	14.1	23.5	0
18	Th	14.5	22.7	0
19	Fr	15.1	23.7	0
20	Sa	10.1	22.9	0
21	Su	13.2	28.5	0
22	Mo	13.4	27.3	0
23	Tu	16.8	25	1.7
24	We	15.1	25.4	1.2
25	Th	14.8	23.8	0
26	Fr	13.1	27	0
27	Sa	10.8	27.3	0
28	Su	12.1	24.4	0
29	Mo	15.2	26.9	0
30	Tu	13	26	0
31	We	16.8	22.1	1.2

Appendix 10.1 – Statistical analysis of 2008 cereal trial

Total Beneficials Somersby

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
planting	17.46	2	8.73	<0.001
days	85.53	9	9.50	<0.001
variety	31.66	3	10.55	<0.001
planting.days	60.39	11	5.49	<0.001
planting.variety	8.32	6	1.39	0.216
days.variety	50.71	27	1.88	0.004
planting.days.variety	47.86	33	1.45	0.046

Table of predicted means for planting.days.variety

	variety	barley	oats	rye	wheat
planting	days				
1	122	2.301	2.213	2.105	1.773
	143	2.543	1.611	3.683	1.812
	164	3.290	2.000	2.452	2.961
	179	*	*	*	*
	185	1.519	2.307	1.985	1.423
	214	1.642	2.322	1.249	0.400
	234	3.290	2.000	2.452	2.961
	255	2.302	1.524	1.146	1.029
	276	2.976	2.417	1.559	2.247
	305	*	*	*	*
2	122	1.723	2.361	1.559	1.395
	143	2.055	1.694	2.049	1.973
	164	*	*	*	*
	179	2.165	1.995	2.068	2.249
	185	1.000	0.930	1.629	1.429
	214	2.952	3.102	2.103	1.366
	234	1.989	3.056	1.684	1.493
	255	1.866	2.324	2.238	1.029
	276	2.762	2.540	1.623	2.106
	305	*	*	*	*
3	122	*	*	*	*
	143	*	*	*	*
	164	0.930	0.746	1.340	0.766
	179	*	*	*	*
	185	1.229	1.546	0.746	0.800
	214	2.368	1.620	1.346	1.768
	234	2.190	2.266	1.722	1.856
	255	2.088	2.883	1.886	1.373
	276	2.261	2.375	2.155	1.519
	305	3.576	4.055	2.095	2.430

Standard error of difference = 0.5471

Total Aphids Somersby

Fixed term	Wald statistic	d.f.	Wald/d.f.	chi pr
planting	14.58	2	7.29	<0.001
days	101.53	9	11.28	<0.001
variety	103.29	3	34.43	<0.001
planting.days	86.09	11	7.83	<0.001
planting.variety	5.11	6	0.85	0.529
days.variety	74.20	27	2.75	<0.001
planting.days.variety	56.83	33	1.72	0.006

Table of predicted means for planting.days.variety

	variety	barley	oats	rye	wheat
planting	days				
1	122	5.746	4.216	4.161	2.053
	143	5.926	4.847	3.382	2.132
	164	2.336	5.985	2.460	1.477
	179	*	*	*	*
	185	2.190	6.585	2.821	2.250
	214	3.129	2.961	1.922	1.213
	234	2.336	5.985	2.460	1.477
	255	3.037	2.384	1.146	0.683
	276	2.187	2.253	1.013	1.413
	305	*	*	*	*
2	122	2.138	1.468	0.800	1.505
	143	2.942	1.802	1.602	1.029
	164	*	*	*	*
	179	5.678	5.236	3.819	2.750
	185	4.638	6.418	3.297	2.666
	214	7.041	12.520	3.925	3.395
	234	3.134	10.675	4.836	2.083
	255	1.712	1.862	2.434	0.600
	276	6.831	1.540	1.000	2.808
	305	*	*	*	*
3	122	*	*	*	*
	143	*	*	*	*
	164	2.177	2.131	1.200	0.847
	179	*	*	*	*
	185	3.970	4.263	2.589	3.122
	214	4.877	8.449	2.879	5.305
	234	1.884	4.940	2.438	2.093
	255	1.462	2.211	1.906	0.766
	276	2.294	2.238	0.883	0.683
	305	1.346	2.851	0.283	0.000

Standard errors of difference = 1.386

Total Beneficials Yanco

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
planting	79.40	2	39.66	11.0	<0.001
days	39.06	5	7.81	184.5	<0.001
variety	78.82	3	26.27	186.3	<0.001
planting.days	34.31	5	6.86	184.7	<0.001
planting.variety	18.45	6	3.08	187.3	0.007
days.variety	24.70	15	1.65	184.5	0.065
planting.days.variety	24.66	15	1.64	184.8	0.066

Table of predicted means for planting.days.variety

	variety	barley	oats	rye	wheat
planting	days				
1	133	3.557	2.080	1.958	3.366
	155	2.019	0.929	0.483	2.150
	175	1.395	0.766	0.893	1.486
	210	1.841	1.924	1.029	1.173
	231	*	*	*	*
	253	*	*	*	*
2	133	2.994	1.594	3.071	2.552
	155	4.507	1.730	2.001	2.501
	175	2.872	1.558	2.477	3.353
	210	3.016	1.229	1.801	1.449
	231	*	*	*	*
	253	*	*	*	*
3	133	*	*	*	*
	155	1.859	1.319	0.800	0.800
	175	2.064	0.200	1.595	1.600
	210	2.415	1.338	0.976	1.602
	231	1.519	0.800	0.400	0.483
	253	1.359	1.049	0.200	0.600

Standard errors of difference: 0.5376

Total Aphids - Yanco

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
planting	41.57	2	20.75	15.7	<0.001
days	12.19	5	2.44	186.3	0.036
variety	61.80	3	20.60	188.2	<0.001
planting.days	16.01	5	3.20	186.5	0.008
planting.variety	13.14	6	2.19	189.0	0.046
days.variety	13.24	15	0.88	186.4	0.584
planting.days.variety	27.97	15	1.86	186.6	0.029

Table of predicted means for planting.days.variety

	variety	barley	oats	rye	wheat
planting	days				
1	133	1.8822	1.0293	0.2000	0.2828
	155	1.1121	0.4828	0.2000	0.4000
	175	0.0000	0.6828	0.2000	0.2828
	210	0.2000	0.9464	0.0000	0.2000
	231	*	*	*	*
	253	*	*	*	*
2	133	1.3936	0.6828	0.9463	0.9727
	155	1.9827	0.9301	0.9142	1.0325
	175	2.6949	1.2828	1.7976	0.6828
	210	1.7545	0.4000	0.5097	0.2000
	231	*	*	*	*
	253	*	*	*	*
3	133	*	*	*	*
	155	1.1121	0.8828	0.9464	0.4828
	175	2.9791	1.0000	0.8828	0.9464
	210	2.4704	1.2585	0.2000	0.8000
	231	1.2765	0.6828	0.2000	0.4828
	253	1.3981	1.7119	0.9464	0.4828

Standard errors of differences Average: 0.5190 *1.96 =lsd

Appendix 10. 2 – Statistical analysis of 2009 cereal trial

Yanco ANOVA Summary

Site	Method	Days	Treat	Total Aphids	Total beneficials	Total insects	Total pests
Yanco	Bugvac	162	Barley	14.3	6.5	47.7	17.5
			Lettuce	2.7	6.5	31.7	9.3
		F-prob		**0.020**	**0.979**	**0.001**	**0.009**
Yanco	Bugvac	181	Barley	61.00	15.8	108.0	65.2
			Lettuce	37.8	6.7	68.2	41.5
		F-prob		**0.190**	**0.036**	**0.046**	**0.111**
Yanco	Bugvac	203	Barley	293	14.2	329	296
			Lettuce	110	14.3	152	124
		F-prob		**0.037**	**0.487**	**0.048**	**0.053**
Yanco	Visual	162	Barley	0	Too low	3.33	2.17
			Lettuce	0	Too low	2.17	0.83
		F-prob		**-**	**-**	**0.524**	**0.317**
Yanco	Visual	181	Barley	166	1.0	176	171. 169.
			Lettuce	166	1.0	174	
		F-prob		**-**	**-**	**0.589**	**0.579**
Yanco	Visual	203	Barley	781	9	830	818
			Lettuce	1422	4.2	1483	1472
		F-prob		**0.34**	**0.212**	**0.301**	**0.298**

Somersby ANOVA Summary

Site	Method	Days	Treat	Total Aphids	Total beneficials	Total insects	Total pests
Somersby	Bugvac	161	Lettuce	0.67	1.2	6.5	1.3
			Oats	6	1.7	24.2	13.7
		F-prob		**0.007**	**0.706**	**0.021**	**0.003**
Somersby	Bugvac	181	Lettuce	4.3	3.7	24.0	5.3
			Oats	16.7	7.0	45.2	24.0
		F-prob		**0.013**	**0.229**	**0.072**	**<0.001**
Somersby	Bugvac	202	Lettuce	16.3	7.3	33.7	16.7
			Oats	28.3	3.5	45.3	31.0
		F-prob		**0.106**	**0.174**	**0.177**	**0.039**
Somersby	Visual	161	Lettuce	2.67	2.0	7.5	3.0
			Oats	2.00	2.0	6.7	2.5
		F-prob		**0.443**	**0.67**	**0.558**	**0.446**
Somersby	Visual	181	Lettuce	9.2	1.8	14.8	9.3
			Oats	14.7	6.8	32.3	16.2
		F-prob		**0.975**	**0.373**	**0.474**	**0.795**
Somersby	Visual	202	Lettuce	24.8	5.5	31.8	25.3
			Oats	20.3	3.7	26.5	20.5
		F-prob		**0.166**	**0.12**	**0.307**	**0.141**

Appendix 13. 1

Background to Lettuce Integrated Pest Management and Questions sent to lettuce processors

Sandra McDougall (NSW DPI) Yanco

Sent: March 2009

As project leader on a national lettuce integrated pest management (IPM) project I am contacting you as one of the players in the lettuce market chain. I am canvassing the players in the lettuce market chain about how you each interact with lettuce growers on issues about how they grow their lettuce, as well as what drivers or barriers there are from the market chain for greater adoption of IPM. Ideally I'd like that the lettuce market chain and the lettuce IPM project can work collaboratively or at least in a complementary way in improving lettuce pest management.

Lettuce IPM through the Market Chain

Although we involved the market-end more in the organising and as participants at the lettuce conferences (2000, 2002, 2005) we haven't properly engaged with it around IPM, particularly since we ceased organising the national lettuce conferences on the request of AUSVEG. The movement towards quality management and risk management has obviously led to more prescriptions on what growers do. In many ways the arrival of CLA has led to the demise of a biologically based IPM given many processors at least initially require growers to use imidacloprid. The lettuce IPM project has 18 months to 2 years left and I do not expect to seek further funding. We have seen almost the whole lettuce industry adopt crop monitoring and all now use some of the selective insecticides but we have only small pockets of growers that are using the natural enemies in their systems to assist with pest control. I need to clarify where the real barriers and drivers to greater IPM adoption are.

Issues to address with market chain:

Crop specifications, particularly acceptable insect contamination levels
Level of monitoring of lettuce quality at receival
Potential for post-harvest insect removal
Residue risk versus consumer aversion to insects-in-their lettuce
Insecticide prescriptions
    Detection of *Bacillus antracis* and *Bacillus thuringiensis*

What aims do we have in common?
Where do we differ and can we find strategies or solutions that serve both objectives?

A few questions that may assist in seeing where there is common ground and where we may have differing needs, and where we may be able to interact.

1. Do you have specifications on lettuce quality that relate to insects or insect pest management?
    a. If so are they available for us to look at?
2. Do you have any influence over, or interest in insecticides your suppliers use or do not use?
    a. If so what insecticides do you encourage or discourage?
3. Do you provide any insect management assistance, i.e. an agronomist who gives advice
4. Do you test for insecticide residues?
5. Do you do quality assessments that include numbers of insects found in a sample?
    a. If so do you keep records of the numbers? Is a summary available?
6. Do you keep records of complaints based on insect contamination?
    a. Again if so is a summary available?
7. Do you have any information on the types of insects or proportions that come out in washing? i.e. I understand Rutherglen bugs are quite difficult to wash out but that dead ones are easier than live ones.
    a. Would you be interested in trials to get data on effectiveness of washing process on insect removal?
8. What is your company's policy on trying to adopt an IPM or minimal insecticide use protocol over the coming years.
9. Do you think this approach is more suited to some crops than others ?

  a. If so which crops or products that you deal with do you think are most suited to the adoption of IPM ?

10. Would your company be open to collaborating with the Lettuce IPM team?
    a. Possible areas include:
        i. Meeting with field staff to discuss what is IPM
        ii. Getting actual data on insect numbers on lettuce at receival
        iii. Training for quality assessment staff to recognize different insect groups
        iv. Studies on numbers of insects on lettuce pre and post washing
        v. In-confidence collation of data of insect contamination, complaints and residual data?
        vi. Input on pest management aspect of food safety and environmental guidelines that you may be developing

If you would like some more background to IPM or the lettuce IPM projects directions see below:

IPM as a strategy

IPM as you may know is about managing pests using a range of tools with an emphasis of using natural enemies as the basis where possible, and then giving priority to complementary tools (selective insecticides or bioinsecticides) and only using broadspectrum insecticides as a last resort to get the required quality product. The motivation is driven by two aspects – one is that insects – particularly our 'key' pests evolve quickly and develop insecticide resistance hence having a primarily chemical approach to pest management leads to an ever increasing reliance on pesticide applications as efficacy diminishes (i.e. more and more frequent). This clearly has potential issues with MRLs and levels of pesticides in our foods. Secondly it often leads to failure – i.e having no insecticides that adequately control a pest i.e. situation with *Helicoverpa spp.* and Diamond Back Moth in the mid 1990ies. IPM works on developing an environment where pests are largely managed by their natural enemies hence it is resilient to pest invasion and in the long term a more reliable pest management strategy. An IPM strategy reduces the selection pressure for resistance as chemicals become a smaller part of the strategy. However it does mean that we do actually want insects – predatory or parasitic insects in the system to do the basic control of our pests. The benefits of IPM are crops have to be routinely monitored so there should not be any surprises at harvest on the pest status of a crop, secondly it should mean that there are a lot fewer insecticides used and those used are more selective often with very low mammalian toxicity hence less of a residue concern. Both aspects that I would assume that we would agree are desirable attributes. However small numbers of insects may be present in the crop, IPM crops shouldn't have extreme numbers that can be seen with insecticide resistant pests in a chemically managed crop but some are likely to be present. It is arguable whether there are more in a well managed IPM crop or a conventionally grown crop but the main difference is that in an IPM crop we are not seeking a complete eradication which is where we may have a conflict of interests.

Australian Lettuce IPM Projects (1998-)

The Lettuce IPM projects have focused on developing or making available options for growers to manage their insect pests with more selective insecticides and 'beneficials' [the natural enemies or predators of the insect pests]. Early focus was on efficacy trials for the selective chemistry to assist in getting these registered or permitted for use by lettuce growers. Crop monitoring protocols and information on cultural as well as biological control was collated to raise the awareness of growers and their consultants to better manage their pests. Some spray application work was conducted and demonstrations to again focus on improving the industries performance in this area be it IPM or conventional growers.

We now have a high level of awareness of IPM, pest management has improved in all areas, and in some areas we have IPM growers successfully managing their pests with very few judicious applications of insecticides. However when consulting with lettuce growers a number highlight that they cannot adopt an IPM strategy because the market has a zero tolerance for insects and they cannot risk their markets. In particular the arrival of Currant Lettuce Aphid (*Nasonovia ribis-nigri*) CLA has meant that most of the industry are now using Confidor® (imidacloprid) treated seedlings and this practice disrupts the biological control of a number of other pests. As a project team we feel the industry is leaving itself open to major problems down the track with insecticide resistance either to CLA and confidor or in managing other pests such as Western flower thrips and tomato spotted wilt virus (hydroponic lettuce only has access to one chemical and it already is showing resistance).

Appendix 13. 2

Email responses by lettuce processors

Processor 1. response to first email March 2009

We require all of our incoming produce to be insect free which is contradictory to the philosophy of IPM. Beneficial insects such as lady birds and lace wing bugs are deemed to be foreign matter. Our quality assessments are carried out at time of delivery of produce. Produce shall be of merchantable quality and free from disease, bruising, wilting, pest or foreign matter. In the event insects are discovered, the percentage of contamination throughout the consignment is recorded. It is not common practice to count the number of bugs per head, although there is a review of collection data during very high insect activity periods.

Our customers (retailers) expect that our product will be free from all foreign material – including insects. The consumer who purchases our product also expects that product will not contain any foreign material. All customer complaints are recorded. Often complaints are about foreign objects-bugs/ flies in salads, etc. This is seen as equally unacceptable as if there was glass or other foreign material in the product.

We encourage sustainable good farming practice which includes the use of selective and target specific insecticides and the limited use of broad spectrum insecticides. The imidacloprid drench will be a necessary precaution for us to ensure our incoming produce is pest free until science can offer us suitable NR varietal alternatives. We do not ask our growers to use any specific insecticides, however we do expect them to comply with the Australian Food Standards Code criteria for chemical residue in food. We monitor MRL by requesting MRL tests results annually on produce supplied. Our growers are audited annually and their chemical records are reviewed. Most of our suppliers are managing their pests using a range of tools, which include pest resistant cultivars, crop scouting and IPM. We see IPM as a tool for our growers to complement their existing pest management strategies. IPM will not suit every grower and every region.

The arrival of CLA (currant lettuce aphid) requires the use of NR resistant varieties or the imidacloprid drench (Confidor®). More work has to be done on NR varieties for us to recommend to our growers to use a particular variety of lettuce.
I see IPM more practical on fruit crops as opposed to leaf crops. (tomatoes, capsicum, cucumber)

Follow-up email questions (Appendix 13.2) were not responded to, and phone calls were not returned after email response was given.

Processor 2 (responses in red)

1. Do you have specifications on lettuce quality that relate to insects or insect pest management? Yes, we have limits in our material specifications.
2. Do you have any influence over or interest in insecticides your suppliers use or not use? Our contracts specify only registered chemicals to be used.
3. Do you provide any insect management assistance, i.e. an agronomist who gives advice. Not as such, but our field officers can share information.
4. Do you test for insecticide residues? Yes, we conduct an internal cycle of MRL validation testing in addition to requiring our growers to test.
5. Do you do quality assessments that include numbers of insects found in a sample? Yes
6. If so do you keep records of the numbers? Not separately.
7. Do you keep records of complaints based on insect contamination? Not separately.
8. Do you have any information on the types of insects or proportions that come out in washing? i.e. I understand Rutherglen bugs are quite difficult to wash out but that dead ones are easier than live ones. Apart from your example of dead vs live, we also know that washing will only remove low counts of insects.
9. What is your company's policy on trying to adopt an IPM or minimal insecticide use protocol over the coming years. We have no formal policy today, but have been actively encouraging it

for a few years. It is envisaged that we will be developing a comprehensive policy to deal with Food Safety and Environmental Sustainability over the next 6 months.

10. Do you think this approach is more suited to some crops than others ? If so which crops or products that you deal with do you think are most suited to the adoption of IPM ? In principle, no, I don't think so.

Follow-up email (Appendix 13.2) was not responded to.

Followup email with Processors 1&2

Sent Apr 2009

Thanks for your response -I am conscious that there are not many lettuce processors. Do you think your company would be open to working with the Lettuce IPM project on ways to reduce the insecticide residue risk or in promoting IPM? What do you think is the potential of improving post-harvest insect removal?

Issues to address:

- Crop specifications, particularly acceptable insect contamination levels
- Level of monitoring of lettuce quality at receival
- Potential for post-harvest insect removal
- Residue risk versus consumer aversion to insects-in-their lettuce
- Insecticide prescriptions

Detection of *Bacillus antracis* and confounding with residues of *Bacillus thuringiensis* (is this a problem you face?)

- What aims do we have in common? ... happy customers wanting to buy lettuce, processors suppling market with quality lettuce products, viable lettuce growers suppling quality product, lettuce growers consistently managing their pests using best -available information with minimal residues and minimal insect contaminants...

Where do we differ (? residues vs contaminants?) and can we find strategies or solutions that serve both objectives?

Regards,
Sandra

This email was not responded to by either processors.

