Further developing integrated pest management for lettuce

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Project Number: VG05044

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry.

ISBN 0 7341 1896 1

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
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FINAL REPORT

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2008

Sandra McDougall *et al.*

NSW Department of Primary Industries

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Report Completed: 2008

Purpose: To build upon a successful demonstration of IPM in iceberg lettuce at Devonport in 2004-5 (VG04067) by growing pilot crops of both iceberg and loose-leaf cultivars on major commercial farms, and to build upon the previous lettuce IPM projects to address barriers to IPM adoption.

Funding:
The researchers acknowledge the financial support for this project from NSW DPI, Horticulture Australia, AUSVEG, SARDI, DAWA, TasDPI&W, QDPI&F, and the grower collaborators Greg Fehlberg and Houstons Farms, Peter Schreurs & Sons, P&M Samarges, EM&J Pateras, Galea, Newmans,.

Media Summary

Lettuce integrated pest management (IPM) has been in development in Australia since 1998 with lettuce growers able to manage the then key pest, *Helicoverpa spp*. with a range of integrated control options. The spread of western flower thrips (WFT), a effective vector of tomato spotted wilt virus in lettuce during the last decade and the arrival of the currant lettuce aphid (CLA) into Tasmania in 2004 and its subsequent movement into all major lettuce producing areas has provided an effective barrier to the widespread adoption of an IPM strategy that utilizes pest natural enemies or 'beneficials'.

A Horticulture Australia project in 2004-5 demonstrated that CLA could be controlled in Tasmanian lettuce crops by farmland predatory insects. The beneficial insects were harnessed by the grower using IPM concepts such as sequential, adjacent plantings, looking before spraying and choosing selective or 'soft' pesticides as far as possible. The predators entered lettuce hearts, ate the aphids and moved on before harvest. Insecticidal sprays failed because this pest lives deep inside lettuces unlike other aphids on lettuce.

CLA is one of the few insects where there are lettuce varieties that are resistant to attack (*Nas*-resistant). These varieties had been selected and bred in Europe where CLA originates and is a major lettuce pest. Some of the varieties available to Australian growers particularly the 'fancy' lettuce are *Nas*-resistant and the lettuce seed companies are all trying to incorporate *Nas*-resistance into all their lettuce varieties. In the northern European summer of 2007 a new CLA biotype was found feeding in *Nas*-resistant varieties which emphasises the importance of not relying on a single control mechanism. In 2006 68% of growers were using some *Nas* –resistant varieties.

Most (94%) Australian lettuce growers have chosen to use a systemic (travels from roots through plant) insecticide on *Nas*-susceptible lettuce. This insecticide while very effective for controlling aphids for 6-8 weeks does not control caterpillars nor WFT and research has shown that it can cause secondary poisoning to an important aphid and caterpillar predator, the brown lacewing.

This national vegetable levy funded project aimed to extend the results of the 2004-5 northern Tasmanian trial into southern Tasmania and the Sydney basin and to monitor the transition that Victorian IPM growers were making with the arrival of CLA. A range of other monitoring and research activities were included to assist with addressing regionally specific barriers to IPM adoption.

In 2005-6, iceberg and loose-leaf lettuces were grown under commercial conditions by two major growers near Hobart. Control in iceberg lettuce was good for six plantings and management of thrips was integrated with that of aphids. In loose-leaf lettuce control was initially promising but failed after the sixth planting.

Since CLA arrived in Victoria in May 2005 it has been controlled using an IPM strategy on several commercial farms in both Werribee South and Cranbourne. CLA populations on susceptible lettuce without insecticide drenches have been effectively controlled by aphid predators, particularly the brown lacewing.

A winter IPM trial in the Sydney basin failed to control CLA in susceptible undrenched lettuce. Aphid predators were in very small numbers over the winter but increased in the spring and effectively controlled CLA in susceptible lettuce.

CLA is not being found on weeds in and around lettuce production areas. In most areas the CLA population dynamic through the year was difficult to study with most lettuce being either CLA resistant varieties or treated with a systemic insecticide that generally lasted the whole crop.

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. It is not yet known whether increasing numbers will contribute significantly to controlling CLA or thrips.

61% of lettuce growers surveyed identified as IPM growers, 100% of IPM growers and 83% non-IPM grower monitored their crops for pests but less than 40% looked for beneficials. 28% used a consultant to monitor. 42% of non-IPM growers were 'calendar' sprayers – spraying on a regular – usually weekly basis.

Consultants who monitored lettuce were confident in their pest identification, less so of their disease identification. They were confident when to spray and to assess it's effectiveness but not particularly confident about providing advice on beneficials or their conservation. Consultants who were confident about their knowledge and skills with using beneficials were positive about growers attitudes to IPM whereas consultants lacking confidence with beneficials felt growers negative attitudes to IPM was the major barrier.

Technical Summary

The project included commercial-scale IPM trials in headlettuce 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 pilot crops of iceberg and loose-leaf lettuce were grown on two major, commercial lettuce farms near Hobart in 2005/6 to replicate successful IPM with iceberg lettuce in northern Tasmania in the previous season and to extrapolate IPM principles into loose-leaf lettuce.

Six consecutive and adjacent iceberg crops comprising 3,000 plants of one cultivar were managed using normal commercial practices except insect management followed advice from the project team. Three cultivars (Target, Titanic and Oxley) were used in all. Lettuces were assessed for pest infestation when ready for cutting by commercial standards. Plantings commenced in January 2006 and the last assessment occurred in July 2006. Oats were grown on either side of the trial area to foster natural enemies of aphids. Spinosad was applied once to the first five plantings as a possible defence against tomato spotted wilt virus that appeared in early plantings.

Eleven loose-leaf crops were similarly grown using normal commercial practices except the insect management. Each consecutive and adjacent plantings comprised 3-5,000 plants each of 4-7 red and green cultivars, most often four susceptible cultivars but additionally 2 *Nasonovia*-resistant cultivars in early plantings. Lettuces were assessed for pest infestation when ready for cutting by commercial standards. Plantings commenced in November 2005 and the last assessment occurred in July 2006.

The mean number (per lettuce) of all aphids in the six iceberg plantings were 1, 9, 26, 5, 19, 12 and 12 respectively. Distribution of aphids was clumped. Tomato spotted wilt virus (transmitted by thrips) was present but did not become a major problem.

The mean number (per lettuce) of all aphids in the 11 loose-leaf plantings were 5, 7, 32, 25, 2, 3, 589, 404, 732, 18 and 80. The first six planting were considered promising for a pilot trial although the grower had concerns about the feasibility of washing crops with mean counts of 20-30 aphids per lettuce. Although all major predators remained present in several life stages in lettuce until June they did not control the aphid population after early March. The gap in planting dates between the last successful planting and the first unsuccessful planting (P6 to P7) was large - 30 days compared to a mean of 15 days for the preceding plantings. Fungal infections of aphid appeared in late March in P7 and peaked in May-June but aphids, dead and alive, remained numerous.

Three large Victorian commercial iceberg and cos lettuce growers have successfully grown using IPM principals, harvested and sold their CLA susceptible lettuce without rejection since CLA arrived in May 2005. In 2007/8 season most crops received a pymetrozine (Chess®) spray in the first week after transplant. Brown lacewings (*Micromus tasmaniae)* have consistently proven to be the main aphid predator with populations following increases in CLA numbers per lettuce and both reducing prior to lettuce maturity and harvest.

In Sydney, on a commercial lettuce farm near Camden two blocks of 20,000 lettuce each were managed using IPM principles. The blocks were transplanted on June 1 2006 and mature at the end of August. Less than 4 aphid predators per 100 lettuce were collected in the 6 weekly vacuum samples and only increased to greater than 1 per lettuce in destructive visual samples when the crops were mature. CLA numbers were approximately 300 per lettuce at harvest. Two other spring plantings of susceptible lettuce were monitored to harvest and the aphid predators were effective with 1.8 and 18.8 CLA per lettuce at harvest. The grower's subsequent plantings were *Nas*-resistant varieties or treated with imidacloprid in the following autumn. Syrphid larvae were most numerous aphid predator in early spring, and ladybeetles (Coccinellidae) most numerous in late spring. Brown lacewings were present throughout the spring with 6 per lettuce in an early November sample.

Monitoring of hydroponic and field lettuce growers crops in the Sydney basin found CLA present throughout the year with 74% of lettuce samples having CLA in April 2007. Rutherglen bugs (*Nysius vinitor*) were the next most abundant 'pest' and were present in greatest numbers over spring. Thrips were present in low numbers sporadically. Beneficial insects were found in less than 50% of samples. The aphid predators, particularly Syrphids and Coccinellids were most abundant in October and November. Spiders were present all year in low numbers.

In Western Australia monitoring of field grown head lettuce close to Perth found CLA present throughout the year and were more abundant in winter-spring and less abundant during hot, dry weather (December-March). Thrips were the most abundant pest and western flower thrips, *Frankliniella occidentalis* were the most common thrips, particularly in late spring. Spiders comprised 45% of beneficial samples. Brown lacewings comprised 25% of beneficial samples and were most abundant in late spring.

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. It is not yet known whether increasing numbers will contribute significantly to controlling CLA or thrips.

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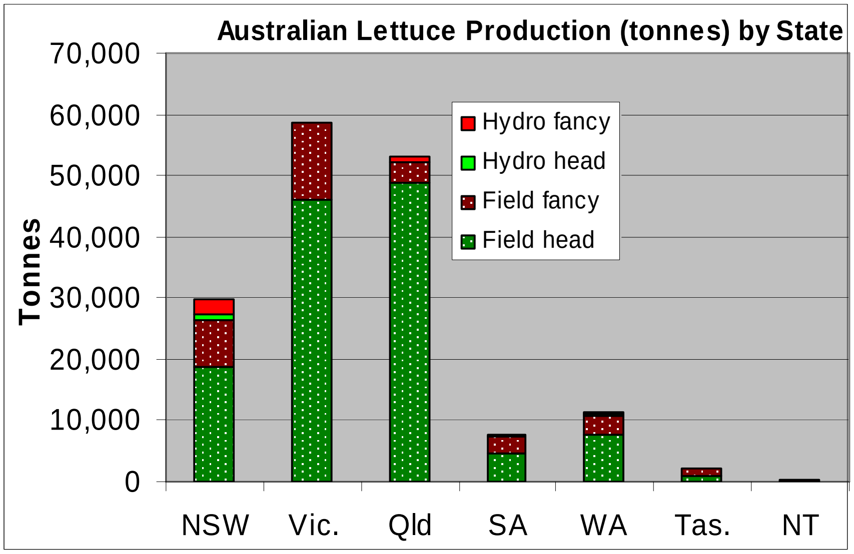
Introduction

Lettuce production in Australia is worth $174 million (ABS 2008). Queensland, Victoria and NSW are the main lettuce producing states with lettuce production valued at $62m, $51m and $37m respectively (ABS 2007) although by weight Victoria produces the most with 59,000 tonnes out of the Australian total production of 163,000 tonnes (ABS 2008). 97% of lettuce is grown in field and 79% is head lettuce (Figure 1).

Figure 1



(ABS 71210DO003 Agricultural Commodities, Australia, 2005-06 (Additional))

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 introduce vegetable industry levy (VG98048). This project was a collaboration between NSW Agriculture (now NSW DPI) and QDPI (now QDPI &F) with a voluntary contribution from Golden State Foods (GSF) which 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; as well as sclerotinia management options. When VG98048 was being developed David O'Donnell (then of Vic DPI) surveyed growers about whether heliothis were a problem and given they were not, Vic DPI applied for a separate project to focus on tipburn which was the major problem facing Victorian lettuce growers at the time (VG98082). However flights of *H. armigera* into Victoria in 1999 caused major damage and the Vic DPI project included monitoring of heliothis and efficacy trials. The project team for VG98048 conducted some extension work into Victoria directly and via the lettuce processor GSF and Costas. At this time Paul Horne from IPM Technologies an IPM consultancy company had begun a celery IPM project in Victoria. Many of the collaborating celery growers were also lettuce growers and the *H. armigera* flights were causing problems in both crops. These were the first lettuce growers to adopt an IPM strategy.

By the finish 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 indicated pests and diseases were seasonal as expected 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 pests, diseases or beneficials that 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) 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.

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] arrived to devastate the NZ lettuce industry in 2002 (Stufkens *et al.* 2002). Western flower thrips (*Franklienella occidentalis*) [WFT] was expanding it's 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 and we had some evidence that they were also toxic to some of the generalist predators.

VG01028 distributed the lettuce IPM information guide and both produced and distributed the Pest, Beneficials, Diseases and Disorders in Lettuce: field identification guides (McDougall & Creek 2003) to all lettuce growers. The Lettuce Leaf newsletter continued keep the industry informed on research advances and industry issues as did the second and third Australian lettuce conferences which were 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 have developed insecticide resistance. An IPM strategy must have regular crop monitoring of pests as well as beneficial insects, all reasonable efforts need to be made to reduce the chances of pests colonizing crops and maximising chances of beneficials to manage the pests. Important cultural management practices include ensuring seeds and seedlings are pest and disease free, removing sources of pests and diseases including finished crops, infested/infected hosts and weed hosts. If pest numbers are high enough to be causing damage insecticide choice considers the impact on beneficials present and where possible chooses options that complement the beneficials.

Currant Lettuce Aphid IPM projects

Currant lettuce aphid (CLA) arrived in 2002 and spread throughout New Zealand within the year and was probably blown across to Tasmania in late January 2004 (Stufkens *et al.* 2004). 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, Lionel Hill (VG04067). 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 lettuce harvest during spring and that a fungi species, *Erynia neoaphidis* contributed to CLA control over winter. We also knew 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 as seedlings but with most 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 that 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.

Currant Lettuce Aphid Incursion

In January 2004, storms and associated easterly winds extensively damaged production of Tasmanian head lettuce. In February increasing insect problems in lettuce despite increasing insecticide application, control was not achieved. Aphid samples were sent from a head lettuce and a loose leaf farm for identification in mid-March and were identified as CLA.

Within days the Office of the Chief Plant Protection Officer (OCPPO) prohibited lettuce exports to the mainland and co-ordinated a response to the incursion. Within four weeks OCPPO determined that the pest was non eradicable in Tasmania. An Australia-wide survey of lettuce crops had established that lettuce aphid was restricted to Tasmania. A total ban on head lettuce movement to the mainland was imposed but loose leaf lettuce was allowed following rigorous protocol development and testing. Movement of other CLA hosts was also banned.

An emergency permit (PER7416) was provided by the Australian Pesticides and Veterinary Medicines Authority for the use of imidacloprid (Confidor®) as a seedling treatment for lettuce as a precautionary measure and on the basis "that Integrated Pest Management (IPM) and Insecticide Resistant Management (IRM) strategies be developed by the lettuce industry as a high priority to complement seedling drench treatments (when required)."

AUSVEG organised a Lettuce Aphid Advisory Group meeting on 28th February 2005 to which regulatory staff from each state were invited and it was resolved that:

1. no interstate trade barriers be imposed on any of SA, VIC, NSW or QLD lettuce produce.
2. protocols will apply to seedling nurseries and the interstate movement of transplants.
3. if the pest first arrives in WA interstate trading protocols should apply.
4. the existing arrangements should remain between Tasmania and the mainland.

In early May 2005 CLA was detected in outer-eastern metropolitan Melbourne. All other mainland states immediately placed interstate movement restrictions on lettuce and other CLA hosts coming from Victoria. The restrictions varied between states but most required the crop to have been grown from imidacloprid treated seedlings and/or to be *Nas*-resistant varieties. In November 2005 an agreement was reached on a protocol for NSW to accept IPM lettuce from Victoria.

CLA was not initially found in commercial lettuce and was found at a time when most Victorian growers had a winter break in lettuce production. By October 2005 it was confirmed in all the lettuce production areas east of Melbourne and in Werribee. Destructive sample surveys in other states for CLA continued on approximately a monthly basis. On the 30th January 2006 CLA was detected in southern Sydney. By March it was found north of Sydney and on isolated properties in the northern Tablelands (via seedlings) and in May in central western NSW. On May 8th 2006 CLA was detected in South Australia, October in Queensland at Bayscliff and in early December just north of Perth.

In the European summer of 2007 a strain of CLA was found successfully feeding and breeding on *Nas* resistant varieties in seven areas of northern Europe (Bealde pers com.)

Project Scope

VG05044 Further developing lettuce integrated pest management was designed to:

1. have the IPM trials/demonstrations in Victoria and Tasmania in the first year, NSW and SA in the second year.
2. investigate CLA seasonal abundance and weed host preference
3. conduct field surveys to better understand the role of beneficial insects in WA and Sydney basin
4. investigate the role of predatory mites for management of thrips
5. Support adoption of IPM through IPM Case studies, field days, providing technical support and training for crop scouts/consultants and other locally appropriate means
6. communicate via the national vegetable conferences to be organised by AUSVEG and through the lettuce leaf newsletter.

A1. IPM Demonstration/Trial – Tasmania

Lionel Hill and Cathy Young
Department of Primary Industries and Water, Tasmania

Introduction

In 2004-5 at Devonport in northern Tasmania a sequence of nine plantings of iceberg lettuce (total 55,000) were grown using the best available IPM knowledge in simulated commercial conditions and the first seven were marketed successfully. Aphid and caterpillars were the prime pests managed. Control declined in the last two plantings possibly because large areas of lettuce treated with systemic seedling drenches were introduced adjacently (disrupting the dispersal of predators as well as killing some of them) and/or because seasonal conditions allowed the aphids to outstrip the dispersal and growth rates of predators.

This project sought:

- to assist major Tasmanian lettuce farms to grow pilot IPM crops;
- to repeat the IPM success in another region (southern versus northern Tasmania) and in other lettuce varieties (loose-leaf as well as iceberg lettuce);

Material & Methods

Terminology

The abbreviations P1, P2 … P13 are used for plantings 1 to 13. The term loose-leaf lettuce is used for fresh-cut, loose-leaf cultivars that are transplanted, have a relatively open form and are cut as loose leaves for washing, mixing and packing. These are not strictly baby-leaf lettuce, which are sown directly and more densely.

Scientific names of insects and allied organisms are given in Appendix 1.

Technology transfer (Extension)

Technology transfer was inherent in this project. It was conducted on two dominant, commercial farms with planting, growing and harvesting operations conducted by the farmers. Measurements of pest activity were conducted by staff of DPIW and IPM Technologies in the presence of and with assistance of farm staff. Discussions of results and amendments to strategy were done in the field as the sequence of crops progressed.

Agronomy

The crops grown were:

- Loose-leaf lettuce at a farm operated by Houston's Farm, a few kilometres north-east of **Richmond** and
- Iceberg lettuce at Brownwood Farm, operated by Mr Greg Fehlberg, several kilometres north of **Campania**

Both sites were in south-eastern Tasmania and included the major Tasmanian lettuce production sites, practices and pests not previously addressed in Project VG04067 in north-western Tasmania in the preceding season.

Lettuces were grown by growers following their usual commercial practices but the insecticide program was modified, crop areas were relatively small, crop planting intervals relatively long for loose-leaf lettuce and, at the iceberg lettuce site, relatively large areas of oats were grown adjacent to lettuce to harbour cereal aphids as a nursery for aphid predators and parasites. Residues of loose-leaf crops also persisted longer than usual because the crops were not harvested and retained as sources of beneficial insects. At both farms, irrigation was applied by solid-set sprinklers.

Iceberg lettuce

Brownwood Farm grows brassica vegetables and iceberg lettuce. The IPM area was 200m x 20m. Each planting contained 3,000 lettuce in beds of three rows with wheel spacings of 1.65 m and plant spacing of 300 mm within rows. Plantings commenced in the east and progressed westwards each as very long, narrow areas. Each planting occupied 2-3 beds.

In addition, oats were grown on both sides (east and west, each 200 x 3 m) of the IPM lettuce site. The eastern oats were cut on 19 April 2006 and the western oats a month later.

Each planting of iceberg lettuce received one application each of Bravo® and Filan® fungicides as well as one application of spinosad (Success®) against thrips (except P6) because tomato spotted wilt virus appeared in the early plantings.

Cauliflowers, sprayed with some unselective insectcides, were grown to the east of the trial early in the season and imidacloprid-drenched lettuce west of the trial late in the season with fallow at other times. Imidacloprid-drenched lettuce were grown extensively to the south of the IPM site throughout the season. The hinterland of the farm was mostly pasture that dried off in December 2005 before the first IPM planting occurred. Table A1.1 summarises the planting and harvest assessment dates. The iceberg trial did not include spring plantings.

Table A1.1 Planting and maturity dates of the six plantings of iceberg lettuce at Brownwood Farm, Campania.

Planting	Cultivar	Planted	Final visual assessment near crop maturity
1	Target	18 January 2006	8 March 2006
2	Target	31 January 2006	29 March 2006
3	Titanic	14 February 2006	12 April 2006
4	Titanic	28 February 2006	17 May 2006
5	Oxley	14 March 2006	5 June 2006
6	Oxley	28 March 2006	-

Loose-leaf lettuce

The area used for the IPM trial was near Richmond and previously grew lucerne and pasture. The paddock was about 200 x 60 m. Several hectares of non irrigated lucerne grew to the south of the trial site. The hinterland of the farm was mostly pasture that dried off in December 2005. Appendices A1.6 and A1.7 provide details of layout. Plantings commenced in the east and progressed westwards. Plantings rocket, P12 and P13 used the same area as the initial plantings, P1 and P2, but were too late to be assessed here.

Cultivars were typical of those used by Houstons Farm in their main production farms elsewhere or were *Nas*-resistant cultivars with potential future use. The latter were abandoned after P4 in order to focus attention on management of *Nas*-susceptible cultivars. Tables A1.2 and A1.3 summarise the composition and dates of plantings.

Pirimicarb was applied as a foliar spray to three of six adjoining beds of Deltona green oak lettuce in P4 on 6 January 2006 to test its usefulness in an IPM strategy when CLA appeared to be advancing ahead of predators. Otherwise, no insecticides were applied for the control of aphids, caterpillars, thrips, bugs or other pests. All plantings of the loose-leaf lettuce received one application of Kerb herbicide and one of Filan fungicide at or soon after planting.

In mid and late January a few dozen mature lettuce were cut from P3 and P5 respectively and placed between beds of P6 in an effort to hasten dispersal of predators from older to younger plantings.

Table A1.2 Cultivars of *Nas*-susceptible and *Nas*-resistant (Nr) loose-leaf lettuce grown at Richmond.

Leaf form	Cultivar	Plantings
Green oak	Deltona	All
Green coral	Virjile	All except P4
Green frilly	Tarragona	P1, P2 and P3
Red oak	Jamai RZ 83-48	All
Red coral	Lagon	All
Red Oak Nr	Sirmai RZ 83-57	P1, P2, P3 and P4
Red coral Nr	Obregon RZ 79-79	P1, P2 and P3

Table A1.3 Planting and maturity dates of the thirteen plantings of loose-leaf lettuce and one of rocket at Richmond. Nr indicates *Nas*-resistant cultivar.

Planting	Cultivars	Planted	Final visual assessment near crop maturity
1	7 including 2 red Nr	4 November 2005	16 December 2005
2	7 including 2 red Nr	18 November 2005	5 January 2006
3	7 including 2 red Nr	1 December 2005	12 January 2006
4	4 including 1 red Nr	15 December 2005	18 January 2006
5	4	29 December 2005	2 February 2006
6	4	18 January 2006	1 March 2006
7	4	17 February 2006	12 April 2006
8	4	23 February 2006	5 May 2006
9	4	8 March 2006	17 May 2006
10	4	22 March 2006	8 June 2006
rocket	Rocket brassica	5 April 2006	
11	4	5 April 2006	20 July 2006
12	4	26 April 2006	-
13	4	31 May 2006	-

Monitoring

For the purpose of deciding on pesticide interventions the population trends of pests and beneficials were assessed by weekly to fortnightly visual examination of several lettuces of each cultivar in the field. These observations were supplemented by vacuuming 50 or more lettuce in each planting.

Assessment

Counts of fauna

Lettuces were taken for destructive (leaf-by-leaf) visual counts of insects at commercial maturity and, in two instances (P2 and P6 of loose-leaf lettuce) also at 9-15 days before maturity. Sample sizes were 15-30 lettuces per treatment. New Town Laboratories (DPIW), Hobart provided facilities for sorting, counting and identifying insects in samples of lettuces taken from the two farms. Lettuces were inspected on a bench in a laboratory, leaf by leaf, by entomological technicians using eyes, hand lenses and microscopes as needed.

Commercial sales

Most iceberg lettuce were sold by the grower to his usual markets. Small consignments were also cut and marketed by the project team to gain extra feedback from greengrocers.

Small consignments of loose-leaf lettuce were harvested by the project team and sold by several cooperating greengrocers to test consumer feedback. Some of these lettuces were sold whole, while others were cut to loosen leaves and washed. Bulk commercial sales of washed and packaged lettuce could not be pursued because of constraints on use of the processing factory arising from an interstate phytosanitary trading protocol.

Results

Iceberg lettuce

Table A1.4 summarises the abundance of pests and predators in six plantings of iceberg lettuce lettuce. CLA was most abundant at the southern ends of P3-P5 where waterlogging was conspicuous.

The grower had some rejections of lettuce from the third planting but circumvented further rejections by bypassing the waterlogged sections during harvest. Lettuces rejected by retailers or consumers typically contained 200 aphids. Raw data underlying Table A1.4 is given in Appendix A1.1 and reveals the typical patchiness of aphid infestation.

Table A1.4: Brownwood Farm, Campania, destructive inspection of iceberg lettuce at maturity.

Mean insects per plant	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	Mean
Date of planting	18-Jan-06	31-Jan-06	14-Feb-06	28-Feb-06	14-Mar-06	28-Mar-06	for
Date of assessment	8-Mar-06	29-Mar-06	12-Apr-06	17-May-06	5-Jul-06	5-Jul-06	P1-P5
Days from planting	49	57	57	78	113	99	
Cultivar	Target	Target	Titanic	Titanic	Oxley	Oxley	
Currant lettuce aphid	0.33	8.53	25.93	5.03	18.70	12.20	11.7
Brown sowthistle aphid	0.07	0.00	0.17	0.13	0.07	0.07	0.1
Other aphids	0.07	0.40	0.00	0.03	0.00	0.00	0.1
Total of all aphids	*0.47*	*8.93*	*26.10*	*5.19*	*18.77*	*12.27*	11.9
caterpillars	0.00	0.00	0.00	0.00	0.00	0.00	0.0
plant-feeding thrips	0.67	1.43	0.30	0.00	0.00	0.07	0.5
Brown lacewing larvae	0.60	0.13	0.03	0.03	0.00	0.00	0.2
Brown lacewing adults	0.30	0.07	0.00	0.00	0.00	0.03	0.1
hoverfly larvae and pupae	0.03	0.07	0.03	0.00	0.00	0.00	0.0
ladybird larvae and pupae	0.00	0.00	0.00	0.00	0.00	0.00	0.0
ladybird adults	0.00	0.00	0.00	0.00	0.00	0.00	0.0
ladybird eggs	0.20	0.00	0.00	0.00	0.00	0.00	0.0
spiders	0.20	0.17	0.13	0.00	0.10	0.07	0.1
predatory mites	0.00	0.07	0.00	0.27	0.10	0.53	0.1
predatory thrips	0.03	0.20	0.00	0.00	0.03	0.00	0.1

Notes:
Sample size was 30 lettuces per assessment
P3 sampled 1 week before commercial maturity.
Planting 6 sampled three or more weeks before maturity

Loose-leaf lettuce

Table A1.5 summarises the abundance of pests and predators in P1-P11 for the *Nas*-susceptible cultivars (Appendices A1.3 and A1.4 give data for all cultivars). Aphid infestation was low in the first six plantings. It remains unclear whether the levels in P3, P4 and P10 were manageable in large-scale commercial washing and packing processes. However, hand washing of small batches from P1-P6 and P10 produced acceptable loose-leaf lettuce for greengrocers.

Table A1.5: Richmond, destructive visual inspection of *Nas*-susceptible loose-leaf lettuce near commercial maturity (but P11 premature). Larger numbers rounded off.

	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
Date of planting	4-Nov	18-Nov	1-Dec	15-Dec	29-Dec	18-Jan	17-Feb	23-Feb	8-Mar	22-Mar	5-Apr
Date of harvest	16-Dec	5-Jan	12-Jan	18-Jan	2-Feb	1-Mar	12-Apr	5-May	17-May	8-Jun	20-Jul
Interval, days	-	14	13	14	14	20	30	6	13	14	14
Days old at assessment	42	48	42	34	35	42	54	71	70	78	106
Currant lettuce aphid	**2**	**5**	**30**	**24**	**2**	**3**	**588**	**403**	**731**	**17**	**80**
All aphids	5	7	32	25	2	3	589	404	732	18	80
Lacewings excl. eggs	0.7	0.5	0.5	0.2	0.7	0.9	1.9	0.2	0.3	0.2	0.2
Hoverflies excl. eggs	0.1	0.6	0.4	0.1	1.3	1.2	0.6	0.8	0.5	0.0	0.1
Ladybirds incl. eggs	0.2	0.4	0.3	0.2	0.6	0.3	1.4	0.1	0.1	0.0	0.0
Ratio of all aphids to predators	**5**	**5**	**28**	**49**	**1**	**1**	**154**	**425**	**813**	**78**	**400**

Cultivars

Table A1.6 summarises aphid infestation for the four main cultivars. An analysis of variance (using plantings as replicates) confirmed there were no differences. Appendix A1.8 shows this data graphically. Caterpillar abundance was too low to reveal any differences (Table A1.7).

Table A1.6: CLA per lettuce for 4-5 *Nas*-susceptible cultivars over 11 plantings.

Currant lettuce aphids	Deltona Green oak	Virjile Green coral	Jamai Red oak	Lagon Red coral	Tarragona Green frilly	MEAN Excl. Tarragona
P1	1.7	4.1	0.0	4.1	2.1	2.5
P2	0.2	10.7	7.1	5.6	0.2	5.9
P3	19.1	38.2	35.0	30.5	28.1	30.7
P4	20.1		26.8	24.1		23.7
P5	0.0	5.3	2.3	0.1		1.9
P6	0.1	1.3	9.5	1.5		3.1
P7	826.7	413.3	366.7	746.7		588.4
P8	270.7	82.7	720.0	540.0		403.4
P9	796.7	593.3	686.7	846.7		730.9
P10	5.7	8.9	35.6	18.6		17.2
P11	11.1	38.5	174.4	95.9		80.0
MEAN	177	120	188	210		

Table A1.7: Caterpillars per lettuce for 4-5 *Nas*-susceptible cultivars over 11 plantings.

caterpillars	Deltona Green oak	Virjile Green coral	Jamai Red oak	Lagon Red coral	Tarragona Green frilly	MEAN Excl. Tarragona
P1	0.00	0.00	0.00	0.10	0.00	0.03
P2	0.10	0.10	0.10	0.10	0.00	0.10
P3	0.00	0.00	0.00	0.00	0.00	0.00
P4	0.00		0.00	0.00		0.00
P5	0.00	0.00	0.00	0.00		0.00
P6	0.10	0.00	0.00	0.00		0.03
P7	0.00	0.00	0.10	0.10		0.05
P8	0.00	0.00	0.10	0.10		0.05
P9	0.00	0.00	0.10	0.10		0.05
P10	0.00	0.00	0.00	0.00		0.00
P11	0.00	0.00	0.00	0.00		0.00
MEAN	0.02	0.01	0.04	0.05		

Beneficial species encountered

The common beneficial insects were brown lacewing, 11-spotted ladybird, white-collared ladybird, transverse ladybird, *Melangyna* and, to a lesser extent, *Simosyrphus* hoverflies, several spider species, damsel bugs, many microwasp parasites and predatory mites.

Brown lacewing was the only lacewing encountered in lettuce. They were present at various levels throughout the November to July observation period. Their eggs were present at least as late as May and larvae as late as June.

Three species of ladybirds (Coccinellidae) were regularly encountered. These were spotted amber ladybird, 11-spotted ladybird and transverse ladybird. Spotted amber ladybird was first detected in Tasmania at several sites near Devonport in late 2002 and early 2003 but was not detected in the 2004-5 lettuce trial near Devonport. In contrast, spotted amber ladybird was present in the southern lettuces and probably more common than either 11-spotted or transverse ladybirds. Spotted amber and transverse ladybirds were present from December to at least May. The 11-spotted ladybird was present from November to at least April. A parasitic wasp that forms a cocoon under the beetle of 11-spotted ladybird was noted in November 2005 and January 2006 in the loose-leaf lettuce. Two-spotted ladybird was occasionally noted in lettuce (January, March and May). Southern ladybird was noted once in lettuce (March). Common spotted ladybird and striped ladybird were not encountered in the Richmond and Campania crops nor in the 2004-5 Devonport lettuce trial.

Hoverfly larvae were the most conspicuous predator of aphids present. They were noted from November to June and pupae from November to April. Adults were present in November and December when observations commenced and noted again in March and April but no trapping or systematic observations of adults were made. *Melangyna* was the dominant genus on the wing and reared from several hoverfly puparia but a few adult *Simosyrphus* were noted in autumn. The wasp that parasitises hoverfly, *Diplazon* was noted in March and April both flying and reared from hoverfly puparia found in lettuce. The presence of dead hoverfly larvae and associated black liquid in January suggests that a bacterial disease may have occurred in the hoverfly population.

Damsel bug, a predator of caterpillars, was present in January in loose-leaf lettuce and seen in March and May in the oats at the Campania site but was not common.