Appendix 14-1 - Labels used on bags of fresh lettuce mix

Appendix 15.1 Consumer Survey questions

Introduction

This survey is about your likes and dislikes when buying fruit and vegetables, especially vegetables. We want to know about what things turn you off, what doesn't bother you, and what things you like. The results will be used to help the Australian vegetable industry supply products that meet consumers' needs.

1. Which of these statements best describes you:
   1 *I am a keen gardener and grow as many vegetables and herbs as I can*
   2 *I occasionally grow a few vegetables and/or herbs for my own use*
   3 *Although I am not growing any now, I have grown vegetables for my own use in the past*
   4 *I can't OR I am not interested in growing vegetables*

2. Please think about what matters most to you when buying fresh fruit and vegetables and rank the following in order of importance from 1 = most important to 10 = least important.

   Appearance
   Clean / dirt free
   Freshness / quality
   In season
   Locally grown
   No rots or bruises
   No insects
   Pesticide free
   Price
   Taste / aroma

2. A. When purchasing fresh fruit and vegetables do you choose organic products...?
   1 Always / often
   2 Occasionally
   3 Rarely
   4 Never / don't know

Now please indicate how much you agree or disagree with the following statements:

5 = Strongly agree
4 = Mildly agree
3 = Neither agree or disagree
2 = Mildly disagree
1 = Strongly disagree
0 = Don't know

3. Environment and horticulture

1 The quality of the Australian environment has been greatly reduced since European settlement
2 Most fruit and vegetables are grown in an environmentally friendly way
3 Many fruit and vegetable farmers are not responsible in their use of pesticides
4 Fruit and vegetables grown in Australia are safe to eat
5 Pesticide use in Australia is controlled by the Government
6 Supermarkets should favour suppliers who can show they use environmentally friendly production methods
7 Protecting the environment is very important to me

4. **Insect contamination**
   8 If I see a fly or mosquito in my home I usually kill it with fly spray
   9 Finding a ladybeetle sitting on some fresh herbs I had purchased would not bother me
   10 I would not eat salad if I had seen a bug in it, even if it had been washed to remove the bug
   11 If I found a caterpillar inside a lettuce I had purchased I would remove the damaged leaves and then wash and eat the rest of the lettuce
   12 If I found a bug inside a packet of salad leaves (eg rocket or Caeser salad kit) I would throw the whole thing away
   13 If I found a bug inside a packet of salad leaves I would definitely complain to the store I bought it from
   14 If I found a cockroach inside a packet of salad leaves I would throw the whole thing away

5. **Disgust**
   15 I might be willing to try eating monkey meat, under some circumstances
   16 Seeing a cockroach in someone else's house doesn't bother me
   17 If I see someone vomit, it makes me sick to my stomach
   18 I probably would not go to my favourite restaurant if I found out that the cook had a cold
   19 It would bother me to see a rat run across my path in a park
   20 Even if I was hungry, I would not eat a bowl of my favourite soup if it had been stirred by a used but thoroughly washed fly swatter

6. The red tipped bananas shown at the right are available in many retail stores. They are different to normal bananas because; (choose one answer only)
   1 They have been treated so they ripen more slowly
   2 They have been treated to stop them getting disease
   3 They are a different, sweeter variety
   4 They are grown with care for the environment
   5 They are organic
   6 Don't know / never seen before

IPM and Insects

Vegetable farmers often have to use pesticides on their crops at some stage during growing to control pests and diseases. In contrast, organic farmers don't use any synthetic chemical fertilisers or pesticides. Between these two is a third option known as "integrated pest management" (IPM).

Farmers who grow with IPM use predatory insects and cultural methods to control pests. At times they also use pesticides, but wherever possible these are "soft" pesticides that specifically target the pest and minimise impact on the environment. The result is that IPM grown vegetables may have less pesticides but more insects (such as ladybeetles) on them compared to conventional vegetables.

7. Which of these statements best reflects your feelings about growing vegetables with IPM:
   1 IPM doesn't go far enough as farmers can still use pesticides
   2 It sounds like an improvement on the way farmers currently grow vegetables
   3 I am happy with the way farmers normally grow vegetables and there's no need to change
   4 I don't want there to be more insects on vegetables I buy

8. Would you be interested in purchasing vegetables grown using this method?
   1 Very interested
   2 Possibly interested
   3 Neither interested or not interested
   4 Definitely not interested / turned off

9. Given a choice between vegetables grown normally or a similar quality product grown using IPM *I would*:

1 Buy the cheapest one
2 Buy the normal vegetables because that's what I usually buy and I'm happy with them
3 Buy the IPM vegetables so long as the price wasn't >10% above that of the normal product
4 Buy the IPM vegetables even if they cost 20 - 30% more than the normal product

10. Thinking back over the last 6 months, the number of times I've found insects in purchased leafy vegetables (eg whole lettuce) is:
1 Never
2 Once
3 Two or three times
4 More than three times

Lettuce

11. Before using pre-prepared loose leaves in a salad (eg packaged lettuce mix, rocket or baby spinach leaves) *I would*
1 Always or usually wash them
2 Occasionally wash them
3 Rarely or never wash them as they have already been washed
4 I never use these products

12. In summer, I buy lettuce
1 Weekly, or more often
2 Fortnightly
3 Occasionally
4 *Never* - (skip next 2 questions)

13. I most frequently buy
1 Iceberg lettuce
2 Cos lettuce
3 Loose leaf types (eg butter, coral, oakleaf)
4 Prepared lettuce mix, either loose or bagged

14. Before I use whole lettuce leaves in a salad I would
1 Always wash them
2 Usually wash them
3 Occasionally wash them if they looked dirty
4 Rarely or never wash them

Appendix 16. 1 Lettuce IPM Consultation

Have your say on the directions of future Lettuce IPM work….

Background

Over the 2 years of VG05044 lettuce IPM project a number of IPM demonstrations were conducted, resource materials produced and extension activities and crop monitoring were conducted to varying degrees in each state. The demonstrations did show that CLA can be controlled by predatory insects but that autumn and winter is more difficult or if the predators are knocked out in the process of managing other pests. The demonstrations and crop monitoring in the Sydney basin also highlighted that good pest management is not just a factor of having beneficials and chemicals but also of having crops monitored by capable scouts who can pick up potential problems early, having systems in place to maximise cultural control methods such as weed management, optimal irrigation and nutritional programs, and effective spray application when sprays are applied.

Situation

Since the arrival of CLA in each production area we have witnessed a reduction in IPM adoption!

With VG05044 we expected to have an increase in IPM adoption so rather than start the next 2 years Lettuce IPM work on false pretences we need to consult with lettuce growers on what areas the project team works on.

We expect that CLA will develop resistance to Confidor® however that may be in 1 year or 10. We also know that CLA can develop resistance to the Nas Resistant varieties so we propose continuing to develop tools that growers can use to improve their pest management now and in the event of chemical failure.

Proposal

We propose continuing the mix of extension and research activities with IPM demonstrations (priority to WA and QLD), further investigation of the potential of predatory mites for control of thrips and aphids, investigating using cereal crops as nurseries for beneficial insects, the importance of common weeds as disease hosts or pest reservoirs, and entering into a 'dialogue' with the supermarkets and processors about IPM.

Please come along to the consultation meetings –
If you can't then fax back your comments with your priorities for the next two years of Lettuce IPM research & extension.

Lettuce IPM Consultation Meetings
SA: 21st April – Virginia Hort Centre 1.30-4.30pm
WA: 22nd April – Wanneroo Tavern 4.30-6pm
QLD: 23rd April – Gatton Research Station – 2-6pm [SLW field day]
Vic: ?1st May – Werribee am, Cranbourne pm – more info to follow
NSW: 2nd May – Pioneer Room, UWS Richmond – 2-4pm

Please come along to voice your opinion

Your opinions will be collated and the project team together with a grower from each state and HAL will meet on 21st May to discuss the projects future directions.

Lettuce IPM Contacts
SA: Greg Baker, Tony Burfield (08 8303 9580)
WA: Sonia Broughton (08 9368 3271)
QLD: David Carey (07 5466 2244)
Vic: Paul Horne (0419 891 575)
NSW: Sandra McDougall (02 6951 2728)

If you can't come to a meeting please fill this in and fax back

Lettuce IPM Consultation

Name: (Optional) (please ☑)

Field lettuce grower ☐ Hydrolettuce grower ☐ allied industry ☐

Proposed work areas for June 08- June10:

1. Commercial scale IPM Demonstrations (priority to QLD & WA)
2. Potential for enhancing predatory mites – research use of soil amendments, feeding trials with mites
3. Trials of cereal crops as nurseries for beneficial insects within lettuce, particularly in autumn- winter period
4. Weeds as source of pests & diseases – field demonstrations of impact of keeping weeds cleared and resource materials on which weeds are more important to remove as sources of diseases or pests
5. Improving attitudes of Processors & Supermarkets towards IPM – having discussions and forum with processors and supermarkets to see what their attitudes are to IPM and whether there is potential to work together
6. Lettuce Leaf newsletter

Please give priority rating	low 1	2	3	4	high 5	shouldn't fund	Comments
IPM Demonstrations	○	○	○	○	○	☐	
Beneficial nursery crops	○	○	○	○	○	☐	
Predatory mites	○	○	○	○	○	☐	
Weeds as pest & disease hosts	○	○	○	○	○	☐	
Supermarkets & processors	○	○	○	○	○	☐	
Lettuce leaf newsletter	○	○	○	○	○	☐	
IPM Case studies	○	○	○	○	○	☐	
Information handouts	○	○	○	○	○	☐	
Practical workshop activities	○	○	○	○	○	☐	

Handout options (*tick ones you think would be helpful):* CLA alternative host poster ☐ Aphids on lettuce poster ☐ Key weed hosts of lettuce pests & disease ☐ Nas & downy resistant lettuce varieties ☐

Other suggestions____

Workshop options *(tick ones you would like to do):* Pest identification ☐ Beneficial identification ☐ Disease identification ☐ Weeds as pest & disease hosts ☐ Spray application ☐ How do Insects develop resistance ☐ Using biological pesticides ☐

Other suggestions____

Do you support continuing funding of lettuce IPM ? ☐ Yes ☐ No Why?

____

Return FAX 02 6951 2692 or
Sandra McDougall YAI, Yanco NSW 2703

NSW DEPARTMENT OF PRIMARY INDUSTRIES · Department of Agriculture Government of Western Australia · Tasmania · Queensland Government Department of Primary Industries and Fisheries · HAL Know-how for Horticulture™ · Vegetable R&D Your national vegetable levy at work · AUSVEG · SARDI South Australian Research and Development Institute

Australia -all TOTAL=26
Field lettuce grower 19 Hydrolettuce grower 1 allied industry 4 +2 not listed

Summary Lettuce IPM Consultation

Proposed work areas for June 08- June10:

Please give priority rating low 1 2 3 4 high 5 shouldn't fund Comments

IPM Demonstrations 0------1------4------10------8 1 only if reasonable numbers of growers turn up (4); has problems with survey (3); Good to see how well it works (3); much better than just chemical control (4)

Beneficial nursery crops 0------2------3------3------12 4 n/a hydro (didn't answer); not a question for grower (no response); uses IPM specialist does not need to know about the details (shouldn't fund); good to encourage predatory insects (3)

Predatory mites 3------2------3------5------10 2 n/a hydro- added to plugs?(1); Good need to educate buyers and processors (2); Very important (5)

Weeds as pest & disease hosts 1------0------3----- 4------15 0 also host of beneficials (5), all weeds a problem (3); great need to control (5)

Supermarkets & processors 2------3------4 -----2------10 3 maybe they are not interested (don't fund); don't understand (no response); more education for general public. IPM lettuce a disadvantage because Confidor lettuce is very clean. (5); need educating (5); growers need to understand IPM better first (3), changing consumer & markets attitudes towards bugs in lettuce critical (5); always learn from those intouch with consumers (3)

Lettuce leaf newsletter 2------2------4------5------11 0 very useful (5); good articles to look through (5); valuable communication from research (4)

IPM Case studies 1------0------5------5------11 2 good (5); for certain regions growers know who it is (5); depends on area/time of year/climatic conditions (4)

Information handouts 0------2------4------6------10 3 very useful (5); pictures can sometimes be confusing (4); always valuable for better management skills (4) [grower who didn't rate this is illiterate and so written handouts are of little use]

Practical workshop activities 0------1------3------7------12 2 interesting (5); only if reasonable numbers of growers turn up (5); if close to home otherwise financially hard to justify (4)

Handout options*:* CLA alternative host poster 8 Aphids on lettuce poster 9 Key weed hosts of lettuce pests & disease 15 Nas & downy resistant lettuce varieties 17
Other suggestions: DVD

Workshop options*:* Pest identification 14 Beneficial identification 17
Disease identification 14 Weeds as pest & disease hosts 14
Spray application 9 How do Insects develop resistance 7 Using biological pesticides 18 Other suggestions: Introducing new predator species
- spray application – we should all know that

Do you support continuing funding of lettuce IPM ? 21 Yes 3 No
give us enviro friendly approaches to attack pests; will be needed in the future; long term- no other choice; % implementation low and needs to increase; Source information; Because it is the future; because we can't do the research that you can do; IPM work better than more pesticides; gone too far to turn back; They need help even if they don't know it (allied)

As a grower who used IPM on lettuce instead of confidor & conventional program I can attest to its ability to work really well. The main problem is that the chem. Used is UV susceptible and needs to be sprayed in late afternoon /night. Funding should be used to help develop an additive to increase the UV tolerance. If farmers can spray when they want to the IPM becomes more practical and will be taken up by more people.
Everything that could possibly help us grow better produce is very important to me.

Appendix 16.2 Final Grower Survey Report

Introduction

In 2006 lettuce growers were surveyed as part of VG05044 to gauge attitudes to IPM, levels of adoption as well as some information on specific insect pest and disease management practices. In 2010 a one year Vegetable IPM Coordination project (VG09191) considered options for benchmarking IPM adoption in the vegetable industry. One of the options was a standardised grower benchmarking survey that could be used to collect survey data that could be used to monitor changes in crop protection practices. The questions were an amalgam of previous survey questions used in vegetable IPM projects and expanded to cover the suite of pests. Although the number of questions was large the feedback from stakeholders was that they were all useful questions.

This survey uses a modified version of the Vegetable Grower Benchmarking IPM survey to only include lettuce and not other crops, and include some project specific qualitative evaluation questions.

To get a true evaluation of a project or a proper benchmark of adoption of IPM practices it was important to try to survey a broad cross-section of lettuce growers, from those who engaged with the project to those who did not. To do this however, requires a comprehensive database of lettuce contacts. Each State grower association and Department of Primary Industry holds a list of growers in their state with varying degrees of information about what crops they grow. Due to Privacy legislation this contact information cannot be shared readily and each state was handled differently.

Materials and methods

An electronic survey was constructed in SurveyMonkey [http://www.surveymonkey.net]. The survey was divided into three parts including a short project evaluation (five questions), a set of 33 standardised tick-box questions on pest management practices, and another 8 questions that involved estimating levels of pest damage over the previous year and changes in practices and costs over the previous 5 years. A concluding section allowed for suggestions or comments about future research or any other related issue.

The survey link was publicised in the Lettuce Leaf newsletter issue 40, in the Vegetable Industry Development Program (VIDP) electronic newsletter and again on the cover letter that went out with the Lettuce Crop Protection Toolkit. Growers could complete the survey themselves on-line, request a printed version to fill in or answer over the phone.

Initially InnoVeg, the extension team of the VIDP, was contacted about the survey, they then passed the request onto the State grower associations. The State grower associations were then subsequently contacted directly by the project leader to see if they were prepared to conduct the survey of their state's lettuce growers or whether they were prepared to contact growers on our behalf. The interstate collaborators on this project were subsequently contacted as to whether they could contact lettuce growers to facilitate the completion of the survey. Although it was seen as preferable to have someone independent from the project conduct the survey there was the difficulty of accessing contact information. Through this and previous projects we had some contact information but had largely relied on interstate colleagues or the Vegetable Industry Development Officers for distribution of project related information in each state.

In Queensland David Carey, Extension Horticulturist from DEEDI contacted growers for the survey and in most cases visited them to do the survey face to face. Alison Anderson, the previous Vegetable Industry Development Officer for NSW (Sydney Basin) and the coordinator of the Lettuce Think tank (VG09057) was contracted to contact lettuce growers in

NSW (Sydney basin), Victoria and SA. She was seen as someone with trust and respect of lettuce growers but without direct involvement in this project. She contacted growers initially by telephone and then either did the survey over the phone or emailed them the link for them to do on-line. Similarly Bronwyn Walsh, a PhD student who has previous experience running IPM projects in Queensland, contacted WA lettuce growers to do the survey. David Troldahl, NSW DPI District Horticulturist contacted Tasmanian lettuce growers to encourage them to do the on-line version of the survey. Tony Napier, NSW DPI District Horticulturist visited the Hay lettuce growers and did the survey face to face.

All surveys were entered into SurveyMonkey and a results file downloaded for analysis.

Results

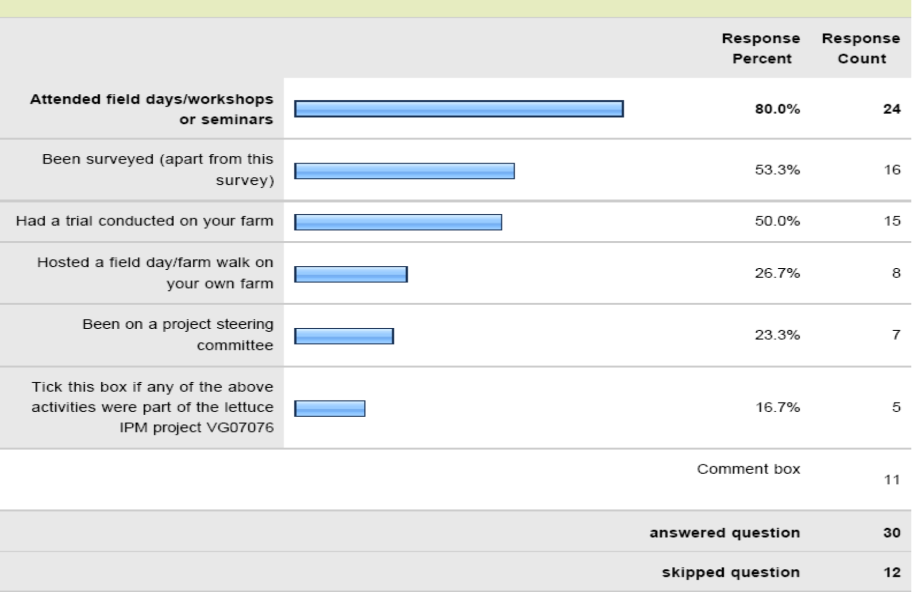
The first three questions were of their name, business name and the date of the survey. In total 42 lettuce growers completed the survey, with some from each State as well as the only NT lettuce grower. In NSW growers from the two main production areas were surveyed: Sydney basin (10) and Hay (5). In Queensland all growers surveyed were from Gatton, in SA the 3 growers were from the periurban area of Adelaide and the two main lettuce growers from Tasmania completed surveys, 9 lettuce growers in Western Australia from the peri-urban areas of Perth and 6 in Victoria.

Table 1. Respondents State and postcode of lettuce business.

Q4. In which state is your lettuce production business located?			**Q5. Postcode**
Answer Options	**Response Percent**	**Response Count**	**Post codes**
NSW	35.7%	15	2157, 2179, 2 x 2570, 2571, 5 x 2711, 3 x 2756, 2794, 2795
QLD	14.3%	6	6 x 4343
SA	7.1%	3	5253
Tas	4.8%	2	7025, 7310
Vic	11.9%	5	3030, 3221, 3865, 3912, 3977
WA	23.8%	10	6033, 2 x 6065, 6121, 2 x 6258, 4 x 6503
NT	2.4%	1	870
answered question			**42**
skipped question			**0**

Over 80% of the growers who completed the survey had attended field days or workshops, and 50% had hosted a trial on their farms hence could be considered as growers engaged with the RDE process (Table 2). Of those only 17% had been specifically engaged in those activities related to this lettuce RDE project although there is confusion at times about which project had sponsored or organised which event.