Spiders of diverse, small species were common at both sites throughout the season. The predacious common brown earwig was found in or near lettuce at Campania and Richmond

Pests species encountered

The major pests detected were aphids. Currant lettuce aphid dominated. It was present in November but initially less common than brown sow thistle aphid. Currant lettuce aphid persisted through summer and autumn to winter. Juveniles and winged and wingless adults were present up to 20 July 2006 on loose-leaf lettuce at Richmond when observations ceased. An aphid-killing fungus became common in the CLA population from April to July. Appendix A1.9 illustrates daily temperature data at Richmond and Table 10 summarises this.

Table A1.8. Air temperatures at Richmond**.**

	Lowest Daily Min Temp	Highest Daily Max Temp	Average
January	5.9	39.5	17.6
February	5.1	31.8	17.0
March	3.5	26.8	15.0
April	1.5	31.8	14.4
May	-6.3	19.0	9.4
June	-6.6	15.4	7.6
July	-5.7	17.5	7.7

Other common species of aphids on lettuce were brown sow thistle aphid, potato aphid, foxglove aphid, green peach aphid and a *Brachycaudus* species. Brown sowthistle aphid was present from November to June. Potato aphid was most noticeable from March to June.

Caterpillars were scarce (Appendices A1.2 and A1.4) comprising a few noctuid and geometrid individuals. Yellow leafhopper adults, Rutherglen bugs, thrips and slugs were also present but did not require specific management except that the appearance of Tomato Spotted Wilt Virus, probably transmitted by onion thrips, prompted the use of spinosad in the iceberg trial. Rutherglen bugs, mostly adults, were present in lettuce a low levels for a long period following a massive immigration from the mainland around 3 November 2005.

Notable absences were the pests vegetable leafhopper, western flower thrips, cluster caterpillar, lucerne leafroller and silverleaf whitefly and the predators common spotted ladybird, minute pirate bug, bigeyed bug, assassin bug and predatory shield bug.

Birds

Birds became destructive predators in May and June at the loose-leaf trial site. Flocks of white fronted chats fed on insects in lettuce, tore leaves and left droppings in lettuce. Smaller flocks of black faced cuckoo shrikes also fed in or among plants in March and May-June.

Pirimor in IPM

A foliar application (1 kg/ha in warm conditions) of Pirimor (pirimicarb) to three of six beds of Deltona (*Nas*-susceptible green oak lettuce) in P4 at Richmond did not reduce the population of currant lettuce aphid below that in the unsprayed beds (Appendices A1.3 and A1.4).

Discussion

Aphid life cycle

Currant lettuce aphid clearly maintained its 'summer' breeding cycle well into winter at Richmond and Campania. Mean monthly temperatures at Richmond in June and July were 7.6°C and 7.7°C respectively. Diaz and Fereres (2005) showed that currant lettuce aphid multiplied fastest at constant 24°C and slowest at constant 8°C but remained fecund at 8°C whereas temperatures of constant 28°C stopped reproduction and caused high mortality of existing individuals. They concluded that this aphid is well adapted to reproduce and develop under low temperatures.

Crop duration

The degree of biological control achieved in any particular planting always depends upon the relative numbers of pests (lettuce aphids) and beneficials (lacewings, ladybird beetles, hoverflies or pathogens).

The short duration of loose-leaf crops strains biological control when the target is not artificially inundated with predators or parasites. In some early plantings control came just before the harvest date and often improved in the fortnight following (most plants were not actually harvested but remained for a few weeks before being mowed and cultivated). In P6 aphids declined from 33 to 42 days after planting and in P2 a lesser decline occurred between day 33 and day 48 (Appendix A1.4). In the 2004-5 iceberg IPM project at Devonport substantial declines in aphid populations occurred in several plantings in weeks 5, 6 and 7 after planting (Report VG04067).

The causes of loss of control in loose-leaf plantings P7-P9 in autumn cannot be clearly identified. For most pests and crops the first planting is regarded as the most likely to fail when waiting for predators to establish in a sequence of adjacent crops. However in the currently reported loose-leaf trial, in the previous iceberg trial at Devonport and in related iceberg trials in Victoria, plantings such as the 6th – 8th have had weakest control rather than the first planting. This is attributed to the aphids producing winged forms which move from early plantings into later plantings before the aphid population becomes high in the early plantings. Significantly, they move into these later plantings before the populations of predators have gained control. The 2005-6 iceberg trial at Campania commenced in mid growing season and ended before any such phenomenon became apparent.

Liu (2004) showed that the dispersal rate of CLA is more consistent than in other aphid species because winged forms are produced continually - 10% were winged at all population densities that he observed in field cages but he did not observe extremely crowded populations. Diaz and Fereres (2005) showed that temperature does affect production of winged currant lettuce aphids. The proportion of winged aphids remained below 7% at 16 °C and increased to 40-57% above 20 °C. At the Richmond loose-leaf trial winged currant lettuce aphids were constantly present (Appendix A1.9 shows temperatures at Richmond). Temperatures in winter were probably marginal and mortality from fungal infections were substantial with perhaps half of the July colonies having conspicuous infections.

Loose-leaf Planting 7 – loss of control

The interval in planting dates between the last successful and the first unsuccessful loose-leaf planting (P6 to P7) was 30 days compared to a mean of 15 days for the preceding plantings. The subsequent gap between planting dates of P7 and P8 was only 6 days.

P7 was planted in mid February when aphids were peaking in P6 and before they succumbed to predation. At 6 days after planting (23 February) there was one winged aphid per red coral plant (adjacent to P6), fewer aphids on intervening cultivars and none on green oak plants, which were furthest from P6. Some red coral plants of P7 adjoining P6 already had colonies of 10 or so juveniles but only one adult ladybird was seen on 80 plants (all cultivars) and no lacewings or hoverfly larvae. By 12 days after planting (1 March) aphids were not conspicuously more abundant in P7. Also seen were four adult white-collared ladybirds on 100 plants, some hoverfly larvae in aphid colonies but no lacewings were seen or vacuumed. In the next three weeks aphids outbred their predators. By 34 days after planting there were 100 aphids per plant although some ladybird adults and lacewing larvae were observed. At 41 days after planting many dead bodies of aphids, relatively many parasitised aphids, hoverfly larvae and ladybird eggs were present but no adult ladybirds and 'few' lacewing larvae were noted in field observations. Fungal disease was also common in the aphids probably accounting for many of the 'dead aphid bodies' recorded but some 'bodies' may have been predated or simply skins shed in growth.

However, the numbers of lacewing larvae recorded in the destructive sample on 12 April 2006 (1.9 per plant, 54 days after planting P7) is twice that of any other planting including 'successful' plantings (Appendix A1.7 or Table 5). This is much more than suggested by the field note made 13 days previously of a 'few'. For ladybirds, both the field notes and the harvest assessment (1.4 adults, larvae and/or eggs per plant) suggest that ladybirds, including eggs, were conspicuous in P7. In subsequent plantings lacewings and ladybird counts at harvest date (P8, 5 May 2006) were low.

In the 2004-5 Devonport iceberg trial control first failed in planting 8 in which the numbers of aphids vacuumed at weeks 2, 3 and 4 were not high but lacewing counts were very low. Lacewings subsequently multiplied until at maturity (20 April 2005, 9 weeks after planting) they were relatively abundant but aphids were much more so. (Report VG04067, Tables 8 and 10)

Looseleaf Planting 10

Substantial biological control was temporarily regained in P10 after its loss in P7-P9. Planting 10 grew through April and May. Cooler 'autumn' temperatures began abruptly in late April (see Appendix A1.9) perhaps temporarily allowing existing predators to overtake a slowed aphid population but then temperatures declined further to prevent regeneration of the predator population.

One factor that could have contributed to the poor and somewhat erratic level of biological control was the fact that there were not weekly plantings of lettuce, but the interval varied between mostly 2 and 4 weeks (Table A1.5). That is there was not a continuous, even range of lettuce for aphids and predators to colonise. The aim was to make the lettuce crops the source of predators for later plantings rather than rely on continuous immigration from outside the crop, but this is less likely with longer planting intervals. The greatest movement of predators into lettuce crops is most likely to be in spring, and least in late autumn – winter.

Technology Transfer

The pilot crops of IPM *Nas*-susceptible iceberg lettuce were not encouraging enough for the grower to consider growing more in the next season. The introduction of bagging lettuce for supermarkets will preoccupy his attention in the coming season.

In the longer term this grower wants access to cool season *Nas*-resistant lettuce but fears that most selection trials in Australia will focus on warm season cultivars. The grower sees a resistant cultivar strategy as more consistently reliable. Serious aphid infestations appeared to correlate with waterlogged sections of plantings which the grower avoided harvesting once the problem was recognised. He did not receive other complaints from his market. It would appear that repeated demonstrations of susceptible IPM crops with consistent results are needed.

The pilot crops of IPM *Nas*-susceptible, loose-leaf lettuce failed in P6-P9 and P11 and although results were promising in P1-P5 the grower's field staff had concerns about the washability of 24-30 aphids per plant (P3 and P4). This doubt could not be resolved by a commercial-scale washing test during the project but the grower is continually developing washing technique to better handle all insects (similar washing trials are being undertaken in Victoria.).

The grower remains primarily interested in finding *Nas*-resistant cultivars of loose-leaf lettuce to facilitate resting imidacloprid drenches and delay the development of insecticide resistance. There are also issues of long crop durations in winter requiring higher seedling drench rates.

This grower also had concerns about accommodating plantings of non-crop vegetation to foster beneficial insects. The concerns include a shortage of land area in cool months when crop life is extended relatively more than market demand is diminished and the greater complexity in weed and perhaps irrigation management.

Recommendations

IPM for iceberg lettuce should continue to be demonstrated in pilot crops to advisors and commercial growers because it is a viable option provided it is supervised by a competent IPM agronomist. However, replication of success is likely to be needed to overcome scepticism.

IPM for loose-leaf lettuce requires more investigation before it can be demonstrated to growers at a pilot commercial level. However this is best done as subsidised pilot crops with growers working under commercial constraints.

Growers remain most interested in *Nas*-resistant cultivars with special qualities such as iceberg forms suited to Tasmanian spring and autumn conditions and loose-leaf forms with wide seasonal performance to obviate frequent changes in package labels, which must specify cultivars.

Packaging of iceberg lettuce is likely to further complicate delivery of IPM advice because many otherwise transient insects will be trapped with produce.

Acknowledgements

The following entomological staff of DPIW, Tasmania conducted the field observations, sampling and laboratory assessment of lettuce: Lionel Hill, Dr Cathy Young, Graeme Anderson, Wayne Williams, Kellie Gillespie and Michaela Young.

The following owners and staff at Houstons Farm, Richmond provided land, knowledge and resources to grow loose-leaf lettuce: Colin Houston, Dr Lee Peterson, Ricky Munford, Kate Smith and others. Kate Smith also assisted greatly with field observations and crop records.

Greg Fehlberg, owner and operator at Brownwood Farm, Campania provided land, knowledge and resources to grow iceberg lettuce.

Dr Paul Horne and Jessica Page from IPM Technologies P/L provided key professional knowledge and commercial experience in vegetable IPM to the research team and to growers.

The national vegetable levy provided funds for seedlings and towards technical staff and travel for professional staff for this project.

Dr Sandra McDougall of the NSW Department of Primary Industries obtained project funding, provided liaison with Horticulture Australia Limited and Ausveg, professional advice and access to the *Lettuce Leaf* newsletter.

A2 Currant Lettuce Aphid studies in Victoria

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Summary

Currant lettuce aphid and its control using an IPM strategy has been studied in several commercial lettuce crops in Victoria since its arrival. Sites were in 2 production areas, Werribee South and Cranbourne. Currant lettuce aphid was controlled without insecticide drenches at these sites by a range of predatory species of insects. Brown lacewings (*Micromus tasmaniae*) were most important predators at these sites.

Introduction

Currant lettuce aphid (CLA) was first recorded in Victoria in 2005 and soon spread to crops throughout both Werribee South and Cranbourne districts. The 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®, 1.1ml 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 CLA and the 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.

Methods

Commercial crops were monitored weekly and populations of CLA and their predators were observed, each year since the arrival of CLA. In Werribee South the crops were iceberg lettuce, and in Cranbourne there were initially only Cos lettuce but for the last two seasons also iceberg lettuce crops grown using IPM.

The IPM crops avoided broad-spectrum insecticides for any pests, and did not use drenches of imidacloprid. In 2007-2008 some crops were sprayed with pymetrozine (Chess®) in the early stages. No aphicides were used in 2005 – 2006.

Laboratory bioassays were conducted to determine the effects of imidacloprid drenches on the main predator, *Micromus tasmaniae*.

Results

Commercial crops of lettuce have been grown successfully using IPM in both Werribee and Cranbourne every year since the arrival of CLA. 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. In addition to CLA, other pests that had to be dealt with include: Heliothis (*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 in an IPM strategy and overall, problems with CLA at harvest were minimal. Brown lacewings (BLW) and hoverflies (HF) were the main predators controlling CLA Figure A2.1 illustrates how these predators controlled CLA 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 CLA at harvest were less than indicated (see figure A2.2), and no lettuces were rejected from these sites because of CLA.

Figure A2.1: Biological control of CLA in a commercial iceberg lettuce crop in Werribee South, 2005 – 2006.

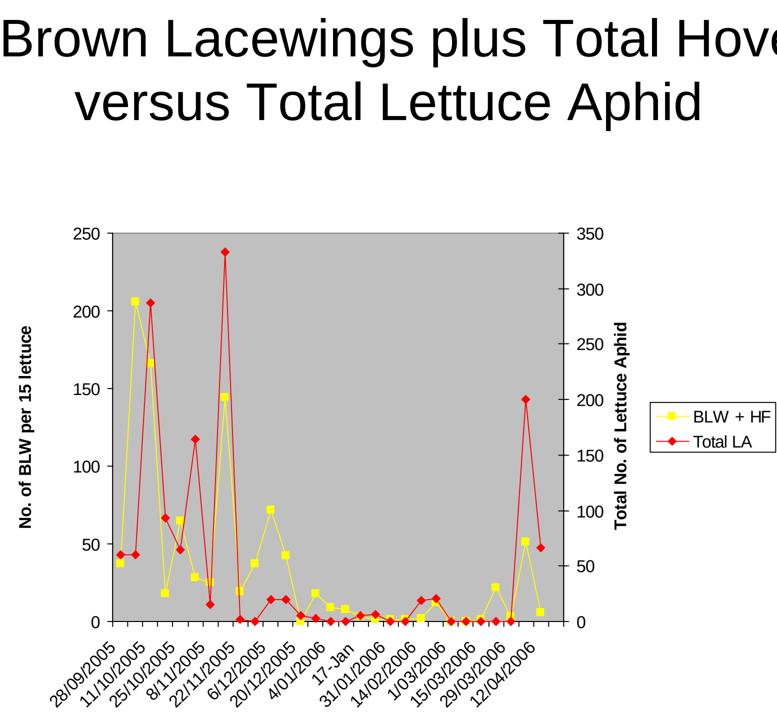

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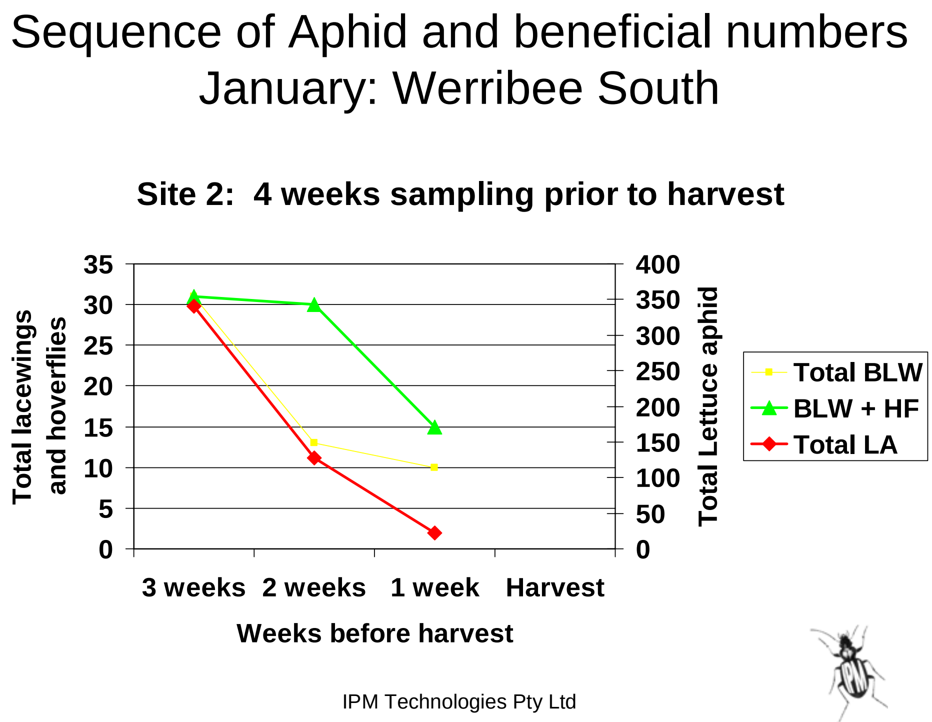
Figure A2.2: Reduction in CLA numbers approaching harvest, 2005 - 2006.

BLW = Brown lacewings, HF = hoverflies, LA = Currant lettuce aphid

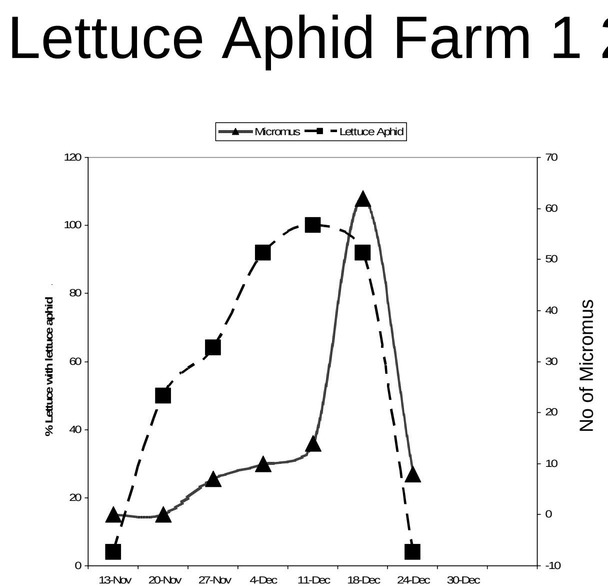


A field day was held near Cranbourne at Peter Schreurs and Sons farm to demonstrate how CLA had been controlled in Cos lettuce since its arrival. A video of this field day was produced by the IDO. That farm has grown Cos lettuce continually since that time and still has never used Confidor drenched seedlings,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

The same result has been achieved in Werribee South with participating growers since the arrival of CLA. 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 CLA again. Results for one planting are shown in Figure A2.3.

Once again the final assessment was made a week before harvest and there was no CLA found in the crop at the time of harvest. Similarly brown lacewings also left the crop once their food source (CLA) was exhausted.

Figure A2.3: Numbers of *Micromus* BLW found in 10 lettuce and the percentage of lettuce with CLA present throughout the life of one planting.



In the laboratory, bioassays were conducted to assess the impact of imidacloprid drenches on brown lacewings (BLW), the main predator of CLA in Victoria. It was found that BLW 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).

Discussion

CLA can clearly be controlled without imidacloprid drenches as part of an IPM strategy dealing with all pests. However, utilizing the naturally occurring predators of CLA relies on there being no insecticides applied for other pests that will kill beneficials or reduce their performance. The growers involved in these trials point to the added difficulty of controlling Heliothis 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 CLA, much more practical.

A3. IPM Demonstration/Trial – Sydney Basin

Sandra McDougall (NSW DPI), Paul Horne (IPM Technologies), Andy Ryland (Beneficial bug Co.), Eddie Galea (F&H Galea and Son)

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 currant lettuce aphid (CLA), *Nasonovia ribis-nigri* 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 areas where there are no existing commercial scale IPM growers adoption tends to get stuck at crop monitoring and using some new chemistry and is unlikely to move forward unless there is a major crisis in control using the existing practices. 'Seeing is believing' or is at least more powerful than 'reading' or 'hearing'. Growers tend to be very practical people and seeing a concept in practice, particularly under conditions similar to their own is hard to doubt. One of the aims of this phase of lettuce IPM development was to have demonstration/trials on growers farms in each of the major lettuce production areas. Western flower thrips (WFT) were not a pest in either of the Tasmanian nor Victorian demonstrations, and growers in the other states were sceptical that IPM could be adopted without frequent use of broadspectrum insecticides for the control of WFT.

Eddie Galea is a field lettuce grower in the Sydney basin who was very sympathetic to the principals behind IPM, supported the need for research and development, and had recently contracted a consultant to monitor his crops. He first saw CLA in his crops in April 2006. He had been managing his pests with the assistance of Andy Ryland from Beneficial Bug Company using integrated pest management (IPM) principles. It has been a learning curve for both that was severely challenged by CLA. In July of 2006 Paul Horne from IPM Technologies in Victoria and Sandra McDougall from NSW DPI met with Eddie Galea and his crop consultant Andy Ryland to discuss using a planting of Eddie's for an IPM demonstration. Each region has it's lettuce 'season' and this was to be the first winter planting infested with CLA to be managed using an IPM strategy.

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 52ha 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 planting area is native bushland. Three recycling dams are within the cultivated area. The land to the south is weedy grassland.

Methods

Seven blocks (20,000 plants each) of CLA susceptible lettuce, var *Patagonia* planted on north-south running beds, 4 rows to a bed, with overhead sprinklers were assessed during this trial. In 2006 prior to 1st June, seventeen blocks of lettuce had been grown, some which had been heavily infested with CLA. None of the lettuce in this trial had been treated with imidacloprid Confidor®. After "planting 7" in this trial all plantings were of *Nas* resistant varieties.

The trial plantings were managed as commercial plantings. Andy Ryland, an IPM crop consultant initially monitored 100 plants per week with a vacuum sampler for 6 weeks in the first two plantings or until the lettuce began to heart. After hearting had begun lettuce was visually monitored by cutting 15 heads and stripping back each leaf to count insects. At harvest 30 heads were sampled. Only planting 1 and 2 had the full set of vacuum and visual sampling. Other plantings were monitored as time permitted (see Table A3.1 & A3.2).

Management recommendations were made in consultation with Paul Horne and Sandra McDougall.

Table A3.1. Crop information for the plantings monitored

Planting	Block	Variety	Planting Date	Harvest Date
P1	11	Patagonia	1/06/2006	28/08/2006
P2	10	Patagonia	1/06/2006	7/09/2006
P3	7	Patagonia	24/08/2006	12/10/2006
P4	6	Patagonia	31/08/2006	
P5	5	Patagonia	31/08/2006	
P6	4	Patagonia	14/09/2006	
P7	3	Patagonia	21/09/2006	9/11/2006

Table A3.2. Monitoring and spray application data

Planting	Vacuum sample (DAP)	Visual Sample (DAP)	**Insecticide applications** (target insect)
P1	7,14,20,28,35,41	49,62,70,77,88	32 DAP & 42 DAP Pirimor (CLA), 63 DAP Success (thrips), 69 DAP Chess (CLA)
P2	7,14,20,28,35,41	49,62,70,77,91,98	63 DAP Success, 69 DAP Chess
P3		28, 35, 42, 49	21 DAP Chess (CLA) & Vivus (Heliothis), 35 DAP Avatar (Vegetable weevil) & Pirimor (CLA), 42 Success (thrips)
P4	21		
P5	21		
P6	7,13,21		
P7	15	28, 36, 42, 49	7 DAP Avatar (Vegetable weevil) & Pirimor (CLA), 14 DAP Success (thrips), 28 DAP Vivus (Heliothis)

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

Results

Vacuum sampling

From the 100 plants vacuum sampled each sample date a few species (see Table 3) in small numbers (Table A3.4) were collected.

Table A3.3. Pest and Beneficial insects collected in vacuum sampling June–Oct 2006

PEST SPECIES	
Currant Lettuce aphid	*Nasonovia ribis-nigri*
Brown Sowthistle aphid	*Uroleucon sonchi*
Onion thrips	*Thrips tobaci*
Common brown leafhopper	*Orosius argentatus*
Vegetable leafhopper	*Austroasca viridigrisea*
Rutherglen bug	*Nysius vinitor*
Heliothis	*Helicoverpa punctigera*
Vegetable weevil	*Listroderes difficilis*
BENEFICIAL SPECIES	
Transverse ladybeetle	*Coccinella transversalis*
Parasitoids	Aphilinidae
Spiders	various
Damsel bugs	*Nabis kinbergi*
Pirate bugs	*Orius sp.*

Table A3.4. Vacuum sampling of 100 lettuce plants by planting and date sampled

Planting	**DAP**	Date monitored	**CLA**	**Predators**	**Pests***
1	**7**	8-Jun	0	3	0
1	**14**	15-Jun	1	1	1
1	**20**	21-Jun	0	1	6
1	**28**	29-Jun	1	4	1
1	**35**	6-Jul	0	3	0
1	**41**	12-Jul	2	2	0
2	**7**	8-Jun	0	4	0
2	**14**	15-Jun	0	2	2
2	**20**	21-Jun	1	3	4
2	**28**	29-Jun	0	1	1
2	**35**	6-Jul	2	3	0
2	**41**	12-Jul	3	1	0
4	**21**	21-Sep	60	13	51
5	**21**	21-Sep	18	13	83
6	**7**	21-Sep	4	4	60
6	**13**	27-Sep	8	9	88
6	**21**	5-Oct	8	3	87
7	**14**	5-Oct	4	10	89

* not including aphids

With the exception of 4 brown sowthistle aphids (BSA) all aphids collected were currant lettuce aphids (CLA). All the thrips identified were onion thrips. Two species of leafhoppers were collected, common brown and vegetable (*Orosius argentatus* and *Austroasca viridigrisea*). Rutherglen bugs was the next most numerous pest after CLA and two *Helicoverpa punctigera* larvae were picked up in the 21st September monitoring (Figure A3.1).

Figure A3.1

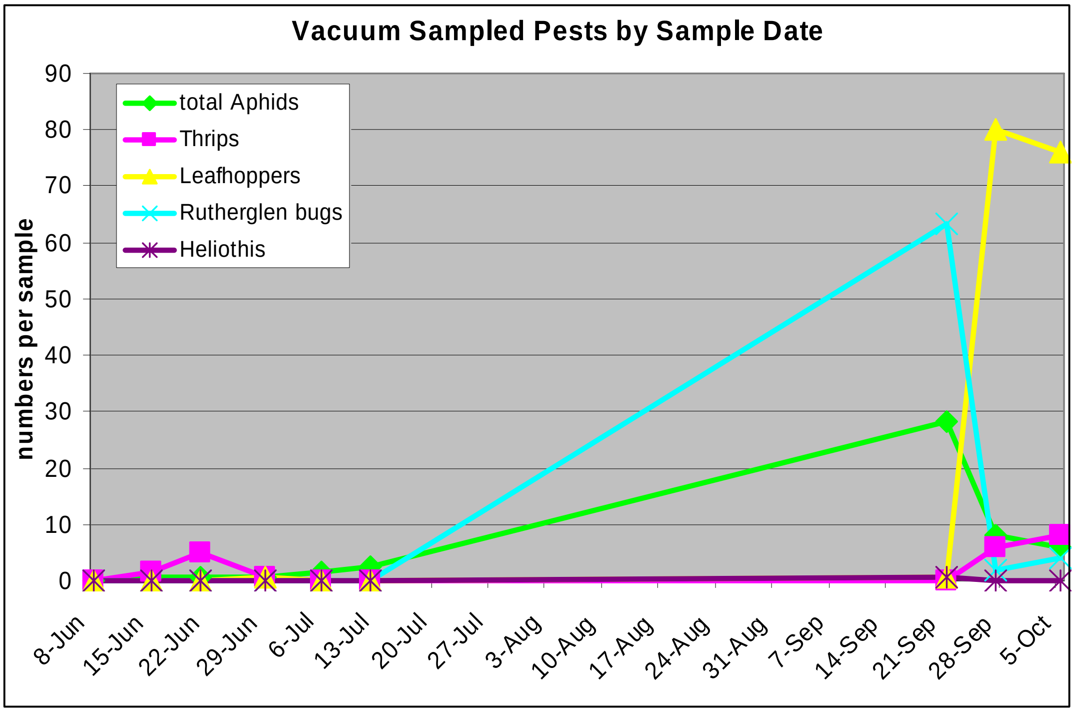
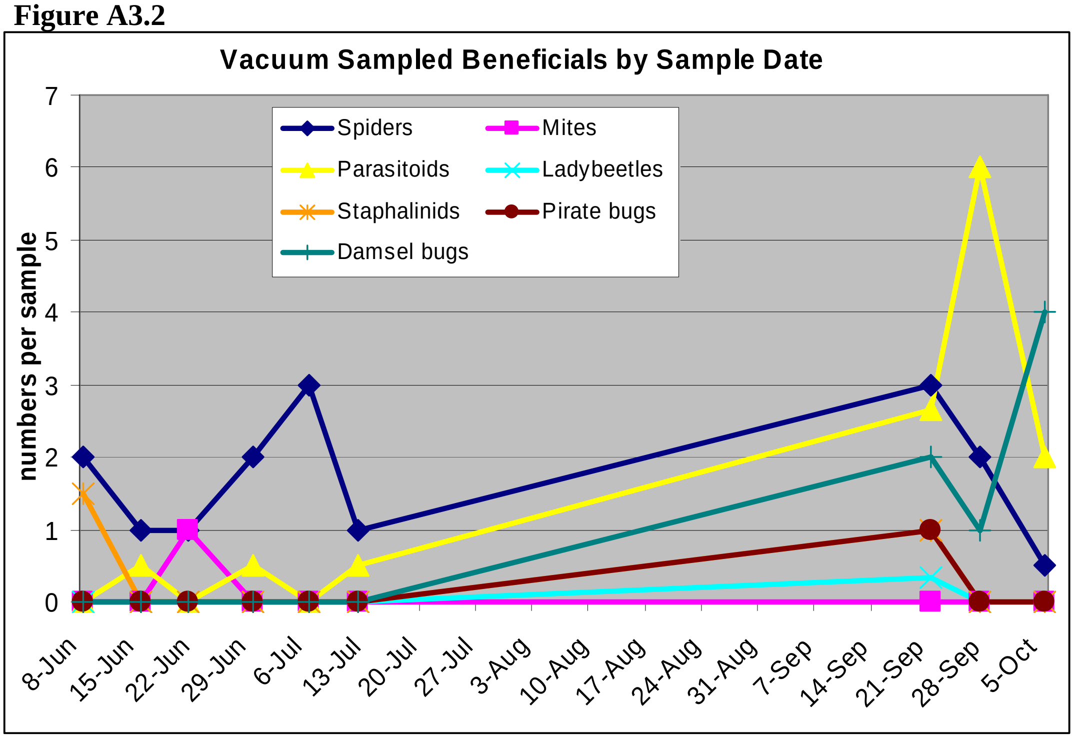


Figure A3.2

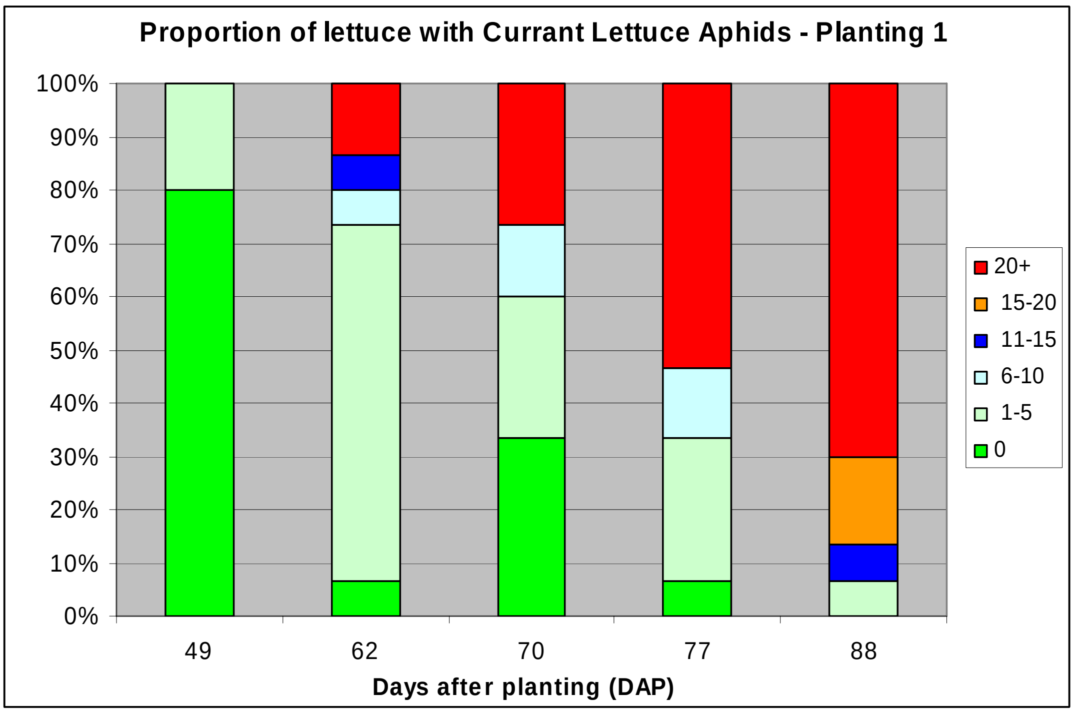


Spiders were the most numerous and consistent beneficial collected in vacuum sampling (Figure A3.2). Small numbers of other predators were collected including predatory mites, predatory beetles (Staphilinids), predatory bugs (Damsel and Pirate bugs) and various parasitoid wasps (Figure A3.2). Prior to 21st September no common aphid predators (ladybeetles, syrphids, lacewings or damsel bugs) were sampled.

Visual sampling

Once the heart began forming in the lettuce, vacuum sampling had to stop and visual sampling began. At each sampling period 15 lettuce and at harvest 30 lettuce were cut and stripped to count insects. Planting 1 had five weeks of visual sampling from which it can be seen that at 49 DAP most lettuce had no CLA present to 88 DAP or harvest most lettuce had 20+ CLA per head (Figure A3.3)

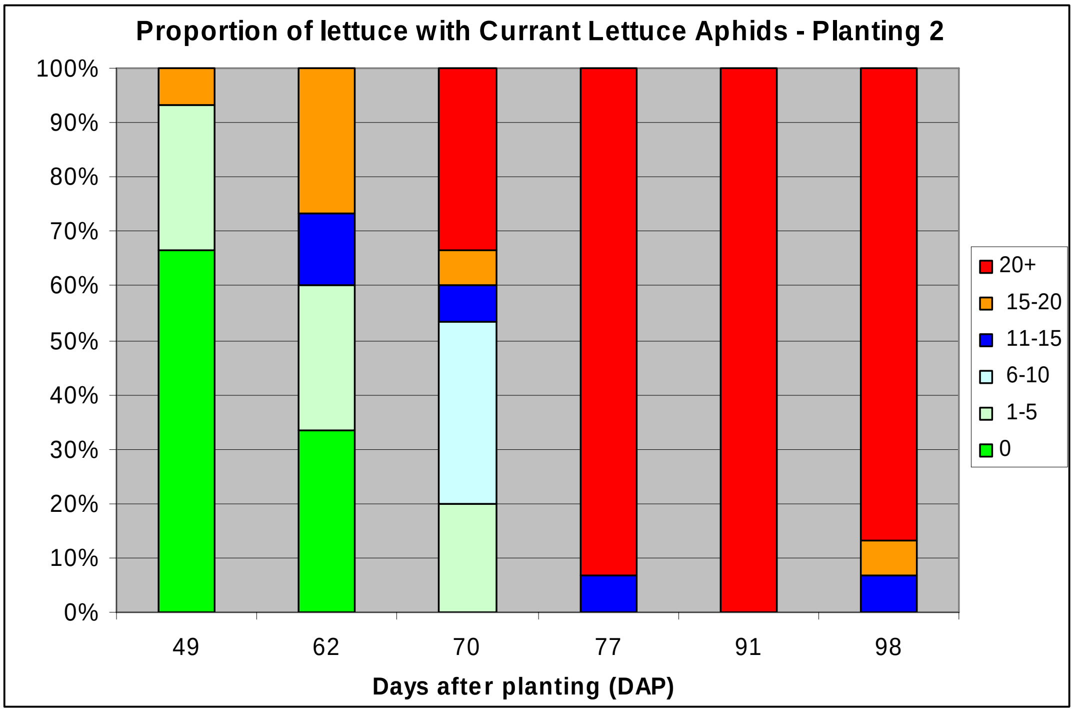
Figure A3.3



Planting 2 was equivalent to Planting 1 in all ways accept that it did not have the two early Pirimor sprays (35 & 42 DAP) and was harvested ten days latter. The proportion of heads infested with CLA grew more quickly with no foliar sprays and no aphid predators present (Figure 4). At the time when Planting 1 was harvested 100% of heads had greater than 20 CLA and at harvest slightly fewer appeared to have such high numbers with an increase in predator numbers but still the crop was unacceptable for commercial harvest.

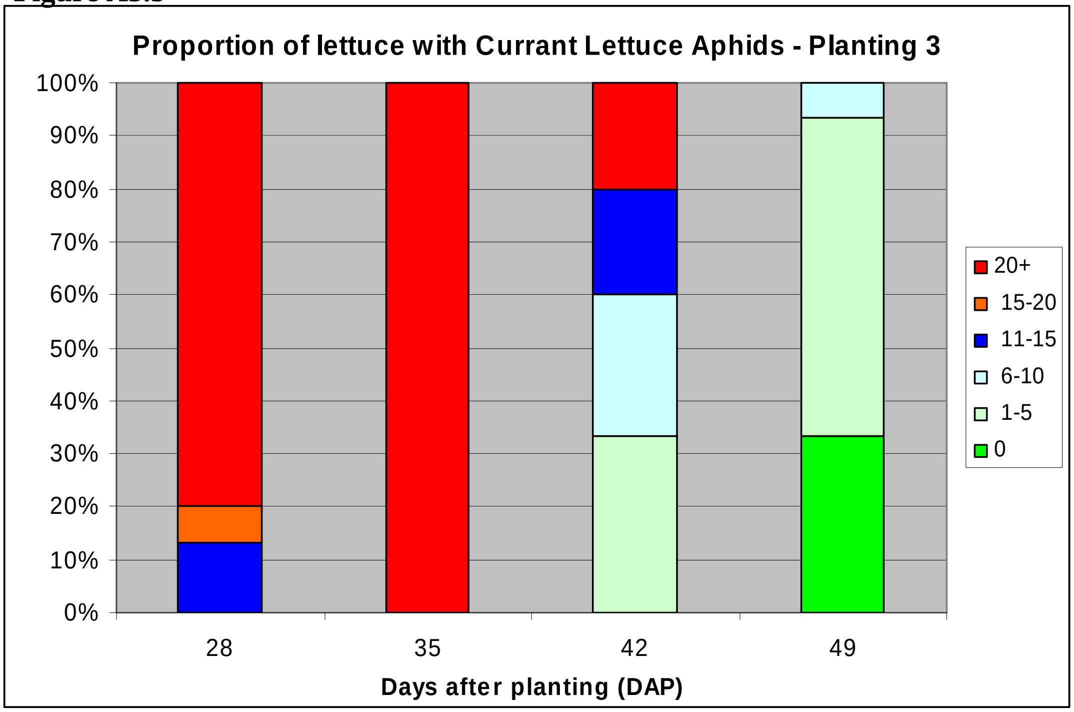
The last sampling period for Planting 1 (28th August 2006, 88 DAP) saw an increase in aphid predators from an average of 0 or 0.1 per lettuce for the four previous sampling periods to an average of 2.3 predators per lettuce. Planting 2 saw a similar increase on 31st August 2006 (91 DAP) to an average of 3.1 predators per lettuce, and on the 7th September 2006 (98 DAP) there were 4.9 predators per lettuce.

Figure A3.4



Planting 3 (Block 7) was planted on the 24th August, almost 3 months after Plantings 1&2. In this planting and the subsequent plantings of susceptible lettuce that were monitored, aphid predators colonised the lettuce more quickly and despite all sampled lettuce being infested with greater than 20 CLA per lettuce 35 DAP at harvest (49 DAP) all the lettuce sampled had less than 10 CLA per lettuce and just over 30% had no CLA at all (Figure A3.5). Aphid predators averaged 3.4, 23.9, 16.8 and 2.8 per head at 28, 35, 42 and 49 DAP respectively.

Figure A3.5



Planting 7 was the only other planting which had a series of visual samples prior to harvest. It was planted on the 21st September 2006 and at 28 DAP almost 90% of the lettuce sampled had greater than 20 CLA per head. At the harvest assessment 49 DAP 10% of the heads still had greater than 20 CLA per head but over 80% had less than 10 CLA (Figure A3.6). Aphid predators averaged 5.2, 15.1, 24.1 and 5.5 per head at 28, 35, 42 and 49 DAP respectively.

Figure A3.6

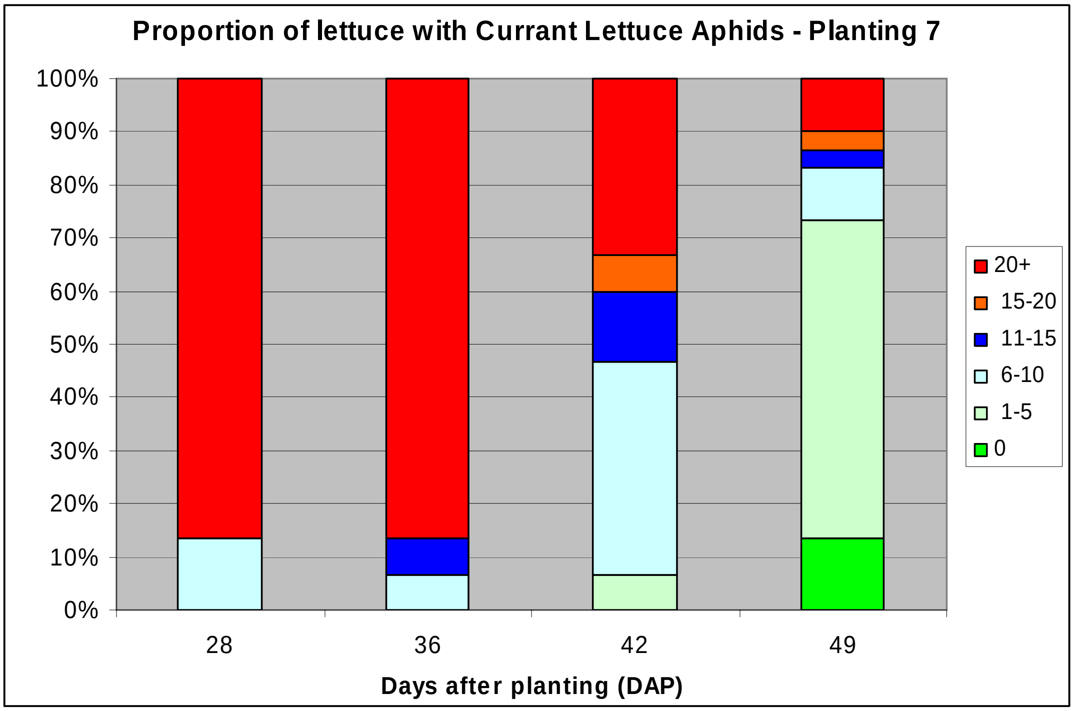
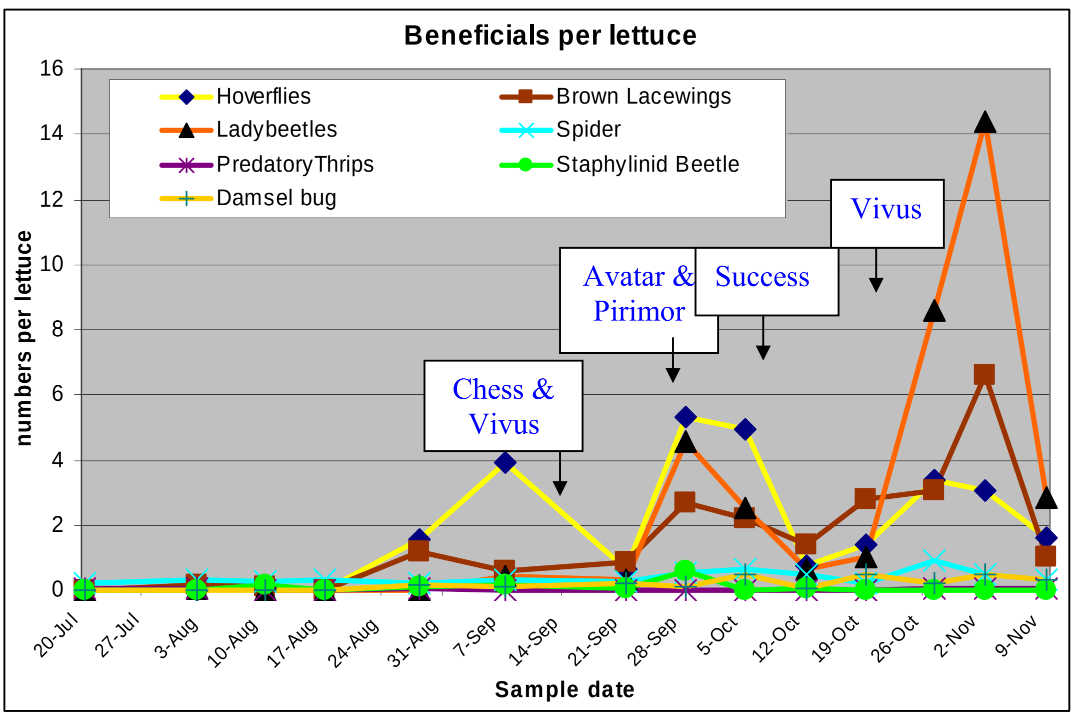


Figure A3.7



Hover fly larvae, brown lacewing larvae and adults and ladybeetle larvae and adults are all aphid predators and were the most numerous beneficial insects found in the visual assessments of lettuce (Figure A3.7). These aphid predators were absent during the colder winter months but began to appear in late August. Of the four plantings followed through the first two, winter grown lettuce were a commercial failure. Planting 3 was the only planting with all the lettuce harvested (Table A3.5)

Table A3.5 Summary Table including Harvest Assessment

	P1	**P2**	**P3**	**P7**
Date of planting	1-Jun	1-Jun	24-Aug	21-Sep
Date of harvest	28-Aug	7-Sep	12-Oct	9-Nov
Interval, days		0	14	28
Days old at assessment	88	98	49	49
Acceptable lettuce^	**33%**	**10%**	**100%**	**90%**
CLA/lettuce	**19.6+***	**287.6**	**1.87**	**18.8**
Lacewings/lettuce	0.67	0.23	0.87	0.47
Hoverfly larvae/lettuce	0.67	0.23	0.87	0.47
Ladybirds/lettuce	0.37	3.90	0.73	1.60
Ratio of all aphids to predators		**65.9**	**0.8**	**7.4**

^acceptable lettuce =lettuce with less than 20 aphids in total
* aphids numbers above 20 were recorded as 20+ so actual average unknown

Field days

Three field days were held to follow through planting 3 & 7. Local growers, consultants, nurseries and resellers were invited to inspect the crops. Andy Ryland and Eddie Galea spoke of their experience with CLA. Paul Horne and Sandra McDougall spoke about integrated pest management. Paul spoke of his experience with Victorian and Tasmanian growers.

At the first field day, 12th October, the few growers present were horrified at the aphid numbers visible in the lettuce, 18 and 81 in plantings 3 and 7 respectively. The presence of the beneficials (10 and 5 respectively) while interesting, did not reassure them.

Two weeks later on 27th October most of planting 3 was harvested but a patch was left for inspection and no aphids were found, 1.9 CLA per lettuce averaged from the visual assessment after the previous field day. Planting 7 still had high numbers of aphids (91) and many more aphid predators (15.1). It was noted that lots of ladybeetle adults and eggs were present but no larvae could be found. One of the growers attending the field day relayed that despite treating his seedlings with Confidor he had not been able to harvest any of his head lettuce all winter.

On the 9th November a third field day inspected the near clean planting 7.

Discussion

Current lettuce aphid arrived at Eddie's in April 2006, he was using Pirimor® (pirimicarb) and Chess® (pymetrozine) sprays to control the aphid numbers and was hoping that aphid predators would colonize and assist in managing the rapidly expanding CLA populations. Unfortunately the beneficial numbers did not increase until the warmer conditions in spring. Eddie and his father Felix were harvesting and selling their lettuce, however the extreme CLA numbers in the 8th and 9th plantings (2006-07 season) meant much was ploughed in. Subsequent plantings were still high but not nearly as bad and harvesting resumed. CLA were worse closest to the farm road and furthest from bushland. Where as when the vegetable weevils appeared they were worst near the bushland.

The initial trial plantings were planted on 1st of June (Block 10 & 11) and were in the ground for over 12 weeks. CLA were picked up in small numbers with the vacuum sampling and much larger numbers when visual monitoring started. Predator numbers were generally greater than CLA numbers in the vacuum sampling however no aphid predators was collected from planting 1 & 2 of the trial. When the lettuce began to heart, monitoring switched to visual sampling and although CAL numbers increased each week, beneficial numbers did not until week 12 and 13. Hence the lettuce was not in a saleable condition. Planting 1 had two additional pirimor sprays prior to hearting which perhaps slightly delayed the build up of CLA – but given this was not a replicated trial and the sample sizes were not large the difference between the two plantings may just reflect sample variability. Pirimor was probably not the best choice in the cooler months and a spray of Chess (pymetrozine) after a rainfall or after an irrigation may have given better results. Investigations into how beneficial insects numbers can be increased or maintained over the winter months needs to be undertaken.

After planting 1 & 2 of the trial there was a gap of almost 2 months before the next planting. The arrival of the beneficials in mid September prompted monitoring in subsequent plantings. Planting 3 (Block 7) and Planting 7 (Block 3) had both vacuum and visual monitoring including a harvest assessment. With the warmer weather other pests, such as vegetable weevils, thrips (Tomato spotted wilt was present) and heliothis arrived and were sprayed for. Within crop and along road weeds may have contributed to both the weevil and thrips numbers. The beneficial insects still managed to colonise the lettuce and feed on the CLA such that we saw the CLA populations reach a peak at 5 weeks then decline until harvest. Beneficial numbers also declined as food became scarcer. It would have been good to have been able to follow more susceptible plantings through however the grower understandably opted for growing *Nas* resistant varieties and in the subsequent autumn- winter season used Confidor seedling treatment prior to planting.

The impact of the field days was not great with only 6-10 growers or industry people present at each, particularly for those who did not attend the last field day they would not have seen the dramatic decline in CLA numbers.

Conclusions

Beneficials do not come into the crop over winter. It is recommended that trials be conducted to assess the potential for cereals planted in early autumn to attract cereal aphids and aphid predators, and if they do whether they move into neighbouring CLA infested lettuce.

Integrated pest management is not just about having good beneficial populations but also maximising the effectiveness of other supportive control measures. Attention to spray application and cultural options are also very important. For example removing the weeds within and around the plantings could have prevented or slowed pests such as vegetable weevil and thrips from moving into the crop and then avoided the application of insecticides which probably slowed the build up of beneficials in the earliest warmth of spring.

There is a learning curve for growers, advisors and researchers when adopting new practices.

Acknowledgements

Thanks to Eddie's family. Stacey Azzopardi from VG03098 did much of the leg work in organising the field days. Alan Boulton confirmed aphid identifications. Leigh James organised the lunch on the first field day.

A4. Monitoring Lettuce in Sydney Basin

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NSW DPI

Aim

There were three main objectives to the work conducted in the Sydney Basin:

1. to understand levels of interest and understanding of integrated pest management (IPM) in hydroponic and field lettuce growers and to find potential collaborators for an IPM trial
2. to introduce lettuce growers to crop monitoring, and
3. to determine what insect pest pressure growers were experiencing in hydroponic and field lettuce, what numbers of beneficial insects were present, what control methods they were using and how effective their strategy was.

Introduction

Lettuce IPM has been in development for a decade, with most of the on-farm trials being conducted in field lettuce crops in Hay and the Central West of NSW, or in other States. Because of this, lettuce growers in the Sydney basin had only received information sessions or seen IPM trials in other vegetable crops prior to the initiation of this project. Therefore, an IPM demonstration in field and hydroponic lettuce in the Sydney Basin was considered an important first step in the development of lettuce IPM in this region. Co-ordinating activities with the IPM for Insects and Viruses in Sydney Vegetables (VG03098) project was also an important step in developing an IPM strategy that was functional and facilitated adoption.

After an initial IPM trial in field lettuce, a number of hydroponic lettuce growers were approached as potential collaborators. However, the hydroponic lettuce growers felt that western flower thrips (WFT) was a more significant pest than currant lettuce aphid (CLA), meaning that their only option for WFT control was to spray with chemical insecticides. In response to this, it was decided to offer insect monitoring of hydroponic crops as an intital step to introduce the concepts of IPM. Following the monitoring of one planting of hydroponic lettuce, still no growers were willing to collaborate in an IPM trial, so a group of field lettuce growers were selected and a planting was similarly followed.

Methods

Eleven hydroponic growers were interviewed about their crop protection practices and attitudes to IPM. A late spring-summer planting of lettuce was followed through with fortnightly visits in 2006 and other plantings in the winter and spring of 2007. Six field lettuce growers were interviewed and crops surveyed in autumn through spring 2007. In autumn 2008 a follow-up interview was conducted by NSW DPI staff not involved in the crop surveys to evaluate the benefit of the surveys to the growers.

Lettuce growers were initially contacted by phone and if agreeable a visit was made. On the initial visit the growers were interviewed about their crop protection practices as well as their understanding of IPM. Up to three recently transplanted crops of different varieties were visually monitored for arthropods (insects, mites and spiders). Each fortnight the grower was contacted by phone and if agreeable a visit was made to monitor the selected plantings of lettuce. One to three varieties of *Nas*-susceptible lettuce were monitored and those varieties did vary between growers. At each monitoring 15 lettuce were visually inspected and all insects found were recorded. Weeds were also monitored at each visit for the presence of

CLA. Results from the monitoring exercise were provided to the growers and information regarding any control strategies used in the previous fortnight was requested by the staff member. At the end of the season spray records were requested to verify the timing and frequency of insecticide use.

A numerical statistical analysis could not be performed on the insect monitoring data as each grower varied in management practice, varieties grown, planting dates and the small sample size per variety per monitoring day. The data presented illustrates trends only.

Two NSW DPI extension officers, one who services field vegetable growers and the other who services hydroponic growers, interviewed their growers who had co-operated with this trial. Questions were asked to understand from the growers' perspectives whether they valued the regular monitoring and whether any of their practices had changed as a result.

Grower Survey results

From the pre-monitoring interview of the 11 hydroponic growers in November 2006 it was obvious that at least half (6) were routine or calendar sprayers for at least some pests and four were using imidacloprid (Confidor®) treated seedlings (Table A4.1). Four of the growers used a consultant to monitor their crops for insects and one of the growers said he monitored his own. At least half of the growers (6) had some *Nas*-resistant varieties they were trialling while three growers already grew *Nas*-resistant varieties almost exclusively. Although a large proportion of the growers (7) had seen CLA recently they were more concerned about WFT and three growers were also concerned about Rutherglen bug (RGB). When asked about their control methods for CLA and thrips all the growers answered "spray" and two mentioned monitoring or *Nas*-resistant varieties.

The six field lettuce growers were surveyed in February 2007 and all except for a certified organic grower used at least some Confidor treated seedlings (Table A4.1). Most (4) were using a few *Nas*-resistant varieties but there was a distinct lack of *Nas*-resistant varieties suitable for some growing windows. Only two growers had seen CLA recently and only one considered thrips a major pest. Heliothis was considered the major pest by four of the growers. Two growers used an IPM consultant to monitor their crops and these growers were those that opted for using biological pesticides. A third grower had a consultant from a chemical reseller monitor his crops and the other three growers stated they routinely monitored their own crops.

Eight of the 11 hydroponic growers were re-surveyed and another new grower surveyed in August 2007 prior to spring monitoring (Table A4.1). Six of eight hydroponic growers who were interviewed a second time had improved their pest management practices. They reported reduced chemical use (two had stopped using Confidor), they had increased their use of *Nas*-resistant varieties and started monitoring their crops for insects. There was also an increased uptake of thrips management practices, including roguing diseased plants and weed management. Of the other two growers surveyed, one hadn't changed their practices and one had begun using unnecessary Confidor seedling treatments while growing "mostly" *Nas*-resistant varieties.

Table A4.1. Summary of survey responses of hydroponic and field growers

Year Interviewed	**Hydroponic 2006**	**Hydroponic 2007**	**Field 2007**
# growers interviewed	**11**	**9**	**6**
Farm size (ha)	1.789 +/- 0.726	1.82 +/- 0.79	2.4 +/- 1.34
Imidacloprid (Confidor)	36%	22%	83%
Pirimicarb	100%	56%	83%
Methomyl	91%	*	50%
Carbaryl	9%	0%	0%
Maldison	36%	56%	0%
Dimethoate	64%	11%	17%
Pyrethrum mix	36%	11%	0%
Alpha-cypermethrin	9%	22%	0%
Pymetrozine	9%	0%	34%
Spinosad	91%	67%	100%
Indoxacarb	0%	0%	34%
Heliothis npv (Gemstar)	0%	0%	34%
Bt	0%	0%	34%
Calendar spraying	54%	22%	0%
Sprayed recently	55%	0%	0%
Use *Nas*-resistant varieties (few/some : most/all)	55%: 27%	33%: 67%	67%: 0%
Had CLA recently	64%	0%	34%
	82% WFT	11% WFT	26% diseases
	27% RGB	44% RGB	67% Heliothis
Biggest problem pest?	36% CLA		17% thrips
Control methods for Thrips?	100% sprays 9% roguing	100% sprays 44% roguing	34% sprayed 66% not problem
Uses a consultant	36%	33%	50%
Monitors crops	45%	100%	100%
Grows own seedlings	82%	44%	17%
Sells lettuce to Supermarket	36%	22%	0%
Sells lettuce at Central Market	64%	66%	83%
Sells lettuce to Processor	0%	0%	17%
Sells lettuce to restaurant/farmers market	9%	0%	50%^

* registration withdrawn ^ one grower suppliers organic market

Summary of hydroponic lettuce insect survey 2006 (96 samples)

The visual inspection of 96 samples (15 hydroponic lettuce per sample) for insects in 2006 showed that relatively few insects were found. The most common insect pests were WFT (33% of samples), RGB (32%) and wingless CLA (21%). 53% of samples did not have any insect pests (Table A4.2). The most common beneficial insects were hoverfly larvae (8% of samples), spiders (4%) and Transverse ladybeetles (4%). 77% of samples did not have any beneficial insects (Table A4.3). If we assume that dead insects are a result of insecticide use, it can be said that control of WFT, other thrips, other aphids and RGB was evident (Table A4.2).

When looking at the individual hydroponic grower's data for November - December 2006 indicated that most growers sprayed at least one insecticide on a weekly basis, although we did not have confidence in all the sprays reported and records were not always kept. The most common target pests are aphids, thrips and RGB. The grower with the highest proportion of samples with no insect pests also had the highest proportion of samples with beneficial insects and this grower also monitored their crop. The grower with the highest proportion of samples with insect pests reported spraying for insects other than CLA on a weekly/monthly basis.

Two growers had no samples containing beneficial insects (Table A4.4). Both sprayed weekly with some insecticide, but other growers also did this without the same effect on beneficial numbers.

Table A4.2. Number of lettuce samples in 2006 with low, medium or high levels of infestation by insect pests and the total number of samples with infestations of each insect pest.

Insect pest	**Incidence**			
	Low 1-10 insects/sample	**Medium** 11-20 insects/sample	**High** >21 insects/sample	**Total**
WFT (alive)	28	3	1	**32**
WFT (dead)	4	0	0	**4**
Other thrips (alive)	3	0	0	**3**
Other thrips (dead)	1	0	0	**1**
CLA (winged)	1	0	0	**1**
CLA (wingless)	10	1	9	**20**
Brown sowthistle aphid	3	0	0	**3**
Other aphids (alive)	2	0	0	**2**
Other caterpillars	2	0	0	**2**
RGB (alive)	27	3	1	**31**
RGB (dead)	3	0	0	**3**
Other pests	8	0	0	**8**
No pests	**51**			

Table A4.3. Number of lettuce samples in 2006 with low, medium or high levels of infestation by beneficial insects and the total number of samples with infestations of each beneficial insect.

Beneficial insect	**Incidence**			
	Low 1-10 insects/sample	**Medium** 11-20 insects/sample	**High** >21 insects/sample	**Total**
Spiders	4	0	0	**4**
Transverse ladybeetle	4	0	0	**4**
Hoverfly larvae	8	0	0	**8**
Aphid parasitoids	2	0	0	**2**
Other beneficials	1	0	0	**1**
No beneficials	**74**			

Table A4.4. Percentage of lettuce samples in 2006 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests or beneficial insects summarised on a grower basis.

Grower	No. of samples	Insect pest	Incidence	Beneficial insect	Incidence
A	9	WFT (alive)	56% Low	Spiders	11% Low
		WFT (dead)	33% Low		
		Other thrips	22% Low		
		RGB	78% Low		
		Other pests	11% Low	Transverse LB	11% Low
		No pests	**11%**	**No beneficials**	**78%**
B	9	WFT (dead)	11% Low	Hoverfly larvae	11% Low
		Other thrips (alive)	11% Low		
		Other thrips (dead)	11% Low		
		CLA (wingless)	11% Low 11% High		
		BST	33% Low		
		RGB (dead)	33% Low		
		Other pests	22% Low		
		No pests	**22%**	**No beneficials**	**89%**
C	9	WFT	89% Low	Spiders	11% Low
		CLA (wingless)	11% Low	Transverse LB	11% Low
		CLA (winged)	22% Low 11% High	Hoverfly larvae	11% Low
		RGB	89% Low		
		No pests	**0%**	**No beneficials**	**67%**
D	9	WFT	44% Low 22% Med	Spiders	11% Low
		CLA (wingless)	44% Low 11% Med 44% High		
		Heliothis	11% Low	Transverse LB	11% Low
		Other caterpillars	11% Low		
		RGB	56% Low 11% Med 11% High	**No beneficials**	**89%**
		No pests	**33%**		
E	9	RGB	33% Low	**No beneficials**	**100%**
		No pests	**67%**		
F	9	WFT	67% Low 11% Med 11% High	**No beneficials**	**100%**
		Other pests	11% Low		
		No pests	**11%**		
G	9	Other aphids	11% Low	Hoverfly larvae	22% Low
		Other pests	22% Low		
		No pests	**67%**	**No beneficials**	**78%**

Table A4.4. (continued) Percentage of lettuce samples in 2006 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests or beneficial insects summarised on a grower basis.

Grower	No. of samples	Insect pest	Incidence		Beneficial insect	Incidence
H	9	CLA (wingless)	33% Low 33% High		Hoverfly larvae	22% Low
		Other caterpillars	11% Low			
		Other pests	11% Low			
		No pests	**25%**		**No beneficials**	**78%**
I	6	RGB	17% Low		Hoverfly larvae	17% Low
					Other beneficials	17% Low
		No pests	**83%**		**No beneficials**	**67%**
J	9	WFT	56% Low		Spiders	11% Low
		Other aphids	11% Low		Transverse LB	11% Low
		RGB	22% Med		Aphid parasitoids	22% Low
		Other pests	11% Low			
		No pests	**33%**		**No beneficials**	**78%**
K	9	RGB	33% Low		Hoverfly larvae	11% Low
		No pests	**67%**		**No beneficials**	**89%**

Only four growers had CLA at any time during the monitoring. Two of the growers using Confidor-treated seedlings had aphids in low levels at one monitoring. One grower using Confidor also treated with Pirimor® (pirimicarb) and still had some aphids. The grower who neither used Confidor nor Pirimor and had quite high levels of CLA had used methomyl for WFT control during the monitoring period.

Of the six growers with WFT during the monitoring, four had low levels and two had high levels in mid December. One of the growers with high levels reported using Fastac® (alpha-cypermethrin) as their control measure against WFT, they also used a pyrethrum mix as recommended by their consultant. The other growers reported using Lannate® (methomyl) or Success® (spinosad) for WFT control.

Summary of lettuce insect survey 2007 (365 samples)

Fourteen growers consisting of six growers of field lettuce and eight growers of hydroponic lettuce were monitored. The most common insect pests were brown sowthistle aphids (BST) (33% of samples), RGB (28%), other pests (including fungus gnats, green leafhoppers and whiteflies) (17%), aphids other than CLA or BST (14%), and wingless CLA (13%). Other aphids besides BST and CLA were cotton aphid, green peach aphid, potato aphid, leaf curl plum aphid, poplar gall aphid, cowpea aphid, bluegreen aphid, oat aphid and foxglove aphid. Most of these aphids were winged forms and with no wingless forms found it is expected that they would not have been breeding on lettuce. Green peach aphid, potato aphid and foxglove aphids can all breed on lettuce. Winged CLA were found in 6% of samples, unwinged CLA in 13% of samples and WFT in 4% of samples.

The most common beneficial insects were spiders (13% of samples), transverse ladybeetles (10%) *Hippodamia* ladybeetles (9%), other beneficial insects (including damsel bugs, brown lacewings, wasps and beetles) (9%), and adult hoverflies (6%).

If we assume that dead insects are a result of insecticide use, it can be said that thrips other than WFT, aphids other than CLA or BST, and Rutherglen bugs are the pests that were controlled by insecticides (Table A4.5). Likewise, *Hippodamia* ladybeetles, transverse ladybeetles and adult brown lacewings are the beneficial insects killed by insecticides (Table A4.6).

Table A4.5. Number of lettuce samples in 2007 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests and the total number of samples with infestations of each insect pest.

Insect pest	Incidence			
	Low 1-10 insects/sample	**Medium** 11-20 insects/sample	**High** >21 insects/sample	**Total**
WFT	10	3	1	**14**
Other thrips (alive)	16	0	0	**16**
Other thrips (dead)	3	0	0	**3**
CLA (winged)	15	3	5	**23**
CLA (wingless)	27	9	10	**46**
Brown sowthistle aphid	100	6	13	**119**
Other aphids (alive)	49	1	1	**51**
Other aphids (dead)	1	0	0	**1**
Heliothis	29	3	4	**36**
Other caterpillars	6	0	0	**6**
RGB (alive)	60	26	16	**102**
RGB (dead)	8	0	0	**8**
Other pests	49	5	3	**57**
No pests	**99**			

Table A4.6. Number of lettuce samples in 2007 with low (1-10), medium (11-20) or high (>20) levels of infestation by beneficial insects and the total number of samples with infestations of each beneficial insect.