Table 2. Participation in RDE project activities



6. Have you ever participated in any of the following project activities run by the government or private providers in the last 3 years? (please tick all that apply)

	Response Percent	Response Count
Attended field days/workshops or seminars	**80.0%**	**24**
Been surveyed (apart from this survey)	53.3%	16
Had a trial conducted on your farm	50.0%	15
Hosted a field day/farm walk on your own farm	26.7%	8
Been on a project steering committee	23.3%	7
Tick this box if any of the above activities were part of the lettuce IPM project VG07076	16.7%	5
	Comment box	11
	answered question	**30**
	skipped question	**12**

Comments

Time factor to attend is the biggest issue

Not sure if lettuce IPM project related. Has been to lettuce conference in Richmond.

Would like to attend some local events but haven't in the past

Attended the Think Tank in Adelaide also. Field day was Werribee.

Haven't been able to afford the time off the farm. Margins tight so need to be on-farm to manage everything; so nothing goes wrong. Others in family business may attend.

Think the on-farm trials and workshops were part of the IPM Adoption project with Stacey Azzopardi and Sylvia Jelinek.

Have attended sweet corn and lettuce workshops but not sure what project they were part of. They were organised by NSW DPI.

Have attended field days in the past but don't think in the last 3 years.

Overall rating of some of the activities or outputs from the project were above average although the spread was very broad with some rating the activities as very poor through to excellent but with the overall majority scoring "NOT SEEN" for all outputs except the lettuce leaf newsletter.

Table 3. Rating of lettuce project extension activities.

Q7. How would you rate the following lettuce project activities on a scale of 1 (very poor) to 5 (excellent).

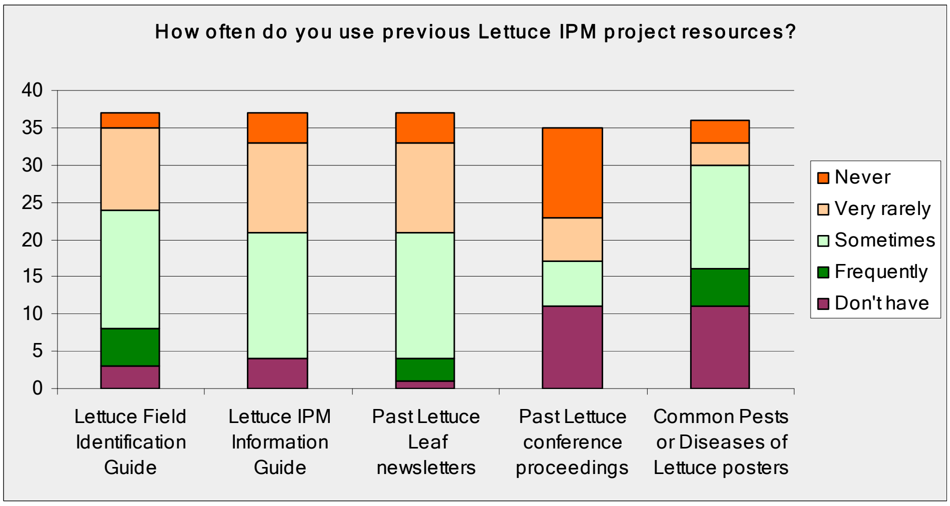
Answer Options	very poor	poor	satisfactory	good	excellent	NOT SEEN	Rating Average	Response Count
Lettuce Leaf newsletter	2	0	15	18	3	2	3.53	40
IPM demonstrations	1	1	2	7	3	24	3.71	38
DVD- grower casestudies	1	2	4	8	0	25	3.27	40
DVD- resource library	1	1	3	6	1	28	3.42	40
							answered question	**40**
							skipped question	**2**

In reference to use of resources produced in previous Lettuce IPM projects the Field Identification Guide and the Common Pests or Diseases of Lettuce Posters were the most referred to with the past conference proceedings being largely "never" used, and these latter two resources had not been distributed as widely hence a third of the growers did not have these resources (Table 4, Figure 1).

Table 4. Frequency of use of lettuce information resources

Q8. How often do you use previous Lettuce IPM project resources?						
Answer Options	**Never**	**Very rarely**	**Sometimes**	**Frequently**	**Don't have**	**Response Count**
Lettuce Field Identification Guide	2	11	16	5	3	37
Lettuce IPM Information Guide	4	12	17	0	4	37
Past Lettuce Leaf newsletters	4	12	17	3	1	37
Past Lettuce conference proceedings	12	6	6	0	11	35
Common Pests or Diseases of Lettuce posters	3	3	14	5	11	36
					answered question	**37**
					skipped question	**5**

Figure 1. Frequency of use of lettuce information resources



In reference to rating of the RDE investment into lettuce over the past 12 years the growers again voiced a wide range of opinions, with half agreeing with the statement that the projects had produced some useful information and that they, the growers had changed some practices (Table 5). However 17% thought they were a waste of money and 14% and 12% thought they were 'quite' or 'very' useful respectively and had changed the way they grew lettuce.

Table 5. Rating of investment spending into lettuce IPM

Q9. How do you rate the investment into lettuce IPM over the last 12 years? (please tick most appropriate)		
Answer Options	**Response Percent**	**Response Count**
Waste of money - I have not changed one practice	16.7%	6
Not really effective - I may have changed practices but not related to the projects	8.3%	3
Some useful results and information - I have adopted some new practices related to the projects	50.0%	18
Quite useful - The projects have changed how I manage lettuce pests	13.9%	5
Very useful - The projects have completely changed how I manage lettuce pests	11.1%	4
Comments		15
	answered question	**36**
	skipped question	**6**

Comments: (edited to remove names and 'none')

Use consultant so indirectly use information. Probably have the guides and posters, but not sure. As a result of having a crop consultant who visits fortnightly have completely changed how I manage pests, not using harsh chemicals anymore. Also get information from other growers.

Not sure as not growing lettuce at the moment. Keep resources on file in case I need to refer to them in the future.

Not sure as not growing lettuce at the moment. Identification and information guide good and still do refer to them occasionally in case they can assist in pest management in other crops. Keep them and old newsletters just in case I need to refer to them. Haven't read the newsletter lately because not growing lettuce.

Use bug checker so they see all that

Information used when required. Most problems are common so haven't had to use. Not many problems at the moment.

Usually ask someone rather than looking at the information I have.

Good information, haven't radically changed.

have changed practices as a result.

Staff use posters more often - probably frequently

Have always kept farm clean, weeds under control to minimise insect pests - got advice from a grower when started (and they may have got their information from the lettuce project)

Growing baby leaf mostly - anthracnose has been a problem.

Baby leaf can't have any imperfection so need to manage differently to iceberg lettuce (grown on other farms owned by the family).

Have learnt over time so know how to manage common pests and diseases now.

Have completely changed my approach to pest management

What I have learned from lettuce IPM I have transferred to other crops. I've also learnt from sweet corn IPM project.

calendar spray works best for my farm, tried ipm 3 years ago and was only time i got rejected for insects

Until the consumer changes their buying habits to not discriminate a purchase (or rejection of product) based on the presence of ladybirds and beneficial insects

Benchmarking practices

The following questions were based on the crop protection benchmarking grower survey and document current crop protection practices used by lettuce growers.

The growers surveyed reflect the mix of lettuce production systems found in Australia, with all growers growing for the domestic market, the majority growing field iceberg lettuce (747 ha), and most a small area of field grown cos lettuce (143 ha). Fancy (161 ha) and baby leaf (75 ha) were primarily grown in field with two growers using open hydroponics and one grower using an enclosed hydroponic system. 1126 ha of lettuce is covered by this survey. Approximately one quarter of the iceberg (23%) and cos (27%) lettuce was processed, and almost all (83%) of the babyleaf lettuce.

Q10. Please describe your lettuce production & marketing outlet in the table below (select options from drop-down menus): (GH = greenhouse)

- All lettuce was grown for the domestic market
- All iceberg lettuce was field grown (~932 ha), 67% was sold on the fresh market (~622 ha) and 33% for processing (~310 ha)
- All, but 1 ha of cos lettuce was field grown (~206 ha), 54% was sold on the fresh market (~112 ha) and 46% for processing (~95 ha)
- All fancy lettuce was sold on the fresh market (~175 ha), 91% was grown in the field, 4% in enclosed greenhouse and 3% on open hydroponic tables.
- The ~138 ha of babyleaf lettuce was field grown and 81% (~112 ha) was processed and 19% (~26 ha) was sold on fresh market.

Over half of the growers used seedlings from commercial nurseries (62%) and 38% directly seeded, only 21% grew their own seedlings (Table 6).

Table 6. Lettuce production method – seed or seedling

Q11. How do you grow your lettuce?		
Answer Options	**Response Percent**	**Response Count**
Direct seeded	38.2%	13
Seedlings (grow own)	20.6%	7
Seedlings (purchase from commercial nursery)	61.8%	21
	answered question	**34**
	skipped question	**8**

Almost three quarters (69%) of growers use a standard boom sprayer and a quarter use air-assist (Table 7). The three hydroponic growers who answered this question use a canon sprayer.

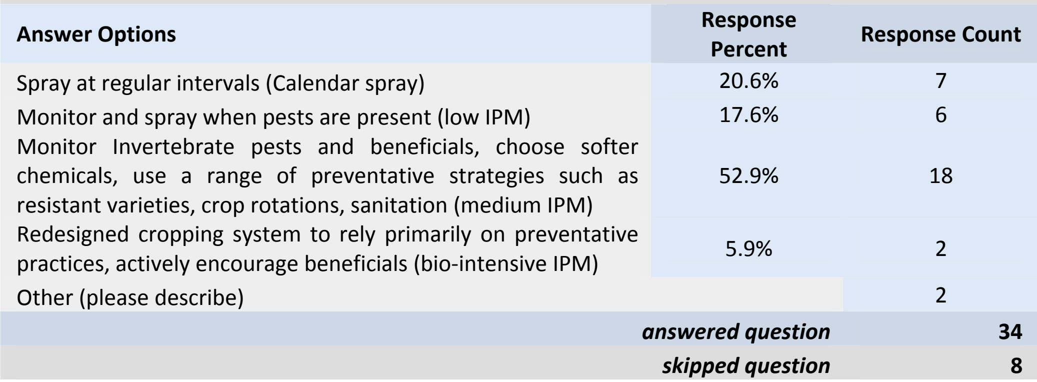
Table 7. Type of sprayer used.

Q12. What sort of sprayer(s) do you use? (select all that apply)		
Answer Options	**Response Percent**	**Response Count**
Standard Boom	68.8%	22
Boom with droppers	3.1%	1
Air-assist	25.0%	8
CDA	0.0%	0
SARDI head	0.0%	0
Canon	9.4%	3
Backpack	0.0%	0
Other (please describe)		2
	answered question	**32**
	skipped question	**10**

Other: GreenTech head (similar to SARDI head)

There was some confusion in this question with a number of growers ticking multiple boxes so if we rank the growers according to the furthest along the IPM spectrum that they nominated then 21% nominated that they were ‘Calendar sprayers’ and the remainder nominated one of the three IPM categories (Table 8). Just over half of the growers, 53% nominated that they used a ‘medium IPM’ crop protection strategy and 18% a ‘low IPM’ strategy with 2 growers nominating ‘bio-intensive IPM’. Two growers clarified that they used ‘calendar spraying’ for managing fungus diseases which helps explain the multiple nominations, one used ‘medium IPM’ for invertebrate pests and the other said they didn’t have insect pests in babyleaf but used IPM for other non-lettuce crops.

Table 8. Current crop protection strategy



Q13. What are your current crop protection strategies? (choose option that best applies to you)		
Answer Options	**Response Percent**	**Response Count**
Spray at regular intervals (Calendar spray)	20.6%	7
Monitor and spray when pests are present (low IPM)	17.6%	6
Monitor Invertebrate pests and beneficials, choose softer chemicals, use a range of preventative strategies such as resistant varieties, crop rotations, sanitation (medium IPM)	52.9%	18
Redesigned cropping system to rely primarily on preventative practices, actively encourage beneficials (bio-intensive IPM)	5.9%	2
Other (please describe)		2
	answered question	**34**
	skipped question	**8**

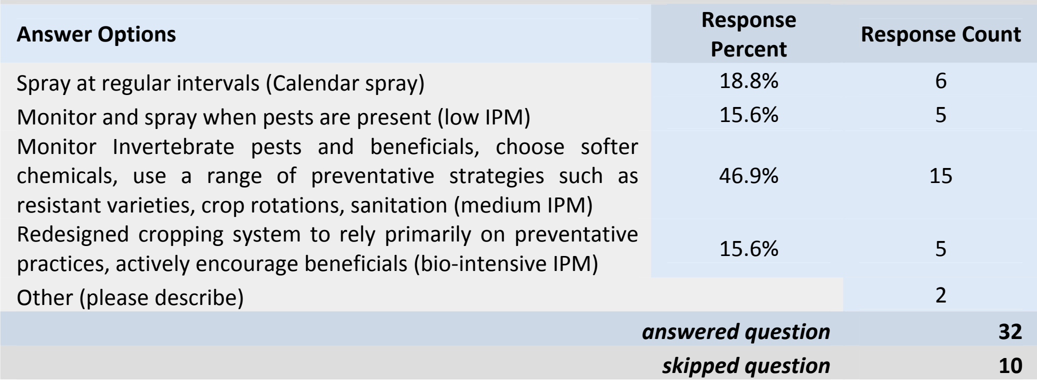
Other:

Spray at regular intervals - fungicides, Monitor invertebrate pests and beneficials etc - insecticides.

Babyleaf can't have any damage and has been humid this year so problem with mildew, for other vegetables IPM rather than calendar spray

When asked what strategy they aspired to be using in 5 years, only 4 growers aspired to something different to what they were currently doing (Table 9, Figure 2). In each case they nominated to be one step further along the IPM continuum, i.e. if ‘low IPM’ then aspire to be ‘medium IPM’ in 5 years and 3 growers who were ‘medium IPM’ aspired to be ‘biointensive IPM’ in 5 years. Two growers nominated that they would not be growing lettuce in 5 years.

Table 9. Crop protection strategy expected to be using in 5 years.



Q14. What strategy do you expect to be using in 5 years? (choose option that best applies to you)		
Answer Options	**Response Percent**	**Response Count**
Spray at regular intervals (Calendar spray)	18.8%	6
Monitor and spray when pests are present (low IPM)	15.6%	5
Monitor Invertebrate pests and beneficials, choose softer chemicals, use a range of preventative strategies such as resistant varieties, crop rotations, sanitation (medium IPM)	46.9%	15
Redesigned cropping system to rely primarily on preventative practices, actively encourage beneficials (bio-intensive IPM)	15.6%	5
Other (please describe)		2
	answered question	**32**
	skipped question	**10**

Other:

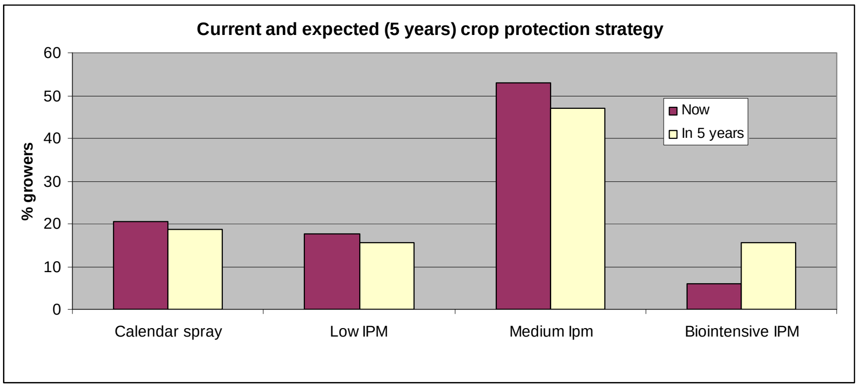
none going to leave industry

The same for fungicides and insecticides.

As required by the crop

Probably won't be growing lettuce in 5 years.

Figure 2. Current and expected (5 years) crop protection strategy

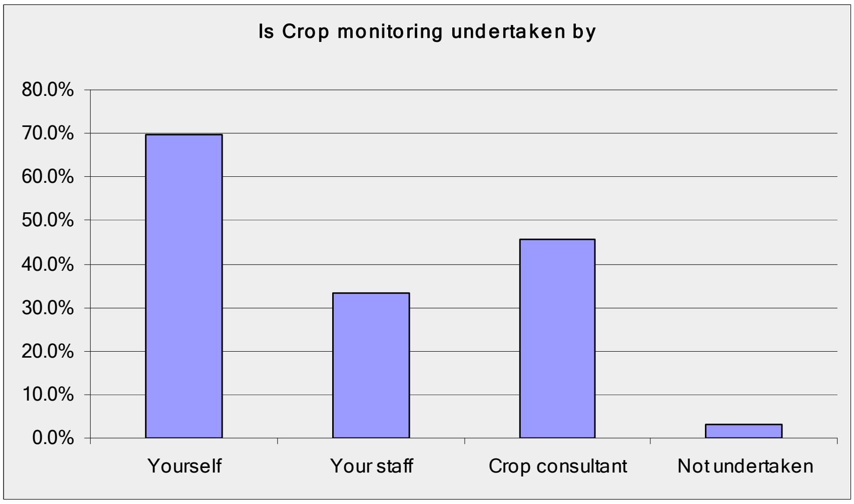


Five of the 7 growers who nominated they were calendar sprayers indicated that they monitored their crops themselves and two nominated monitoring was undertaken by a staff member as well as a crop consultant. One grower who didn't nominate anything on who did the monitoring subsequently answered that monitoring occurred more than once per week. Only one grower said monitoring was not undertaken. Seven of the 18 growers who nominated monitoring for beneficials as well as invertebrate pests did so either by themselves or by one of their staff, the remainder used a crop consultant (Table 10, Figure 3).

Table 10. Who monitors lettuce.

Q 15. Is Crop monitoring undertaken by		
Answer Options	**Response Percent**	**Response Count**
Yourself	69.7%	23
Your staff	33.3%	11
Crop consultant	45.5%	15
Not undertaken	3.0%	1
	answered question	**33**
	skipped question	**9**

Figure 3.

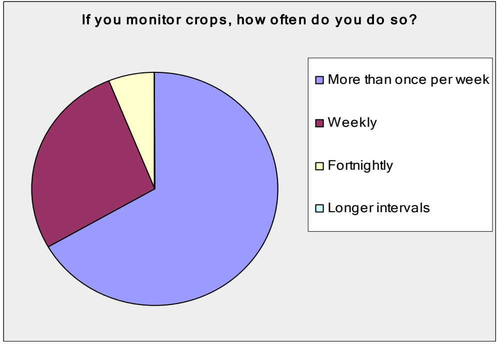


94% of growers monitored at least weekly (Table 11, Figure 4).

Table 11. Frequency of lettuce monitoring.

Q16. If you monitor crops, how often do you do so?		
Answer Options	**Response Percent**	**Response Count**
More than once per week	66.7%	22
Weekly	27.3%	9
Fortnightly	6.1%	2
Longer intervals	0.0%	0
	answered question	**33**
	skipped question	**9**

Figure 4.



All growers monitored for insects, almost all (94%) monitored for diseases, 76% for weeds, 73% for nutritional status and 55% for beneficials (Table 12). Only three growers monitored for nematodes and 7 water quality.

Table 12. What is monitored in lettuce.

Q17. If you monitor crops, what do you monitor for? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Insect pests	100.0%	33
Diseases	93.9%	31
Weeds	75.8%	25
Nutritional deficiency/toxicity	72.7%	24
Soil moisture	66.7%	22
Beneficials (predators or parasitoids of insect or mite pests)	54.5%	18
Mite pests	39.4%	13
Water quality	21.2%	7
Nematodes	9.1%	3
Other (please describe)		3
	answered question	**33**
	skipped question	**9**

Other:

Only mites if very hot; not many beneficials around
Soil moisture visually
Soil moisture is visual by digging a hole

31% of growers ‘always’, 38% don’t, and 31% ‘sometimes’ keep monitoring records (Table 13).

Table 13. Monitoring record keeping.

Q18. Do you keep records of the monitoring results?		
Answer Options	**Response Percent**	**Response Count**
No	31.3%	10
Sometimes	31.3%	10
Always	37.5%	12
	answered question	**32**
	skipped question	**10**

Of the growers who answered the question as to the use of preventative or sanitation practices the top strategies used by over 80% of growers were quality assurance programs (88%), crop rotations (85%), cultivation immediately after harvest (82%), resistant varieties (82%) and weed control (82%) (Table 14). 79% of growers used modified pH to reduce disease problems, 73% used soil amendments, 64% changed irrigation timing to reduce disease pressure and 52% planted consecutively. 39% rogued diseased plants and 36% used herbicide to spray off crops after harvest. Three growers had a biosecurity plan.