Beneficial insect	Incidence			
	Low 1-10 insects/sample	**Medium** 11-20 insects/sample	**High** >21 insects/sample	**Total**
Spiders	43	2	2	**47**
Hippodamia ladybeetle (alive)	28	1	3	**32**
Hippodamia ladybeetle (dead)	4	0	0	**4**
Transverse ladybeetle (alive)	29	2	5	**36**
Transverse ladybeetle (dead)	1	0	0	**1**
2-spotted ladybeetle	1	0	0	**1**
Brown lacewing larvae	7	0	0	**7**
Brown lacewing adult (alive)	11	0	2	**13**
Brown lacewing adult (dead)	3	0	0	**3**
Hoverfly larvae	9	0	0	**9**
Hoverfly adult	20	1	1	**22**
Predatory thrips	5	0	0	**5**
Aphid parasitoids	13	1	1	**15**
Heliothis parasitoids	1	0	0	**1**
Predatory mites	3	0	0	**3**
Other beneficials	33	1	0	**34**
No beneficials	**221**			

None of the hydroponic growers used Confidor but all but one of the field growers did (Table A4.7). All hydroponic growers had CLA at some stage of the monitoring period. None of the growers using Confidor-treated seedlings had CLA. Field growers tended to spray based on monitoring. The field grower who didn't use Confidor was an organic grower and he had one of the highest proportions of lettuce samples with no pests, despite having a wide range of pests in relatively high numbers. This grower also had the highest proportion of samples with beneficial insects. There was a lot of diversity in the insect pests and beneficial insects present in the surveys.

Table A4.7. Percentage of lettuce samples in 2007 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests or beneficial insects summarised on a grower basis.

Grower (system)	No. of samples	Pest	Incidence	Beneficial insect	Incidence
J (hydro)	17	CLA (wingless)	12% Low 6% High	Spiders	24% Low
		BST	65% Low	Hippodamia	6% Low
		RGB	35% Low 12% Med 35% High	Transverse LB	6% Low
		Other pests	6% Low	Hoverfly adult	18% Low
				Aphid parasitoids	12% Low
				Other beneficials	29% Low
		No pests	**6%**	**No beneficials**	**47%**
G (hydro)	26	WFT	15% Low 4% Med	Spiders	12% Low
		Other thrips	15% Low	Hippodamia	12% Low
		CLA (wingless)	8% Low 8% Med	Transverse LB	8% Low
		CLA (winged)	4% Low	BLW adult	4% Low
		BST	8% Low 4% Med	Predatory thrips	4% Low
		Heliothis	19% Low	Aphid parasitoids	4% Low
		RGB	12% Low 42% Med 8% High	Other beneficials	4% Low 4% Med
		Other pests	12% Low		
		No pests	**15%**	**No beneficials**	**69%**
E (hydro)	29	WFT	10% Low	Spiders	3% Low
		Other thrips (alive)	17% Low	Hippodamia (alive)	3% Low
		Other thrips (dead)	3% Low	Hippodamia (dead)	7% Low
		CLA (wingless)	14% Low 3% Med	Transverse LB (alive)	3% Low
		CLA (winged)	10% Low	Transverse LB (dead)	3% Low
		BST	24% Low 3% Med	BLW adult	3% Low
		Other aphids	10% Low	Heliothis parasitoids	3% Low
		Heliothis	7% Low 3% High	Other beneficials	14% Low
		RGB (alive)	45% Low 14% Med		
		RGB (dead)	28% Low		
		Other pests	10% Low		
		No pests	**17%**	**No beneficials**	**66%**

Table A4.7. (continued) Percentage of lettuce samples in 2007 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests or beneficial insects summarised on a grower basis.

Grower (system)	**No. of samples**	**Pest**	**Incidence**		**Beneficial insect**	**Incidence**
H (hydro)	14	WFT	14% Med		Spiders	14% Low
		Other thrips	14% Low		Hippodamia (alive)	7% Low
		CLA (wingless)	21% Low		Hippodamia (dead)	14% Low
		CLA (winged)	7% Low		Transverse LB	7% Low
		BST	36% Low		BLW adult (dead)	7% Low
		Heliothis	7% Low		Hoverfly adult	7% Low
		RGB	50% Low 14% Med 7% High		Aphid parasitoids	14% Low
		Other pests	29% Low		Other beneficials	14% Low
		No pests	**7%**		**No beneficials**	**43%**
L (field)	31	WFT	3% Low		Spiders	6% Low
		BST	19% Low		Hippodamia	23% Low 3% Med
		Other aphids	19% Low		Transverse LB	10% Low 3% Med
		Heliothis	23% Low 3% Med 3% High		BLW adult	3% Low
		Other caterpillars	3% Low		Hoverfly adult	19% Low
		RGB	10% Low 3% Med 13% High		Aphid parasitoids	3% Low
		Other pests	29% Low 13% Med 10% High		Other beneficials	6% Low
		No pests	**3%**		**No beneficials**	**55%**
M (field)	31	Other thrips (dead)	6% Low		Spiders	3% Low
		BST	16% Low		2-spotted LB	3% Low
		Other aphids	32% Low 3% High		BLW adult (dead)	3% Low
		Heliothis	13% Low		Hoverfly larvae	3% Low
		RGB	3% Low		Other beneficials	6% Low
		Other pests	3% Low 3% Med			
		No pests	**48%**		**No beneficials**	**84%**
N (field)	13	BST	15% Low		Transverse LB	8% Low
		Other aphids (alive)	31% Low		Aphid parasitoids	8% Low
		Other aphids (dead)	8% Low			
		Heliothis	38% Low 8% Med			
		RGB	15% Low			
		Other pests	8% Low			
		No pests	**15%**		**No beneficials**	**85%**

Table A4.7. (cont.) Percentage of lettuce samples in 2007 with low (1-10), medium (11-20) or high (>20) levels of infestation by insect pests or beneficial insects summarised by grower.

Grower (system)	No. of samples	Pest	Incidence		Beneficial insect	Incidence
O (field)	32	WFT	3% Low		Spiders	13% Low 6% Med 3% High
		Other thrips	3% Low		Hippodamia	3% High
		BST	25% Low		Transverse LB	6% Low 3% High
		Other aphids	22% Low		BLW adult	3% Low 3% High
		Heliothis	6% Low 3% Med		Predatory thrips	3% Low
		Other caterpillars	6% Low		Predatory mites	3% Low
		RGB	6% Low 6% Med 9% High		Other beneficials	22% Low
		Other pests	34% Low			
		No pests	**34%**		**No beneficials**	**56%**
P (field)	54	CLA (wingless)	7% Low 2% Med		Spiders	44% Low 2% High
		CLA (winged)	4% Low		Hippodamia	2% Low 2% High
		BST	31% Low 2% Med 17% High		Transverse LB	2% Med 2% High
		Other aphids	6% Low 2% Med		BLW larvae	6% Low
		Heliothis	2% Low 2% High		BLW adult	2% High
		Other caterpillars	2% Low		Hoverfly larvae	11% Low
					Hoverfly adult	4% Low 2% High
					Predatory mites	4% Low
					Other beneficials	7% Low
		No pests	**43%**		**No beneficials**	**41%**
Q (field)	104	WFT	1% Low 1% High		Spiders	2% Low
		Other thrips	4% Low		Hippodamia	13% Low 1% High
		CLA (wingless)	11% Low 4% Med 6% High		Transverse LB	17% Low 3% High
		CLA (winged)	8% Low 3% Med 5% High		BLW larvae	4% Low
		BST	36% Low 1% Med 4% High		BLW adult	6% Low
		Other aphids	15% Low		BLW adult (dead)	1% Low
		Heliothis	2% Low 1% High		Hoverfly larvae	2% Low
		Other caterpillars	2% Low		Hoverfly adult	7% Low 1% Med
		RGB	15% Low 3% Med		Predatory thrips	3% Low
					Aphid parasitoids	3% Low
		Other pests	11% Low		Other beneficials	3% Low
		No pests	**31%**		**No beneficials**	**68%**

Overall both pest and beneficials numbers were lowest in winter and at the end of summer but present throughout the year (Figure A4.1). In all cases the proportion of samples with pests was greater than those with beneficials

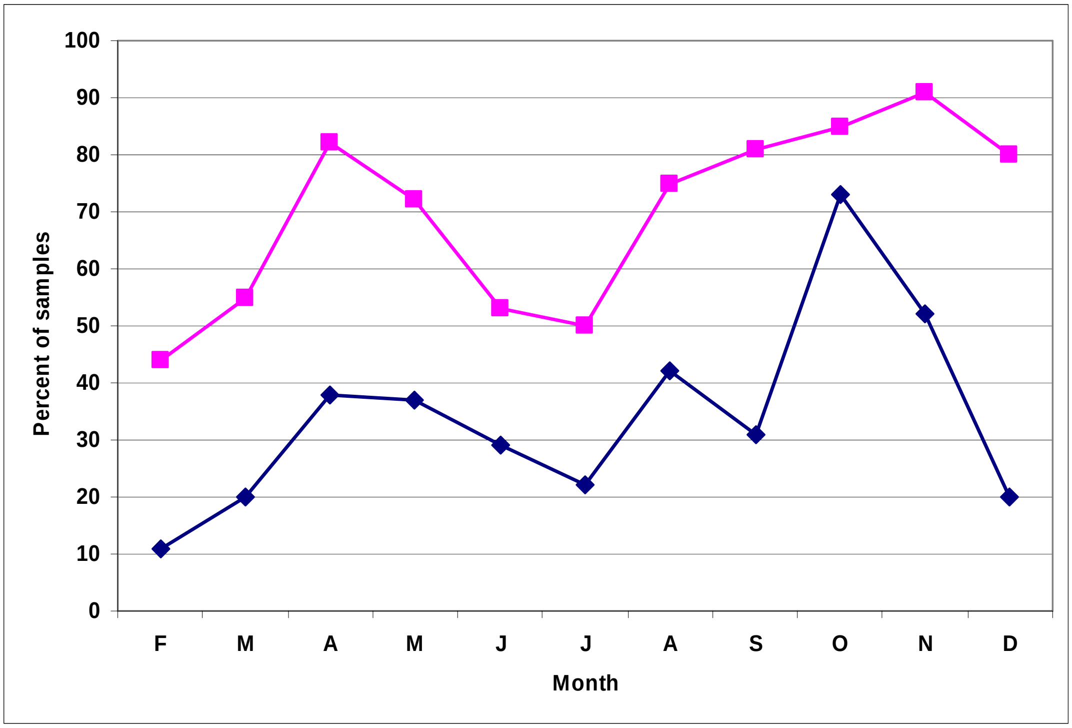

Figure A4.1. Percentage of lettuce samples infested with pest (pink) and beneficial (blue) insects in 2007.

CLA were the most common aphids and the most common pest, found all year and in greatest proportion of samples in April (Figure A4.2). Rutherglen bugs were primarily found over spring in greater than 50% of samples. Thrips were present in a small proportion of samples scattered throughout the year.

Beneficials were generally present in less than 50% of the samples (Figure A4.3). More beneficials were found in October and November than any other months. Spiders, ladybeetles and hoverflies were the most prevalent beneficials and were present in most months in a few samples.

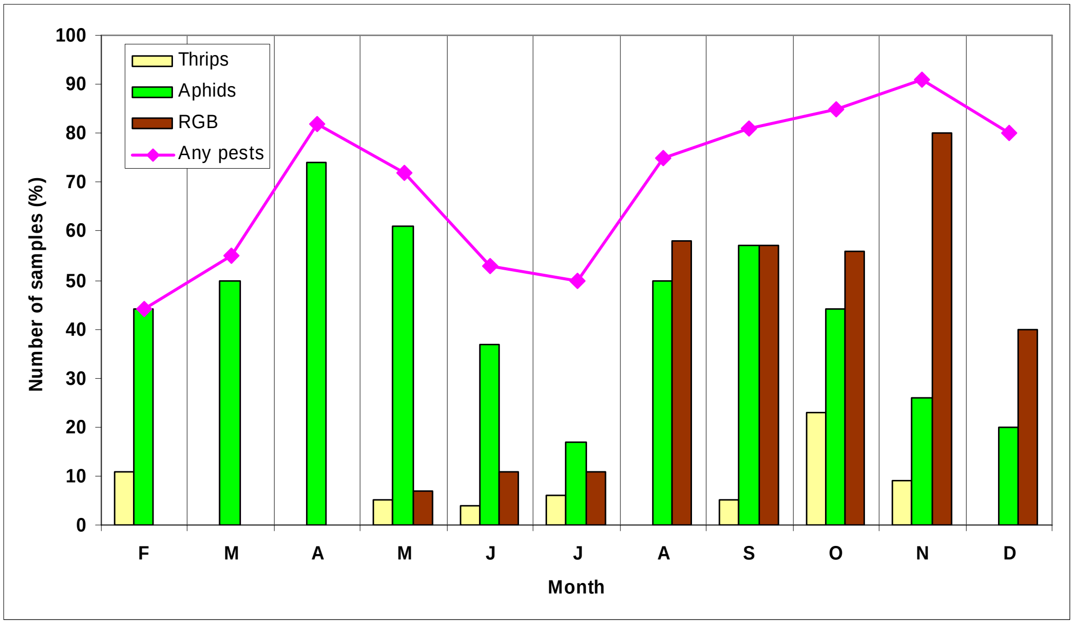

Figure A4.2. Overall numbers of pests (blue line) and specific groups of pests on lettuce during 2007.

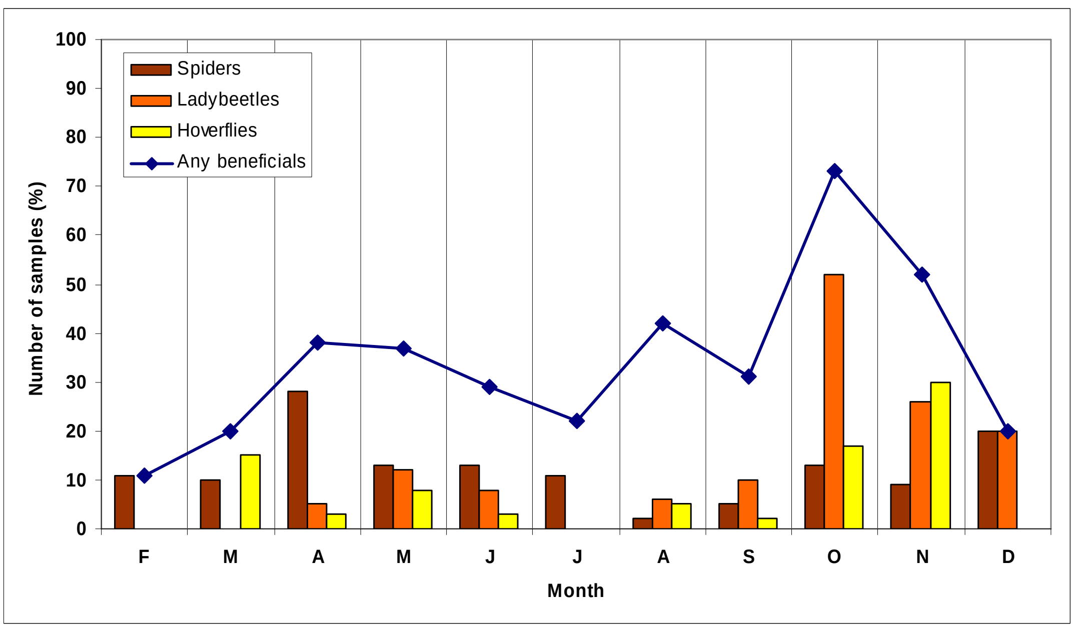

Figure A4.3. Overall numbers of beneficial insects (blue line) and specific groups of beneficial insects on lettuce during 2007.

In 2007 the growers were given a weediness score at each monitoring. A score of 1 indicated very few weeds, a score of 3 indicated many weeds. The number of samples with no pests generally increases (albeit slightly) with weediness of the growing area (Table A4.8). If the data from the organic grower is omitted from the data summary (noting that most samples from this grower fall within weed category 3), the opposite trend is observed, with weedier growing areas resulting in more pests in lettuce samples (Table A4.9). However, the actual differences are not very large in either case.

The number of samples with no beneficials does not change considerably in accordance with weediness (Table A4.8). Omitting the organic grower's data, it seems that numbers of lettuce samples with beneficials decreases slightly with the weediness of the growing area (Table A4.9). WFT is only detected in samples grown in areas with some weed coverage. The diversity of beneficial insects increases with weediness of the growing area.

Table A4.8. Percentages of lettuce samples from crops grown with different weed scores with low (1-10), medium (11-20) or high (>20) numbers of pests and beneficial insects in 2007.

Weed score	No. of samples	Pest	Incidence	Beneficial	Incidence
1	48	Other thrips	2% Low	Spiders	17% Low
		CLA (wingless)	8% Low 2% High	Transverse LB	2% Low
		BST	38% Low 2% Med 2% High	BLW larvae	2% Low
		Other aphids	33% Low	Hoverfly larvae	2% Low
		Heliothis	6% Low	Hoverfly adult	8% Low
		RGB	6% Low 10% High	Predatory thrips	2% Low
		Other pests	8% Low	Aphid parasitoids	4% Low 2% High
				Predatory mites	2% Low
				Other beneficials	17% Low
		No pests	**23%**	**No beneficials**	**58%**
2	121	WFT	6% Low 2% Med	Spiders	11% Low 2% Med 1% High
		Other thrips (alive)	8% Low	Hippodamia (alive)	5% Low 1% High
		Other thrips (dead)	2% Low	Hippodamia (dead)	2% Low
		CLA (wingless)	6% Low 1% Med 1% High	Transverse LB (alive)	4% Low 1% High
		CLA (winged)	3% Low	Transverse LB (dead)	1% Low
		BST	24% Low 1% Med 2% High	BLW larvae	1% Low
		Other aphids (alive)	17% Low 1% Med	BLW adults (alive)	4% Low 1% High
		Other aphids (dead)	1% Low	BLW adults (dead)	2% Low
		Heliothis	12% Low 2% Med 1% High	Hoverfly larvae	2% Low
		Other caterpillars	2% Low	Hoverfly adult	2% Low
		RGB (alive)	24% Low 10% Med 3% High	Predatory thrips	1% Low
		RGB (dead)	7% Low	Aphid parastoids	4% Low
		Other pests	12% Low 1% Med 1% High	Heliothis parasitoids	1% Low
				Other beneficials	12% Low 1% Med
		No pests	**25%**	**No beneficials**	**61%**

Table A4.8. (continued) Percentages of lettuce samples from crops grown with different weed scores with low (1-10), medium (11-20) or high (>20) numbers of pests and beneficial insects in 2007.

Weed score	**No. of samples**	**Pest**	**Incidence**	**Beneficial**	**Incidence**
3	68	WFT	1% Low	Spiders	26% Low 1% High
		Other thrips	1% Low	Hippodamia	6% Low 3% High
		CLA (wingless)	12% Low 7% Med 7% High	Transverse LB	10% Low 1% Med 6% High
		CLA (winged)	9% Low 6% High	2-spotted LB	1% Low
		BST	18% Low 1% Med 7% High	BLW larvae	6% Low
		Heliothis	6% Low 1% High	BLW adults (alive)	4% Low 1% High
				BLW adults (dead)	1% Low
		Rutherglen bug	13% Low 10% Med 3% High	Hoverfly larvae	6% Low
		Other pests	10% Low 1% Med	Hoverfly adult	3% Low 1% Med 1% High
				Aphid parasitoids	3% Low
				Predatory mites	4% Low
				Other beneficials	7% Low
		No pests	**35%**	**No beneficials**	**46%**

A reasonable proportion of the data used to generate this table was from an organic grower and more weeds were generally present on their property. Table A4.9 presents data with the organic grower's data omitted.

Table A4.9. Percentages of lettuce samples from crops grown in areas with different weed scores with no pests or beneficial insects in 2007. Data collected from organic grower omitted.

Weed score	**No. of samples**	**No pests**	**No beneficials**
1	40	25%	63%
2	111	24%	62%
3	32	16%	53%

There were 32 lettuce samples with some symptoms of tomato spotted wilt virus (TSWV). Of these samples, one sample had both WFT and other thrips present and one sample had other thrips only. These lettuce samples were from seven different growers, three were hydroponic growers and four were field growers, with different levels of weediness, although weeds were generally present at some density.

Grower Evaluation of Monitoring

Ten hydroponic growers and six field growers agreed to interviews (summary of responses in Appendix A4.1). All the field growers were aware of who the project officer was and what project she was working on, 9/10 of the hydroponic growers knew who she was but none correctly named the project she was working on. When questioned on whether the visits were helpful on a scale of 1-5, with 1 = "not at all" and 5= "a lot"; 50% of the hydro growers nominated 1, 20% , 10% and 20% nominated 3, 4 and 5 respectively. Four of the six field growers nominated 4 and the remaining 2 split between 2 and 5.

The hydroponic growers were similarly polarized when asked more specifics about whether the monitoring helped identify pests, beneficials or weeds whereas the field growers were more favourable (Table A4.10).

Table A4.10 Questions 6-9 Not at all ---------------------------- a lot

Q	Did the monitoring help …..		1	2	3	4	5
6	Identify pests you didn't know you had?	Hydro	3/10	3/10	0	3/10	1/10
		Field	1/6	0	0	3/6	2/6
7	Identify beneficials you didn't know you had?	Hydro	3/10	2/10	2/10	2/10	1/10
		Field	0	0	0	4/5	1/5
8	Identify weeds as a problem?	Hydro	2/10	5/10	1/10	2/10	0
		Field	0	0	2/5	2/5	1/5
9	Did the information she provided from the monitoring change you management strategies?	Hydro	3/10	0	4/10	2/10	1/10
		Field	1/6	0	5/6	0	0

Six of the hydroponic growers didn't think the monitoring changed their practices at all. Four hydroponic growers felt some or many of their practices had changed as a result of the monitoring (Table A4.11). Four of the field growers changed something they did as a result of the monitoring. Of the remaining two growers, one didn't comment as he had only a few visits and the other has a regular IPM consultant.

Table A4.11 Questions 10-14

Q	Did you change your….	Hydro YES	Field YES
10	Spray timing?	3/10	3/5
11	Chemical choice?	2/10	1/5
12	Weed management?	3/10	1/4
13	Spray frequency?	2/10	1/5
14	Own monitoring practices?	4/10	3/5

Discussion

Initially the monitoring started with interested hydroponic growers as a means of finding a grower to host an IPM demonstration/trial. The criteria for hosting a trial was that the majority of their lettuce was CLA susceptible lettuce and not treated with Confidor and that for at least one planting they would spray only the insecticides that were recommended by the monitoring team which might include the grower's own consultant, Paul Horne and Sandra McDougall. We were unsuccessful in finding a grower to meet these criteria. One of the reasons for failing with the hydroponic growers was that the previous lettuce IPM work had focused virtually exclusively on field growers and mostly in areas other than the Sydney Basin so the project team had little experience with hydroponic growers or systems. Secondly almost all the hydroponic growers grew a majority of *Nas*-resistant varieties. Nevertheless we wanted to see whether regular visits following a planting would improve pest management practices as well as give us actual information on what problems growers were having.

The actual crop monitoring of the six hydroponic growers was at a time when there were frequent rain showers and insect numbers were lower than expected and the growers sprayed less than expected. Even the "calendar" sprayers modify their spray choices depending on weather and to some extent on 'feedback' such as the monitoring reports. There were not strong correlations between frequency of spray applications and insect numbers. Rutherglen bug contamination appeared to be the most concerning pest at the time although past experience with WFT had most of the growers applying routine sprays for it. The follow up in the following spring had more growers reporting reduced spray applications and more spraying as a response to monitoring. More of the growers reported roguing and weed management as a strategy for managing WFT but it is possible that the growers were more aware of what we wanted to hear having had the early period of monitoring and feedback. Observations on the relative weediness of the farms at the time of the interviews didn't indicate a significant change in practice. However, on monitoring data there appears to be a correlation that WFT is only found when there are some weeds around – but are not present in all samples when weeds are around. In the separate evaluation interviews the hydroponic growers rejected that the monitoring helped them identify weeds as a problem which appears to contradict the second reporting of practice survey in spring 2007.

In autumn field lettuce growers were contacted and six growers were positive about having monitoring. Field lettuce growers predominantly grow iceberg and cos lettuce both of which form hearts. These growers were all using Confidor on at least some of their lettuce (with the exception of the organic grower). They were all more positive about IPM as a concept and three used a commercial crop consultant. Unlike the hydroponic growers the field growers nominated Heliothis as a more serious pest than WFT. They also were more positive about the benefits of having another person monitoring their crops and the resultant feedback on pests and beneficials present.

Overlapping this project was another project VG03098 *Regional extension strategy for managing western flower thrips and tomato spotted wilt virus in the Sydney Region.* This project had started working with a few vegetable crops (primarily protected crops) and had already started working with hydroponic lettuce growers. They were planning to do more work with hydroponic lettuce growers on improving WFT management using IPM. Many of the project aims and methods were similar, so the two projects agreed to collaborate although, this did cause some understandable confusion with the hydroponic growers about whether the lettuce project officer was part of the WFT project.

One of the conclusions from this process was that survey or interview questions can be misleading in the information that it obtains in that it appears that relatively few of the growers who reported to be calendar sprayers sprayed as frequently as they initially reported and that many of the growers who 'monitored' their own crops still sprayed frequently despite very small numbers being observed in the project monitoring. Chemical reporting is a sensitive issue and it is probable that many of the growers did not 'trust' our use of their chemical information and for some their record keeping practices meant they were unable to look up their information even if they wanted to.

Weed management does not appear to be a major priority for most hydroponic growers even though WFT and particularly the disease it can spread - tomato spotted wilt virus (TSWV), is their 'major' pest. The majority of the weeds monitored (see weed survey report) are recorded hosts of TSWV and most are probably suitable host for a key TSWV vector, WFT. WFT as well as tomato thrips and onion thrips are effective vectors of TSWV to lettuce, the adults can only transmit TSWV if their nymphs have fed on TSWV infected plants. Given not all TSWV infected plants show virus symptoms it is not possible to look at weeds and say whether they are currently reservoirs of TSWV. Hence growers with significant numbers of weeds around or within their crop may be supporting a disease reservoir. It is recommended that more specific research that is designed to be statistically robust be conducted to test whether weeds around hydroponic and field lettuce farms are contributing to levels of TSWV.

At present there are no 'soft' options for RGB management. RGB doesn't breed on lettuce and is immigrating in from other hosts. It is primarily a contamination pest and appears only to cause direct feeding damage when numbers are high on young seedlings however it was regularly sprayed for. The sprays registered for RGB control are organo-phosphates and have broad activity which includes many beneficial insects. Other cultural, biological or post-harvest options need to be developed.

Acknowledgements

Thanks to all the growers who collaborated with this project. Thanks to Stacey Azzopardi and Silvia Jellinek from VG03098 for many forms of assistance. Alan Boulton identified aphid samples. Leigh James interviewed the field lettuce growers for the evaluation and Jeremy Badgery-Parker the hydroponic lettuce growers.

A5 Monitoring Lettuce in Western Australia

Sonya Broughton and David Cousins, DAWA

Key pests and beneficials occurring in Western Australia

	J	F	M	A	M	J	J	A	S	O	N	D
Pests												
Thrips (all species)												
TSWV												
Currant lettuce aphid												
Green Peach Aphid, potato aphid, spirea aphid												
Rutherglen bug												
Beneficials												
Brown lacewing												
ladybird												

Key pests

Thrips

- Based on abundance, the main pest species of lettuce in Western Australia is western flower thrips (WFT), *Frankliniella occidentalis*.
- Feeding damage caused by thrips was low during the study, and was generally less than 5%.
- Thrips are more likely to cause crop damage by transmission of tomato spotted wilt virus (TSWV). Since the incidence of TSWV is low from June-October, growers may not need to regularly spray for thrips during this 'window'. However, further monitoring is required for verification.

Aphids

- Currant lettuce aphid (CLA), *Nasonovia ribisnigi,* was the most abundant aphid species and compared to other aphids, was present for a longer period in the field. Since CLA is likely to be less abundant during the hotter months from November through to March, growers may not need to treat their crops for CLA during this time.
- The presence of CLA was difficult to monitor in the field which may be attributed to grower use of imidacloprid drenching or *Nas*-resistant varieties. Sentinel plants placed in the field did not attract CLA and weeds sampled in the field were not infested with CLA.
- Other species occurring in lettuce included spiraea aphid, *Aphis spiraecola* and Green peach aphid, *Myzus persicae,* which were most abundant in July and August. However, numbers never reached damaging numbers during our study.

Rutherglen bug

- Rutherglen bug (RGB) *Nysius vinitor*. is a native species considered to be a contaminant pest. Adults do not feed on lettuce and are unable to reproduce on the crop.

- Rutherglen bugs were present from October through April, with highest numbers recorded in November and December.

Key Beneficials

- Spiders were the most abundant group of predators found during the study. They are known to be generalist predators.
- Brown lacewings and ladybirds included spotted amber ladybird (*Hippodamia variegata*) and transverse ladybird (*Coccinella transversalis*).
- Ladybird abundance was highest in October-December, when aphid populations are also high and may therefore be useful for biological control of aphids.

Introduction

Western Australia produces over 12,000 tonnes of lettuce (based on 2006 figures). Main production areas include the northern Perth area, Baldivis, Manjimup and Albany. Production can be year round such as in the northern Perth area, with lettuce planted sequentially. Harvest dates from planting are shorter in summer (42 days) and longer in winter (84 days).

Since knowledge of pests and beneficials is a fundamental requirement for developing an integrated control program for local growers, the main aim of this project was to collect this data.

Materials and methods

Study Sites

To collect data on pests and beneficials, three monitoring sites were established at Marginiup, Carabooda and Gingin in October 2006. A second Gingin site was added in December 2007 (Table A5.1). Growers at Marginiup and Carabooda were within the per-urban area, whilst the Gingin sites were within rural areas that were relatively isolated from other grower's properties.

Table A5.1: study sites

Location	Lettuce crop	Surrounding land use	Other crops grown in or near site	Confidor drenching?
Marginiup	Fancy	Peri-urban	Strawberry	Yes
Carabooda	Head	Peri-urban	Asian vegetables	Yes
Gingin site 1	Fancy	Native bush	Onions, maize (as wind break)	No
Gingin site 2	Fancy	Bush/pasture	-	No

Sampling

Traps. Traps were used to sample for wind-borne invertebrates and D-Vac was used to sample foliage-associated invertebrates. Traps consisted of an 18cm x 27 cm board of white corflute. White contact was attached to the corflute, sticky side down. The non-sticky side was painted with a thin layer of tac-gel (Rentokil®, Tac-Gel Formula 3) to give an adhesive surface of 15 cm x 22 cm. Traps were installed in the middle of a lettuce crop, approximately

1m off the ground and replaced either weekly (spring-autumn) or fortnightly (winter). The number of traps per property differed depending on property size and stage of maturity of the lettuce crop. Traps were used to monitor for invertebrates over the period 14 January 2006 to 17 July 2007.

D-Vac. Invertebrates associated with foliage were sampled using a vacuum sampler (blower/vac, Briggs & Stratton 24.5cc engine) fitted with a plastic ice-cream container (16.5 cm diameter). The floor of the container was fitted with thrips-proof mesh. The vacuum was placed over a lettuce plant for approximately 5 seconds and invertebrates were sucked into the ice-cream container; 100 individual plants were randomly selected and sampled per block. After 100 plants had been sampled, invertebrates were tapped into a plastic zip-loc bag (35.7cm x 42.7cm) and sprayed with alcohol to kill them. Bags were marked with sample site, collection date and crop stage (e.g. transplant, mature crop, harvesting). In addition, estimates were made of the percentage of the crop affected by thrips feeding damage and tomato spotted wilt virus. A total of 462 D-vac samples were taken over the period 19 October 2006 to 2 July 2007.

Sentinel plants

From October 2007, sentinel plants were installed on monitoring sites to monitor for CLA since most growers were planting imidacloprid-drenched transplants or *Nas*-resistant cultivars (Fig. A5.1). Sentinels consisted of seedlings of CLA susceptible head lettuce planted into a plastic tote box (32cm wide, 42 cm long and 12.5 cm deep) filled with potting mix (Baileys potting mix (Baileys Fertilisers, Rockingham, WA), a commercial soil mix consisting of organic matter and granular material. Sentinels were placed at the edge of the commercial lettuce crop and checked for CLA weekly from spring-autumn and every fortnight in winter. Plants were watered by overhead sprinklers as part of normal grower practice and replaced when they became unthrifty (approximately 3 months).

Figure A5.1. Sentinel plants at the Carabooda site.

Specimen Identification

In the laboratory, D-vac samples were transferred to plastic vials containing 70% ethanol for later identification. Under a dissecting microscope (50X magnification) arthropods were identified as adult or juvenile and classified to Order, and wherever possible to family, genus and species. Adult thrips were identified to species using the criteria of Moritz *et al*. (2001). Aphids were identified using the lettuce key in Blackman and Eastop (2000) or Fletcher (2005) from alcohol preserved specimens, or cleared and slide mounted specimens. All taxa were allocated to one of three groups; pests (agricultural pests); beneficial (known and potential beneficial invertebrates) and non-target (all remaining invertebrates not recorded as pest or beneficial).

Results and discussion

Pest species

Eighteen pest species from four main groups were identified from 69,746 specimens collected from sticky traps and 33,815 specimens from D-Vac samples. Thrips were the most abundant pest group, comprising 63% of total pest specimens collected from D-vac samples and 99% from sticky traps (Fig. A5.2). Ferment flies were the next most abundant group (34% total specimens); no ferment flies were caught on sticky traps (Fig. A5.2). Rutherglen bug comprised 2% of total specimens collected from sticky and 27% of D-vac samples. Aphids were the least abundant pest, comprising less than 2% of total specimens (Fig. A5.2). Interestingly heliothis, considered to be a key pest of lettuce in Australia, was only found on six sampling dates. Two adults were caught on sticky traps and twelve heliothis larvae and 8 adults were collected from D-Vac samples in January-March. However, the low numbers of heliothis in our samples may not reflect true pest abundance. Heliothis can infest lettuce in high numbers in WA, especially if growers are not applying weekly insecticides for their control.

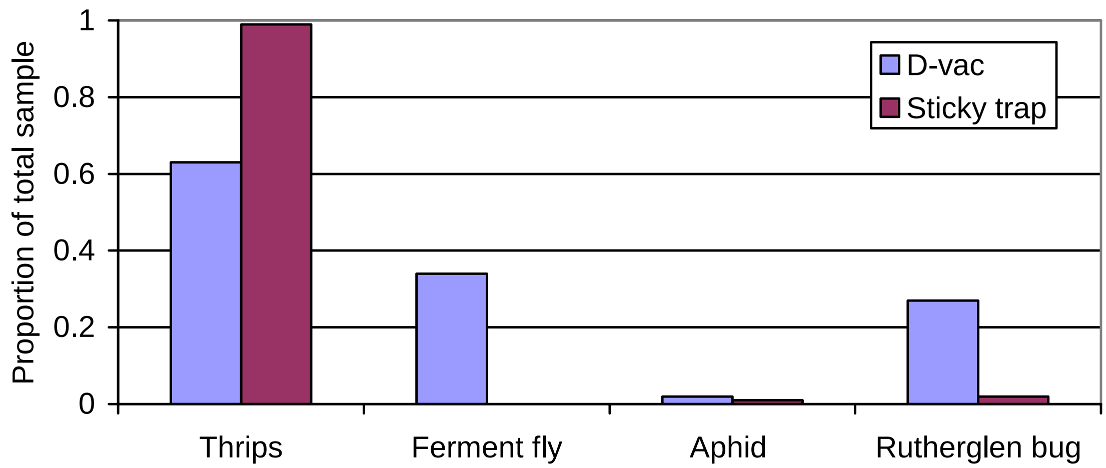

Figure A5.2. Abundance of pest species for all sites between October 2006 and July 2008

Ferment flies

Ferment flies are considered to be a contaminant pest since they do not attack lettuce, but are attracted to rotting vegetation in and around the crop and can become harvested with the crop. Ferment flies were found at all samples sites, and abundance did not appear to differ with site. Ferment flies first appeared at some sites in October/November and again in January/February, and were absent during winter. Abundance ranged from 1 ferment fly/100 plants up to 216 flies/100 plants.

Rutherglen bug

Rutherglen bug (RGB), *Nysius vinitor*, is a native species considered to be a contaminant pest. Adults do not feed on lettuce and are unable to reproduce on the crop. RGBs are thought to move onto lettuce in large numbers from surrounding vegetation in summer. RGB were found at all sample sites, though were more abundant at sites in peri-urban areas (92.2% of all RGB samples). Specimens were collected from lettuce at all growth stages and were present from October through April, with highest numbers recorded in November and December. The average number of specimens per 100 plants ranged from 0.66 up to 164.7 individuals. From May through September, RGB were rare, though populations (3 specimens per 100 plants) were occasionally detected.

Aphids

Aphids appear to be a sporadic pest in WA lettuce, but can cause significant crop loss if populations are large close to harvest. Aphids can also cause reduced or abnormal lettuce growth, as aphids vector several viruses. Aphids comprised less than 1% of all pests collected from sticky traps and 1.25% of D-vac samples. The majority of specimens were winged adults (683 specimens D-vac samples, 460 sticky traps); 103 specimens were either wingless adults or nymphs (all D-vac samples).

Since aphid identification keys are based on wingless adults and the host plant on which they are found, few specimens could be identified to species. CLA was the most abundant species (52.4% total sample). In December 2006, CLA, was detected for the first time in commercially grown head lettuce in northern Perth. CLA has been found at all four sampling sites, but was not picked up using either sampling method at site 1. Generalist species included spiraea aphid, *Aphis spiraecola* (16.5%), cotton or melon aphid, *A. gossypii* (8.25%) and green peach aphid, *Myzus persicae* (6.21%). These species have a wide host range that includes weeds. Single specimens of *Prociphilus*, a root-dwelling aphid and *Uroleucon* were collected from lettuce at Gingin site 2. These aphids are likely to have migrated into lettuce from a nearby potato crop.

Growth stage and aphid abundance

The growth stage of the crop appears to be correlated with aphid abundance, with more aphids collected from mature (403 specimens) plants, than semi mature (208 specimens) or transplants (41 specimens). The highest aphid populations were recorded at Gingin site 1 (306 specimens), followed by Marginiup (170), Wanneroo (135) and Gingin site 2 (67 specimens).

Table A5.2: Aphid species collected from D-vac samples of lettuce within four sample sites between October 2006 and July 2008, in decreasing order of abundance.

		Site			
Species	**Months found**	**1**	**2**	**3**	**4**
Currant lettuce aphid, *Nasonovia ribisnigri* (Mosley)	April- June, September	0	2	71	3
Aphis sp.	August	0	0	14	0
spiraea aphid, *Aphis spiraecola* Patch	July, August	3	3	18	0
Green peach aphid, *Myzus persicae* (Sulzer)	July, August	2	4	3	0
Cotton/melon aphid, *Aphis gossypii* Glover	July, August, December	4	1	7	0
Potato aphid, *Macrosiphum euphorbiae* (Thomas)	July	0	6	0	0
Foxglove aphid, *Aulacorthum solani* (Kaltenbach)	July, August	0	2	0	0
Prociphilus sp.	June	0	0	0	1
Uroleucon sp.	June	0	0	0	1

1 = Carabooda, 2 = Marginiup, 3 = Gingin 1, 4 = Gingin 2

Seasonal abundance

Aphids were present throughout the year. Dispersal of aphids is mainly as winged adults and there appeared to be adult flights in January 2006, July-October 2006 and June 2008 (Fig. A5.3). Winged aphids caught on sticky traps ranged from 0.14 aphids/trap/site to 11.5 aphids/trap/site. Aphids were more abundant in winter-spring and smallest during hot, dry weather (December-March). D-Vac sampling showed a similar population trend, though higher numbers of aphids were extracted from D-Vac samples (0.3 aphids/100 plants up to 15 aphids/100 plants) compared to sticky traps. This suggests that aphid population levels in the crop are best monitored by direct plant sampling.

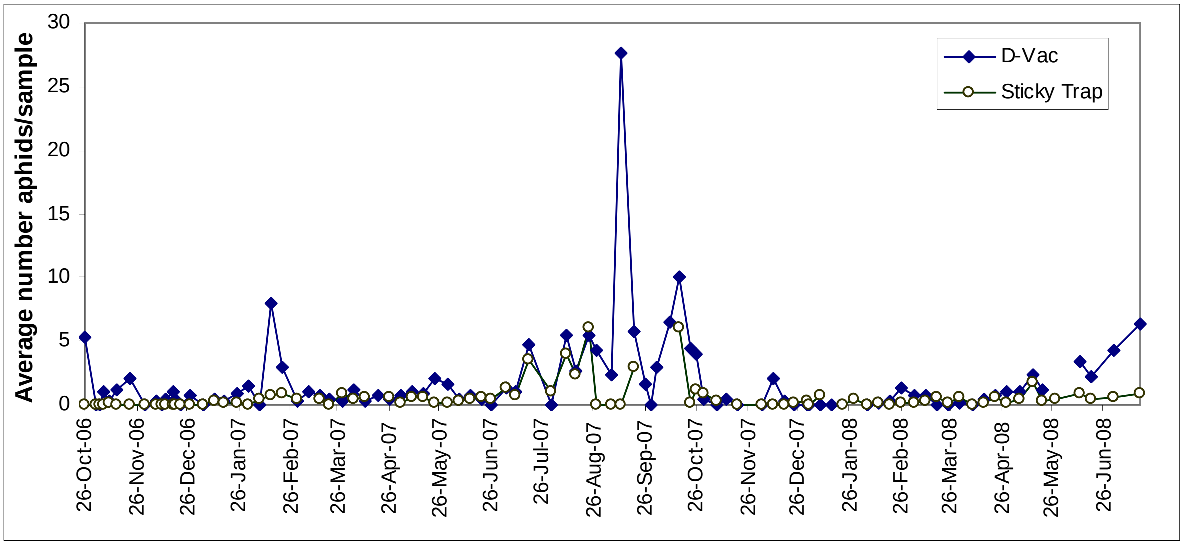

Figure A5.3. Seasonal abundance of aphids on D-Vac compared to sticky trap sampling at the four sample sites.

Sentinel plants

No aphids were collected from sentinel lettuce plants during the study.

Thrips

Thrips are an important lettuce pest, damaging plants by direct feeding on leaves or by transmitting tomato spotted wilt virus (TSWV) (Table A5.3). Western flower thrips (WFT) were the most common species collected from D-Vac samples (81.1%), followed by plague (*T. imaginis*, 13.2%), tomato (*F. schultzei*, 3.3%), and onion thrips (*Thrips tabaci*, 0.7%). 'Other' thrips comprised 1.6% of the total adult sample and included non-pest species such as *Thrips australis* (Bagnall) and predatory thrips. On sticky traps, plague thrips was the most common and abundant species, comprising 77.1% of the total sample, followed by tomato (11.5%), onion (9%) and western flower thrips (2.01%). The differences in pest abundance and sampling method suggest that direct sampling or inspection of lettuce is important for estimating WFT abundance. All pest species were collected from all sample sites (Table A5.4).

Table A5.3: Pest thrips species collected from lettuce within four sample sites between October 2006 and July 2008, in decreasing order of abundance.

Thrips species	Damage
Western flower thrips, *Frankliniella occidentalis* (Pergande)	Feeding damage, vector of TSWV
tomato thrips, *Frankliniella schultzei* (Trybom)	vector of TSWV
Onion thrips, *Thrips tabaci* Lindeman	vector of TSWV
Plague thrips, *Thrips imaginis* Bagnall	Native species, does not transmit TSWV

Growth stage and thrips abundance

Lettuce at all stages of plant growth supported thrips, though more thrips were found on older plants. More western flower (X_2 = 461.03, df=2, P<0.0001), plague (X_2 = 291.5, df=2, *P*<0.0001), tomato (X_2 = 161.6, df=2, *P*<0.0001) and onion thrips (X_2 = 44.8, df=2, *P*<0.0001) were present on mature plants than on plants nearing maturity and transplants. Similarly, more larvae were present on mature plants (X_2 = 54.5, df=2, *P*<0.0001).

Seasonal abundance

All thrips species were abundant in October-November. Plague thrips was the only species that did not occur in lettuce at other times of the year. The incidence of thrips feeding damage to lettuce and percentage of the crop affected by tomato spotted wilt virus (TSWV) is shown in figure A5.4. Thrips feeding damage and the incidence of TSWV appears to be correlated with peaks in thrips abundance, with highest levels of crop damage recorded in October – December. The incidence of TSWV is low from June-October, suggesting that growers may not need to spray for thrips during this period. However, further monitoring is required for verification.

		Site							
		1	2	3	4	1	2	3	4
Species	**Months found**	**D-Vac sampling**				**Sticky traps**			
Frankliniella occidentalis	year round, peaks in Oct-Dec, Mar-May	5177	108	1918	1111	68	121	1176	10
Frankliniella schultzei	year round, peaks in Oct-Nov	131	128	422	6	387	677	6769	7
Thrips imaginis	Oct-Nov	52	256	2358	15	1393	4087	47227	73
Thrips tabaci	year round, population peak in Oct	38	7	157	0	181	235	5744	11

1 = Carabooda, 2 = Marginiup, 3 = Gingin 1, 4 = Gingin

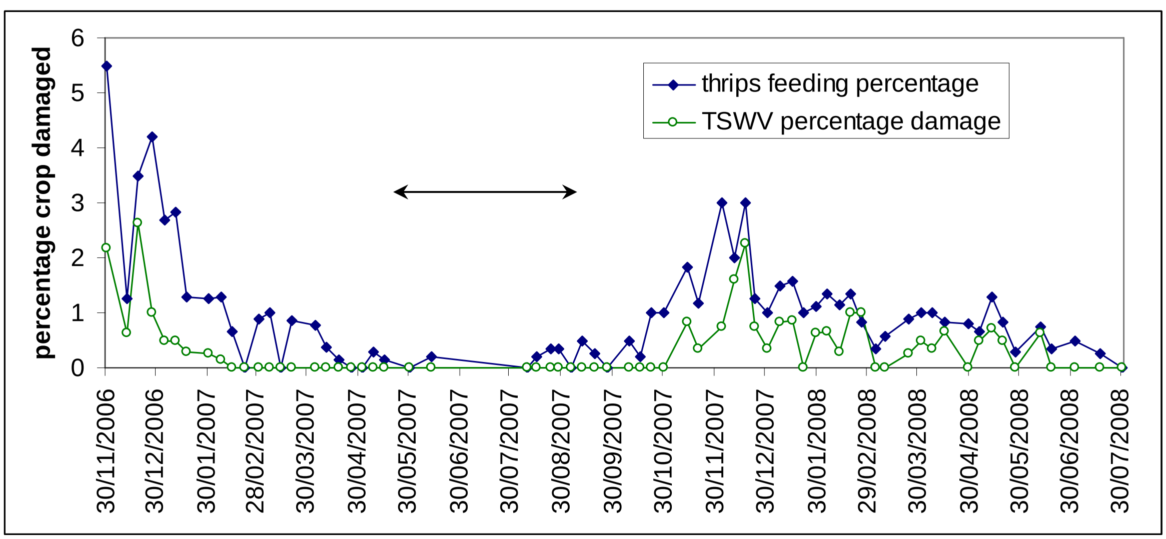

Figure A5.4. Feeding damage and incidence of TSWV at the four sample sites. The arrow indicates a possible window where due to low incidence of TSWV, growers may be able to avoid spraying for thrips.

Beneficials

Beneficials were identified from 490 specimens collected from sticky traps and 1,549 specimens from D-Vac samples and included brown and green lacewings (Neuroptera), spiders (Araneae), mites (Acarina) and ladybirds (Coccinellidae) (Fig. A5.5). Spiders were the single largest group of predators, comprising 45% of the total sample (Fig. A5.5).

Families included Salticidae (jumping spiders), Zodaraiidae (ant spiders) and Lycosidae (wolf spiders). Spiders are known to be generalist predators, however, their populations do not increase with an increase in abundance of prey. Brown lacewings (Hemerobiidae) were the next largest group, comprising 27% of the sample and were recorded from all sample sites. Brown lacewings are known to feed on aphids, moth eggs and small larvae, scale insects, and whitefly. Whilst most specimens were adults (540 specimens, sticky traps and D-vac samples), larvae were also collected from D-Vac samples (8 specimens). Brown lacewing activity as measured by adult abundance was highest from October through December, with a second population peak in late March/early April. The numbers of adults ranged from 0.5 up to 8.5 adults/100 plants sampled. Green lacewing (Chrysopidae) adults (0.3%) were caught on sticky traps, but their larvae were not found in D-Vac samples.

Ladybirds (14%) included spotted amber ladybird (*Hippodamia variegata* (Goeze)) and transverse ladybird (*Coccinella transversalis* Fabricius), and were found at all sampling sites. Like lacewings, ladybirds are generalist predators and feed on the same range of prey. Transverse ladybirds were more abundant (174 specimens) than spotted amber ladybirds (111 specimens), and more ladybirds were caught on sticky traps than D-vac samples. The number of adults ranged from 0.5 up to 8/100 plants for *C. transversalis* and 0.5-1 adult/100 plants for *H. variegata*. No eggs or larvae were found. There appeared to be two peaks in abundance: November/December and a smaller peak in April/May.

Acarina (mites) comprised 7% of the total sample and were only found in D-vac samples. Mites occurred at all sample sites and numbers ranged from 0.25 to 15.5 per 100 plants. The genus *Pergamasus* was confirmed to be present in lettuce in WA. *Pergamasus* is a predatory mite and has been observed feeding on thrips.

Syrphids or hover flies are regarded to be a major predator of aphids overseas (e.g. Smith and Chaney 2007). In our samples, syrphids comprised only 1.57% of the total trap catch and do not appear to be important aphid predators in WA (Fig. A5.5). Syrphid larvae were not recovered from D-vac samples.

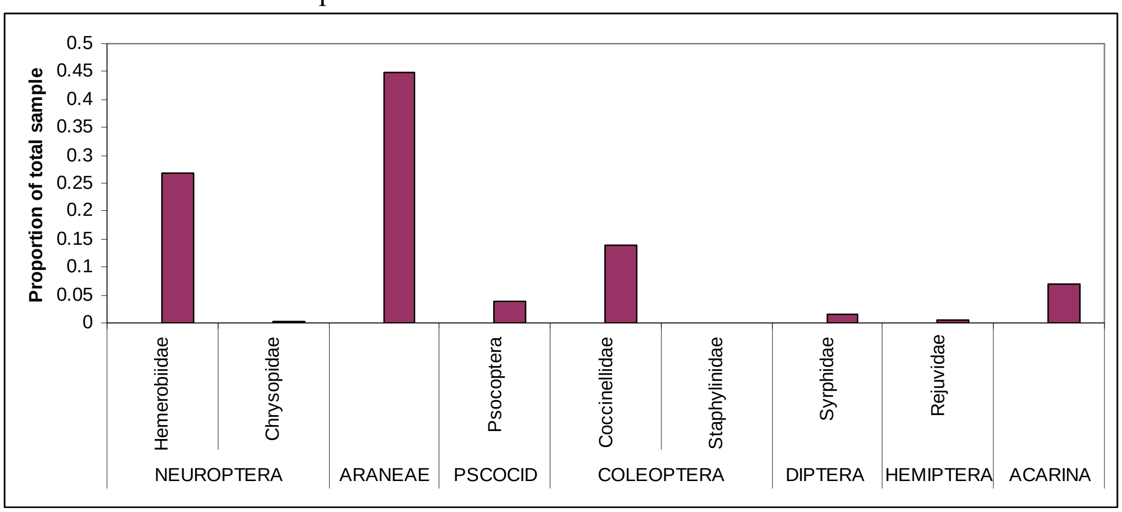

Figure A5.5. Beneficial insects found in D-vac and sticky trap samples.

R1 The Potential for Biological Control in Lettuce Crops with Soil-dwelling Predatory Mites

Greg Baker and Peter Crisp, SARDI

As part of a broader initiative to develop an IPM system for the key pests of lettuce a study of the soil-dwelling predatory mites that naturally occur in lettuce crops, and their potential for the biological control of western flower thrips (WFT) and CLA, was initiated.

Soil predator surveys

A survey of arthropod populations in soils collected from lettuce fields was conducted in three states (SA, Vic and NSW) in 2006 and 2007. Additionally selected specimen mites were collected in WA and forwarded to SA for identification.

Sampling

Soil samples were collected when moisture levels were high in soil, preferably within 24 hours of watering. Five samples were collected at each lettuce field site, in some cases from each of two depths (0–2.5 cm and 2.5–5.0 cm). Arthropods were extracted from these samples by placing 150 ml samples in Berlese funnels for 48 hours.

A summary of mean densities of selected soil arthropods collected by the Berlese Funnel extraction is presented in Table R1.1.

Population densities of these selected soil arthropods, namely collembolans (springtails), *Tyrophagus* mites (fungivores), oribatid mites (fungivores) and predatory mites were generally low in most soil samples received from lettuce fields. The low arthropod densities in these fields is likely due to the combined pressures of regular cultivation disturbance, multiple pesticide applications and low soil organic carbon. While samples have been collected from four distinct regions, arthropod densities and species composition appear more specific to individual growers than particular regions. However, the South Australian samples yielded higher densities than the interstate sites; whether this is due to transporting of samples or other factors, such as site selection, soil type, management or soil carbon, is unclear.

The densities of predatory mites in these soil samples varied from 0.0 to 4.4 per 150 ml sample. The majority (≥95%) of the predatory mites present in these samples were mesostigmatid mites, including *Hypoaspis* spp., *Machrochelidae* spp., *Pachylaelaps* sp. (*P. australicus*?), *Pergamasus* sp., *Protogamasellus mica*, *Dendrolealaps* sp., *Athasiella relata* and Parasitidae spp.. Species from all these groups have been found in citrus orchard soils in the Riverland of SA, where they are associated with the reduced survival of thrips (Kelly's citrus thrips) pupae.

Two predatory mite species that were present in at least some soil samples from all states, *Hypoaspis* sp. and *Pergamasus* sp., were collected at Murray Bridge in SA and Werribee in Victoria, from plant and soil samples where insecticides, including organophosphates, had been applied. *Hypoaspis* spp., commercially available as biological control agents are known predators of thrips and other small arthropods at or near soil surface level. *Pergamasus* spp. are large (2mm) dark brown mites that are fast moving, highly mobile, hunter-predator mites that are visible without magnification and are known to feed on other small arthropods. *Pergamasus* sp. was also collected from lettuce in Western Australia.

High densities of *Pergamasus* sp. (Figure R1.1), up to 20 mites per plant, were detected in lettuce at Murray Bridge where large volumes of chicken manure had been applied prior to planting seedlings. The *Pergamasus* sp. and related mites from other lettuce crops have been observed feeding on thrips. Their effect on CLA is unknown. Greenhouse trials were initiated to assess the potential of *Pergamasus* as a biological control of CLA: however, these trials were inconclusive due to difficulties experienced maintaining populations of CLA on potted lettuce in the greenhouse.

Another predatory mite species, *Pachylaelaps australicus*, which was present in soil samples at one of the sites sampled near Murray Bridge SA, is known to feed on nematodes and is possibly associated with the control of thrips in citrus, but appears to forage only in soil and not on the plant itself reducing its potential for controlling CLA. The Machrochelidae are also present in soils that have reduced emergence of thrips; they are a robust, slow moving predator, and while potentially useful in an IPM system have so far been difficult to rear in laboratory conditions.

The populations of these species in soils in Australian citrus is strongly positively correlated with soil organic carbon levels (Baker *et al.* 2005) and a similar association between other soil dwelling predatory mite populations and soil carbon has been reported previously.

There are numerous studies reporting a negative correlation between insecticide usage (particularly organophosphates) and the abundance and diversity of soil dwelling predatory mites. These populations are greater where there is the combination of high organic carbon and no pesticide application, and lesser where there is a combination of low organic carbon and high pesticide use.

Figure R1.1: Predatory mite, *Pergamasus* sp., on lettuce leaf from Murray Bridge.

Compost trials

To evaluate the potential of compost to enhance populations of predatory mites in lettuce crops, in particular *Pergamasus* sp., and to thereby suppress populations of CLA, trials were established at Virginia and Gumeracha, SA.

The trial at Virginia in March-April 2007 was a small scale trial to assess the potential risks of applying high rates of compost to the crop. Composted urban green waste was applied one week prior to planting at a rate of 100 m^3 or 200 m^3 per ha to plots (10 m. length and three row width) and compared to plots where no compost was applied in a 4 replicate randomized block trial. All seedlings were Confidor® dipped prior to planting.

The Gumeracha trial was established in November 2007 with an Iceberg lettuce crop and included four treatments in a three replicate design, which accommodated the grower's interest of convenience rather than experimental rigour (Figs. R1.2 and R1. 3). The compost treatment was applied at a rate of 100 m^3 per ha and was spread onto the treated bays prior to final bed forming, so that the compost was partially incorporated into the top 10 cm of the soil. The trial area was 40 metres in length and 5 rows wide (plus an untreated irrigation row). One row in each plot was planted with seedlings that were not Confidor® -drenched. Soil samples were taken prior to the application of compost and fortnightly for six weeks post-application, and finally in July 2008. Mites were extracted from 150 ml samples of soil using Berlese funnels.

In both the Virginia and Gumeracha trials the compost was Jeffries Soils organic compost, which is made from recycled green waste, and had a carbon to nitrogen ratio of approximately 18:1. Samples taken from the compost prior to application to the soil and subjected to Berlese extraction did not contain any mites.

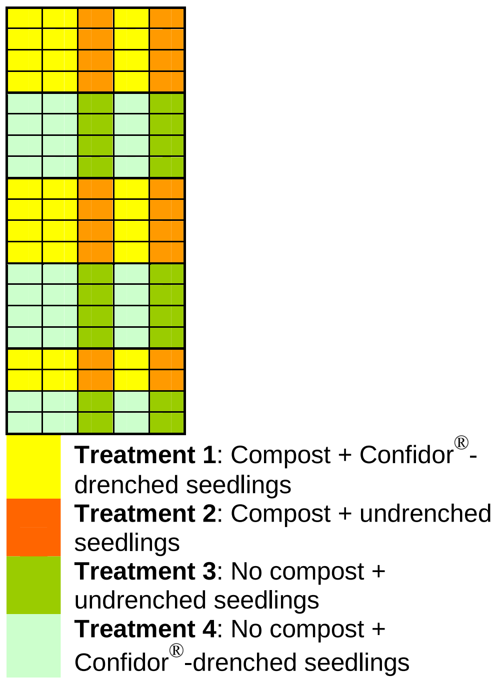

Figure R1.2: Plot layout for the compost trial at Gumeracha SA, November 2007.

Figure R1.3; Plot layout at Gumeracha SA showing compost prior to incorporation with the soil (19/11/2007).

CLA was not detected throughout the assessment period of either the Virginia or Gumeracha trials. This was to be expected with the Confidor® drenched plants, as the trials were only of six and five weeks duration respectively. However the non-drenched seedlings at the Gumeracha trial site were expected to become infested if CLA were present. Although CLA did not colonize the Gumeracha trial site, the non-drenched seedlings did suffer significant damage from an influx of plague thrips.

There were no apparent negative side-effects on crop growth and performance from the application of the compost treatments. The lettuces in compost-treated soils at Gumeracha were harvestable one week prior to those in untreated soils, and were assessed by the grower as more consistent in size.

No soil arthropods were detected in the soil samples prior to establishing the compost trial at Virginia. During the six weeks of the trial no predatory mites were collected from soil samples taken from the untreated plots. Low densities (generally less than 1.0 mite per sample) of mesostigmatid predatory mites were detected in soil samples taken from the plots treated with the compost amendment. The majority of these were *Hypoaspis* sp., but at the low population density observed would not provide significant control of lettuce pests.

Pre-treatment populations of predatory mites at the Gumeracha site averaged 0.75 predatory mites per 150 ml sample. The majority (approx 50%) of the predatory mites at this site prior to the trial were *Pergamasus* sp., and the remainder were a mixture of *Hypoaspis* sp. and a range of smaller mesostigmatid mites. The mean density of predatory mites in the untreated soil plots increased to 1.5 (range of 0.0-5.0 mites per individual sample) per sample during the six week trial period, and the species composition remained the same as that of the pre-treatment samples. By contrast, in the samples from the compost-treated plots the mean predatory mite density per sample increased to 9.5 (range of 6.0-26.0 mites per sample). Greater than 90% of the predatory mites in the soil samples from compost-treated plots were *Pergamasus* sp.. Also, the population density of *Pergamasus* sp. mites was noticeably higher under outer leaves and on lettuce plants in compost-treated plots. A similar increase in the population density of *Pergamasus* sp. was evident in onion trials which trialled the use of a similar compost soil amendment.

There was no significant difference in mite densities or species composition among soil samples taken from plots planted with Confidor®-treated and un-treated lettuce. This contrasts with results obtained in citrus orchard soils, where the application of Confidor® as an in-field soil drench had very deleterious effects on soil invertebrate, including predatory mite, population densities (Baker and Crisp, unpubl. data). It indicates that the seedling drench method of applying Confidor® is relatively safe to many soil invertebrates, in contrast to its detrimental effect on macro-predators (eg. lacewings) that consume CLA on the treated lettuce foliage (Cole and Horne 2006). Hence for growers that are not presently willing to forego prophylactic reliance on Confidor® drenches, a partial IPM system may be able to be established around the use of predatory mites for WFT management. Trial work to test the capacity of managing WFT by predatory mite biological control, either through conserving resident mite populations using soil amendments and/or innundative release of commercially reared predatory mites, may be warranted.

The differences in pre-treatment mite populations between the two sites may have been a result of lesser cultivation at the Gumeracha trial site and/or higher background soil carbon levels.

While further evaluation of these naturally-occurring predatory mites is needed, their apparent tolerance to pesticides and their presence in the outer leaves of lettuce plants, particularly *Pergamasus* sp., suggests that they may have potential as biological control agents of several pests (eg. thrips, aphids, neonate caterpillars and pest mites). These mites persisted in the soil between crops at Gumeracha, particularly where compost had been applied, probably feeding on other mites, collembolans and other small arthropods. They could be seen moving across the foliage or soil and often gathered on the soil under the cover of the outer leaves.

Research by Baker and Crisp indicates that some of these soil-dwelling predatory mites have either developed resistance to, or are naturally tolerant of some of the common insecticides used in Australian horticulture, and that the reduction in their population densities in soils where pesticides have been applied is likely due to a lack of suitable prey.

Pergamasus sp. was relatively easy to rear and maintain on a small scale in the laboratory, and could probably be reared cost effectively by commercial insectaries. The value of innundative release of *Pergamasus* sp. needs to be further evaluated.

Native vegetation

There is growing evidence that strips of selected native plant species growing along the margins of crops in replacement of weedy hosts of pests such as WFT, can result in lesser carryover of these pests between crops, and can also provide a reservoir of beneficial insect species that may migrate into crops and suppress pest populations.

A trial was established in late 2007 at Virginia with 50 m strips of native plants planted along the fence line where lettuce is planned for planting in late 2008. Populations of beneficial insects will be assessed within the native plant strips and at intervals into the crop (Figure R1.4).

Figure R1.4: Native plant trial at Virginia SA in October 2007 (at planting) and August 2008

Summary

CLA is present in South Australia and appears to be able to overwinter in isolated pockets in the Adelaide Hills region. There are few known alternate hosts for CLA in the Northern Adelaide Plains, Adelaide Hills and Murray Bridge lettuce growing areas. This was confirmed by searching adjacent weeds. Hence it is most likely that populations are persisting on unharvested lettuce heads. The surveys conducted as part of this research indicate that CLA also can persist between crops on stray lettuce at the edge of crops. The biggest concern is that the aphids on unharvested or edge plants will colonize subsequent plantings, particularly as the protection provided by Confidor® dipping decreases as plantings age. Quick effective cleanup of crop remnants may help limit the persistence of CLA in production systems.

Compost amendments added to soil prior to planting have the potential to increase population densities of predatory mites, although the rate of population increase may be too slow to provide control of insect pests unless the base densities can be maintained between crops at levels higher than those detected in these trials. The most promising of the predatory mite species, *Pergamasus* sp., is easily reared and provides an ideal option for innundative release at planting. However, further evaluation is required to assess its efficacy and economic viability as a biological control agent for WFT, CLA and other insect pests of lettuce.

Table R1.1: Soil arthropod populations for selected sites.

Site	Area and State	Date	Samples	Mean density per 150 ml soil sample			
				Collembola (Average)	Tyrophagous (Average)	Oribatids (Average)	**Predators (Average)**
Clyde	Werribee Vic	2-Nov-05	4	25	1	0.25	**3.75**
Clyde (2)	Werribee Vic	2-Nov-05	3	27.6	0.3	1.6	**0.6**
Swamp 1		25-Nov-05	5	6.25	2.6	1.6	**0.4**
Swamp 2		25-Nov-05	4	6	1.5	0.75	**0**
Swamp 3		25-Nov-05	4	4	1.5	0.5	**0**
Unlabeled 1	Vic ?	18-Jan-06	4	0.6	0.2	0.2	**0**
Unlabeled 2	Vic ?	18-Jan-06	4	0	0.4	0	**0.2**
Unlabeled 3	Vic ?	18-Jan-06	4	3	0.25	0.25	**0**
AA Lower	Werribee Vic	24-Jan-06	5	0.2	0	0	**0.2**
CB Lower	Werribee Vic	24-Jan-06	5	2	0	0.2	**0.2**
CB Upper	Werribee Vic	24-Jan-06	5	5	1	2	**4**
JP 1 Upper	Werribee Vic	24-Jan-06	5	1.5	0	0.2	**0**
JP Lower	Werribee Vic	24-Jan-06	5	0	0.2	0	**0.2**
JP2	Werribee Vic	24-Jan-06	5	0.8	0	0	**0**
Deruvo	Virginia SA	29-Mar-06	10	4.1	0.7	3.5	**1.4**
Joseph	Virginia SA	29-Mar-06	10	7.4	0	0	**0.6**
Gargaro	Hay NSW	4-Apr-06*	5	0.2	0.4	1.4	**0**
Gargaro	Hay NSW	4-Apr-06†	5	1.2	0.2	1	**0.2**
Langley	Hay NSW	4-Apr-06*	5	0.2	0	0	**0.4**
Langley	Hay NSW	4-Apr-06†	5	0	0	0	**0.6**
Langley (confidor)	Hay NSW	4-Apr-06*	5	1	5.6	0.2	**0**
Langley (confidor)	Hay NSW	4-Apr-06†	5	0.8	2.6	0	**0**
Perotta (confidor)	Hay NSW	4-Apr-06*	5	0.8	0.2	0	**0.2**
Perotta (confidor)	Hay NSW	4-Apr-06†	5	2.2	0.2	0.2	**0.4**
DeRuggerio	Murray Bridge	6-Apr-06	8	3.75	0.6	0	**1.2**
Cobbledick	SA	22-May-06	4	3.5	0	0.25	**1**
DeRuggerio	Murray Bridge	22-May-06	4	0	1	0	**1.25**
Romeo	Virginia SA	1-Jun-06	4	70	0	2.25	**1**
Balustim	Virginia SA	1-Jul-06	4	14	0.25	1	**1.25**
Deruvo	Virginia SA	1-Jul-06	5	19.2	1	2	**4.4**
Cox	Hay NSW	27-Oct-06	4	24.25	2	4.25	**1.25**
Domalie	Hay NSW	27-Oct-06	4	11.25	0	5.25	**0**
Gargaro	Hay NSW	27-Oct-06	5	12.6	3.6	1.4	**0.6**
Gravina	Hay NSW	27-Oct-06	5	9.8	1.8	0.8	**0.8**
Langley	Hay NSW	27-Oct-06	4	11	0.5	0	**0**
Mirabelli	Hay NSW	27-Oct-06	4	2	1.75	0.5	**0**
Ruberto	Hay NSW	27-Oct-06	4	13	1.75	1.5	**0.25**
Attand	Maroota NSW	25-Sep-07*	4	14.00	9.00	0.00	**0.00**
Attand	Maroota NSW	25-Sep-07†	4	8.60	4.40	0.00	**0.60**
Vella	Freemans Reach NSW	25-Sep-07*	5	0.8	2.4	0.2	**0.6**
Vella	Freemans Reach NSW	25-Sep-07†	5	4	0.6	0.4	**0.8**
Galea	Werombi NSW	25-Sep-07*	5	2.80	0.20	0.20	**2.00**
Galea	Werombi NSW	25-Sep-07†	5	5.00	1.40	0.80	**1.40**
Grech	Theresa Park NSW	25-Sep-07*	5	2.2	1.8	0.4	**1.6**
Grech	Theresa Park NSW	25-Sep-07†	5	2.6	5	0.2	**0.4**
Champion	Mangrove Mountain NSW	09-Oct-07	10	2.3	1.1	0.4	**0.1**
Murray	Coleambally NSW	17-Oct-07	24	1.79	1.38	1.58	**0.04**

* Samples taken at 0.0-2.5 cm depth. † Samples taken at 2.5-5.0 cm depth.