Table 14. Sanitation and preventative pest management practices used.

Q19. Which of the following sanitation or preventative practices do you have/use or have you used? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
A Quality Assurance program	87.9%	29
Crop rotation to reduce diseases	84.8%	28
Slash or cultivate crop in straight after harvest	81.8%	27
Use resistant varieties	81.8%	27
Control weeds to reduce pests	81.8%	27
Modify pH to reduce specific disease problems	78.8%	26
Soil amendments to improve soil health and to reduce disease problems	72.7%	24
Have changed the timing of irrigation to reduce disease pressure	63.6%	21
Plant crops consecutively	51.5%	17
Pull out plants showing disease symptoms and dispose of	39.4%	13
Spray off harvested crops with quick action herbicide (eg Spray Seed)	36.4%	12
Workflow designed to work in clean areas/crops first and in dirty/infested areas last	30.3%	10
Pull out plants showing disease symptoms and leave on ground	30.3%	10
An Environmental Management Strategy	24.2%	8
Have changed the method of irrigation to reduce disease pressure	24.2%	8
Don't plant new crops next to old crops	24.2%	8
Avoid hot spots	21.2%	7
Reuse water and test water quality	9.1%	3
A biosecurity plan	9.1%	3
Designate clean (disease or invertebrate pest-free) areas	9.1%	3
Reuse water with a strategy/method to reduce disease innoculum	9.1%	3
Plant new crops up wind of old crops/problem areas	9.1%	3
Spray out old crops with insecticide	9.1%	3
Other (please describe)		4
answered question		**33**
skipped question		**9**

Other:

Uses Round-up on weeds in areas not being used, within 2 yr rotation. Spray twice per year
Test water quality
Will drop QA as no advantage - costs $5000 of admin time
Using a light device to attract moths and pests which then drowns them - have one and it is meant to cover 5 - 10 ha

Question 20 asked about sanitation practices recommended for use in greenhouses. Only two growers surveyed grow lettuce in a greenhouse, one used a footbath before entering the greenhouse. Question 21 asked about sanitising hydroponic channels and the one of the three hydroponic growers sanitised annually or at other set intervals. Another washed out channels without using sanitisers between crops and the other sanitises if needed, which presumably means if he has disease problems in a previous crop.

None of the growers answered that they did not have a chemical user certificate, although almost half were unsure as to the AQF level of the certificate (Table 15).

Table 15. Chemical user certificates.

Q27. Which level of chemical user certificate do you have?		
Answer Options	**Response Percent**	**Response Count**
AQF 3	43.3%	13
AQF 4	0.0%	0
AQF 5	10.0%	3
Not sure	46.7%	14
None	0.0%	0
	answered question	**30**
	skipped question	**12**

Although no grower nominated that they never calibrated their sprayer, one has only done so once (Table 16). The remaining 32 growers who responded were evenly spread between calibrating every time they spray (24%), every 6 months (24%), annually (24%) and monthly to quarterly (24%).

Table 16. Sprayer calibration frequency.

Q23. How often do you calibrate your sprayer?		
Answer Options	**Response Percent**	**Response Count**
Every spray	24.2%	8
Monthly - quarterly	24.2%	8
Half yearly	24.2%	8
Annually	24.2%	8
Once only	3.0%	1
Never	0.0%	0
	answered question	**33**
	skipped question	**9**

Nine growers used quantitative methods for checking spray coverage (Table 17 and comments). Four used water sensitive paper, three used dye deposits on leaves and another two had spray equipment that monitored nozzle output. The majority (70%) looked at leaf wetness, another three had similarly imprecise methods and 5 or 17% didn't check at all.

Table 17. Spray coverage checks.

Q24. How do you check your sprayer setup for coverage? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Water sensitive paper	13.3%	4
Dye	10.0%	3
Look at leaf wetness	70.0%	21
Don't check	16.7%	5
Other (please specify)		5
	answered question	**30**
	skipped question	**12**

Other:
Make sure nozzles are clean and flowing - with water
only if have a problem
computer controlled output
Check spray tank levels to area sprayed.
Callibrate using timed nozzle and fluid delivery

Of the 27 of the 32 growers with a quality assurance program tested for residues, the majority (56%) used a ‘standard lab test’ which is unlikely to cover the new generation chemistry that most lettuce growers use (Table 18). Five growers who responded to this question did not residue test at all, all were NSW growers and one had a quality assurance program, two nominated to be ‘calendar’ sprayers.

Table 18. Chemical residue testing.

Q25. How do you residue test your produce?		
Answer Options	**Response Percent**	**Response Count**
Test for all chemicals used on property	25.0%	8
Standard lab test (write test name in comments field)	56.3%	18
Not sure what test	3.1%	1
Do not residue test	15.6%	5
If standard lab test, please specify test used:		9
	answered question	**32**
	skipped question	**10**

Lab test used:
To suit QA requirements
Full residue analysis and heavy metals
Med vet
part of QA for market agent, range of pesticides
c3 test
FreshTest - whatever they test for
freshtest
Sent to govt labs
symbio

Most of the growers (72%) who tested their lettuce for chemical residues did so once a year as is required by their quality assurance programs, eight or 29% of the growers tested more frequently (Table 19).

Table 19. Residue test frequency.

Q 26. If you do residue test, how often do you do it?		
Answer Options	**Response Percent**	**Response Count**
Once a year	71.4%	20
3-4 times per year	21.4%	6
5-10 times per year	7.1%	2
every planting	0.0%	0
	answered question	**28**
	skipped question	**14**

Three of the five growers who nominated that they didn't manage an insecticide resistant insect pest were calendar sprayers and two were 'low IPM' (Table 20). One commented that they don't have insect problems with babyleaf. Except for 2 growers, all growers who managed insecticide resistant pests managed *Helicoverpa armigera*. Of the 5 who nominated Silverleaf whitefly (*Bemisia tabacci* biotype B) 3 are not in known infestation areas. Western flower thrips (*Frankliniella occidentalis*) was nominated in the Sydney basin, Perth, Adelaide and Melbourne but not Gatton, Tasmania or Alice Springs.

Table 20. Numbers of growers who manage an insecticide resistant insect pest.

Q27. Do you manage an insecticide resistant invertebrate pest?(please tick all that apply)

Answer Options	**Response Percent**	**Response Count**
No	15.6%	5
Helicoverpa armigera (Heliothis)	78.1%	25
Silverleaf whitefly [SLW]	15.6%	5
Western flower thrips [WFT]	37.5%	12
Other (please specify)		4
	answered question	**32**
	skipped question	**10**

Other:
Heliothis only sometimes and SLW very rarely
Lettuce aphid
Pests have not been a major problem in babyleaf
wtf is that

The insecticide resistance management strategy recommended for *Frankliniella occidentalis* (WFT) is a three spray strategy, then rotate chemical groups (not possible in hydroponics as only one chemical is registered for use in lettuce). Eight of the 12 growers who manage WFT use the recommended strategy (Table 21). The one grower who self nominated *Nasonovia ribis-nigri* as an insecticide resistant pest uses *Nas*-resistant lettuce. Another grower who manages *Helicoverpa armigera* nominated using tolerant varieties which do not exist for *H. armigera.*

Table 21 Insecticide resistance management strategy used.

Q28. If you do manage an insecticide-resistant pest, what resistance management strategy do you use?

Answer Options	**Response Percent**	**Response Count**
Rotate chemical groups	89.3%	25
Use the three spray strategy	28.6%	8
Other (please describe)		3
	answered question	**28**
	skipped question	**14**

Other:
use tolerant varieties
Resistant varieties
Do not rotate if working

In question 29 growers were asked to nominate any fungicide resistant diseases they manage, two nominated Sclerotinia, and three Downy mildew. One Sydney basin field lettuce grower commented they no longer used fungicides on their farm.

Thistles were the only herbicide resistant weed nominated, by a Western Australian grower.

85% or 28 of the 33 growers who answered this question use preventative fungicide sprays and 90% modify applications depending on weather, 59% based on monitoring, 41% depending on varieties, and 38% on leaf wetness (Table 22). No grower uses the available, although experimental Downy mildew models, although one has in the past.

Table 22. Factors used to modify fungicide applications.

Q32. If you do use fungicides, do you modify applications depending on: (please tick all that apply)

Answer Options	**Response Percent**	**Response Count**
Weather	89.7%	26
Monitoring	58.6%	17
Varieties	41.4%	12
Leaf wetness	37.9%	11
Models	0.0%	0
Other (please specify)		2
	answered question	**29**
	skipped question	**13**

Comments:

On receival of seedlings

Used models but not any more.

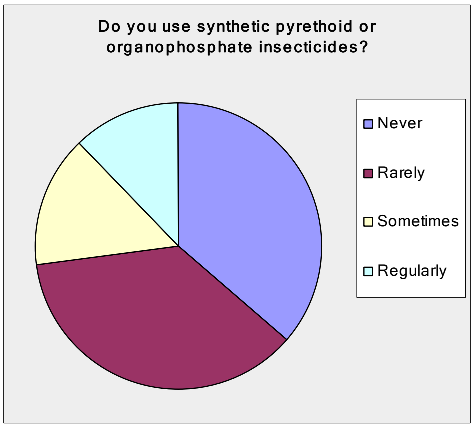
Almost three quarters of growers 'never' or 'rarely' use use synthetic pyrethroids (SPs) or organophosphate (OPs) insecticides (Table 23, Figure 5). Three of the four growers who "regularly" use SPs or OPs insecticides nominated as being 'calendar sprayers', and one as 'low IPM'. Two 'calendar sprayers' 'never' use SPs or OPs, one had clarified that they only regularly sprayed fungicides on their babyleaf lettuce. The growers who nominated as being 'biointensive IPM' 'never' used OPs or SPs. Two of the seven 'low IPM' growers 'rarely' use OPs and SPs, one 'sometimes' and one 'never'. Of the 18 'medium IPM' eight 'never', eight 'rarely' and two 'sometimes' used OPs and SPs.

Table 23. Use of broadspectrum synthetic pyrethroid and organophosphate insecticides.

Q33. Do you use synthetic pyrethoid or organophosphate insecticides?

Answer Options	**Response Percent**	**Response Count**
Never	36.4%	12
Rarely (in less than 10% of your plantings)	36.4%	12
Sometimes (in less than 50% of your plantings)	15.2%	5
Regularly (in more than 50% of your plantings)	12.1%	4
	answered question	**33**
	skipped question	**9**

Figure 5. Use of old chemistry (SPs & OPs)

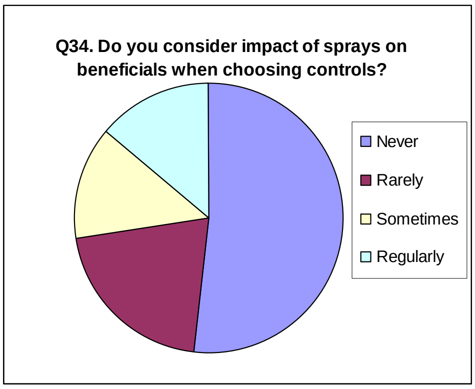


Overall half the growers 'regularly' considers the impact of sprays on beneficials when choosing control options, another quarter 'sometimes' considers impact and the remainder 'rarely' or 'never' considers impact (Table 24, Figure 6). Both 'biointensive IPM' growers regularly consider the impact of pesticide sprays on beneficials. Interestingly one 'calendar sprayer' also 'regularly' considers impact of pesticides on beneficials when choosing sprays. The remainder of the 'calendar sprayers' two each 'never', 'rarely' and 'sometimes' considers spray impact on beneficials. Of the 'low IPM' one 'never', two 'rarely', three 'sometimes' and one 'regularly' considers the spray impact on beneficials. And of the 'medium IPM' growers one 'never', two 'sometimes' and 13 'regularly' considers spray impact on beneficials.

Table 24. Frequency of consideration of spray impact on beneficials.

Q 34. Do you consider the impact of sprays on beneficials when choosing control options?		
Answer Options	**Response Percent**	**Response Count**
Regularly (in more than 50% of your plantings)	51.5%	17
Sometimes (in less than 50% of your plantings)	24.2%	8
Rarely (in less than 10% of your plantings)	12.1%	4
Never	12.1%	4
	answered question	**33**
	skipped question	**9**

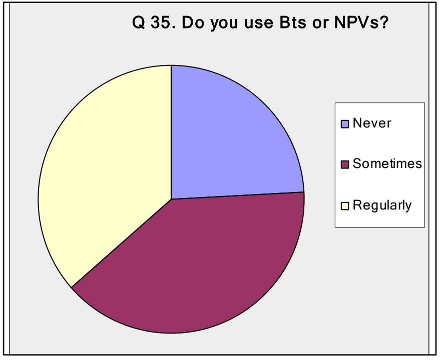
Figure 6. Consideration of Beneficials in spray choice



Three quarters of growers 'sometimes' or 'regularly' use biological insecticides such as Bts (*Bacillus thuringiensis)* or nuclearpolyhedrosis virus (Table 25, Figure 7). Again one of the 'calendar sprayers' 'regularly' and one 'sometimes' uses biological insecticides, two each 'never', 'rarely' and 'sometimes' use them. Of the 'low IPM' growers one 'never', one 'rarely', three 'sometimes' and two 'regularly' use biological insecticides. The 'medium IPM' growers are more frequent uses of biological insecticides with six 'regularly', seven 'sometimes' and four 'never' using them. Both 'biointensive IPM' growers 'regularly' use biological insecticides.

Table 25. Frequency of use of 'biological' insecticides. Figure 7.

Q25. Do you use Bts (e.g.Dipel®, Xentari® etc) or NPVs (e.g. Gemstar® or Vivus®)?		
Answer Options	**Response Percent**	**Response Count**
Never	24.2%	8
Sometimes	39.4%	13
Regularly	36.4%	12
	answered question	**33**
	skipped question	**9**



One each of the 'biointensive IPM' and 'medium IPM' growers 'sometimes' purchase commercially reared beneficials for release into their lettuce. However 88% try to conserve endemic beneficials, including three 'calendar sprayers' (Table 26). Choosing softer chemicals is the preferred method (85%), spraying at times when beneficials are not (or less) active (24%), one 'biointensive IPM' grower uses intercrops or refuges and has planted native vegetation, another 'medium IPM' grower has also planted native vegetation and another comments that they have enough native vegetation surrounding their farm.

Table 26. Practices used to conserve beneficials.

Q37. Do you try to conserve beneficials? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Yes - by choosing softer chemicals	84.8%	28
Yes - spray when not active	24.2%	8
yes - use intercrops/refuges	3.0%	1
Yes - planted native vegetation	6.1%	2
No	12.1%	4
Other (please describe)		2
	answered question	**33**
	skipped question	**9**

Other:

Not many beneficials around

Enough vegetation around the farm.

Four growers, one from each pest management strategy category, use *Trichoderma* spp. or other soil biological additives to prevent diseases. One 'medium IPM' grower nominated *Trichoderma* as a common beneficial on their farm. 18 nominated ladybird beetles, 12 mentioned wasps, 10 lacewings, three mentioned hover flies and spiders and one mentioned thrips, mites and pirate bugs (*Orius* sp.). Two growers mentioned beneficials can lead to product rejection.

Growers were asked whether they reviewed crop monitoring (Q40, Table 27), chemical (Q41, Table 28) and harvest (Q42, Table 29) records. Reviewing records is an indication of reflection on effectiveness of current practices and potential willingness to modify practices in the future. 'Calendar sprayers' indicated proportionally more often that they didn't review records (52% aggregated over three record types), and were least likely to review crop monitoring records (71%), 33% of 'Calendar sprayers' reviewed records 'weekly' (aggregated over three record types). One of the 'Low IPM' growers didn't review either monitoring or chemical records and three reviewed all three records 'weekly'. Of the 'Medium IPM' growers 13% (aggregated over three record types) did not review records and 44% (aggregated over three record types) reviewed 'weekly'. Both the 'Biointensive IPM' growers reviewed records ‘occasionally’ (crop monitoring) and ‘weekly’ (chemical and harvest).

Table 27. Frequency of reviewing crop monitoring records.

Q40. How often do you review monitoring records? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Weekly	30.3%	10
Seasonally	15.2%	5
Annually	0.0%	0
Occasionally	24.2%	8
Never	30.3%	10
	answered question	**33**
	skipped question	**9**

Table 28. Frequency of reviewing chemical records.

Q41. How often do you review chemical records? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Weekly	48.5%	16
Seasonally	15.2%	5
Annually	9.1%	3
Occasionally	18.2%	6
Never	12.1%	4
	answered question	**33**
	skipped question	**9**

Table 29. Frequency of reviewing harvest records.

Q42. How often do you review harvest records? (please tick all that apply)		
Answer Options	**Response Percent**	**Response Count**
Weekly	60.6%	20
Seasonally	6.1%	2
Annually	3.0%	1
Occasionally	15.2%	5
Never	15.2%	5
	answered question	**33**
	skipped question	**9**

32% of growers stated that they had never had a consignment rejection, although one of those growers, a ‘Calendar sprayer’ also ticked both insects and diseases as the reason for rejection (Table 30, Figure 8). Three other ‘Calendar sprayers’, one ‘Low IPM’ and five of the nine ‘Medium IPM’ growers have never had a consignment rejected. Three of the seven ‘Calender sprayers’ had rejections for insects, two for diseases, one for size and one for frogs. Six of the ‘Low IPM’ growers have had rejections, three each had a rejection for insects, diseases and size. Of the 12 ‘Medium IPM’ growers who had had rejections seven had rejections for insects, four for diseases and five for size, one for weed contamination and one because market was “oversupplied”. Both the ‘Biointensive IPM’ growers have had rejections for disease and one for insects.

Table 30 Reasons for consignment rejection.

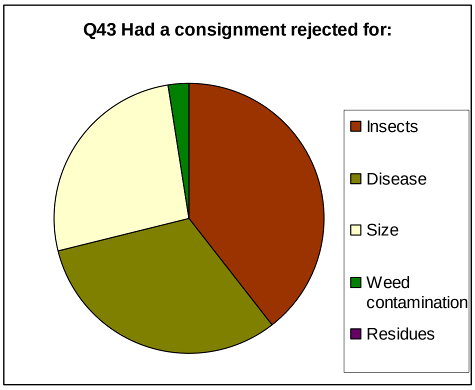
Q43. In the last three years have you had a consignment rejected for (please tick all that apply):

Answer Options	**Response Percent**	**Response Count**
Insect contamination (including contamination by beneficial organisms)	48.4%	15
Disease symptoms	38.7%	12
Size	32.3%	10
Weed contamination	3.2%	1
Residues	0.0%	0
Never had a rejection	32.3%	10
Other (please describe)		5
	answered question	**31**
	skipped question	**11**

Other:

Poor quality - weather related
Moths; and problems with beneficials if they get to the processor
chain store knockout due to oversupply
Frogs

Figure 8. Consignment rejected



To develop a quantitative evaluation of changes in practice estimates of product loss and cost of crop protection practices need to be made. The following questions give the grower estimates of percentage product loss by season (Table 30), loss of income, cost of chemical and non chemical crop protection in the last year.

Insect and mite damage was highest in summer with 6.8 % crop loss on average ± 3.5% (SD), ranging between 0-10%; and lowest in winter with 1.9 ± 2.5%, ranging between 0-5%. Disease loss was highest in autumn with 12.8 ± 18.6% loss, ranging between 0-80%; and lowest in spring with 7.8 ± 8.4% loss, ranging between 0-10%. No loss was recorded due to nematodes. Weed losses were estimated at 7.0 ± 8.8% in summer with estimates ranging between 0-30%; and in winter at 1.3 ± 2.3%, ranging between 0-5%. The highest crop losses were attributed to vertebrate pests in summer at 10.7 ± 11.0% crop loss, ranging between 0-40%; with least damage occurring in winter with estimates of 2.9 ± 3.3%, ranging between 0-10%. Other causes of damage nominated include: 15% to tip burn, up to 40% loss to hail one in four years and 10% hail damage.

Table 30. Grower estimate of percentage loss of marketable lettuce in the last year by season.

	SUMMER		AUTUMN	
Pest Category	mean ± [range]	n	mean ± [range]	n
Insects, mites	6.8 ± 3.5 [0-10%]	17	3.7 ± 3.5 [0-10%]	15
Diseases	10.0 ± 12.9 [0-50%]	14	12.8 ± 18.6 [0-80%]	18
Nematodes	0	7	0	6
Weeds	7.0 ± 8.8 [0-30%]	10	1.7 ± 2.6 [0-5%]	6
Vertebrate pests	10.7 ± 11.0 [0-40%]	15	4.5 ± 4.2 [0-10%]	12

	WINTER		SPRING	
Pest Category	mean ± [range]	n	mean ± [range]	n
Insects, mites	1.9 ± 2.5 [0-5%]	16	5.3 ± 3.7 [0-10%]	17
Diseases	11.6 ± 14.3 [0-20%]	19	7.8 ± 8.4 [0-30%]	18
Nematodes	0	6	0	7
Weeds	1.3 ± 2.3 [0-5%]	8	2.5 ± 2.7 [0-5%]	8
Vertebrate pests	2.9 ± 3.3 [0-10%]	12	7.7 ± 10.3 [0-40%]	15

Other:

tipburn- 15 %
Hail - 1 in 3 years, about 40% loss
Hail 10%
too difficult to answer
Maybe 1% in summer from WFT

In Q45 growers were asked to estimate income lost from pest damage over the last year, many gave a dollar figure between $4,000 and $900,000 and some a percentage loss that ranged from 0 to 15%. For these figures to be comparative they needed to be averaged per hectare grown. In 12 cases sufficient information was provided to make an estimate of the lost income per hectare of lettuce grown. The estimates ranged from $116 - $20,000 /ha and averaged $3,370 ± $5,882 (SD). Chemical costs for managing pests in lettuce in the past year were estimated from 19 growers and ranged between $465 - $4,667 /ha and averaged $1,190 ± $985 /ha. Non chemical crop protection costs for the past year were estimated from 15 growers to be between $0 and $3,000 /ha, and averaged $476 ± $791 /ha. Non chemical costs mentioned were paying crop consultants to monitor and labour for chipping weeds.

Table 31 Clarification comments

Q48. Please make any comments about pest management in your crops or provide clarification on any previous answers.

Field peas for green manure
Monitoring is visual, no records kept
Chemcert Spray qualification
Transitioned from Iceberg to Cos in last 5 years
Babyleaf=rocket+lettuce+mezina
Pest management choices limited by Market Nil tolerance of insect contamination
monitoring - different frequency depending on what being monitored
monitoring seasonally - review pesticides available, damage
The disease losses were mainly due to virus diseases spread by aphids.
Not really any problems this year - Rutherglen bug about 6 weeks ago and last time sprayed, last year good too, year before mite and onion thrips a problem
Insect losses due to Heliothis
Since changing the system losses have been limited - soft chemicals, monitoring, no wastage on ground, diseased plants taken off property

Estimates of percent change in damage levels now compared to five years ago were made by 24 growers (Table 32) but only 4 could be compared to a per hectare figure. There was some confusion with this and the subsequent two questions given some growers indicated at percentage greater than zero in the row with 'damage the same'. Chemical costs were estimated to have gone up by 26% on average but estimates ranged from going up by 100% to decreasing by 20% (Table 33.). Estimating changes in chemical control costs per hectare was possible from 12 of the 20 grower's figures. The average cost of chemicals 5 years ago was 22% higher at $1,493 ± $1,270 /ha compared to this past year's costs equalling $1,219 ± $1,059 /ha. The estimates of changes of non-chemical costs were more confusing with 5 estimates giving greater than zero percent for 'costs the same' (Table 34).

Table 32. Estimate of % change in pest damage compared to 5 years ago

	% change in pest damage	
Change	mean ± [range]	n
Damage levels gone up	12.5 ± 12.6 [0-30%]	4
Damage levels gone down	21.5 ± 16.5 [5-50%]	12
Damage the same	0	6

Table 33. Estimate of % change in chemical control costs compared to 5 years ago

	% change in chemical control costs	
Change	mean ± [range]	n
Chemical costs gone up	36.3 ± 26.5 [5-100%]	15
Chemical costs gone down	12.0 ± 8.4 [0-20%]	5
Chemical costs the same	0	3

Comments on seasonality:

Change of practices
Over all
insects - summer, diseases - winter
Winter and spring
Costs went up
Every year is different
Fungicides up 10%, insecticides down 5%

Table 34 Estimate of % change in non-chemical costs compared to 5 years ago

	% change in non-chemical management costs	
Change	mean ± [range]	n
Non-chemical costs gone up	20.7 ± 16.4 [0-50%]	7
Non-chemical costs gone down		0
Non-chemical costs the same	0	14*

* note that 5 estimates were >0%

Comments:

Don't know
Fuel and labour costs up 20%
Don't know
Monitoring two farms instead of one now

Table 35. Grower comments grouped by topics

Vegetable levy

I think in general r&d is satisfactory!

I think levy should b controlled by commodity groups eg.iceberg lettuce field grown should run there own levy!

I believe levy should b controlled by sole commodity groups eg.iceberg lettuce growers run there own levy,the money will b better used for our commodity!! Hard to swallow for ausveg but past records tell me our money would b better spent and would b more transparent for everyone!

Money collected in Hay district should be spent in Hay district ie duck-off lights for growers

Levy only talken out when price lower than cost of production

Levy Spend

Already doing the water, disease issues that we have.

Ongoing work needs to be done to ensure that we do not loose what we have achieved. If there is to be problems then they can be addressed and dealt with quicly & effectively

Better local extension

Face to face in the field

Person to help like Andrew Creek [Technical officer in earlier Lettuce IPM project]

Stop conferences

Stop glossy magazine

Market Price

Over production is bad for the industry

Supermarket pressure is making it difficult for all small growers.

Problem is the supermarkets rejecting produce that are not completely clean of both pests and beneficials e.g. know of a grower that a supermarket rejected (via the wholesaler) for Hippodamia this year. We know how to grow a great product, need more assistance in finding a market for it. Would like to see some R&D levy money diverted to promotion.

Need better crop sale price.

growers need increased prices to survive. market prices are driving people out of the industry

price is the issue

Why are vegetable prices so dear in shops when on farm prices are so low.

Also need to ensure that profits along the supply chain are fair.

Need better money for product

Percentage mark up is ridiculous.

Marketing

Marketing iceberg

Establish new markets

Need more work to educate consumers so as to increase consumption. And educate consumers about farming - farmers do not just use chemicals for fun as they cost a lot of money. Consumers need to know that vegetables are not covered in chemicals and farmers are trained and educated to make good spray choices.

Marketing, promotion and education programmes. Too many growing projects that do not always have a cost benefit for growers. We need to increase consumption and gain accest to export markets to create ongoing opportunities in this industry.

The market is very poor and there are signals to not plant a range of vegetables - need to get consumers consuming!

Reduce import

1. Testing and monitoring the impact of imports
2. How produce is marketed in Australia

Governmments need to change the level of control big companies have over farmers and the industry.

IPM Projects

The supermarkets are not going to change their standards so we are very much constrained to produce according to their standards, not necessarily but our own dictates or beliefs. The supermarkets need to be involved in these projects as their volumes and market share are driving the direction in this industry, not necessarily our perception of where food production should be heading!

IPM projects should definitely continue - research and extension. For example chemical resistance management and research into making plants resistant to pests and diseases.

IPM projects have run their course, if growers haven't learnt by now they never will.

IPM works for all commodities, just not lettuce, so have been able to transfer knowledge from the lettuce projects to other commodities.

Work to encourage IPM adoption should continue. Need the regular updates and reminders about best practices. The recent Lettuce DVD is a good example.It really made me think what I was doing and I am now considering getting a consultant to assist with monitoring.

Would like to see more IPM information on capsicums, zucchini and eggplant.

More IPM work on capsicums, zucchini and eggplant.

much more investment into procted cropping in regards to nutrient management, appliction and use of chemicals as currently it is very hard to find chemicals you can use in protected cropping crops

Specific Pest Issues

Diseases a much bigger problem than pests for babyleaf.

Enough money spent on insect control

More money spent on disease control e.g. mildew

Chinese cabbage - registration for mildew on brassica leafy vegetables.

Mildew control

Pythium in baby leaf spinach

Anthracnose conntrol in spring in iceberg and cos Pythium control in baby spinach

sclerotinia is difficult to control

NEED MORE SOFT INSECTICIDES AND SYSTEMIC FUNGICIDES SCLEROTINIA DOWNEY MILDEW

NEED BIOLOGICAL CONTROL OF FUNGAL DISEASES AND INSECTS

Need more chemical options

Controlling virus diseases. Control measures for aphids.

Research into lettuce vuruses, which are a major problem that cannot be directly controlled

More solutions for WFT management.

Other

Irrigation - cheaper technology

Buy bulk cartons

Lettuce Project Specific

No publicity negative results of IPM trial

Have not seen any project activity for at least two years

Dept has done a good job.

Clarification

Having an IPM consultant is money well spent. With time the major constraint for reading, attending field days, etc. it is valuable to have the consultants knowledge. He comes fortnightly, I keep a check on pests in between. I have probably used more information from the IPM project than I know because I use a consultant.

Only reason not using lettuce information is because not growing lettuce at the moment, but may in the future.

Percentage of fresh/processing changes. At the moment 100% fresh. But sometimes only 60% fresh.

Discussion

In comparison with the 2006 survey of lettuce growers proportionally the same number of lettuce growers from NSW were surveyed which is also similar to the proportions of NSW growers growing lettuce in Australia (Table 35). Western Australia growers are more highly represented in the 2012 survey compared to 2006 and are overestimated relative to numbers of growers growing lettuce in Australia. Queensland and Victorian lettuce growers are under-represented and Tasmanian growers are overrepresented in the 2012 survey.

This survey is not necessarily reflective of a broad cross-section of lettuce growers. It does cover at least 1620 ha of lettuce production including growers from each State and all production types. Of the 42 grower respondents, 32 or 76% answered more than 75% of the questions in the survey. These growers are engaged with RDE levy funded projects with over 80% having attended field days or workshops in the last three years.

Table 35. Percentage of lettuce growers by state, percentage completing lettuce survey in 2006 and 2012

State	ABS 2008	2006 Survey	2012 Survey
NSW	33.4%	36.7	35.7%
QLD	26.2%	7.6	14.3%
SA	4.2%	11.4	7.1%
Tas	1.7%	15.2	4.8%
Vic	24.2%	21.5	11.9%
WA	9.9%	7.6	23.8%
NT	0.03%	0	2.4%

The first part of this survey gave a wide range of ratings to this lettuce project and of the usefulness of the previous information resources. Distribution of these resources were highlighted with the most recent distribution of the Lettuce Crop Protection Toolkit DVD having not been seen by 28 of the 40 respondents when over 700 were mailed directly or indirectly via the Grower Associations two to three weeks prior to the growers being surveyed. The Lettuce Leaf newsletter was seen by almost all growers which is not surprising given 40 issues have been distributed over 13 years. Similarly it is not surprising that most growers have not seen one of the IPM demonstrations given in this project there was one demonstration in Stanthorpe and one in the Sydney basin, with comparative data collected from Victoria and an IPM casestudy done in WA. In the previous project there was an IPM demonstration in the Sydney Basin and Victoria as well as detailed data collected from IPM trials/demonstrations in Victoria and in Hay NSW.

Of the previously produced and distributed information resources the Lettuce Field Identification Guide [Pests, Beneficials, Diseases and Disorders Field Identification Guide for Lettuce] and the Common Pests or Diseases of Lettuce Posters were the most frequently referred to. The field identification guide, the Lettuce IPM Information Guide and the Lettuce Leaf newsletters were all directly mailed to the known lettuce growers at the time of publication and available to new growers as we become aware of them. The Lettuce Conference proceedings were available to growers at the conferences and by request to others. The Common Pests or Diseases of Lettuce posters have been available at field days or by request, but not mailed to all known lettuce growers.

Half the growers agreed with the statement that the investment in lettuce IPM has produced some useful results and they have adopted some new practices as a result of the projects. A number of growers were very scathing and agreed with the statement that the projects were a waste of money and they hadn’t changed a single practice. In at least three of these cases I know that the growers have changed practices but they are expressing a general dis-satisfaction with the levy and that they have not had much face to face contact within this current project. Lettuce prices were poor at the time of the survey and that does affect grower's general outlook.

If we compare the questions that have a direct comparison from the 2006 lettuce grower survey then we see that the numbers of growers self identifying as IPM growers has increased from 61% to 79% and conversely the numbers identifying as 'calendar sprayers' has reduced from 39% to 21% (Table 36). The numbers of growers monitoring crops is similar although the number of consultants being used to monitor crops has increased from 28% to 46%. Similarly there has been an increase in the numbers of growers monitoring for invertebrate beneficials from 38% to 55% and the use of biological insecticides has increased from 43% to 76%. Use of older chemistry is similar in numbers of growers nominating they use it sometimes or regularly. The satisfaction rating of the Lettuce leaf newsletter dropped from 4.2 to 3.5 out of a scale of 1-5.

Table 36 Comparison between 2006 & 2012 lettuce grower surveys. Only including data where there is a direct comparison.

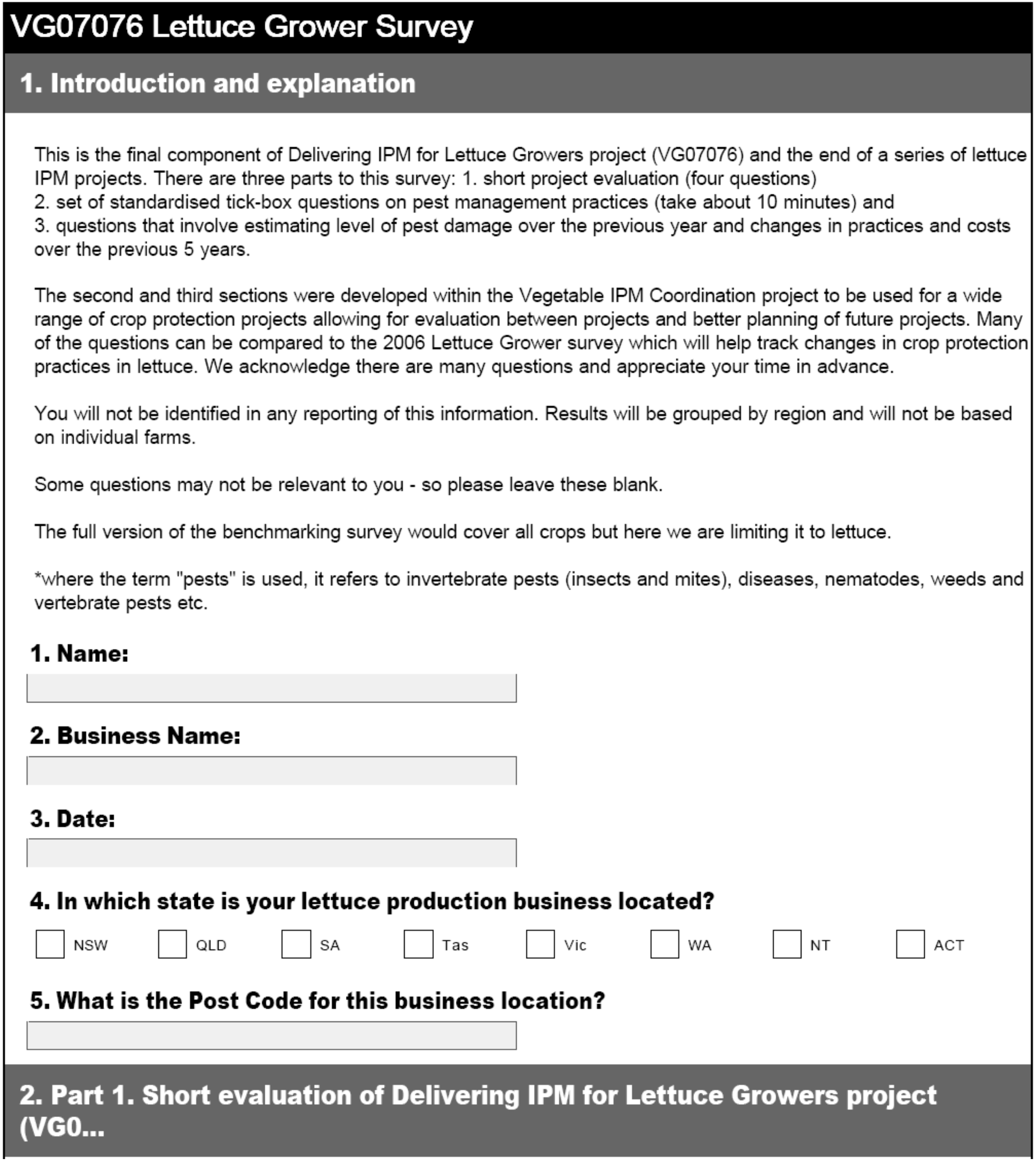
Comparative Questions	**2006 Survey**	**2012 Survey**
Growers surveyed	79	42
Self identified as IPM grower	61%	**79%**
Self identified as 'calendar sprayer'	39%	21%
Monitor crops	91%	97%
Monitor crops self	74%	70%
Consultant monitors crops	28%	**46%**
Monitors for beneficials	38%	**55%**
Beneficial insect releases	10%	5%
Use biological insecticides	43%	**76%** (sometimes or regularly)
Use SPs and OP insecticides	23%	27% (sometimes or regularly)
Use conventional boom sprayer	62%	69%
Use boom with droppers	4%	4%
Use air- assist sprayer	19%	25%
Rating of Lettuce leaf newsletter	4.20	3.5

Conducting this survey has highlighted that communicating with growers has become increasingly difficult, with no easily available or consistent communication channel. Mail-outs are the easiest and can be facilitated by some of the State Grower Associations, although their contact lists are of variable quality with GrowCom in Queensland having stated that they were unable to send out any communication. Even the states where their was a willingness to assist it is evident from the numbers of growers who had 'Not Seen' the DVD, that the mail outs in Victoria and SA either haven't gone out at the time of the survey, their lists are incomplete, the growers have not opened their mail or if someone else opens the mail it hasn't been passed on. It is also possible that some of the growers have received the DVD but had not looked at the DVD although three growers were contacted and said they have not received a copy at all.

The benchmarking component of this survey will be most useful if subsequent surveys use these questions as a standardised set of questions. It was evident that there is some confusion with the wording, particularly in the quantitative section and that should be improved before using again.

Appendix 16.3 Final Grower Survey Questions

On-line grower survey questions



VG07076 Lettuce Grower Survey

1. Introduction and explanation

This is the final component of Delivering IPM for Lettuce Growers project (VG07076) and the end of a series of lettuce IPM projects. There are three parts to this survey: 1. short project evaluation (four questions)
2. set of standardised tick-box questions on pest management practices (take about 10 minutes) and
3. questions that involve estimating level of pest damage over the previous year and changes in practices and costs over the previous 5 years.

The second and third sections were developed within the Vegetable IPM Coordination project to be used for a wide range of crop protection projects allowing for evaluation between projects and better planning of future projects. Many of the questions can be compared to the 2006 Lettuce Grower survey which will help track changes in crop protection practices in lettuce. We acknowledge there are many questions and appreciate your time in advance.

You will not be identified in any reporting of this information. Results will be grouped by region and will not be based on individual farms.

Some questions may not be relevant to you - so please leave these blank.

The full version of the benchmarking survey would cover all crops but here we are limiting it to lettuce.

*where the term "pests" is used, it refers to invertebrate pests (insects and mites), diseases, nematodes, weeds and vertebrate pests etc.