R2 Currant-lettuce Aphid Surveys in South Australia

Greg Baker and Peter Crisp
SARDI

Currant-lettuce aphid, *Nasonovia ribisnigri,* (CLA) was detected and confirmed for the first time in South Australia in May 2006. The initial detection was on hydro and field-grown loose-leaf lettuce at a Northern Adelaide Plains (NAP) property. Comprehensive surveying of SA commercial lettuce properties subsequently detected CLA infestations at a further two NAP properties (on bunch-line endive in both cases) and at an Adelaide Hills property on head lettuce. In all four instances the infestations were of low to moderate density.

In 2007 extensive surveys were conducted for CLA in lettuce crops and other potential reservoirs on the Fleurieu Peninsula of South Australia. CLA was detected in lettuce crops in September at Virginia (NAP) and in October at Murray Bridge. In both instances the lettuce were approximately 12 weeks old and past effective Confidor® dip protection. A single specimen was detected in lettuce at Gumeracha (Adelaide Hills); however, this plot was sprayed with insecticide just prior to sampling and no other CLA were detected. At Murray Bridge the lettuce on which CLA detected were heads left in the field post-harvest, whereas in Virginia the CLA was detected in lettuce at the edge of a crop that had been sprayed with Pirimor® after an apparent outbreak CLA in an adjacent crop. These plants may have been missed by the Pirimor® spray allowing a small population of CLA to persist. The persistence of pests on remnant crops emphasises the need to for quick effective cleanup of harvested plantings. The application of Pirimor® treatments controlled the outbreaks in the adjacent crop and prevented establishment in the sampled crop suggesting that resistance to Pirimor® in the CLA population was unlikely.

To assess the presence of CLA in crops that were Confidor® drench-treated prior to planting, potted trap plants were placed in lettuce crops at Murray Bridge, Currency Creek (southern Adelaide Hills), Virginia and Gumeracha. Ten two-week old potted iceberg lettuce plants were placed in the crops, in spring 2007, and replaced every two weeks for the duration of the crop. No CLA were detected on any of the trap plants at any of the sites. An additional series of trap plants were placed in a fallow field at Murray Bridge, the plants were colonised by predatory mites, *Pergamasus sp*. within the two week placement. It is likely that the moisture from the daily watering attracted the mites to the pots.

No CLA were detected during extensive surveys of potential host weeds in and around the lettuce fields surveyed at Murray Bridge, Currency Creek, Virginia and Gumeracha in spring 2007.

CLA was also detected in September 2007 near Mt. Pleasant, in the Adelaide Hills on a small planting of *Ribes* spp.. CLA were detected on *Crepis* spp. but not on the *Ribes* spp. at the Mt. Pleasant site during summer (2007-08) sampling conducted by Craig Feutrill.

R3 Sydney Weed Survey

Tanya Shaw (monitoring), Katina Lindout (report collation)
NSW DPI

The results presented here are from two different survey groups. One survey looked at the five most common weeds on each property or roadside area and any insects that were present on the weeds. The second survey only recorded aphids that were present on weeds, not all insects. Data from the aphid only survey is noted when presented. Table RP3.1 presents a summary of the weeds found around lettuce crops in the Sydney basin survey the potential lettuce diseases they host (Plant Viruses Online, Parrella *et al.* 2003), and the pests and beneficials observed in the survey.

★ **This star indicates that weeds are known hosts of currant lettuce aphid (CLA).**

★ **This star indicates recorded host of Tomato Spotted Wilt virus (TSWV)**

★ **This star indicates recorded host of TSWV and confirmed transmission by western flower thrips (WFT)**

★ **This star indicates weeds that are a particular risk for harbouring insect pests of lettuce based on the results of this survey.**

FAMILY AMARANTHACEAE

★ **Green Amaranth (*Amaranthus viridius)***

- Surveyed twice
- Plants within a growing crop had 2-spotted mite and whitefly
- Roadside plants had no insects

FAMILY APIACEAE

★ **Fennel *(Foeniculum vulgare)***

- Surveyed eight times
- Spiders were found on two samples
- Aphids were commonly found in high numbers: Coriander aphid (5 times), Cotton aphid (once); honeysuckle aphid (once) and unidentified aphid (once)
- Cotton aphid and coriander aphid found in two separate samples surveyed just for aphids in 2007

FAMILY ASTERACEAE

★ **Capeweed *(Arctotheca calendula)***

- Surveyed four times
- Pests: potato aphid (once); thrips (once); green leafhopper (once)
- Beneficial insects: brown shield bug (once, same plant as green leafhopper)
- Waterlily aphid and artichoke aphid found in a separate sample surveyed just for aphids in 2007

Farmers Friend *(Bidens pilosa)*

- Surveyed three times
- No insects present
- Cotton aphid and apple aphid found in two separate samples surveyed just for aphids in 2007

Black Thistle *(Cirsium vulgare)*

- Surveyed four times
- Thrips (black, not positively identified) found once
- Spiders found once

Fleabane *(Conyza bonariensis)*

- Surveyed once
- No insects present

Canadian Fleabane *(Conyza canadensis)*

- Surveyed eight times
- Unidentified aphids found twice

Carrot Weed *(Cotula australis)*

- Surveyed once
- Green lacewing eggs present

Water Buttons *(Cotula coronopifolia)*

- Surveyed once
- Medium infestation of an unidentifiable aphid

Hawksbeard *(Crepis sp.)*

- Surveyed twice
- Low numbers of brown sowthistle aphid found once
- Brown sowthistle aphid found in a separate sample surveyed just for aphids in 2007

Potato Weed *(Galinsoga parviflora)*

- Green peach aphid, cowpea aphid, green sowthistle aphid and potato aphid found in two separate samples surveyed just for aphids in 2007

Cudweed *(Gnaphalium pensylvanica)*

- Surveyed six times
- Rutherglen bug found on four occasions (samples at the same location, but on two different dates)
- CLA found once (may have fell down from infested endive growing in benches above, but appeared to be feeding on cudweed
- One sample had thrips (black, not positively identified), 2-spotted mite and red spider mite
- One sample had no pest insects, but had brown lacewing eggs.

Jerusalem Artichoke *(Helianthus tuberosum)*

- Surveyed once
- Medium numbers of cotton aphid present
- Coriander aphid and cotton aphid found in two separate samples surveyed just for aphids in 2007

Flatweed *(Hypochoeris radicata)*

- Surveyed five times
- Two samples had thrips present
- One sample had Hippodamia larvae, Transverse ladybug larvae and brown lacewings (also was one of the samples with thrips)
- Another sample had spiders and beetles present (was the other sample with thrips)
- Three samples had no insects present

Prickly Lettuce *(Lactuca serriola)*

- Surveyed three times
- Whitefly found on one sample growing within a crop of lettuce

Fireweed *(Senecio madagascariensis)*

- Surveyed 12 times
- Thrips found on three samples, and WFT on one sample
- Mirids were found on one sample and unidentifiable aphids were found on another
- Seven samples didn't have insects present
- Coriander aphid found in a separate sample surveyed just for aphids in 2007

Common sowthistle *(Sonchus oleraceus)*

- Surveyed 20 times (Samples at 10 different locations)
- Rutherglen bugs found on seven samples
- Aphids found on six samples: Brown sowthistle aphid (3 samples), Green sowthistle aphid (2 samples), one sample had a mixture of green peach aphid, coriander aphid and cotton aphids, one sample had poplar gall aphid in addition to brown and green sowthistle aphids.
- Heliothis eggs were found on one sample
- One sample had plague thrips, WFT and scale insects in addition to Rutherglen bug
- Beneficial insects: one sample had hoverflies and Hippodamia; one sample had Damsel bug; one sample had brown lacewing eggs.
- Eight samples had no insects present, nine samples had no insect pests of lettuce present
- Brown sowthistle aphid, green sowthistle aphid and cotton aphid found in three separate samples surveyed just for aphids in 2007

FAMILY BRASSICACEAE

Twiggy Turnip *(Brassica fruticulosa)*

- Surveyed twice
- A low number of an unidentifiable aphid was found on one sample

Shepherd's Purse *(Capsella bursa-pastoralis)*

- Surveyed once
- No insects present

Buchen Weed *(Hirschfeldia incana)*
- Surveyed twice
- One sample had ants present

FAMILY CHENOPODACEAE

Fat Hen *(Chenopodium album)*
- Surveyed six times
- One sample had Rutherglen bugs present and one sample had weevils present

Crumb Weed *(Chenopodium pumilo)*
- Surveyed twice
- No insects present

FAMILY COMMELINACEAE

Wandering Jew *(Tradescantia albiflora)*
- Surveyed once
- No insects present

FAMILY CUCURBITACEAE

Choko *(Sechium edule)*
- Surveyed once
- No insects present

FAMILY FABACEAE

Burr Medic *(Medicago polymorpha)*
- Surveyed twice
- No insects present

White clover *(Trifolium repens)*
- Surveyed twice
- Plague thrips found on both samples, but samples were from the same property

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FAMILY LAMIACEAE

Dead Nettle *(Lamium amplexicaule)*
- Surveyed once
- Sample had Rutherglen bug, Plague thrips and Transverse ladybugs

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FAMILY MALVACEAE

Mallow (*Malva parviflora)*
- Surveyed seven times
- 2-spotted ladybug found on one sample, fluorescent flies found on one sample and beetles found on one sample
- Green peach aphid and cotton aphid found in a separate sample surveyed just for aphids in 2007

Redflower mallow *(Modiola caroliniana)*

- Surveyed five times
- Mites were found on one sample, an unidentifiable aphid was found on another sample

Pavonia *(Pavonia hastate)*

- Surveyed once
- No insects present

Paddy's Lucerne *(Sida rhombifolia)*

- Surveyed twice
- Beetles found on one sample

FAMILY ONAGRACEAE

Primrose *(Oenothera stricta)*

- Surveyed three times
- An unidentifiable aphid was found on one sample
- Coriander aphid was found in a separate sample surveyed just for aphids in 2007

FAMILY PLANTAGONACEAE

Lambs Tongue *(Plantago lanceolata)*

- Surveyed four times (all at the one location, but different dates)
- Three samples had hoverflies present, even though plants weren't flowering
- One sample had ladybugs in addition to hoverflies
- One sample had brown lacewings

FAMILY POACEAE

***Grasses** *wild oats *Avena fatua* is a TSWV host

- Surveyed twice
- No insects present

FAMILY POLYGONACEAE

Curled Dock *(Rumex crispus)*

- Surveyed eight times
- One sample had potato aphids and Transverse ladybugs
- One sample had whitefly and brown lacewings
- One sample had unidentifiable aphids

FAMILY PORTULACACEAE

Pigweed *(Portulaca oleracea)*

- Surveyed once
- No insects present

FAMILY PRIMULACEAE

Pimpernel *(Anagallis arvensis)*
- Surveyed once
- No insects present

FAMILY ROSACEAE

Blackberry *(Rubus fruticosus)*
- Surveyed once
- Beetles present

FAMILY SOLANACEAE

Common thornapple *(Datura stramonium)*
- Surveyed once
- Hippodamia present; Transverse ladybug eggs and larva present

Blackberry Nightshade *(Solanum nigrum)*
- Surveyed seven times
- 28-spotted ladybug found on one sample
- Beetles found on one sample
- Green lacewing eggs found on one sample

Potato *(Solanum tuberosum)*
- Surveyed three times
- Green lacewing eggs found on one sample
- An unidentifiable aphid was found on another sample

FAMILY URTICACEAE

Stinging Nettle *(Urtica urens)*
- Surveyed five times
- Transverse ladybugs found on three samples, all at the same location

FAMILY VERBENACEAE

Purple Top *(Verbena bonariensis)*
- Surveyed twice
- No insects present

Veined Verbena *(Verbena rigida)*
- Surveyed three times
- Thrips present on two samples

Table R3.1 Sydney basin weeds as disease, pest and beneficial hosts

Family	Scientific name	Common name	Lettuce Diseases (literature)	Pests - observed	Beneficials - observed
AMARANTHACEAE	*Amaranthus viridius*	Green Amaranth	TSWV	WF, TSM	
APIACEAE	*Foeniculum vulgare*	Fennel	TSWV	CA	spiders
ASTERACEAE	*Arctotheca calendula*	Capeweed	TSWV	PA, LH, thrips	Shield bug
	Bidens pilosa	Farmer's Friend	TSWV	CA	
	Cirsium vulgare	Black Thistle	TSWV	WFT	spiders
	Conyza bonariensis	Fleabane	TSWV		
	Conyza canadensis	Canadian Fleabane	TSWV	WFT	
	Cotula australis	Carrot Weed			GLW eggs
	Cotula coronopifolia	Water Buttons			
	Crepis capilliaris	Hawksbeard	TSWV,	WFT, CLA, BSA	
	Galinsoga parviflora	Potato Weed	TSWV	GPA, PA, SA	
	Gnaphalium pensylvanica	Cudweed		RGB, TSM, RSM	BLW eggs
	Helianthus tuberosum	Jerusalem Artichoke			
	Hypochoeris radicata	**Flatweed**		Thrips	BLW, HLB, TLB, spiders
	Lactuca serriola	Prickly Lettuce	TSWV	WFT, WF,	
	Senecio madagascariensis	**Fireweed**		WFT, thrips, mirids	
	Sonchus oleraceus	**Common sowthistle**	TSWV, LNYV, LMV	WFT, RGB, BSA, SA, CA	HLB, Nabid
BRASSICACEAE	*Brassica fruticulosa*	Twiggy Turnip			
	Capsella bursa-pastoralis	Shepherd's Purse	TSWV, BWYV, LMV, TuMV		
	Hirschfeldia incana	Buchen Weed	TSWV		
CHENOPODACEAE	*Chenopodium album*	Fat Hen	TSWV, AMV, LMV	WFT, RGB	
	Chenopodium pumilo	Crumb Weed			
COMMELINACEAE	*Tradescantia albiflora*	Wandering Jew			
CUCURBITACEAE	*Sechium edule*	Choko	TSWV		
FABACEAE	*Medicago polymorpha*	Burr Medic	TSWV, AMV		
	Trifolium repens	White clover	TSWV, AMV, BWTV	WFT, PTh	
LAMIACEAE	*Lamium amplexicaule*	Dead Nettle	TSWV	WFT, RGB, PTh	TLB

MALVACEAE	*Malva parviflora*	Mallow	TSWV, AMV, BWTV	WFT, GPA, CA	TSLB
	Modiola caroliniana	Redflower mallow			
	Pavonia hastate	Pavonia			
	Sida rhombifolia	Paddy's Lucerne			
ONAGRACEAE	*Oenothera stricta*	Primrose			
PLANTAGONACEAE	*Plantago lanceolata*	Lambs Tongue	TSWV	WFT	Syrphids, LB, BLW
POACEAE	*Avena fatua*	Wild oat	TSWV		
POLYGONACEAE	*Rumex crispus*	Curled Dock	TSWV	WFT, PA, WF	TLB, BLW
PORTULACACEAE	*Portulaca oleracea*	Pigweed	TSWV	WFT	
PRIMULACEAE	*Anagallis arvensis*	Pimpernel	TSWV	WFT	
ROSACEAE	*Rubus fruticosus*	Blackberry			
SOLANACEAE	*Datura stramonium*	Common thornapple	TSWV, LNVY, TuMV	WFT	HLB, TLB
	Solanum nigrum	**Blackberry Nightshade**	TSWV, AMV	WFT, 28-SLB	GLW eggs
	Solanum tuberosum	Potato	TSWV, AMV, BWYV	WFT	GLW eggs
URTICACEAE	*Urtica urens*	Stinging Nettle			TLB
VERBENACEAE	*Verbena bonariensis*	Purple Top	TSWV	WFT	
	Verbena rigida	Veined Verbena	TSWV	thrips	

Diseases: TSWV – tomato spotted wilt virus (WFT, onion & tomato thrips)
AMV – lucerne/alfalfa mosaic virus (GPA)
BWYV – beet western yellows virus (**GPA**, PA, CA, BA, FA)
LBVV – lettuce bigvein varicosavirus (fungus: *Olpidium brassicae)*
LNYV – lettuce necrotic yellows virus (SA)
LMV – lettuce mosaic virus (GPA, CA, PA)
TuMV – turnip mosaic virus (GPA, BA)

Pests: BA – Cabbage aphid *Brevicoryne brassicae*, BSA – brown sowthistle aphid, CA – cotton aphid *Aphis gossypii*
CLA – currant lettuce aphid *Nasonovia ribis-nigri* FA – foxglove aphid *Aulacorthum solani* GPA – green peach aphid *Myzus persicae*, PA – potato aphid *Macrosiphum euphorbiae*, SA- sowthistle aphid *Hyperomyzus lactucae*,
PTh – plague thrips TSM- two spotted mite WF- whitefly
WFT – Western flower thrips *Franklienlla occidentalis* 28 SLB – 28 spotted ladybeetle

BLW – brown lacewing *Micromus tasmaniae*, HLB – White collared ladybeetle *Hippodamia viriagata*, TLB – transverse ladybeetle *Coccinellid transversalis*

R5 Evaluation of Gaucho® insecticide as a options for direct sown open head lettuces (salad mixes) against Currant Lettuce Aphid *(Nasonovia ribisnigri)* (CLA) in Victoria

Slobodan Vujovic, Victorian Department of Primary Industries

Background

Since the arrival of Currant lettuce aphid (*Nasonovia ribisnigri*) (CLA) in New Zealand (March 2002) the lettuce industry has started preparing for it's arrival in Australia and Victoria. The lettuce industry in Victoria is currently using three management options to manage CLA and these include resistant varieties, drenching with Confidor® (imidicloprid) and integrated pest management (IPM).

The most used option, especially by iceberg and cos lettuce growers, is Confidor® as a seedling drench at a rate of 35-55ml of product per 1000 plants (APVMA permit number - PER7416). At the time this was also one of the two options lettuce growers had to allow interstate movement of lettuce.

Salad-mix and open head lettuce growers have limited options to manage CLA. There are a limited number of resistant varieties available to growers. Confidor® is registered as a seedling drench while most salad-mixes are direct sown.

The aim of this trial was to assess the effectiveness of seed coating using the Gaucho® formulation of imidacloprid insecticide to control CLA on open head and salad-mix lettuces.

Imidacloprid is a systemic insecticide with activity against plant sucking insects, such as aphids. It is absorbed into the root system and translocated to the seedling and leaves. Insects ingesting imidacloprid stop feeding, reproducing and die.

Methods

A field trial was carried out in Clyde to evaluate Gaucho® as a seed coated insecticide. The trial was conducted in December/January 2005/6 in an area where CLA had been found to be present.

Five treatments were evaluated using two *Nas*-susceptible varieties, 2 rates of imidicloprid and a *Nas*-resistant variety as a control:

1- Monaco 80 (80 gram of active ingredient/1000 pellets)
2 - Monaco 120 (120 gram of active ingredient/1000 pellets)
3 - Shiraz 80 (80 gram of active ingredient/1000 pellets)
4 - Shiraz 120 (120 gram of active ingredient/1000 pellets)
5 - Control Carmoli RZ (85-85) *Nas*- resistant variety

CLA resistant variety Carmoli RZ (85-85) was used as control so as not to encourage the presence of CLA in the rest of the crop. The trial was located on commercial property and if there was high CLA pressure this may have affected the marketing of the commercial crop.

The trial protocol (Appendix R5.1) included five replicates and five treatments (Latin square) with a total number of 25 plots at Clyde. The trial was placed at commercial growers property among his commercial crop that was Confidor® treated prior to sowing.

Field results

The trial was monitored weekly to determine presence of CLA or other aphid species. Each week, forty plants per plot (ten plants randomly chosen from each row) were assessed for presence or absence of aphids. The trial was monitored from germination till harvest.

When the crop was ready for harvest, 40 lettuces were taken at random from each plot and taken back to the laboratory for assessment for presence or absence of aphids. CLA pressure during the Clyde field trial was non-existent and data collection was not possible from weekly monitoring and harvest assessment due to no aphid presence (data was insufficient for statistical differentiation between treatments).

Bioassay

Due to the poor field results bioassays were carried out in the laboratory to endeavour to identify whether or not the treatments were effective. Bioassays using wild populations of CLA (wingless adult aphids) found on hawkweed *Crepis spp.* at Knoxfield were used.

Lettuce leaves for bioassay were collected at the harvest (7 weeks after plantings). Ten randomly chosen leaves per plot were collected and placed into 40cm x 28cm plastic bags and sealed. The leaves were then transported back to the laboratory in a portable ice-box. In the bioassay trial untreated iceberg lettuce was used as the control treatment.

In the bioassay, one wingless CLA was placed in a 30mL Solo plastic cup on a one 2cm leaf discs cut from leaves sampled from the plots. Treatments were randomised by plots and replicates. There were 50 wingless CLA per treatment (10 wingless CLA per replicate). The trays of cups were held at 25°C. Each day, the wingless CLA were checked.

Differences between treatments were considered to be statistically significant if there was no overlap of 95% confidence limits. Mortality of wingless CLA in treatments was adjusted using the Abbott's formula to allow for mortality in the untreated control. Data was analysed with the Genstat® program using a Generalised Linear Model using binomial distribution link. Crop monitoring results were not analysed because of low numbers recorded.

Table R5.1 95% Confidence Interval for survival time

Treatment	After 24 hours			
	K-M estimator	LCI (95%)	UCI(95%)	Log-rank test(df=5)
Monaco 80	0.960	0.849	0.990	Test stats=10.63 0.059
Monaco 120	0.900	0.776	0.957	
Shiraz 80	0.940	0.825	0.980	
Shiraz 120	0.980	0.866	0.997	
RZ	1.000	1.000	1.000	
Control	1.000	1.000	1.000	
	After 48 hours			
Monaco 80	0.780	0.638	0.872	Test stats=7.55 0.183
Monaco 120	0.760	0.616	0.856	
Shiraz 80	0.800	0.660	0.887	
Shiraz 120	0.780	0.638	0.872	
RZ	0.900	0.776	0.957	
Control	0.960	0.849	0.990	
	After 72 hours			
Monaco 80	0.440	0.301	0.571	Test stats=22.28 <0.001***
Monaco 120	0.340	0.214	0.470	
Shiraz 80	0.480	0.337	0.609	
Shiraz 120	0.400	0.265	0.531	
RZ	0.580	0.432	0.702	
Control	0.900	0.776	0.957	
	After 96 hours			
Monaco 80	0.140	0.062	0.250	Test stats=39.635 <0.001***
Monaco 120	0.120	0.049	0.226	
Shiraz 80	0.080	0.026	0.175	
Shiraz 120	0.120	0.049	0.226	
RZ	0.240	0.133	0.364	
Control	0.760	0.616	0.856	
	After 120 hours			
Monaco 80	0.020	0.002	0.092	Test stats=48.62 <0.001***
Monaco 120	0.000	0.000	0.000	
Shiraz 80	0.000	0.000	0.000	
Shiraz 120	0.020	0.002	0.092	
RZ	0.060	0.016	0.149	
Control	0.720	0.574	0.824	

*:p<0.05, **: p<0.01, ***: p<0.001

Table R5.1 shows 95% confidence interval for the probability of surviving beyond certain time (Kaplan-Meier estimate). It also shows the p-value of the log-rank test which was used to compare those survival curves at each time. As shown in Table R5.1, there is no significant difference of survival curves between treatments after 48 hours, but there is significant difference between treatments after 72 hours. For instance, after 72 hours the p-value of log rank test < 0.01, hence there is significant difference between survival curves at this time. Those survival curves except Control are not different.

Table R5.2 Number of Survival at each time

Treatment	No Lettuce aphid	No. survivals after time(hour)					Mortality(%)
		24	48	72	96	120	
Monaco 80	50	48	39	22b	7b	1b	2
Monaco 120	50	45	38	17b	6b	0b	0
Shiraz 120	50	47	40	24b	4b	0b	0
Shiraz 120	50	49	39	20b	6b	1b	2
RZ	50	50	45	29b	12b	3b	6
Control	50	50	48	45a	38a	36a	72

Based on the Table R5.1, after 24 and 48 hours there is no significant difference of survival curves between treatments because there is no overlap between 95% confidence intervals of survival time.

Figure R5.1 and Figure R5.2 show Survival curves and Mortality curves for each treatment, those curves are based on nonlinear models.

Figure R5.1 Survival curves for treatments

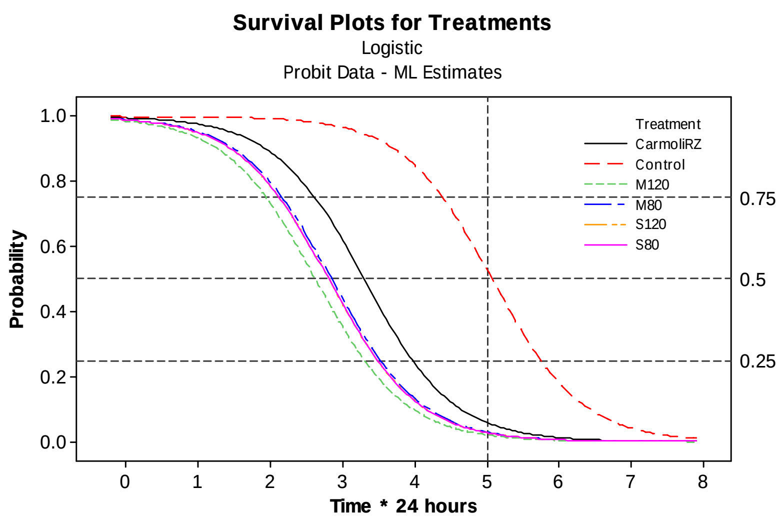


Figure R5. 2 Mortality curves for treatments

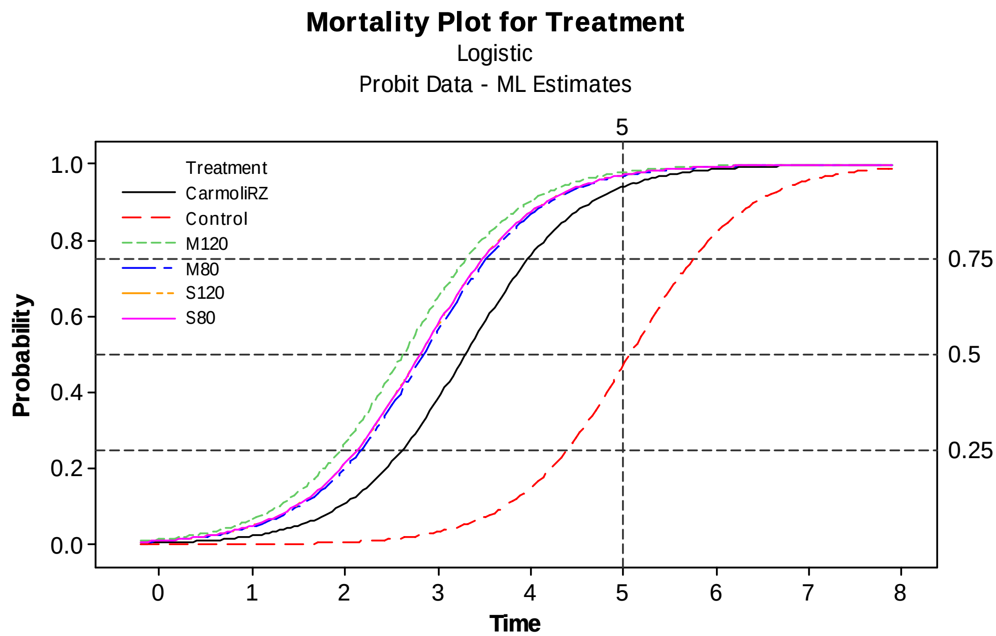


Figure R5. 3 Mortality with Abbott's correction

Analysis of bioassays

All treatments were effective in controlling CLA. There was no significant difference between treatments. All chemical treatments performed well. There was no significant difference between lower (80g of active ingredient/1000 pellets) and higher rate (120g of active ingredient/1000 pellets) of Gaucho® (imidacloprid). There was no significant difference between the two cultivars. Mortality of aphids in resistant variety Carmoly was slightly slower compared with other chemical treatments. The reason for this was that aphids in that treatment died from starvation.

In the control treatment 72% of aphids were alive after 120 hours. Note that those aphids that survived on the control also produced offspring. Seventy eight percent of surviving aphids produced offspring and they had from 3 to 24 nymphs.

Bioassays results indicated that Gaucho® insecticide as a seed treatment was effective in controlling CLA.

Discussion and Recommendations

The low pest pressure in this trial could only have been overcome by having much larger plots and sampling more plants per plot at each sampling occasion. This was a one off trial and it would have been preferable to have several trials throughout the season to try and coincide with high pest pressure.

The necessity of keeping crops clean (on commercial farms) to allow interstate movement of product imposed limitations on the effectiveness of the trial. Location of the trial plots within Confidor® treated crops did not help facilitate infestation of the trial by CLA. It would be desirable to locate these field trials separately from Confidor® treated or resistant crops to increase pest pressure.

The bioassays in a controlled environment indicated the potential effectiveness of the seed treatment with imidicloprid in controlling CLA in direct seeded lettuce at the rates used. This does however need to be demonstrated under field conditions.

S1. Lettuce Integrated Pest Management (IPM) Survey 2006

Kathryn Bechaz, NSW DPI

Summary

An industry wide telephone survey of lettuce growers was conducted to determine their pest management strategies. 117 growers from Tasmania, Victoria, New South Wales (NSW), South Australia (SA), Queensland (Qld) and Western Australia (WA) were contacted, with 79 growers willing to respond to the survey. Of these 79 growers, 48 considered themselves to be IPM growers, whilst 31 were non IPM growers. The most important IPM strategies were crop monitoring, the use of biological insecticides and monitoring for beneficial insects. Non IPM growers managed their pest problems by using newer generation chemicals, weekly sprays and crop monitoring.

Crop monitoring was used by 72 of the 79 growers surveyed. The majority of growers monitored their crops themselves however crop consultants and chemical resellers were also used. Generally most lettuce crops were monitored weekly or twice weekly. Hydroponic growers usually monitored daily when they were harvesting. The number of lettuces checked varied greatly (10 to 5000 plants), depending on the production system in place. Only 81% of growers who monitored their crops felt it was cost effective in decreasing the number of insecticides applied.

Newer generation insecticides were used by 63 growers, the most popular being Success®, followed by Avatar®, Bts and Proclaim®. The most common fungicides sprayed were Ridomil®, Rovral® and Filan®. Kerb® was by far the most frequent herbicide sprayed by growers for weed control.

Currant-lettuce aphid (*Nasonovia ribisnigri* (Mosley)) (CLA) is becoming established in many lettuce growing regions of Australia. This pest is a big concern for all growers even where it has not been detected. Where the aphid is established Confidor®, *Nas*-resistant lettuce varieties, native aphid predators and other chemical strategies have been implemented as control measures. Similarly where it has not been detected growers will or are using Confidor®, *Nas*-resistant lettuce varieties and other chemical strategies to combat this problem.

Growers also commented on the advantages and disadvantages of lettuce IPM strategies. The major benefits of IPM to growers were decreased insecticide usage and cost and better pest control. Threats to IPM were also identified and related to insect contamination of product and new pest occurrences. Some local barriers to adoption of IPM were also recognised.

The usefulness of the lettuce project was revealed by asking growers to rate specific publications and the lettuce conferences. The Lettuce Leaf Newsletter, Ute/Field Guide and Lettuce IPM Information Guide were all rated good to excellent publications. The growers that did attend the Lettuce Conferences also rated them good to excellent. However, the conference proceedings were not rated highly because they were too technical.

Introduction

A telephone survey of lettuce growers was conducted in April and May of 2006. The aim of the survey was to ascertain the pest management strategies of lettuce growers and to determine their level of uptake and understanding of integrated pest management (IPM). The survey form was very similar to the IPM survey form used by Andrew Creek in October 2005 (Appendix S1.1). Additional questions were added which included the use of fungicides and herbicides on lettuce crops, control of sclerotinia, the presence of currant lettuce aphid (CLA) (*Nasonovia ribisnigri* (Mosley)) and local barriers that inhibit the uptake of IPM.

The telephone survey was completed by Kathryn Bechaz - Technical Officer for Lettuce at the Vegetable Industry Centre, Yanco. Lettuce growers from Tasmania, Victoria, NSW, SA, Qld and WA were surveyed. A list of potential survey candidates from Tasmania and Victoria was compiled by Lionel Hill (Researcher) and Patrick Ulloa (Industry Development Officer), respectively. John Duff an Entomologist from Qld, Sonia Broughton also an Entomologist from WA and Greg Baker a Researcher from SA, surveyed growers from their particular states. Other lettuce growers contacted from NSW and some from SA, Vic and WA were selected randomly from a list of growers compiled by NSW DPI throughout the lettuce IPM project.

Telephone surveys can be difficult because they require people to take time out to participate. However, of the 117 growers that were contacted, 79 (68%) chose to complete the survey. This included the 20 growers that had previously responded to the survey in 2005, who were contacted first to answer the additional questions (Appendix S1.2). The 38 growers who did not respond were either not interested in participating in the survey or no longer grew lettuce. Of the 79 growers who participated in the survey, 29 were from NSW, 17 were from Victoria, 12 were from Tasmania, 9 were from SA, 6 were from Qld and 6 were from WA.

Although this survey only reflects the opinions of a small cross section of growers from the Australian lettuce industry, it does however give an indication of the pest management strategies that lettuce growers are currently using. The survey also reveals the attitude towards and the uptake of IPM.

Results

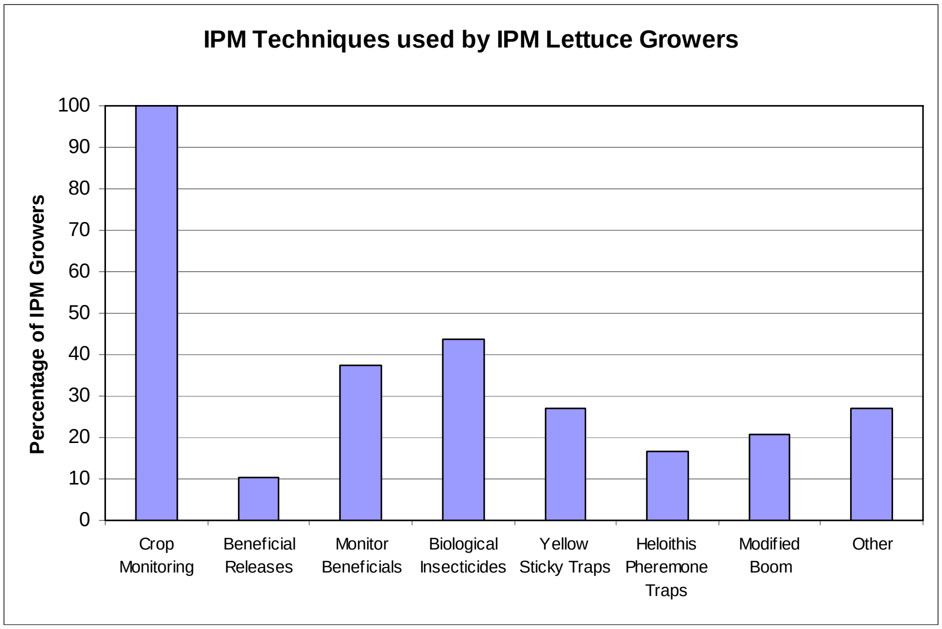
Of the 79 lettuce growers who choose to take part in the survey, 59 were field growers, 15 were hydroponic growers, 2 were organic growers and there was 1 seedling, transplant and non grower. The non grower who participated had been a consultant for many years and was very knowledgeable with the pest management trends in their area.

The Pest Management Strategies of Lettuce Growers

IPM strategies were used by 48 of the 79 (61%) growers who responded to the survey, in the production of lettuce. The other 31 growers (39%) believed they only used traditional techniques to produce lettuce. However, most of these growers used some techniques as part of their lettuce crop management that could be interpreted as an IPM strategy. These techniques included crop monitoring, the use of yellow sticky traps, chemical rotations to avoid resistance, ploughing in old crop residues and only spraying when necessary. More than likely these growers felt that because they were spraying weekly with either traditional or newer generation insecticides that they were not practising IPM strategies.

Crop monitoring was the most important component of IPM, with all of the growers who indicated they used an IPM strategy implementing this technique as part of their crop management (Figure S1.1). The use of biological insecticides and the monitoring of beneficial insects also rated highly, with 44% and 38% of lettuce growers indicating they utilised these techniques, respectively. Other IPM techniques that growers mentioned they used but were not listed included ploughing in old crop residues, only spraying when necessary, the use of newer generation insecticides, chemical rotations, removing suspect plants, waste, debris and weeds, washing insects off plants and using mosquito netting and birds to deter pests.

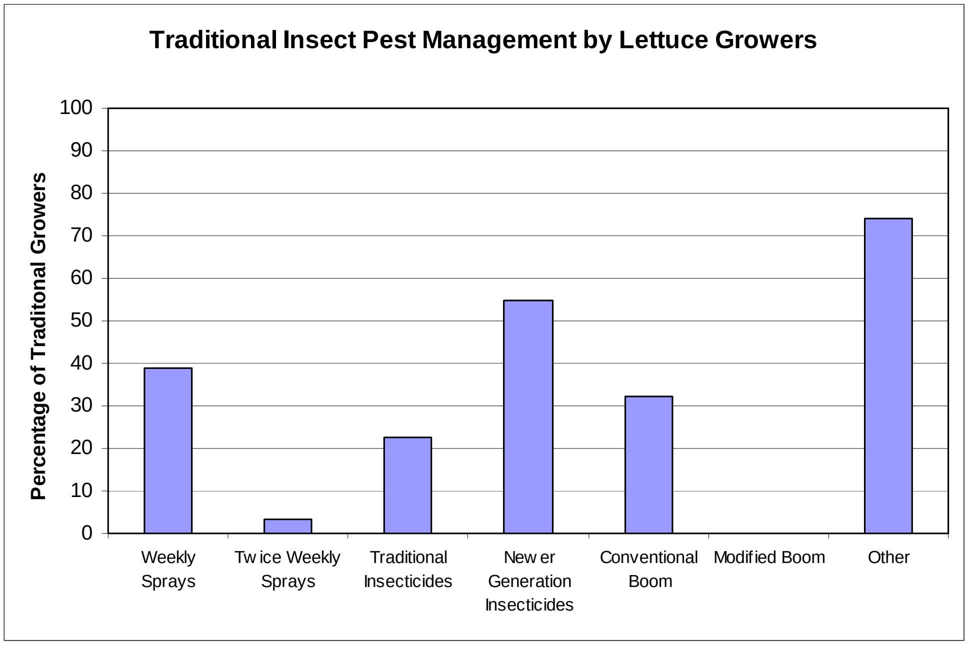
Figure S1.1. The IPM techniques that growers indicated they used as part of an IPM strategy in lettuce production.



The majority of growers (28) who indicated they use IPM strategies have been doing so for 1 to 5 years. The remaining 20 growers adopted IPM strategies more than 5 years ago. The reason some growers adopted IPM strategies was to decrease chemical use (thereby saving money and reducing chemical resistance) and to meet the quality standards set out by the buyers of lettuce. Other growers adopted IPM for sustainability and better pest management for western flower thrips (*Frankliniella occidentalis*) (WFT) and heliothis (*Heliocoverpa armigera*). Increasing beneficial insect numbers was also an important factor in adopting IPM strategies. Finally health reasons were high on the list for some growers. Paul Horne (IPM Technologies) was a major reason why many Victorian growers adopted IPM strategies due to his knowledge and encouragement.

The majority of growers (55%) who did not use an IPM strategy indicated that they used newer generation insecticides such as Success®, Avatar® and Bts in their production of lettuce (Figure S1.2). Weekly sprays (39%), the use of a conventional boom spray (32%) and applying traditional insecticides (23%) were also popular amongst non IPM growers. Other techniques employed by non IPM growers included crop monitoring, the use of yellow sticky traps, chemical rotations to avoid resistance, ploughing in old crop residues, only spraying when necessary, taking advice from an agronomist and using Confidor® treated seedlings.

Figure S1.2. Techniques that non IPM growers use to manage insect pests in lettuce



The non IPM growers were asked "What would it take for you to adopt an IPM strategy?" to which they responded:

- A guarantee that IPM will work 100% of the time. Growers can't afford to lose crops as they may forfeit their contracts/markets
- A market demand for IPM produced lettuce and compensation for the extra cost of implementing IPM (eg crop monitoring and expensive insecticides)
- Greater financial return for IPM produced lettuce
- An acceptance by retailer's and consumers of IPM lettuce, otherwise product will be routinely rejected based on low levels of insect contamination (including beneficial insects)
- More information and consultation is needed from the experts so IPM can be confidently adopted, although it appears that some growers are adopting IPM strategies in most regions
- IPM is time consuming, more time is needed to implement and maintain the strategy
- IPM strategies need to control CLA, therefore decreasing the use of Confidor®
- Beneficial insects that control Rutherglen bug (*Nysius vinitor*) would be valuable
- Commercially available beneficial insects that are reasonably priced
- If IPM is required by Quality Assurance legislation
- As part of the contract with buyers (eg Woollies and Coles)

Crop monitoring was a large part of the growers crop management, with 62 (91%) of the growers surveyed indicating they monitored their lettuce crops (Figure S1.3). Crop monitoring involved 47 of the 48 IPM growers and 25 of the 31 non IPM growers, respectively. The consultant was included in the survey, however crop monitoring was non applicable due to the consultant only giving advice.

It was obvious from the survey that the majority (74%) of the growers monitored their lettuce crops themselves (Figure S1.4). Crop consultants (28%) and chemical resellers (6%) were also employed to monitor lettuce crops. Growers used other sources to help with crop monitoring, including farm mangers, staff, family members, IPM technicians and trainees and Department of Primary Industries (DPI) staff.

Figure S1.3. The number of lettuce growers using crop monitoring

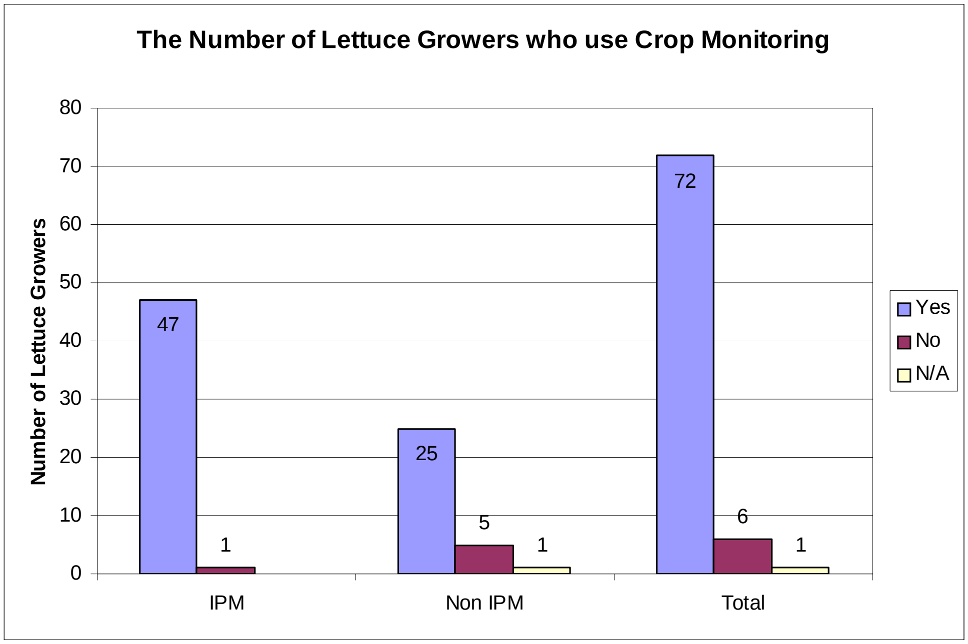
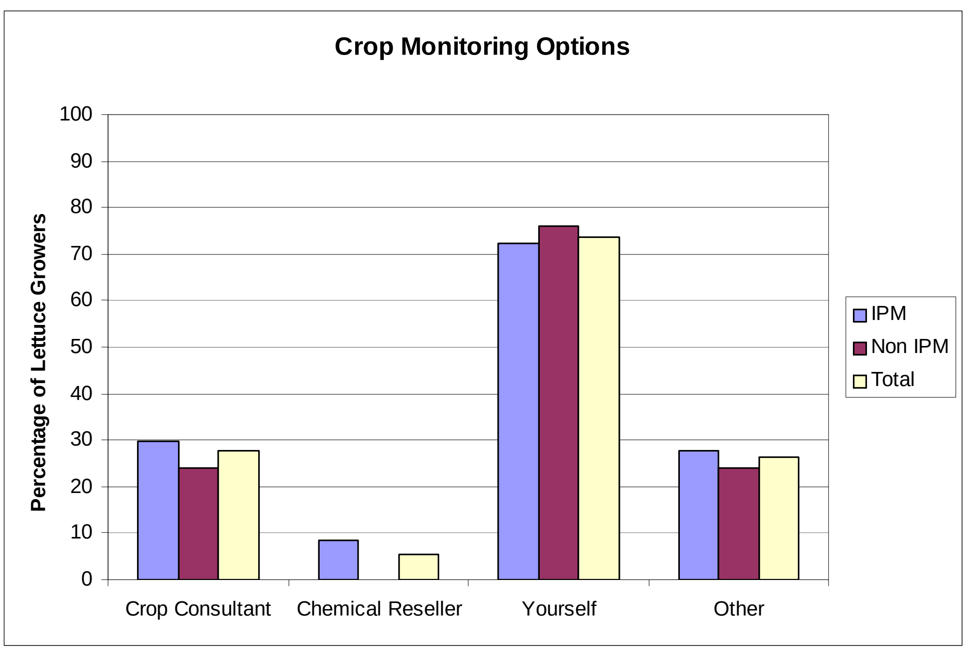


Figure S1.4. The individuals who crop monitor lettuce growers' fields.



Generally most lettuce crops were monitored weekly by the growers themselves or another individual. Some crops were monitored twice weekly depending on pest pressure and season. Hydroponic growers monitored daily while harvesting took place. Other monitoring regimes included 3 or 4 times a week, every 4 to 5 days, fortnightly and as often as possible.

The monitoring protocols varied greatly between lettuce growers and whether or not they were IPM or non IPM growers. Most non IPM growers checked 20 to 100 lettuce plants every time they monitored their crop. The range for IPM growers was large and depended on what type of lettuce grower they were. Field growers tended to check less than organic and hydroponic growers. This was mainly due to the fact that most hydroponic and organic growers monitored their crops daily. Field growers generally checked between 10 and 200 lettuce plants or observed the pest pressure. Most hydroponic and organic growers checked their lettuce crops daily and monitored between 1000 to 5000 plants. The hydroponic and organic growers also indicated that yellow sticky traps were very useful tools for crop monitoring.

The growers that did not use crop monitoring decided on spray programs by using their experience and knowing what times of the year pest pressures were highest. Observing moth activity at night and seasonally adjusting spray programs to suit this activity also proved useful. One grower checked his lettuce crop whilst doing other crop management activities such as fertilising, irrigating and weeding.

Only 81% of growers that used crop monitoring as part of their lettuce crop management felt that it was cost effective in reducing the number of insecticides applied. Some IPM growers thought that the costs increased due to employing crop consultants to do the crop monitoring. It was also felt by some growers that during times of high pest pressure, monitoring was ineffective, since you had to spray anyway.

Chemical Use by Lettuce Growers

Of the growers surveyed, 63 of the 79 used newer generation insecticides. Success® proved to be the most popular newer generation insecticide with 56 of the growers using this product (Table S1.1). The popularity of Success® is due to the efficacy it displays against the two major insect pests heliothis and WFT. Avatar® (32 growers), Bts and Proclaim® (31 growers each) were also popular choices amongst growers for insect pest management. Other insecticides were sprayed, however did not prove to be as popular as the newer generation insecticides.

Table S1.1. Newer generation insecticides that lettuce growers have been spraying.

Insecticide	Active Ingredient	IPM Growers	Non IPM Growers	Total Growers
Success®	Spinosad	35	21	56
Avatar®	Indoxacarb	21	11	32
Bts	*Bacillus thuringiensis*	25	6	31
Proclaim®	Emamectin	22	9	31
NPV®/Gemstar®	Helicoverpa NPV	13	3	16
Other*		17	11	28

***Other** includes newer generation chemistry such as Pirimor® and Chess®, as well as older chemistry such as Lannate®, Fastac® and Dimethoate®.

Older insecticide chemistry such as Lannate®, Fastac® and Dimethoate® were still popular choices amongst growers, even though they were also using the newer generation insecticides. At times some growers felt that the conditions did not suit the biological insecticides (Bts) or the Heliothis nuclear polyhedrosis virus (NPV) and resorted to the older insecticides that work.

Only 16 of the 79 growers surveyed did not use the newer generation insecticides. Interestingly one IPM grower did not use newer generation insecticides because he considered the biological insecticides offered poor efficacy. Other reasons for not using newer generation insecticides were some growers are organic growers and don't use chemicals, some did not spray again once Confidor® treated lettuce was planted.

The most common fungicides used were Ridomil®, Rovral®, Filan® and Dithane® (Table S1.2). Ridomil®, Rovral®, Filan® and Dithane® were used by 38%, 35%, 30% and 22% of growers, respectively. These fungicides primarily control sclerotinia and downy mildew, which are two of the major diseases that affect lettuce. Several other fungicides were used less frequently depending on the conditions present and the disease situation. Some hydroponic growers did not use fungicides because in their situation there were less disease problems.

Sclerotinia control in lettuce crops is important, otherwise substantial crop losses will occur. Four fungicides are currently available to control sclerotinia in lettuce crops and they are Rovral®, Filan®, Amistar® and Folicur®. Of these, Rovral® and Filan® are the most popular fungicides amongst the growers who were surveyed (Table S1.3). The number of applications of each fungicide depended on the presence and severity of disease. Most growers applied the fungicides between 1 and 3 times per crop, with Rovral® being applied at least 4 times in some situations. Some growers did not control sclerotinia because they considered it to be of minor importance. A few growers were disappointed that the new fungicides available did not seem to work as well as the older fungicide Sumisclex®.

Table S1.2. The most common fungicides used by lettuce growers.

Fungicide	Active Ingredient	IPM Growers	Non IPM Growers	Total Growers
Ridomil®	Mancozeb/Metalaxl-M	16	14	30
Rovral®	Iprodione	19	9	28
Filan®	Boscalid	17	7	24
Dithane®	Mancozeb	8	10	18
Polyram®	Metiram	9	8	17
Copper®	Copper Hydroxide	12	4	16
Acrobat®	Dimethomorph	6	6	12
Other*		43	22	65
N/A**		8	7	15

***Other** includes fungicides that are sprayed less frequently.
****N/A** those growers who do not use fungicides for various reasons.

Table S1.3. Fungicides used for the control of sclerotinia

Fungicide	Active Ingredient	IPM Growers	Applications per Crop	Non IPM Growers	Applications per Crop	Total Growers
Rovral®	Iprodione	19	1 to 3	9	1 to 4	28
Filan®	Boscalid	17	1 to 3	9	1 to 3	26
Amistar®	Azoxystrobin	4	1 to 2	3	1	7
Folicur®	Tebuconazole	3	1 to 2	2	1 to 2	5
N/A*		18		16		34

***N/A** those growers who have no need to control sclerotinia for various reasons.

Most growers used herbicides to control a wide range of weed species (both grasses and broadleaf weeds). Kerb® was by far the most popular herbicide with just over half of the growers choosing to use it for their weed management programs (Table S1.4). Most likely

Kerb® is the preferred option because it provides growers with the flexibility of either applying it as a pre – emergent herbicide on direct seeded lettuce crops or straight after lettuce has been transplanted. Kerb® also has the added advantage of offering broad spectrum weed control of grass and broadleaf weeds. Stomp® and RoundUp® (Glyphosate) were other popular herbicides that gave broad spectrum weed control.

Over half of the growers (49) used a conventional boom sprayer to apply their insecticides and fungicides (Table S1.5). Air assist sprayers were the second most popular method of applying insecticides and fungicides. Three IPM growers have modified their conventional boom sprayer and added short droppers to improve spray coverage. Water application spray rates varied considerably depending on the type of lettuce grower (field or hydroponic), the area of lettuce grown, the growth stage of the lettuce crop and the application method used. The water rates varied from 30L/ha up to 1000L/ha. The most commonly used rates were 400L/ha and 600L/ha.

Table S1.4. The most common herbicides used by lettuce growers.

Herbicide	Active Ingredient	IPM Growers	Non IPM Growers	Total Growers
Kerb®	Propyzamide	25	18	43
Stomp®	Pendimethalin	8	4	12
RoundUp®	Glyphosate	5	6	11
Other*		13	13	26
N/A**		13	7	20

***Other** herbicides that are used les frequently.
****N/A** either organic or hydroponic growers who do not use herbicides.

Almost the same number (31) of growers tank mixed their older generation insecticides and fungicides as didn't (21) tank mix them. There was a different trend for newer generation insecticides and fungicides with more growers (48) opting to tank mix, than not (20).

Table S1.5. The method lettuce growers used to apply insecticides and fungicides.

Application Method	IPM Growers	Non IPM Growers	Total Growers
Conventional boom sprayer	28	21	49
Air assist sprayer	10	5	15
CDA sprayer*	0	1	1
Boom sprayer with short droppers	3	0	3
Other**	7	4	11

***CDA sprayer** is a controlled droplet application sprayer.
****Other** is different application methods such as a knapsack sprayer and a hydrostatic sprayer.

Currant-lettuce Aphid

At the time of the survey Currant-lettuce aphid (CLA) was becoming established in lettuce growing areas throughout Australia and was a concern for all growers even where it had not been detected. Of the 79 growers surveyed 41 believed that CLA was established in their growing region, whilst 38 said that CLA was not present. From the survey CLA is present in all of the growing regions in Tasmania, the Sydney basin in NSW and the Werribee and Cranbourne (metropolitan) areas in Victoria. Growers indicated that CLA was not present in the Hay, Bathurst and Northern regions of NSW, country Victoria, Qld, SA and WA. In the areas where CLA was not present most growers correctly believed it was only a matter of time before it arrived.

Where CLA was established as a pest several control strategies had been implemented. Imidacloprid (Confidor®) as either a soil drench or seedling spray was the most nominated control method, with 93% of growers opting for it (Figure S1.5). *Nas*-resistant lettuce varieties were nominated by well over half (68%) of the growers. Native aphid predators and other chemical strategies (Pirimor®, Chess®, Pyrethrum® and Natra Soap®) had been tried by some growers. One organic grower believed that CLA was not a problem for him, so chose not to control it.

Figure S1.**5.** Control methods implemented by lettuce growers where CLA exists.

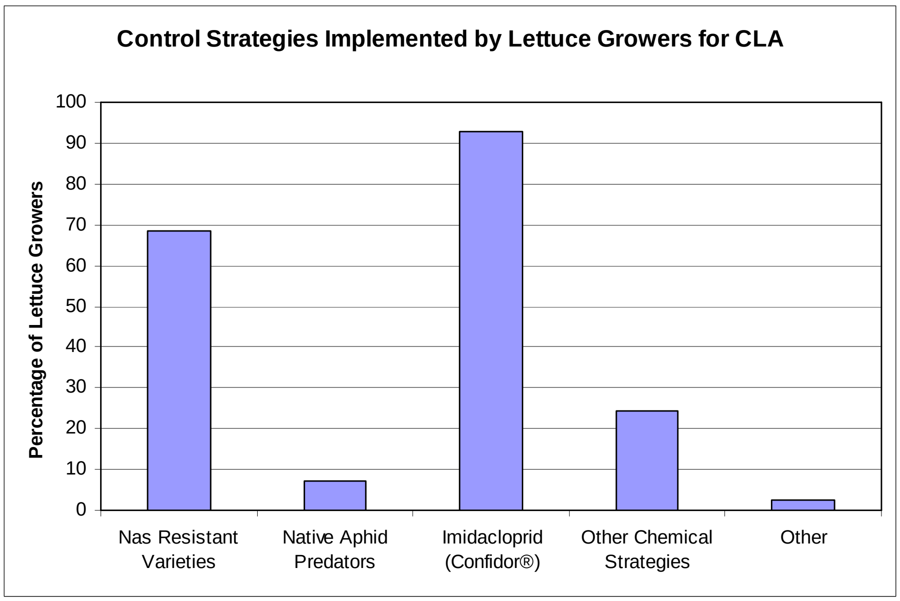
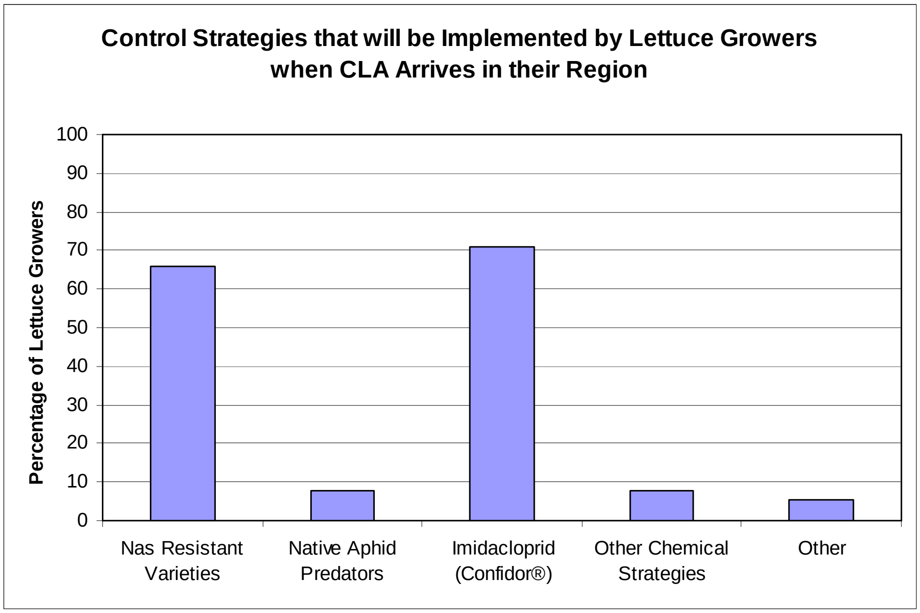


Figure S1.**6.** Control methods when CLA arrives.

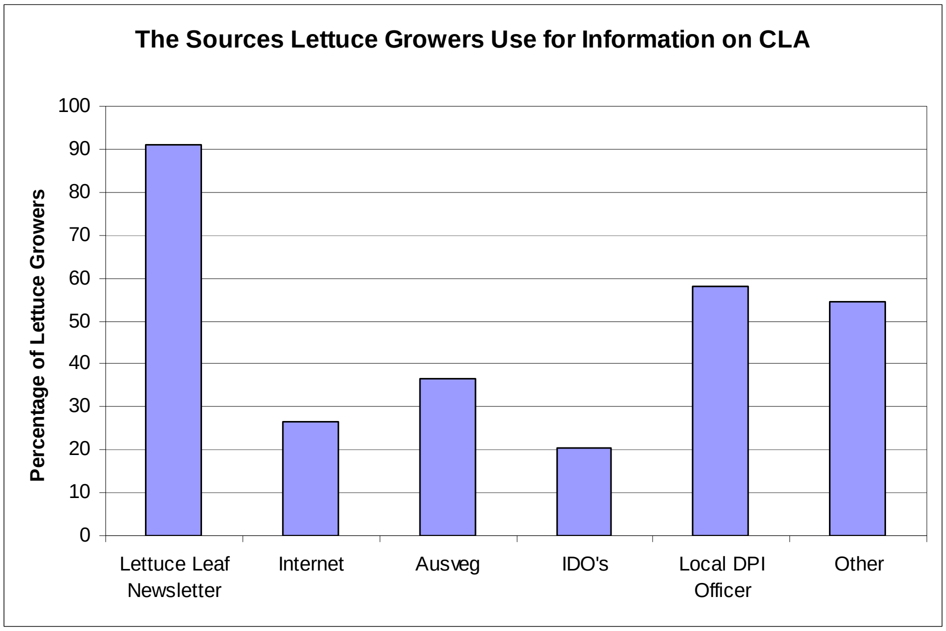


In the regions where CLA was not present most growers said they would either use imidacloprid (seedling spray or soil drench) or *Nas*-resistant varieties when it did arrive (Figure S1.6). These trends were similar to the regions where CLA was present.

The information available on CLA was rated very highly as 96% of the growers were happy with it. Growers commented that the information was generally excellent and they were well informed, particularly after the discovery of CLA in Tasmania. However, most growers thought the spread of CLA was inevitable and very hard to stop. Of the three growers that thought the information was lacking, one thought the problem was bigger in Victoria than had been documented, another thought the information could be better and the other wasn't sure why information was lacking.

Several sources were accessed for information on CLA and included the Lettuce Leaf Newsletter, Internet, Ausveg, Industry Development Officers (IDO's), and local DPI officers (Figure 7). The Lettuce Leaf Newsletter was used by 91% of the growers for their information on CLA. Local DPI officers were also popular sources of information with 58% of the growers choosing to use them. Other areas where growers sourced information were from seedling representatives, workshops and meetings on CLA, local agribusiness and chemical resellers, newsletters other than Lettuce Leaf, chemical companies, researchers, local vegetable markets and general discussions with growers and industry representatives.

Figure S1.7. The sources lettuce growers use to obtain information on CLA.



The Advantages and Disadvantages of IPM Strategies

The growers who adopted IPM as part of their insect pest management strategy experienced many benefits and usually indicated a number of benefits rather than one single benefit (Table S1.6). The main benefits were related to insecticides and their reduction in both use and costs. Growers also indicated that they had better pest control, a greater understanding of insect pests and had the ability to recognise beneficial insects more easily. Other benefits that growers mentioned included healthier beneficials and increased beneficial number, improved health and environment, cleaner and more acceptable product and timing of sprays to match heliothis egg hatch. Two non IPM growers who had in the past practised IPM also confirmed that the benefits for them were similar to the main benefits already mentioned.

Table S1.6. The benefits that growers have found by adopting IPM

Benefit	IPM Growers	Non IPM Growers*	Total Growers
Better pest control	25		25
Greater understanding of insect pests	22		22
Recognise beneficial insects	21	1	22
Reduced insecticide usage	29	1	30
Reduced costs of insecticides	25	1	26
Other**	20	1	21
N/A***		29	29

***Non IPM Growers** these were the benefits when growers used to practise IPM strategies
****Other** is the benefits to growers that were not listed
*****N/A** the non IPM growers

Growers were asked what they perceived to be the weaknesses of an IPM system to control insect pests of lettuce. They responded with the following:

- Consumer/retail acceptance of product, relating to "zero tolerance" of insect infestation including beneficials
- Cost
- A lack of confidence in IPM, especially when insect pest pressure is high. Growers are afraid that outbreaks may occur
- IPM appears not to work in arid environments (eg Bts break down easily and there is a lack of beneficial insects)
- Some growers are worried that the quality of the end product seems to be poorer
- Vigilance by whole farming area is required for IPM to work because if one grower does not practise IPM then the other growers will find it difficult to maintain IPM strategies
- CLA and Confidor® (more of a threat to IPM though)
- Rutherglen Bug is the hardest insect to manage using IPM, chemical strategies are still needed to control this pest
- At times information about the effects of chemicals on beneficial insects is lacking
- Sometimes you are limited to what control method is effective, especially if you are an organic grower
- Reliance on advise from crop consultants
- Isolation because the support and guidance is often not readily available
- Unforseen problems such as a new pest situation

The most common weakness or fear was the lack of confidence in IPM when the insect pest pressure is high. Growers can't afford insect outbreaks resulting in crop losses, as their established markets may be lost. Despite this, some growers thought there were no weaknesses with an IPM system and were pleased with the results.

Techniques and tools that lettuce growers would like to see developed to enhance a lettuce IPM strategy included:

- A fail proof IPM system
- Educational workshops to train and inform growers of IPM strategies, techniques available to use, chemicals that are compatible to an IPM situation and pest and predator identification tools
- Control options and research on CLA
- More work on the quality of *Nas*-resistant lettuce varieties
- Strategies for effective Rutherglen bug and thrips management
- Development of nurseries and research into crop rotations/alternate hosts to build up the beneficial insect population
- Biological insecticides that are effective in high UV and temperature regimes
- The hydroponics growers want research into disease resistant varieties, root systems, better organic products and application of biological agents through irrigation water
- Smaller growers would like better netting options as an IPM tool
- An update every year on newer generation chemicals
- A "Preventative Prediction Tool" based on climatic and growing factors to predict pest build up and time to control them

Growers indicated several threats to the ongoing success of lettuce IPM. Their greatest concern was beneficial insect contamination of lettuce, since growers cannot afford to loose established markets. The growers believed that the retailers and consumers had a lack of awareness of IPM and therefore needed to be educated about IPM. Many retailers and consumers have a "zero tolerance" policy regarding insect contamination and must accept that lettuces grown with an IPM strategy may have some insects present.

CLA was also an important threat to lettuce IPM identified by growers. The use of Confidor® and the likelihood of resistance concerned the growers. Work on developing new *Nas*-resistant lettuce varieties and other control strategies for CLA is important for the continuing success of lettuce IPM. Another concern was the state legislation concerning CLA, where at the time interstate trade restrictions prevented movement of *Nas*-susceptible lettuce grown using IPM.