1. Name:

2. Business Name:

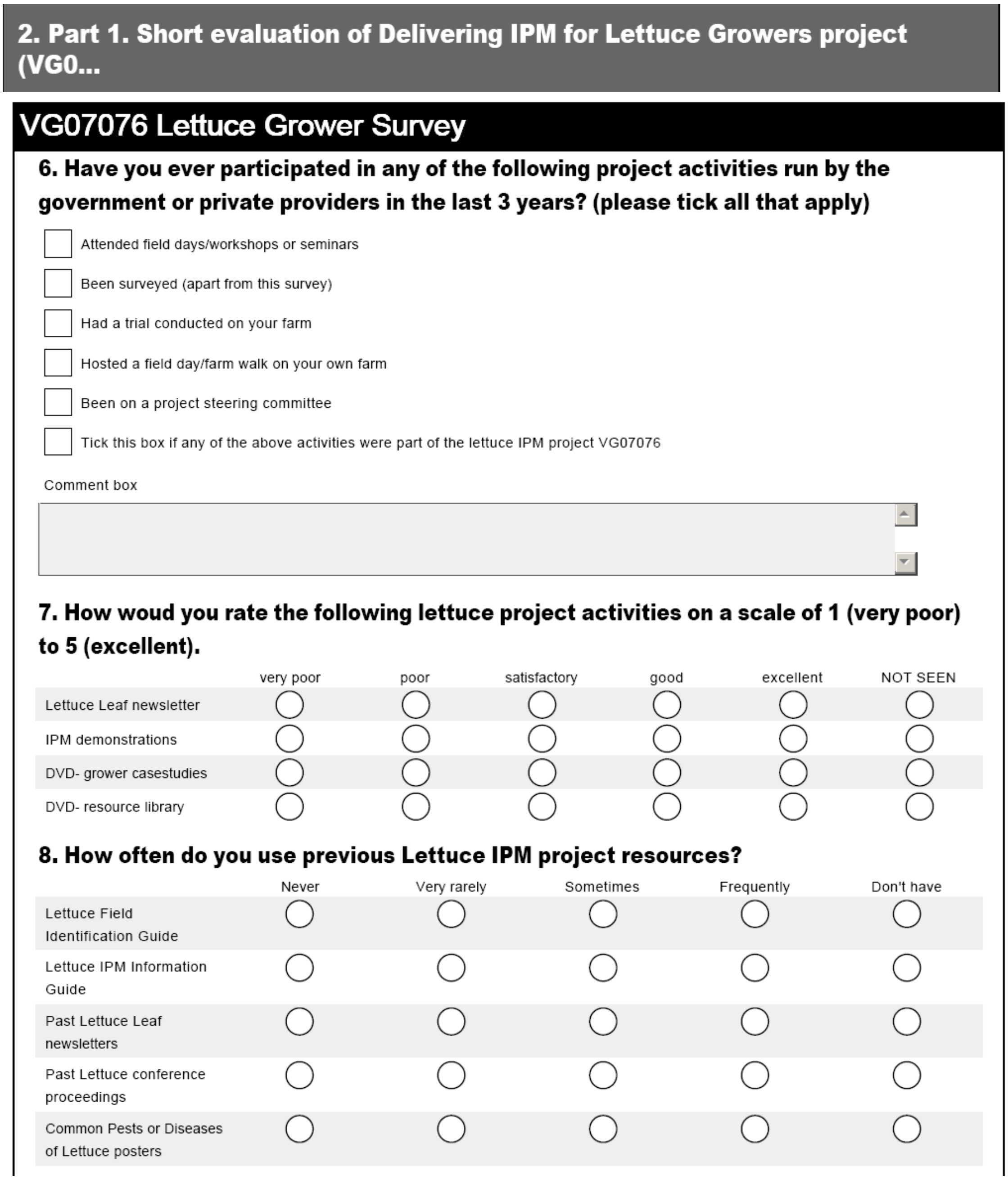
3. Date:

4. In which state is your lettuce production business located?

☐ NSW ☐ QLD ☐ SA ☐ Tas ☐ Vic ☐ WA ☐ NT ☐ ACT

5. What is the Post Code for this business location?

2. Part 1. Short evaluation of Delivering IPM for Lettuce Growers project (VG0...



2. Part 1. Short evaluation of Delivering IPM for Lettuce Growers project (VG0...

VG07076 Lettuce Grower Survey

6. Have you ever participated in any of the following project activities run by the government or private providers in the last 3 years? (please tick all that apply)

- ☐ Attended field days/workshops or seminars
- ☐ Been surveyed (apart from this survey)
- ☐ Had a trial conducted on your farm
- ☐ Hosted a field day/farm walk on your own farm
- ☐ Been on a project steering committee
- ☐ Tick this box if any of the above activities were part of the lettuce IPM project VG07076

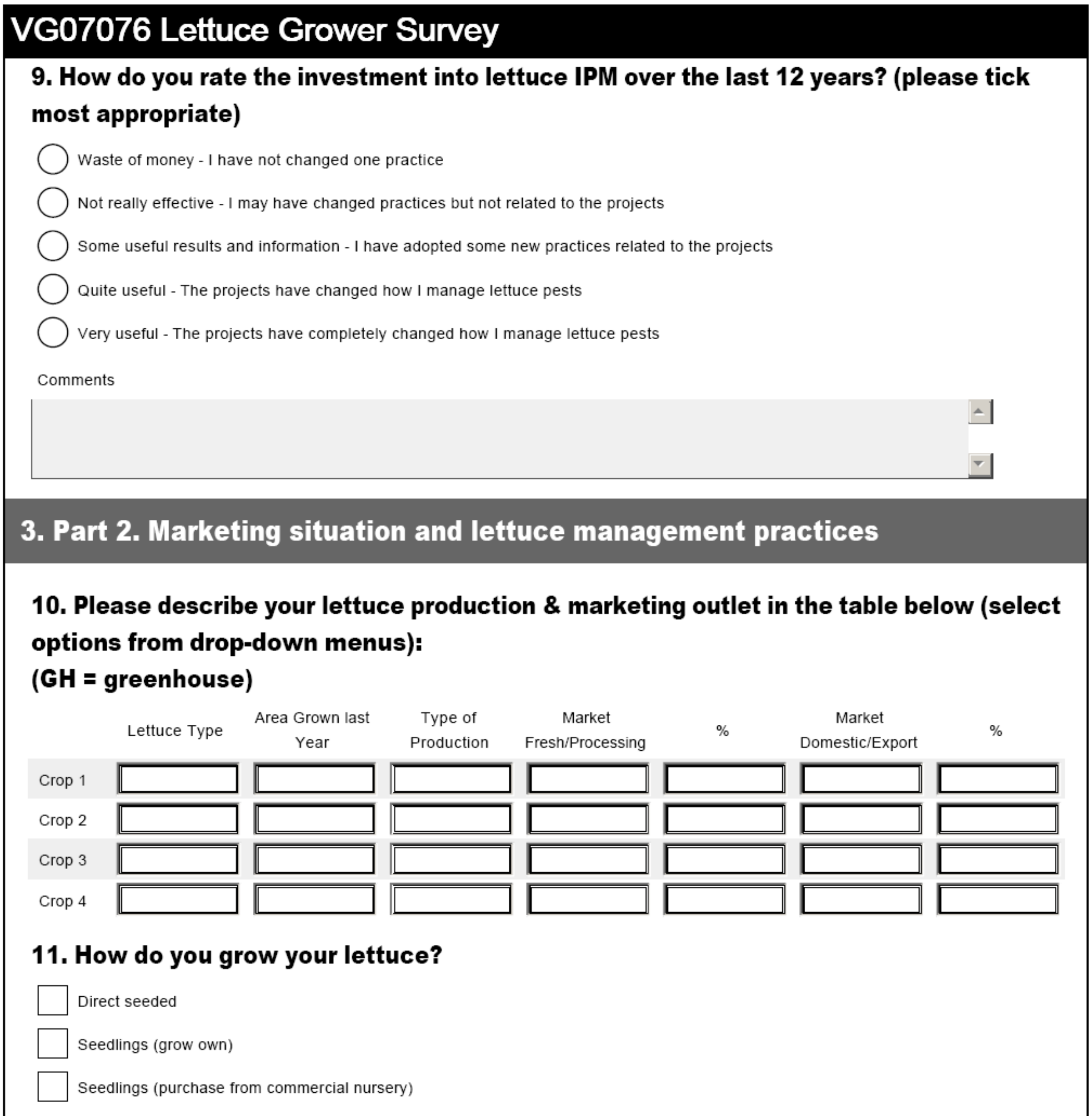
Comment box

7. How woud you rate the following lettuce project activities on a scale of 1 (very poor) to 5 (excellent).

	very poor	poor	satisfactory	good	excellent	NOT SEEN
Lettuce Leaf newsletter	○	○	○	○	○	○
IPM demonstrations	○	○	○	○	○	○
DVD- grower casestudies	○	○	○	○	○	○
DVD- resource library	○	○	○	○	○	○

8. How often do you use previous Lettuce IPM project resources?

	Never	Very rarely	Sometimes	Frequently	Don't have
Lettuce Field Identification Guide	○	○	○	○	○
Lettuce IPM Information Guide	○	○	○	○	○
Past Lettuce Leaf newsletters	○	○	○	○	○
Past Lettuce conference proceedings	○	○	○	○	○
Common Pests or Diseases of Lettuce posters	○	○	○	○	○



VG07076 Lettuce Grower Survey

9. How do you rate the investment into lettuce IPM over the last 12 years? (please tick most appropriate)

○ Waste of money - I have not changed one practice

○ Not really effective - I may have changed practices but not related to the projects

○ Some useful results and information - I have adopted some new practices related to the projects

○ Quite useful - The projects have changed how I manage lettuce pests

○ Very useful - The projects have completely changed how I manage lettuce pests

Comments

3. Part 2. Marketing situation and lettuce management practices

10. Please describe your lettuce production & marketing outlet in the table below (select options from drop-down menus):
(GH = greenhouse)

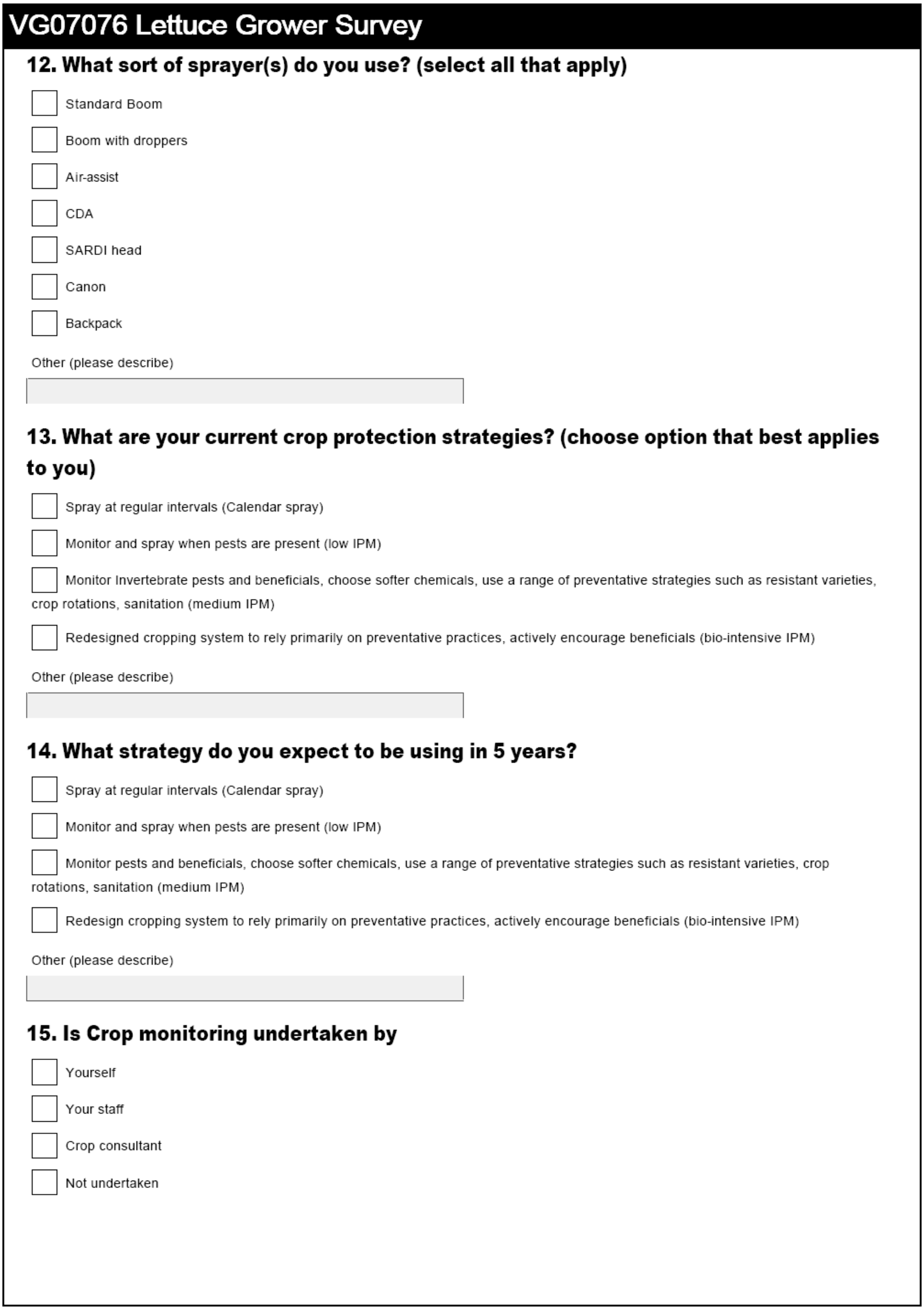
	Lettuce Type	Area Grown last Year	Type of Production	Market Fresh/Processing	%	Market Domestic/Export	%
Crop 1							
Crop 2							
Crop 3							
Crop 4							

11. How do you grow your lettuce?

☐ Direct seeded

☐ Seedlings (grow own)

☐ Seedlings (purchase from commercial nursery)



VG07076 Lettuce Grower Survey

12. What sort of sprayer(s) do you use? (select all that apply)

☐ Standard Boom

☐ Boom with droppers

☐ Air-assist

☐ CDA

☐ SARDI head

☐ Canon

☐ Backpack

Other (please describe)

13. What are your current crop protection strategies? (choose option that best applies to you)

☐ Spray at regular intervals (Calendar spray)

☐ Monitor and spray when pests are present (low IPM)

☐ Monitor Invertebrate pests and beneficials, choose softer chemicals, use a range of preventative strategies such as resistant varieties, crop rotations, sanitation (medium IPM)

☐ Redesigned cropping system to rely primarily on preventative practices, actively encourage beneficials (bio-intensive IPM)

Other (please describe)

14. What strategy do you expect to be using in 5 years?

☐ Spray at regular intervals (Calendar spray)

☐ Monitor and spray when pests are present (low IPM)

☐ Monitor pests and beneficials, choose softer chemicals, use a range of preventative strategies such as resistant varieties, crop rotations, sanitation (medium IPM)

☐ Redesign cropping system to rely primarily on preventative practices, actively encourage beneficials (bio-intensive IPM)

Other (please describe)

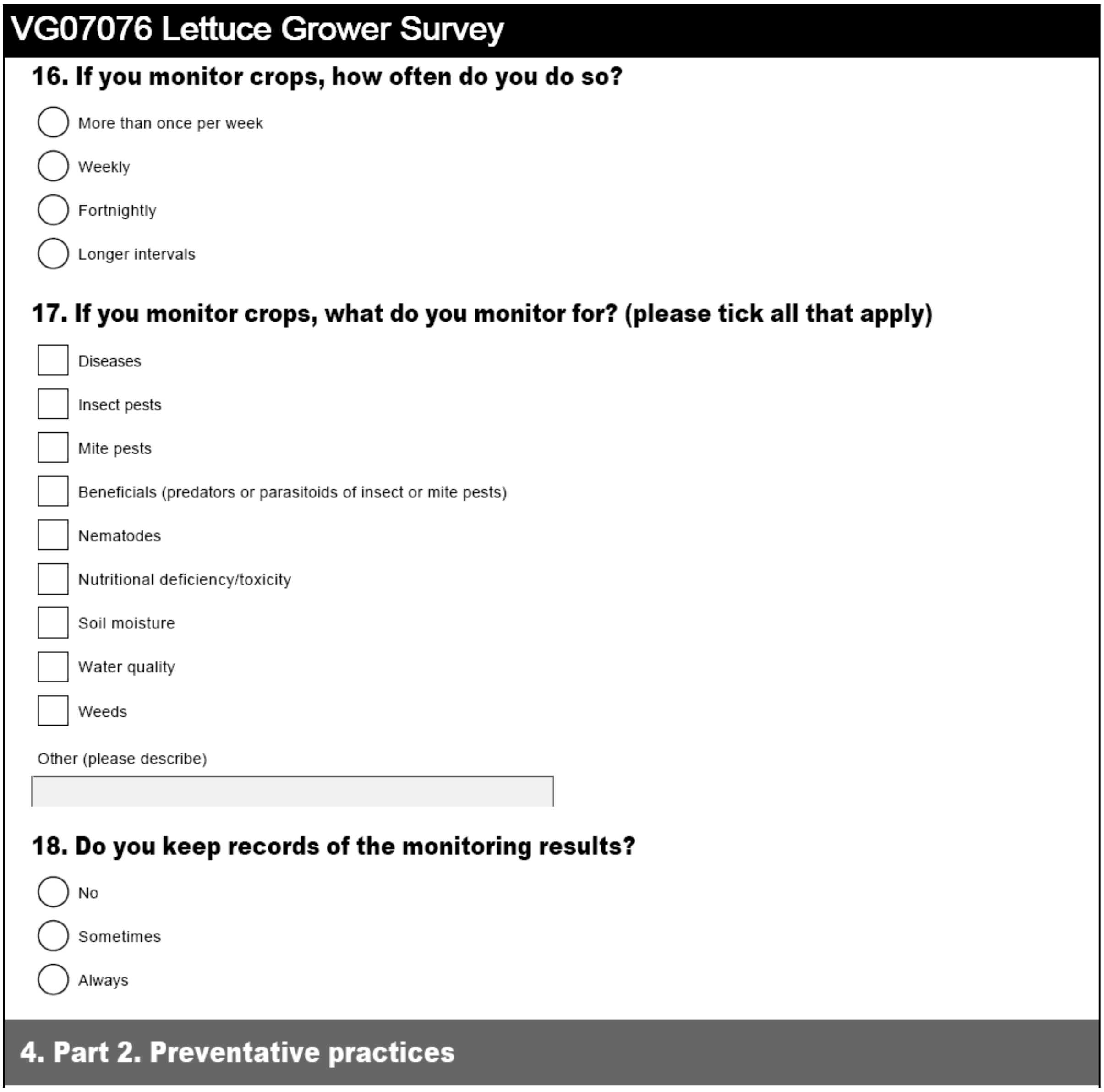
15. Is Crop monitoring undertaken by

☐ Yourself

☐ Your staff

☐ Crop consultant

☐ Not undertaken



VG07076 Lettuce Grower Survey

16. If you monitor crops, how often do you do so?

○ More than once per week

○ Weekly

○ Fortnightly

○ Longer intervals

17. If you monitor crops, what do you monitor for? (please tick all that apply)

☐ Diseases

☐ Insect pests

☐ Mite pests

☐ Beneficials (predators or parasitoids of insect or mite pests)

☐ Nematodes

☐ Nutritional deficiency/toxicity

☐ Soil moisture

☐ Water quality

☐ Weeds

Other (please describe)

18. Do you keep records of the monitoring results?

○ No

○ Sometimes

○ Always

4. Part 2. Preventative practices

4. Part 2. Preventative practices

VG07076 Lettuce Grower Survey

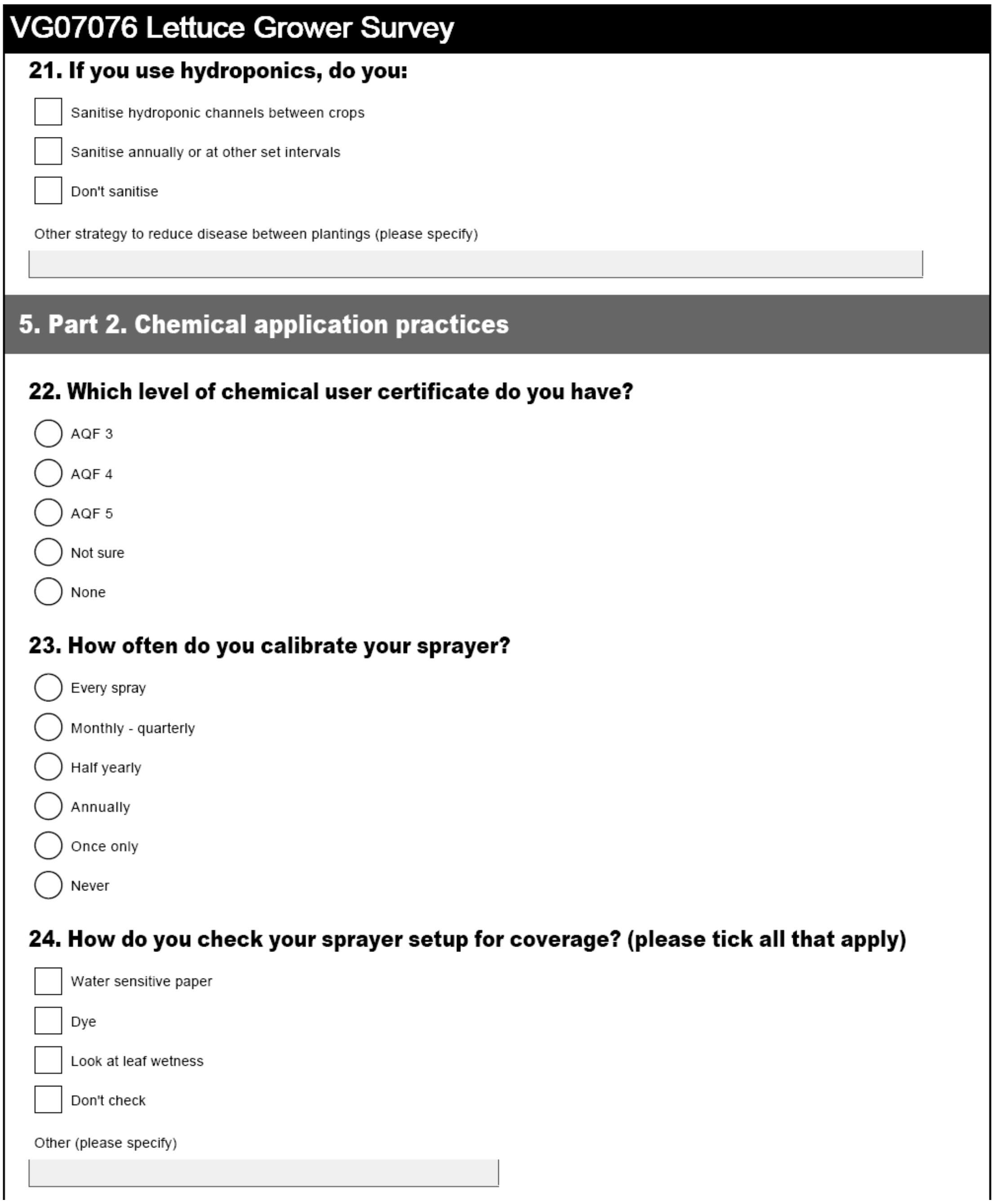
19. Which of the following sanitation or preventative practices do you have/use or have you used? (please tick all that apply)

☐ A biosecurity plan
☐ A Quality Assurance program
☐ An Environmental Management Strategy
☐ Workflow designed to work in clean areas/crops first and in dirty/infested areas last
☐ Use resistant varieties
☐ Crop rotation to reduce diseases
☐ Soil amendments to improve soil health and to reduce disease problems
☐ Modify pH to reduce specific disease problems
☐ Have changed the timing of irrigation to reduce disease pressure
☐ Have changed the method of irrigation to reduce disease pressure
☐ Reuse water with a strategy/method to reduce disease innoculum
☐ Reuse water and test water quality
☐ Control weeds to reduce pests
☐ Designate clean (disease or invertebrate pest-free) areas
☐ Pull out plants showing disease symptoms and leave on ground
☐ Pull out plants showing disease symptoms and dispose of
☐ Don't plant new crops next to old crops
☐ Plant crops consecutively
☐ Plant new crops up wind of old crops/problem areas
☐ Avoid hot spots
☐ Spray out old crops with insecticide
☐ Spray off harvested crops with quick action herbicide (eg Spray Seed)
☐ Slash or cultivate crop in straight after harvest

Other (please describe)

20. If you have a greenhouse, do you have it designed to exclude pests? (please tick all that apply)

☐ Yes - sealed with insect proof screening
☐ Yes - foot bath before entering
☐ Yes - vestibule - double doors on entry way
☐ No



VG07076 Lettuce Grower Survey

21. If you use hydroponics, do you:

☐ Sanitise hydroponic channels between crops

☐ Sanitise annually or at other set intervals

☐ Don't sanitise

Other strategy to reduce disease between plantings (please specify)

5. Part 2. Chemical application practices

22. Which level of chemical user certificate do you have?

○ AQF 3

○ AQF 4

○ AQF 5

○ Not sure

○ None

23. How often do you calibrate your sprayer?

○ Every spray

○ Monthly - quarterly

○ Half yearly

○ Annually

○ Once only

○ Never

24. How do you check your sprayer setup for coverage? (please tick all that apply)

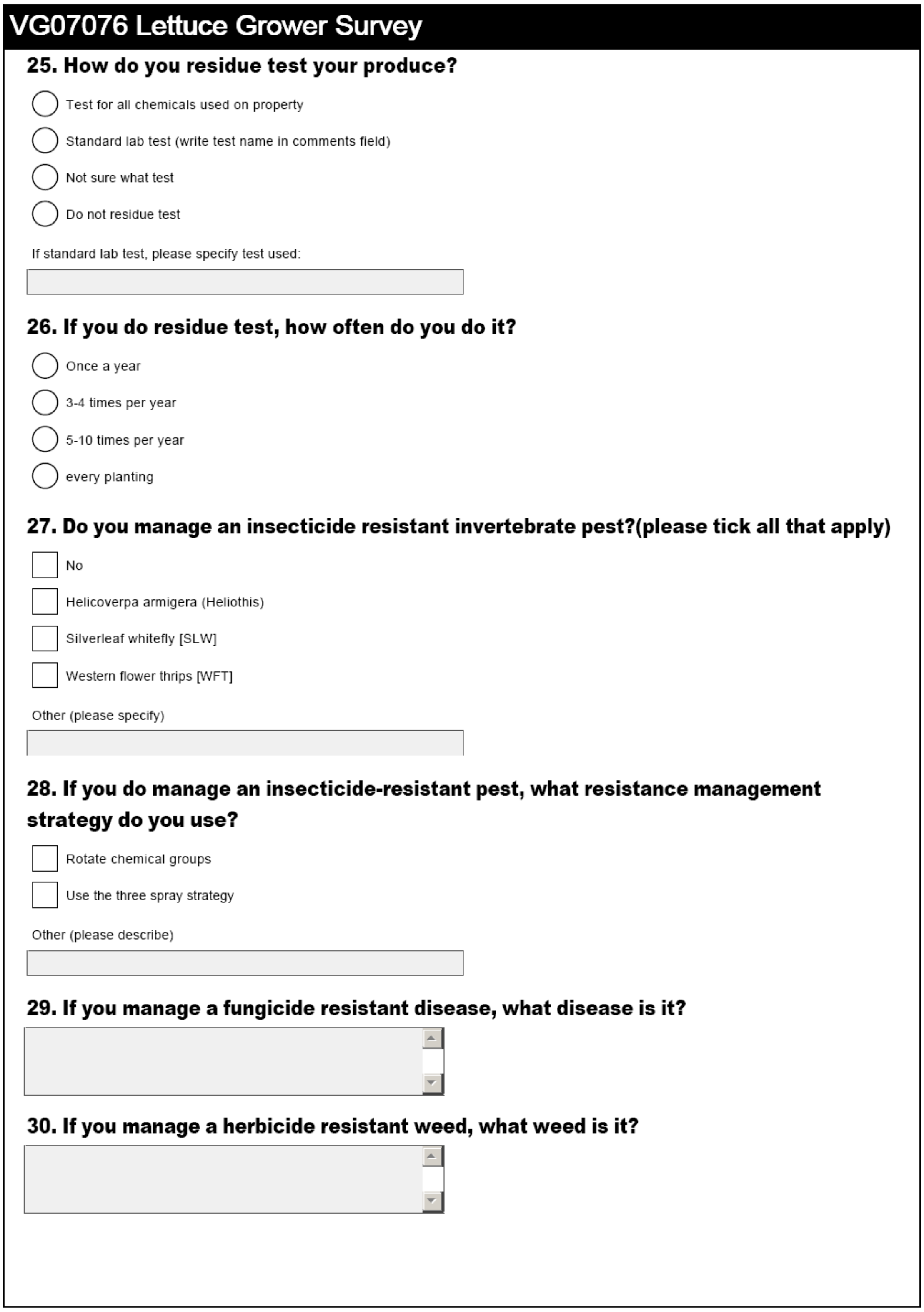
☐ Water sensitive paper

☐ Dye

☐ Look at leaf wetness

☐ Don't check

Other (please specify)



VG07076 Lettuce Grower Survey

25. How do you residue test your produce?

○ Test for all chemicals used on property
○ Standard lab test (write test name in comments field)
○ Not sure what test
○ Do not residue test

If standard lab test, please specify test used:

26. If you do residue test, how often do you do it?

○ Once a year
○ 3-4 times per year
○ 5-10 times per year
○ every planting

27. Do you manage an insecticide resistant invertebrate pest?(please tick all that apply)

☐ No
☐ Helicoverpa armigera (Heliothis)
☐ Silverleaf whitefly [SLW]
☐ Western flower thrips [WFT]

Other (please specify)

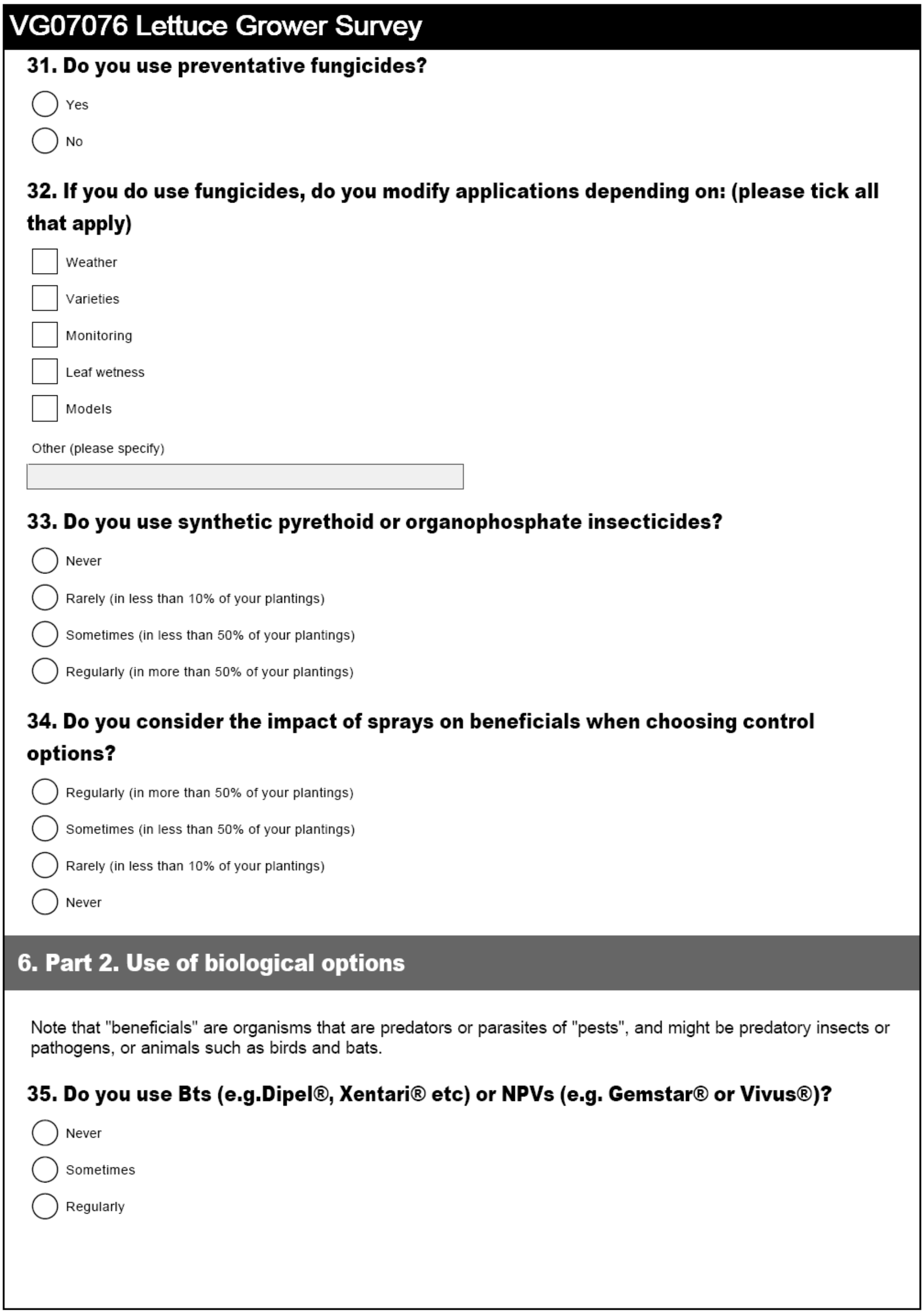
28. If you do manage an insecticide-resistant pest, what resistance management strategy do you use?

☐ Rotate chemical groups
☐ Use the three spray strategy

Other (please describe)

29. If you manage a fungicide resistant disease, what disease is it?

30. If you manage a herbicide resistant weed, what weed is it?



VG07076 Lettuce Grower Survey

31. Do you use preventative fungicides?

○ Yes

○ No

32. If you do use fungicides, do you modify applications depending on: (please tick all that apply)

☐ Weather

☐ Varieties

☐ Monitoring

☐ Leaf wetness

☐ Models

Other (please specify)

33. Do you use synthetic pyrethoid or organophosphate insecticides?

○ Never

○ Rarely (in less than 10% of your plantings)

○ Sometimes (in less than 50% of your plantings)

○ Regularly (in more than 50% of your plantings)

34. Do you consider the impact of sprays on beneficials when choosing control options?

○ Regularly (in more than 50% of your plantings)

○ Sometimes (in less than 50% of your plantings)

○ Rarely (in less than 10% of your plantings)

○ Never

6. Part 2. Use of biological options

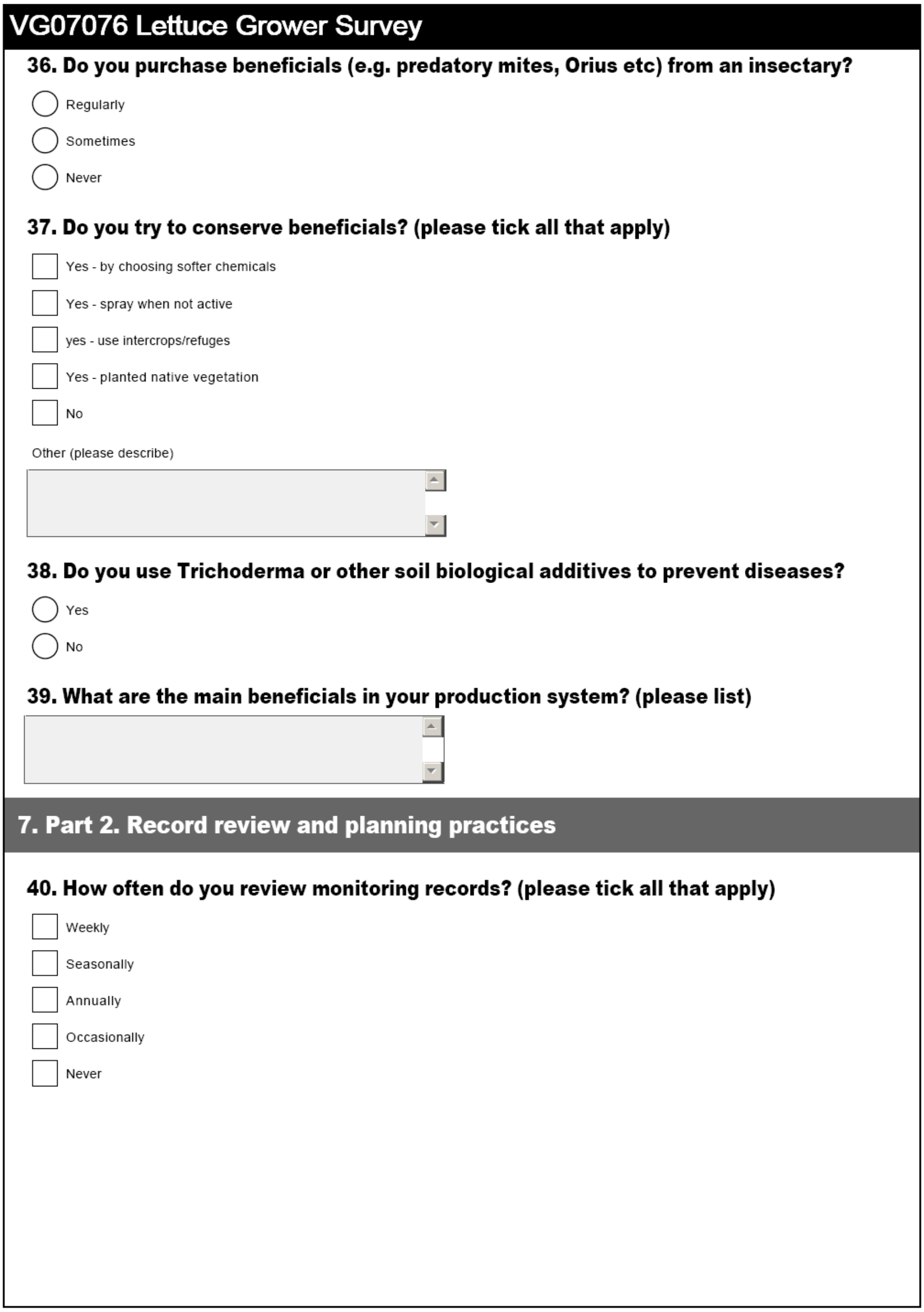
Note that "beneficials" are organisms that are predators or parasites of "pests", and might be predatory insects or pathogens, or animals such as birds and bats.

35. Do you use Bts (e.g.Dipel®, Xentari® etc) or NPVs (e.g. Gemstar® or Vivus®)?

○ Never

○ Sometimes

○ Regularly



VG07076 Lettuce Grower Survey

36. Do you purchase beneficials (e.g. predatory mites, Orius etc) from an insectary?

○ Regularly

○ Sometimes

○ Never

37. Do you try to conserve beneficials? (please tick all that apply)

☐ Yes - by choosing softer chemicals

☐ Yes - spray when not active

☐ yes - use intercrops/refuges

☐ Yes - planted native vegetation

☐ No

Other (please describe)

38. Do you use Trichoderma or other soil biological additives to prevent diseases?

○ Yes

○ No

39. What are the main beneficials in your production system? (please list)

7. Part 2. Record review and planning practices

40. How often do you review monitoring records? (please tick all that apply)

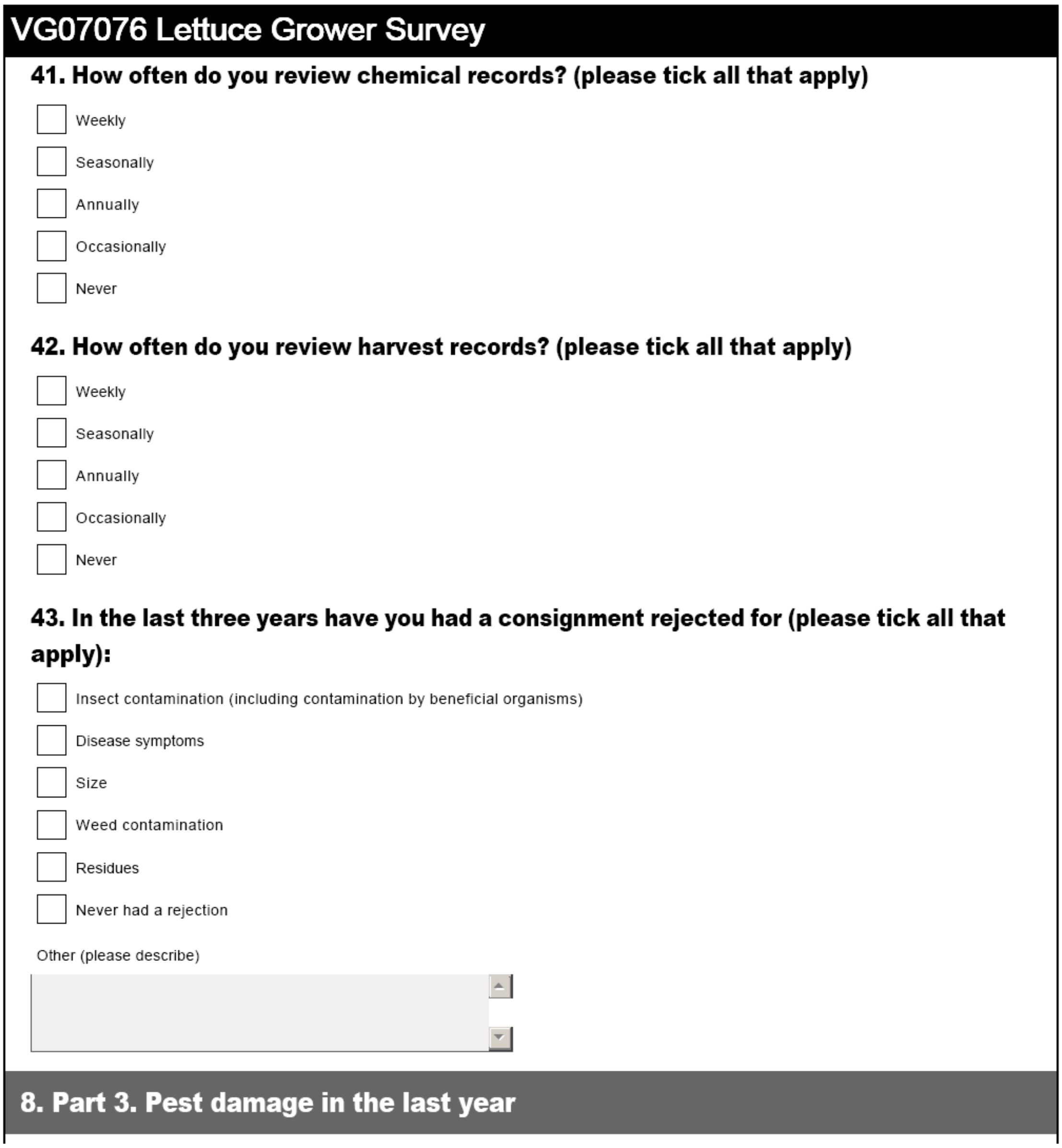
☐ Weekly

☐ Seasonally

☐ Annually

☐ Occasionally

☐ Never



VG07076 Lettuce Grower Survey

41. How often do you review chemical records? (please tick all that apply)

☐ Weekly
☐ Seasonally
☐ Annually
☐ Occasionally
☐ Never

42. How often do you review harvest records? (please tick all that apply)

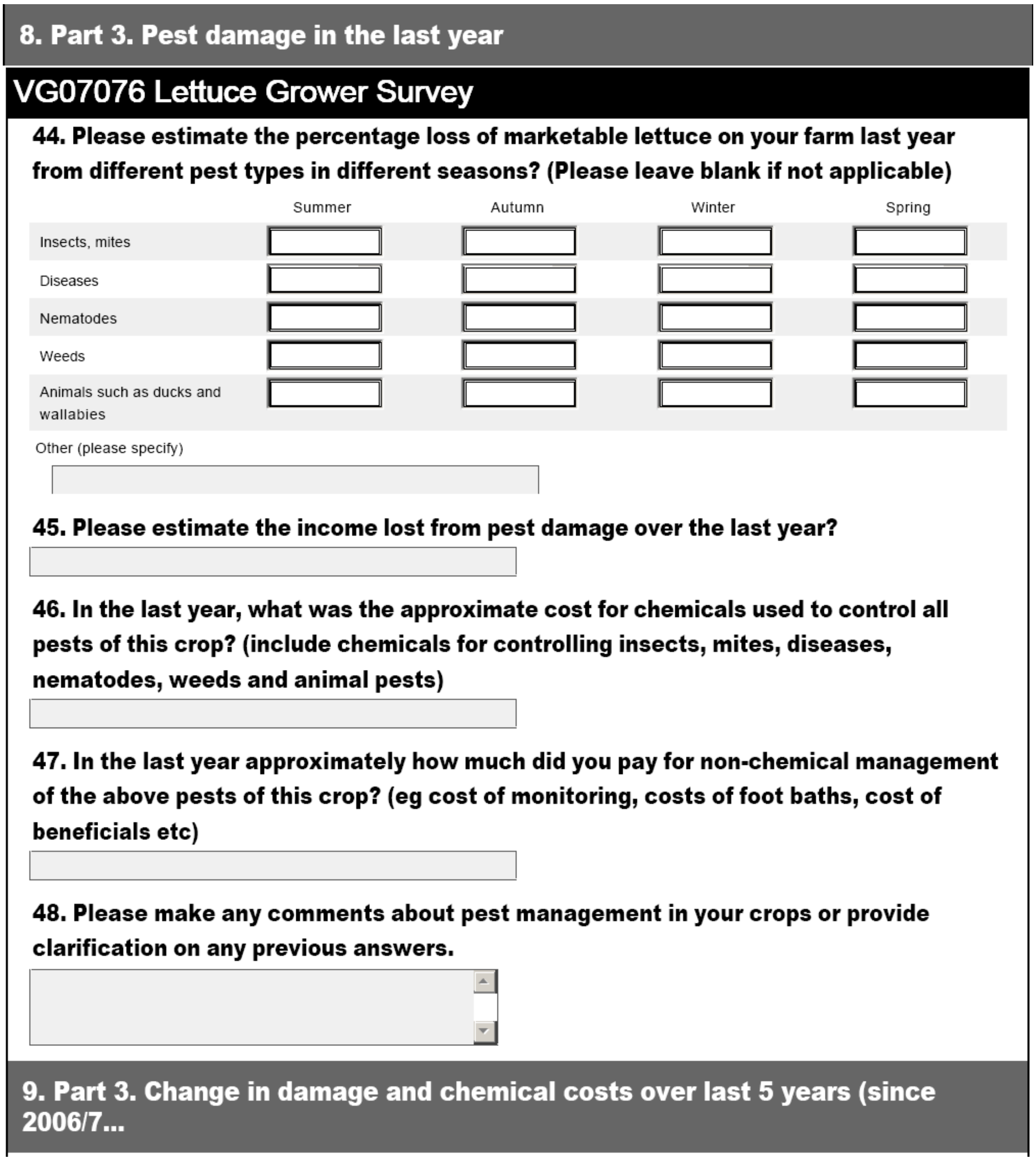
☐ Weekly
☐ Seasonally
☐ Annually
☐ Occasionally
☐ Never

43. In the last three years have you had a consignment rejected for (please tick all that apply):

☐ Insect contamination (including contamination by beneficial organisms)
☐ Disease symptoms
☐ Size
☐ Weed contamination
☐ Residues
☐ Never had a rejection

Other (please describe)

8. Part 3. Pest damage in the last year



8. Part 3. Pest damage in the last year

VG07076 Lettuce Grower Survey

44. Please estimate the percentage loss of marketable lettuce on your farm last year from different pest types in different seasons? (Please leave blank if not applicable)

	Summer	Autumn	Winter	Spring
Insects, mites				
Diseases				
Nematodes				
Weeds				
Animals such as ducks and wallabies				

Other (please specify)

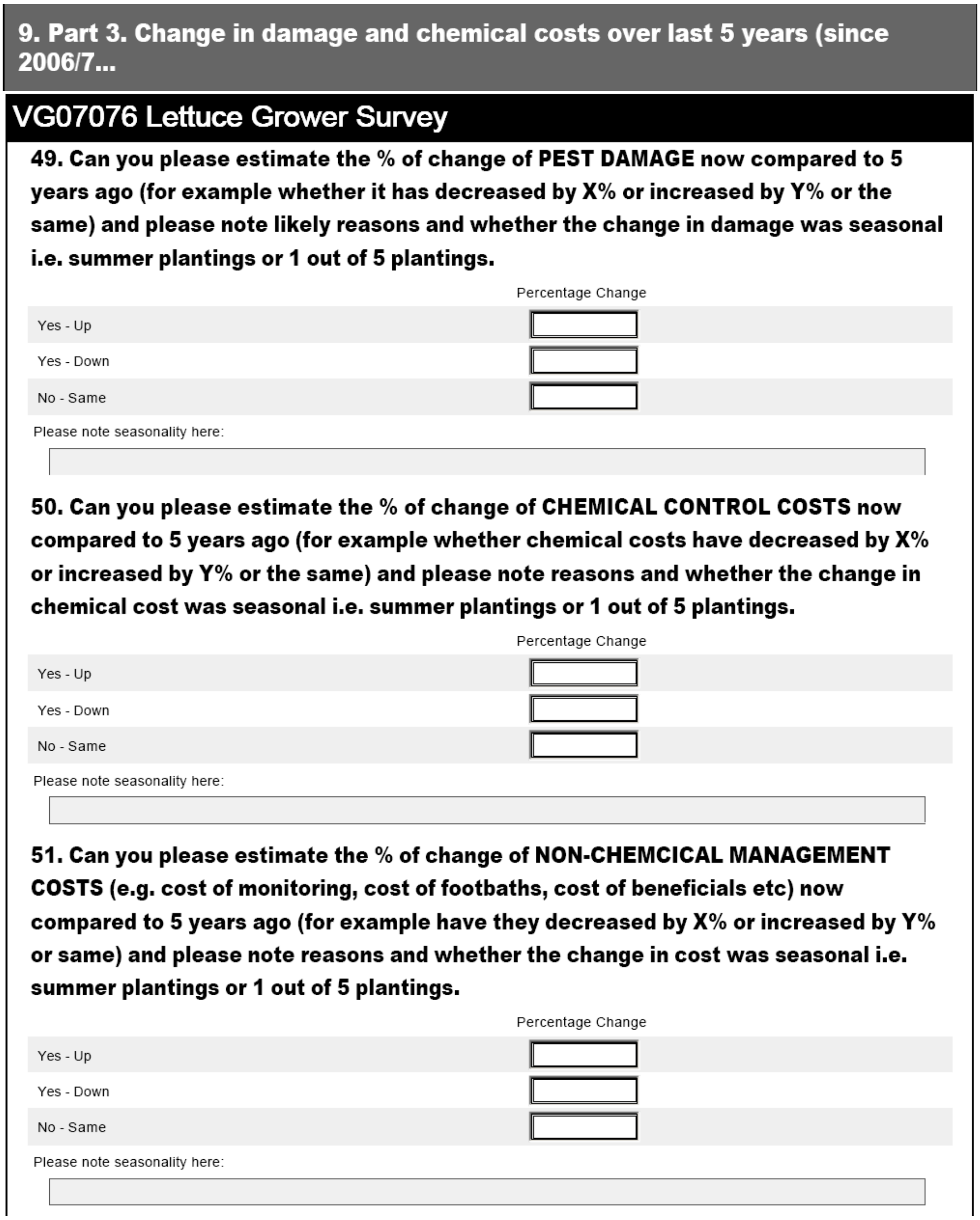
45. Please estimate the income lost from pest damage over the last year?

46. In the last year, what was the approximate cost for chemicals used to control all pests of this crop? (include chemicals for controlling insects, mites, diseases, nematodes, weeds and animal pests)

47. In the last year approximately how much did you pay for non-chemical management of the above pests of this crop? (eg cost of monitoring, costs of foot baths, cost of beneficials etc)

48. Please make any comments about pest management in your crops or provide clarification on any previous answers.

9. Part 3. Change in damage and chemical costs over last 5 years (since 2006/7...



9. Part 3. Change in damage and chemical costs over last 5 years (since 2006/7...

VG07076 Lettuce Grower Survey

49. Can you please estimate the % of change of PEST DAMAGE now compared to 5 years ago (for example whether it has decreased by X% or increased by Y% or the same) and please note likely reasons and whether the change in damage was seasonal i.e. summer plantings or 1 out of 5 plantings.

	Percentage Change
Yes - Up	☐
Yes - Down	☐
No - Same	☐

Please note seasonality here:

50. Can you please estimate the % of change of CHEMICAL CONTROL COSTS now compared to 5 years ago (for example whether chemical costs have decreased by X% or increased by Y% or the same) and please note reasons and whether the change in chemical cost was seasonal i.e. summer plantings or 1 out of 5 plantings.

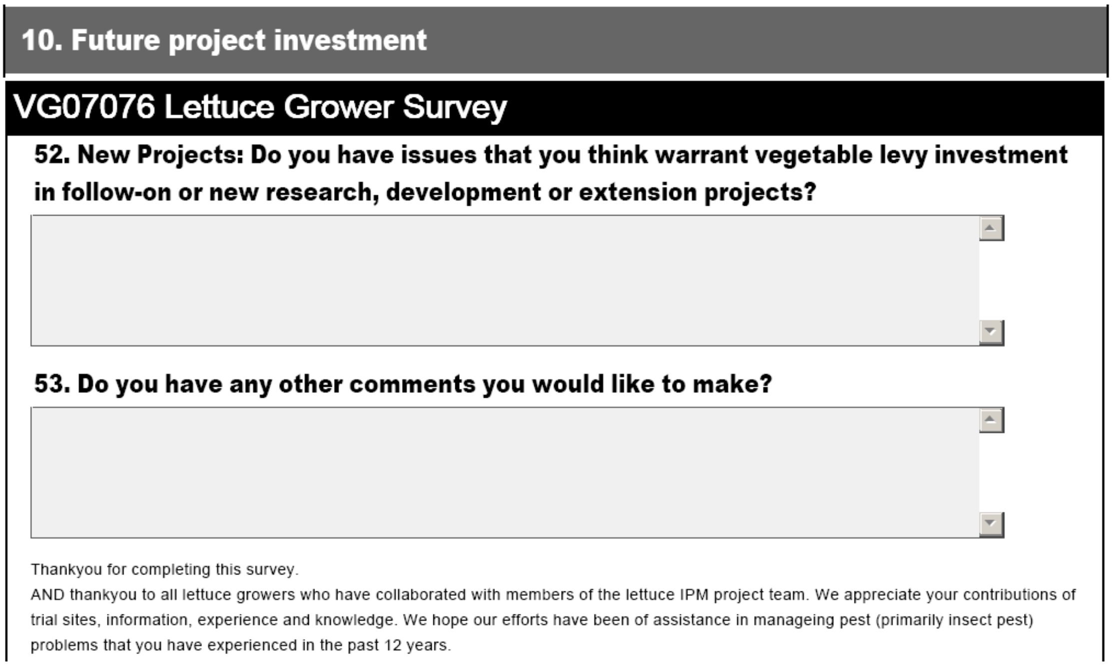
	Percentage Change
Yes - Up	☐
Yes - Down	☐
No - Same	☐

Please note seasonality here:

51. Can you please estimate the % of change of NON-CHEMCICAL MANAGEMENT COSTS (e.g. cost of monitoring, cost of footbaths, cost of beneficials etc) now compared to 5 years ago (for example have they decreased by X% or increased by Y% or same) and please note reasons and whether the change in cost was seasonal i.e. summer plantings or 1 out of 5 plantings.

	Percentage Change
Yes - Up	☐
Yes - Down	☐
No - Same	☐

Please note seasonality here:



10. Future project investment

VG07076 Lettuce Grower Survey

52. New Projects: Do you have issues that you think warrant vegetable levy investment in follow-on or new research, development or extension projects?

53. Do you have any other comments you would like to make?

Thankyou for completing this survey.
AND thankyou to all lettuce growers who have collaborated with members of the lettuce IPM project team. We appreciate your contributions of trial sites, information, experience and knowledge. We hope our efforts have been of assistance in manageing pest (primarily insect pest) problems that you have experienced in the past 12 years.

Appendix 18.1 Lettuce Crop Protection Toolkit DVD submenus

This resource was produced as part of Delivering IPM for the Lettuce Industry (VG07076) project.

Home menu

Schreurs - Lettuce field day 2006
Schreurs - CLA update 2008
Peter Schreurs - Background to IPM adoption & farm history 2009

Video Menu

Factsheets, posters, books.

Lettuce Leaf newsletters.

Training talks & quizzes.

Lettuce conference proceedings and papers.

HAL funded lettuce projects - summaries and final reports 1992-2011, lettuce IPM final reports, recent trial reports, and other lettuce project final reports.

Resource menu

Book:	Lettuce IPM information guide 2002
Booklet:	Lettuce growing guide 2004
Booklet:	Benefit-cost analysis for adoption of IPM in NSW lettuce 2011
Booklet:	Business case for adoption of IPM in lettuce 2011
Booklet:	Farm sanitation workbook-field lettuce 2011
Booklet:	IPM Continuum tables 2011
Booklet:	Optimizing yield and shelf life of iceberg and cos lettuce 2007
Factsheet:	Currant lettuce aphid 2011
Factsheet:	Heliothis in lettuce 2005
Factsheet:	Getting your best out of pesticides 2009
Factsheet:	Lettuce integrated pest management 2011
Factsheet:	Silverleaf whitefly in vegetables 2009
Factsheet:	Useful information resources for lettuce growers 2011
Factsheet:	Western flower thrips and tomato spotted wilt virus 2011
Field Guide:	Lettuce best practice (insect & disease management) 2010
Field Guide:	Pests, beneficials, diseases and disorders of lettuce 2003
Poster:	Common diseases of lettuce 2005
Poster:	Common insect pests of lettuce 2005
Poster:	IPM overview 2010
Poster:	Lettuce products impact guide 2011
Tables:	Lettuce disease summary 2011
Tables:	Lettuce insect pest summary 2011
Tables:	Pesticide impacts on beneficials 2009
Pest Calendar	Tasmania
Pest Calendar	Sydney
Pest Calendar	Stanthorpe
Pest Calendar	Riverina
Pest Calendar	Perth
Pest Calendar	Nth Adelaide Plains
Pest Calendar	Melbourne
Pest Calendar	Lockyer Valley

Factsheet, posters, books menu

Lettuce Leaf Issue 1 Dec 1999
Lettuce Leaf Issue 2 Oct 2000
Lettuce Leaf Issue 3 Feb 2001
Lettuce Leaf Issue 4 Aug 2001
Lettuce Leaf Issue 5 Jan 2002
Lettuce Leaf Issue 6 Sep 2002
Lettuce Leaf Issue 7 Dec 2002
Lettuce Leaf Issue 8 Feb 2003
Lettuce Leaf Issue 9 Apr 2003
Lettuce Leaf Issue 10 Jun 2003
Lettuce Leaf Issue 11 Aug 2003
Lettuce Leaf Issue 12 Oct 2003
Lettuce Leaf Issue 13 Dec 2003
Lettuce Leaf Issue 14 Feb 2004
Lettuce Leaf Issue 15 Apr 2004
Lettuce Leaf Issue 16 Jun 2004
Lettuce Leaf Issue 17 Aug 2004
Lettuce Leaf Issue 18 Dec 2004
Lettuce Leaf Issue 19 Feb 2005
Lettuce Leaf Issue 20 Apr 2005
Lettuce Leaf Issue 21 Jul 2005
Lettuce Leaf Issue 22 Nov 2005
Lettuce Leaf Special Edition Dec 2005
Lettuce Leaf Issue 23 Mar 2006
Lettuce Leaf Issue 24 Jun 2006
Lettuce Leaf Issue 25 Aug 2006
Lettuce Leaf Issue 26 Nov 2006
Lettuce Leaf Issue 27 Feb 2007
Lettuce Leaf Issue 28 Apr 2007
Lettuce Leaf Issue 29 Jul 2007
Lettuce Leaf Issue 30 Sept 2007

Lettuce Leaf Special Edition Dec 2007
Lettuce Leaf Issue 31 Dec 2007
Lettuce Leaf Issue 32 Mar 2008
Lettuce Leaf Issue 33 Jun 2008
Lettuce Leaf Issue 34 Oct 2008
Lettuce Leaf Issue 35 May 2009
Lettuce Leaf Issue 36 Aug 2009
Lettuce Leaf Issue 37 Feb 2010
Lettuce Leaf Issue 38 Jun 2010
Lettuce Leaf Issue 39 Mar 2011

NSW IPM Newsletter 1 Jul 2005
NSW IPM Newsletter 2 Feb 2006
NSW IPM Newsletter 3 Jul 2006
NSW IPM Newsletter 4 Mar 2007
NSW IPM Newsletter 5 Apr 2008
NSW IPM Newsletter 6 Sep 2008
NSW IPM Newsletter 7 Mar 2009
NSW IPM Newsletter 8 Aug 2009
NSW IPM Newsletter 9 Jan 2010
NSW IPM Newsletter 10 Jul 2010

Slides: IPM basic concepts

Slides: How pesticide resistance develops

Slides: Introduction to crop monitoring

Slides: Introduction to beneficials

Slides: Management of key insects & diseases of lettuce

Slides: Currant lettuce aphid - basics

Slides: Managing WFT & TSWV in lettuce

Quiz - Aphids

Quiz - Thrips

Quiz - Lettuce IPM

Newsletter menu

Training talks & quizzes menu

Conference menus

Final report menu (there is another 4 submenus of final reports)