Other factors that growers recognised as threats to the ongoing success of lettuce IPM were:

- The cost effectiveness of lettuce IPM and the fact that no premiums are paid for the extra effort of using IPM strategies
- Low beneficial insect populations and their survival
- Resistance to newer and older generation chemistries
- Use of older chemistries by neighbours
- Rutherglen bug and thrips management
- Compatibility of chemicals in an IPM situation
- New pest occurrences and how to control them
- Ignorance of IPM by the general public

Several local barriers identified by growers affecting the adoption of lettuce IPM were similar to the threats that were mentioned above. These included CLA and spraying Confidor®, the use of older chemistries by neighbours, beneficial insect contamination, cost effectiveness and price premiums and low beneficial insect populations. Growers also identified host weeds and other host crops of pests and their control options, local council legislation, cultural problems, high insect pest pressure due to neighbouring crops such as corn, the delay in death of insects when using newer chemistries and large scale (regionally based) implementation of IPM as local barriers affecting the adoption of IPM. Growers from the Hay region in NSW were concerned about biological insecticides not having the same efficacy as in other regions due to the hot and dry conditions. Some of these insecticides require humidity to work which is not a feature in Hay. Around the Gatton region in Qld, some processors were not accepting IPM grown lettuce due to potential insect contamination and had banned the use of the biological insecticide Bt on product grown for them. The reason for this ban is based on a belief that they are unable to differentiate between *Bacillus thuringiensis* (Bt insecticide) and *Bacillus antracis* (Anthrax) when routinely testing processed product as part of their internal quality assurance and food safety tesing.

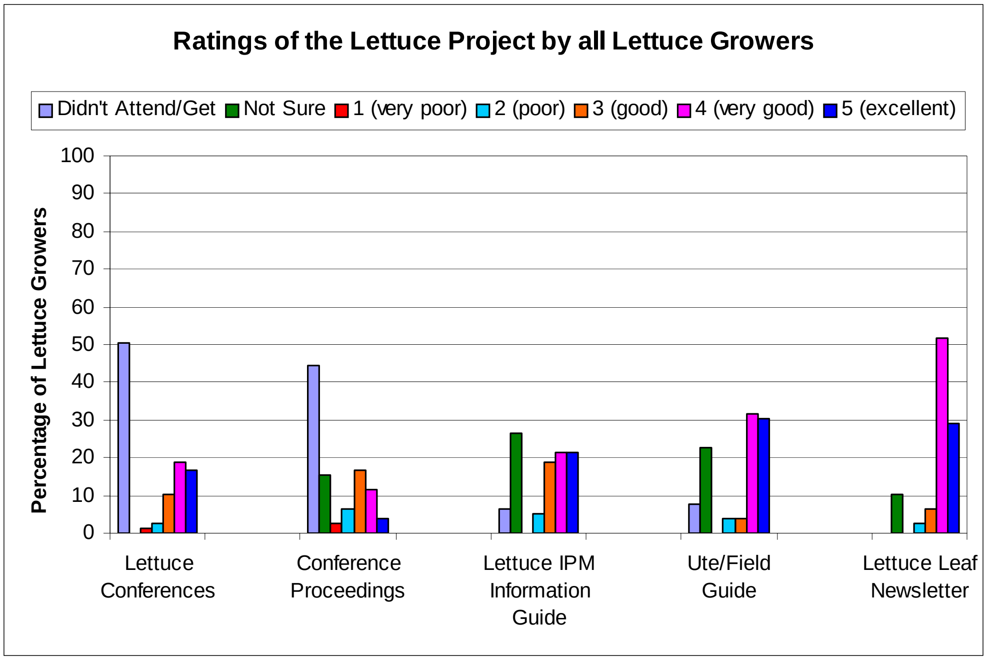
Usefulness of the Lettuce Project

Growers were asked to rate specific publications and the lettuce conferences to ascertain the usefulness of the lettuce project. The Lettuce Leaf Newsletter was rated very good to excellent by 81% of the growers surveyed (Figure S1.8). A lot of the growers mentioned that the newsletter is very interesting and has up to date information which keeps them informed of important issues relating to lettuce. The majority of growers also thought that the Ute/Field Guide was a valuable publication with 62% of the growers rating it as very good to excellent. The Ute/Field Guide assisted the growers with quick identification of important pests, diseases, disorders and beneficials. The Lettuce IPM Information Guide was rated slightly less than the Lettuce Leaf Newsletter and Ute/Field Guide, however 63% of growers still rated it a good to excellent publication.

The Lettuce Conferences were only attended by 49% of the growers surveyed (Figure S1.8). Some growers didn't attend because of the distance they had to travel, whilst hydroponic growers thought the conferences were more related to field based lettuce growers. However, of the growers that did attend the conferences, 92% felt they were good to excellent and were well organised. Generally most growers considered the conferences to be an opportunity to network with fellow growers and industry representatives. The rotation of lettuce conferences around the lettuce growing regions was thought to be a good idea. This would allow growers to experience the different regions and growing conditions that lettuces are subjected to in Australia.

The Lettuce Conference Proceedings was the publication that wasn't rated highly with only 57% of the growers that received the proceedings believing it was good to excellent. Generally growers thought the conference proceedings were too technical and they did not have the time to read them thoroughly. Being brief and less technical publications this may be the reason why the Lettuce Leaf Newsletter and Ute/Field Guide were rated so highly by growers.

Figure S1.8. Grower ratings for Specific Publications and the Lettuce Conferences



Growers were finally asked to make some general comments on the lettuce industry as a whole. The responses can be categorised by the following:

- Prices for lettuces fluctuate too much
- IPM is very useful, but more factual information needs to be forwarded to the growers through educational workshops/training days/seminars
- Initially it is difficult to convert to IPM however with the right guidance anything can be achieved
- Consumer and retailer awareness of IPM products is important
- Chemical misuse is still a problem within lettuce production
- Some growers are interested in organic programs
- There is a thought that too many little growers are in the lettuce industry making it difficult for the bigger growers and vice versa
- Value added lettuce products will be important in the future
- Salad fresh lettuce sales for restaurants have increased at the expense of iceberg lettuce
- The information on variety choices and most aspects of lettuce production is good

Generally most growers were of the opinion that the lettuce industry is heading in the right direction. Growers and nurseries appear to be working together for a better future and the contact between industry and researchers is improving.

Conclusion

This survey of Australian lettuce growers (predominately NSW and Victorian) has demonstrated that the growers are genuinely interested in alternative pest management strategies. More than 60% of growers considered themselves to be IPM growers and used a range of techniques as part of their pest management strategies for lettuce. Crop monitoring was the most popular technique followed by monitoring beneficial numbers and the use of biological insecticides. The non IPM growers (39%) believed they were managing their pest situations traditionally by spraying weekly with older and newer generation chemistries. Despite this, most non IPM growers are using some techniques that are considered to be IPM strategies such as crop monitoring, the use of yellow sticky traps, only spraying when necessary, chemical rotations and ploughing in crop residues.

Regular crop monitoring was a pest management strategy used by 91% of all growers surveyed. In total 74% of the growers monitored their own lettuce crops, whilst consultants and chemical resellers did 34% of the monitoring. Monitoring protocols and frequency varied greatly amongst the growers. This depended on whether they were IPM or non IPM growers and if the lettuces were grown in the field, hydroponically or organically. Those growers that did not monitor their crops relied on their experience, pest pressure at the time and moth activity at night to make their spray decisions. Most growers thought that crop monitoring was cost effective in reducing the number of chemicals sprayed.

The majority of growers have used newer generation insecticides, with Success® the most popular. However, older chemistries such as Lannate®, Fastac® and Dimethoate® were still sprayed because at times growers felt that the conditions suited them better. Dithane®, Filan®, Ridomil® and Rovral® were the fungicides of choice for growers to control downy mildew and sclerotinia. Kerb® was by far the most popular herbicide chosen by growers to manage both grass and broadleaf weeds. Growers' tank mixed both newer and older generation chemicals according to their compatibilities, which decreased costs somewhat.

Conventional boom sprays were used by 49 of the 79 growers surveyed to apply chemicals to their lettuce crops. Three IPM growers modified their conventional boom spray and added short droppers to improve spray coverage. Air assist sprayers were the second most popular method of applying chemicals. Water application rates ranged from 30L/ha up to 1000L/ha, depending on the lettuce growers' situation. However, the most commonly used rates were 400L/ha and 600L/ha.

CLA was the major insect pest concern to come out of the surveys. Most growers believed that CLA was the biggest pest threat to the ongoing success of lettuce IPM and were very happy with the available information on this pest. Confidor® and *Nas*-resistant lettuce varieties are the growers' choice for controlling CLA.

Several benefits of adopting IPM were identified by growers. The main benefit was related to insecticides and the reduction in use and cost. Better pest control, a greater understanding of insect pests and the ability to recognise beneficials were other important benefits. Along with the benefits, weaknesses were also identified with the most common being a lack of confidence in IPM when the pest pressure is high. Growers indicated that with educational workshops the fear of failure may not be as great.

Coupled with CLA being a threat to lettuce IPM is the use of Confidor® to control the aphids. Growers are worried about the implications of spraying Confidor® and resistance problems. As well as CLA being an ongoing threat to the success of lettuce IPM, Rutherglen bug and thrips were other major pest concerns. To enhance lettuce IPM the management of Rutherglen bug and thrips is considered to be important by the growers. This is especially the case when consumers and retailers have a "zero tolerance" for any sort of insect contamination (including beneficials) on product. Many growers cannot afford to lose markets through contamination and are therefore worried about the lack of awareness of retailers and consumers.

Local barriers limiting the adoption of IPM were very similar to the threats. More specifically, Hay lettuce growers were worried that the biological insecticides lacked efficacy in their region due to hot and dry conditions. These insecticides need humidity to work successfully which is not a feature in the Hay region. Around the Gatton region in Qld processors were not accepting IPM lettuces due to insect contamination and had banned the use of the insecticide Bt because of perceived health risks. Other regionally based barriers included high insect pressures from neighbouring crops through to local council legislation.

The growers who were surveyed had a very high opinion of the publications that have been a part of the lettuce project. The Lettuce Leaf Newsletter, Ute/Field Guide and Lettuce IPM Information Guide were all rated good to excellent publications. The bimonthly Lettuce Leaf Newsletter was very popular because it was brief and supplied relevant and interesting information. The Lettuce Conferences were also rated highly by those who attended. The conference proceedings were rated lower than other publications because the growers deemed them to be too technical. Overall it would appear that the lettuce project has proven to be very useful for the growers. Most think that the lettuce industry is heading in the right direction and continued contact between growers, researchers and industry representatives is essential for a sustainable future.

Acknowledgements

The author would like to thank the growers who willingly participated in this survey, without their support it would have been difficult to complete.

S2. IPM Consultants Survey 2006 Summary

Virginia Brunton, NSW DPI

Introduction

This survey was conducted as part of the Lettuce IPM project VG05044 and to complement work in the IPM Stocktake (VG05043). Information was sought on how to best deliver support to agricultural consultants that would enable them to support the development of integrated pest management (IPM) skills among their clients. A telephone survey of consultants for the vegetable and lettuce industries was conducted in July 2006. The purpose of the survey was to determine the level of knowledge of, and confidence in integrated pest management. The survey was modified from the key IPM informant survey used in IPM Stocktake.

A list of consultants was generated through the project's industry network and a total of 12 were interviewed. All those contacted were prepared to undertake the interview. Whilst the number interviewed is small it is virtually the entire population of agricultural consultants in this field. General understandings of the consultants' knowledge and confidence in IPM can be made, and serves as an indicator of the current skill level amongst consultants.

Results

The survey questions were designed to elicit information on the skills and confidence levels the consultants may have in the three main aspects of IPM support, that is: the ability to identify problems at hand, providing suitable recommendations and thirdly providing information about the use of biorational options.

The Agronomic services provided by consultants

The commercial consultants surveyed ranged from small single person operations to large corporations. They provide a wide variety of services to growers. These services include:

- Regular farm visits
- Crop protection services including: sap testing, crop monitoring, and water testing
- Full agronomic services including: crop nutrition, soil monitoring and testing, irrigation management, chemical advice, and crop scheduling
- Chemical sales and advice
- Biocontrol agent supply
- Research and trial work

The smaller consultants tended to provide more restricted or specialised services, or have a limited number of farms for which they provide services. Two consultants provided specialist biocontrol agent services only, whilst one consultant provided purely chemical control advice and services. The largest business services over 200 farms and the smallest services 8 farms. Crops included greenhouse and field crops, cucumbers, strawberries, lettuce, tomatoes, sweet corn, melons, brassicas, celery onions and processing lines including tomatoes, peas and carrots.

Main pest and disease issues

The consultants were asked to identify the main pest and disease issues and the issues or trends in crop protection they or the farmers see (not specifically on lettuce). These are listed in Table S2.1 in order of priority as determined by the frequency of mention.

Table S2. 1

Pest	Disease	Issues raised/perceived trends
		Lack of IPM understanding (growers)
Western Flower Thrips	Foliar fungal diseases	Lack of available chemistry
Aphids	Botrytis	Perceived lack of need for IPM
Nematodes	Sclerotinia	IPM takes time to catch on
Thrips and assoc viruses	Downey mildew	Trends towards use of softer chemicals BT, Pirimicarb, Chess
Heliothis	Leaf diseases	Lettuce Aphid – permits
Diamond back moths	White blister	Lack of resistant varieties
Cutworms	Soil borne fungi	Growers not confident to go non-chemical
Cabbage White Butterfly	Club root	Limited access to BT
Silver Leaf Whitefly	Powdery mildew	With emergence of LA and state trade regs, blanket spraying and overuse of Confidor® leading to decreases in beneficials to control heliothis & WFT. So these are re-emerging as serious pests whereas before under an IPM program they were under control.
Whitefly	Virus from White Fly	Poor prices
Green Peach Aphid	Sudden wilt	Market dominated by supermarkets
Mites		More beneficial controls
Lettuce root aphid		Need for bigger range of chemicals compatible with biocontrols
Tomato russet mite		

Confidence levels in IPM techniques

Consultants were asked to rate their confidence level in the delivery of particular services or providing certain advice. This was to ascertain the skill and capability of delivering IPM messages and services. Where skill or confidence levels are low this could indicate where training or support is needed.

The following graphs indicate how the consultants rated their own confidence levels in particular areas.

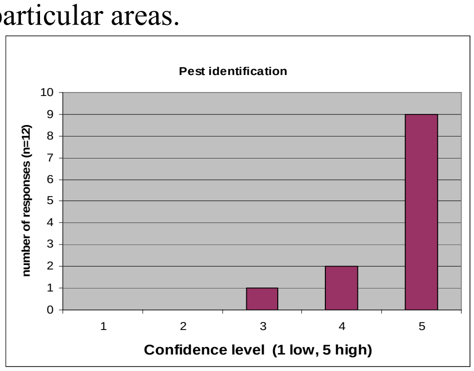


Figure S2.1

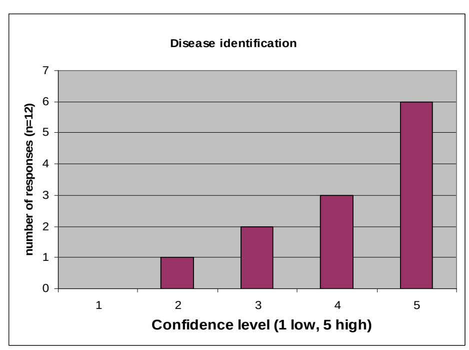


Figure S2.2

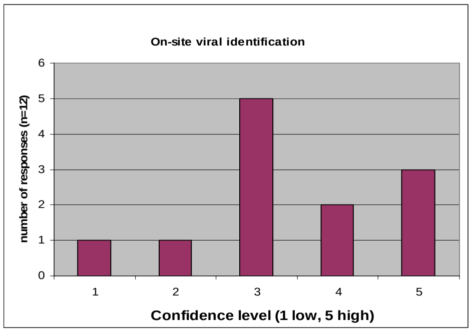


Figure S2.3

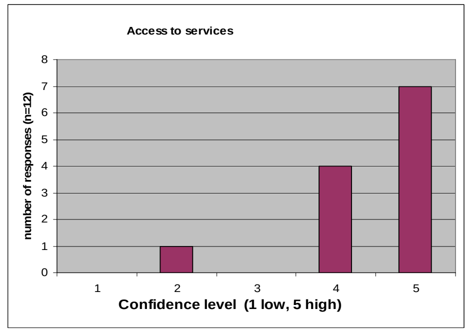


Figure S2.4

These results (Figures. S2. 1- 4) show that consultants are very confident in on-site pest and disease identification, perhaps a little weaker in disease and viral identification. The majority are very confident of having access to services to support positive identification. They also rate their skills in making recommendations and crop monitoring very highly (Figures S2.5 & S2.6). A high level of confidence in pest and disease identification is needed if a consultant is to gain and retain the respect and confidence of their clients. Clearly the consultants are well skilled in these areas. Viral disease recognition is difficult without laboratory testing and confirmation. The lower levels of confidence in viral disease recognition is understandable and is not necessarily a problem provided there is sufficient laboratory services available to assist diagnosis. The two respondents reporting lower levels of confidence also reported reduced access to laboratory services to assist identification. This indicates they are under-resourced in this area.

These consultants are very confident in providing sound recommendations to their clients. Figures S2.5-10 indicate high levels of confidence in their crop monitoring skills, designing scouting methods to suit a particular situation, providing control recommendations, assessing the efficacy of control measures, recommending when to opt for insecticide use rather than persisting with biocontrols and slightly less confidence in recommending thresholds or other decision making triggers. These are areas of strength. The consultant's reputations rely on having these skills. These skills would also support a broadened IPM consultant skills set.

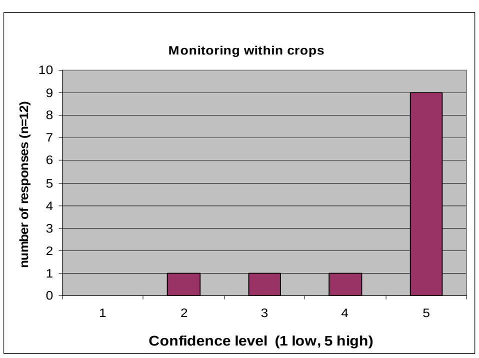


Figure 5

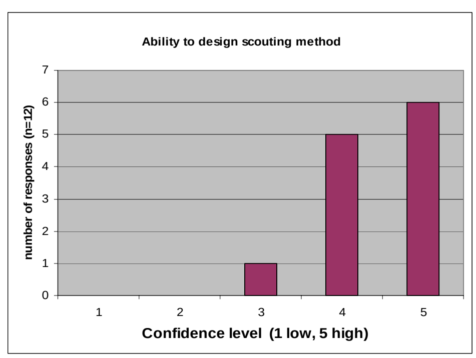


Figure 6

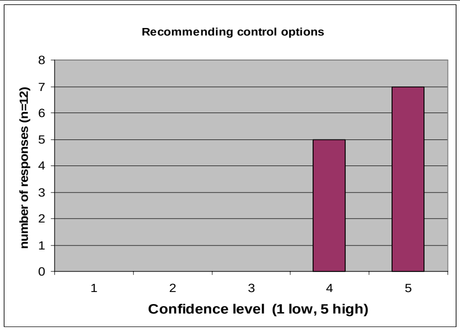


Figure S2. 7

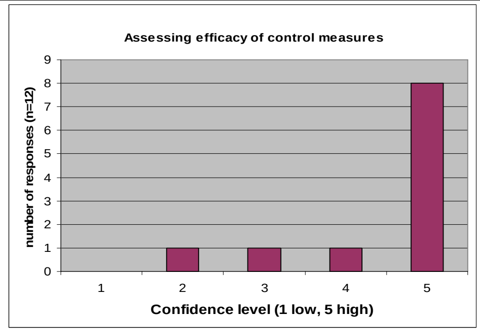


Figure S2.8

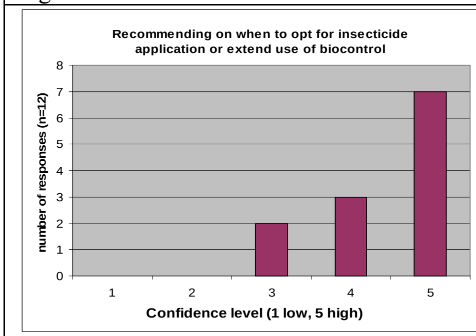


Figure S2. 9

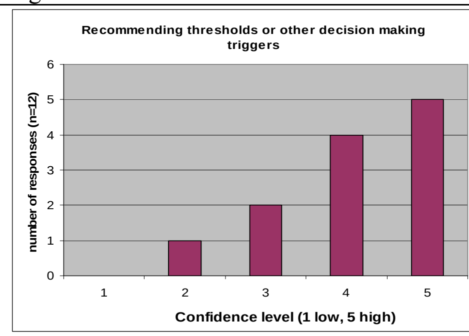


Figure S2.10

Areas in which the consultants report lower levels of confidence concern the use of biocontrol strategies (Figures S2.11-16). Consultants were less confident in providing advice on implementation of biocontrol strategies, conservation of natural enemies, selection of biocontrol agents for particular circumstances, effective release levels, timing of release of biocontrols or maintenance of biocontrols in crops. This indicates that knowledge of biocontrol strategies are an area of weakness for some of these consultants. These areas are the key technical details involved in IPM. Reduced confidence in these skills would result in fewer IPM recommendations being made and IPM strategies being developed.

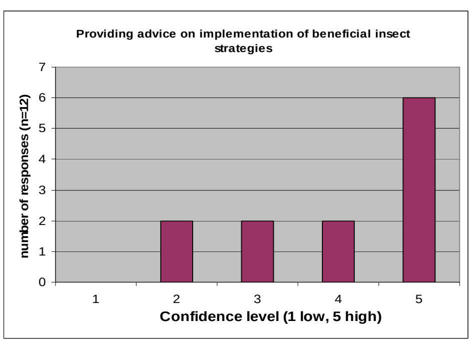


Figure S2.11

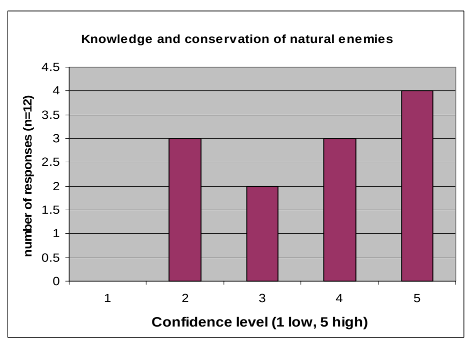
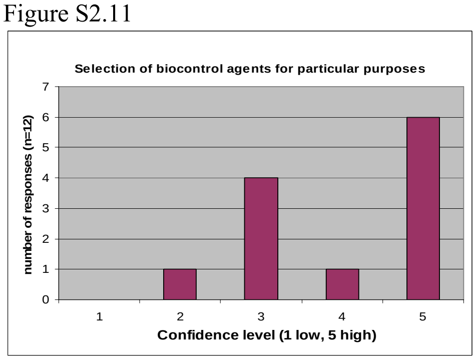


Figure S2.12



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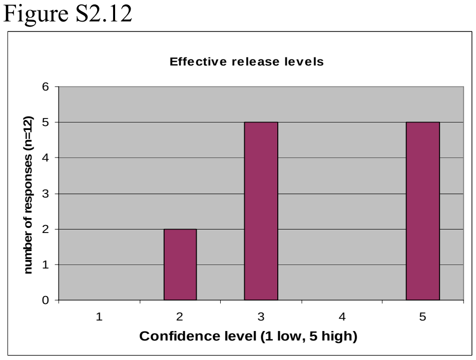


Figure S2. 14

Figure S2.15

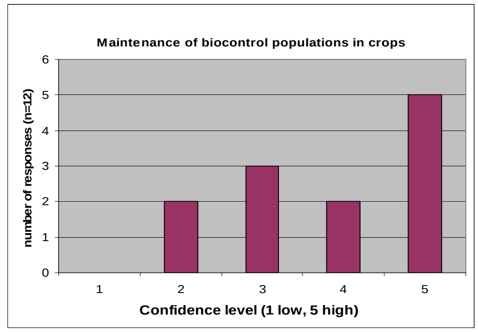


Figure S2.16

The lack of confidence in the consultants own skills is reflected in their comments about farmer confidence in IPM. Those consultants who reported lower self-confidence in IPM related skills also reported lower farmer confidence in IPM. The two biocontrol agent supply consultants and one other consultant were very positive in their perception of the grower's attitudes to IPM. This was reflected in their confidence in their own skills.

One area that would indicate a whole farm approach to pest and disease management would be farm planning. If a consultant's levels in this are were high, it is more likely that they would take a holistic approach to pest management. This is an important aspect of IPM as areas of neglect on a farm can lead to increased or unmanageable pest problems. Figure S2.17 indicates that confidence in this area could be improved.

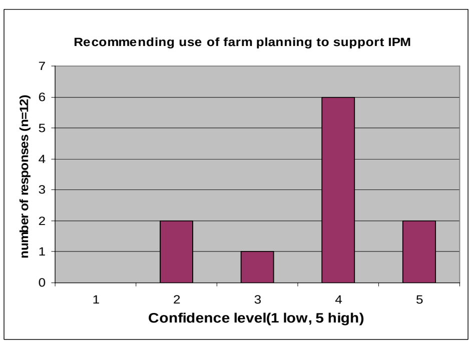


Figure S2.17

Factors assisting grower adoption of IPM

The consultants were asked to identify factors that helped promote or increase grower adoption of IPM. The responses are listed in Appendix S2.1. The factors as suggested by the consultants can be categorised as farmer education, technical issues and market issues. Generally the consultants thought that farmers needed more education and training on IPM. Showing the growers that IPM works through demonstrations on their farms or the farms of others was considered necessary to build their confidence in IPM. Having IPM explained, demonstrated and proved successful on their own farm leads to greater understanding and acceptance. The consultants also recognised that for some 'lazy' farmers IPM was never going to be an option. More information was needed about beneficials and the cost benefits of IPM.

The consultants identified technical issues that increased the adoption of IPM. In particular, the reduced availability of pesticides and the increased incidence of resistance or the threat of resistance were drivers in the adoption of IPM. Improvements in the availability of softer pesticides made the switch to IPM more likely. Other technical issues were the availability of biocontrol options.

It is somewhat difficult to separate the consultants own concerns from those voiced to them by the farmer. And to a large extent the consultants concerns regarding IPM (or perhaps biocontrol) are those of the farmer in any case.

There was a clear call for training on IPM for both growers and consultants. Information on foundations of IPM should be provided to growers so that the consultants did not have to sell the IPM concept as well as the actual mechanics of IPM. The consultants are also asking for training for themselves, recognising there are gaps in their skills and that they could provide enhanced services to their growers if they had more information.

Calls for technical support include: more information about softer or biorational pesticides and their interaction with beneficials, and back up support in identification and problem solving.

It was clear from some responses that there is a need for better communication between IPM specialists so that each are better informed. Consultants were suggesting that there were conflicting and competing messages being delivered on and about IPM and that better networking could improve confidence in IPM as a sound means of pest management.

Discussion

Consultants exhibited a considerable range of commitment to IPM; from committed IPM consultants and biocontrol developers to downright antagonists. The mid-range exhibited an understanding and acceptance of the principles, but were thwarted in developing their skills and IPM on-farm implementation, by lack of understanding and confidence in the farmers they supported. A consultant's lack of IPM confidence may be reflective of or be reflected by a farmer's lack of confidence. One delivers the other. So building the IPM confidence of the consultant is integral to developing IPM successes amongst farmers. A confident consultant can persuade a risk adverse grower provided he/she has sufficient knowledge to back up the confidence.

But a sense of risk taking is not the only barrier to IPM adoption. The consultants identified other barriers including supermarkets' demands for completely insect free produce. This demand causes 'day before spraying' and negates all the benefits of IPM in terms of reduced pesticide use and biocontrol. Consultants were suggesting that this generates a 'what's the point?' attitude amongst growers. Consultants identified a lack of understanding amongst buyers and consumers about IPM and that there are 'good bugs'. This intolerance of 'good bugs' means that growers are required to decontaminate all produce, destroying natural enemies in the field and applying unnecessary pesticides. Attention may need to be paid to the supermarket buyers and agents when developing an IPM strategy to support the IPM efforts the farmers are making.

Consultants suggested that there was also undermining of the IPM message by chemical company representatives. These organisations or individuals have a considerable amount to gain by touting IPM failures. That "failures get heard about quickly" suggests that 'good news IPM stories' are slower to travel.

However there was also an element of hope for the future of IPM; one consultant suggesting the "the new generation taking over has more interest in IPM". This suggests that growers may be increasingly more aware and accepting of IPM strategies and that targeting the new farmers with training and information may be a worthwhile strategy.

Conclusion

This survey of lettuce consultants has demonstrated that these particular consultants generally have a well developed skill set. They report high levels of confidence in providing advice on general agronomic and pest management practices, but lack confidence in providing advice on biocontrol strategies. They have a sound understanding of the concept and principles of IPM but lack detailed knowledge. They are clearly experts on pest and disease recognition and have good access to support services to back up diagnoses. They have high levels of confidence in crop monitoring.

In general the consultant suggest that farmer understanding and acceptance of IPM and the complexity of IPM limit the adoption and that proven on-farm successes and 'outside' influences (lack of available chemicals, resistance crises) improve adoption. Several options for improving support of IPM were identified by consultants. The main suggestion was education or training. Improving the knowledge and awareness of IPM amongst growers makes the job of the consultant easier. They can focus on the details of the IPM strategy with the grower rather than having to educate the grower on the IPM concept. The buyers and consumers also need further information about IPM and biocontrol. If there is a general understanding and acceptance of IPM amongst growers and their customers, adoption can be improved.

Consultants also identified their own training needs and made suggestions including (consultant only) workshops and resources that would assist them to improve IPM consultancy services they offered.

A general impression was gained from the survey that IPM messages are an important part of current and future consultancy services but consultants require greater surety about IPM implementation.

S3. Integrated Pest Management (IPM) Case Studies

Sandra McDougall, Adelle Dun NSW DPI

Aim

To understand in detail why some growers adopt IPM and others don't.

Method

Identify two regions where an IPM grower can be paired with a non IPM grower. The growers should be located in close proximity and have similar farms. Interviews were conducted following a structured set of questions, which varied slightly depending on whether an IPM grower or non-IPM grower (see Appendix S3.1). Details of a 'standard' crop were asked to construct a gross margin following the template of the *Farm Budget Handbook 2001 - NSW Vegetable Crops* (Faour *et al*. 2001). Any information that could not be had on the day of the interview was collected either via telephone or email. When the specific information could not be obtained then an 'assumption' was made, these were cleared with the relevant growers before being included.

Results

In Cranbourne, Victoria and in the Central West of NSW two IPM growers and one non-IPM grower in each area were interviewed. In August 2006 a NSW DPI extension officer, Tony Napier and a project officer, Kathryn Bechaz travelled to Cranbourne to interview the Victorian growers. In September they interviewed the Central West growers after a field day in Cowra. Prior to case study articles being published in the Lettuce Leaf newsletter the growers read and agreed to their publication. The specific details used to construct the gross margins for each grower has been kept confidential although some summary information has been included.

All the growers grew field head and/or cos lettuce for the domestic market (Table S3.1). Three of the IPM growers also sent lettuce for processing and two had small amounts that were exported (one fresh and one processed). Their vegetable production areas varied from 16ha through to 200ha with 2.4-58ha in lettuce. The largest grower was an IPM grower but the non-IPM growers were both larger than the remaining three IPM growers. The smallest grower grew for the organic market.

Table S3.1 Summary of Participating IPM and non IPM Growers

	Region	**Major** Minor Veg crops	Veg. Ha	Lettuce Ha	Lettuce Market			
					Processing	Fresh	Domestic	Export
IPM	NSW	**Lettuce, Brassicas,** Cauliflower, Rhubarb, Seedless Melons & Butternut Pumpkins	16	2.4		✓	✓	
IPM	NSW	**Sweet Corn, Broccoli, Cabbage, Lettuce, Radicchio**	120	12	✓	✓	✓	✓
IPM	Vic	**Celery, Iceberg & Cos Lettuce, Broccoli, Carrots, Asian Vegetables**	240	57.6	✓	✓	✓	
IPM	Vic	**Leeks, Parsnips, Baby Cos Lettuce, Baby Endive, Baby Wombok,** Radicchio, Trevisio, Kohl Rabi	124	5	✓	✓	✓	✓
nonIPM	NSW	**Lettuce, Cauliflowers, Watermelons,** Pumpkins, Sweet Corn	64	20		✓	✓	
nonIPM	Vic	**Celery, Broccoli, Parnips and Lettuce (iceberg & cos)**	200	32		✓	✓	

All the growers monitored their crops three of IPM and one of the non IPM growers had consultants regularly monitor their crops for them and provide crop protection advise. The consultant that the Victorian IPM growers used also provided information on using insectary crops to increase beneficial numbers and managing their whole farm to reduce pest pressure.

All the growers used the 'new generation' chemistry (5A, 6A, 9A, 11C & 22A) (Table S3.2). The Victorian growers all used pirimicarb a narrow spectrum Carbamate (1A), only one of the non IPM growers nominated using methomyl, a broad spectrum Carbamate, the NSW non IPM grower used dimethoate, a broad spectrum organo-phosphate(1B), both non-IPM growers used alpha-cypermethrin, a broadspectrum synthetic pyrethroid. One nonIPM growers nominated using imidacloprid in the initial interview but when specifying the pesticides used in an 'average crop' they did not include it. The organic grower was limited by the chemistry he could use and had only needed to use two insecticides.

Table S3.2 Summary Pesticide Used 2006 by interviewed growers

INSECTICIDES **Active – Name- chemical group**	**IPM Growers**				**Non IPM Growers**	
	NSW	NSW	VIC	VIC	NSW	VIC
Pirimicarb Pirimor® 1A			✓	(✓)		✓x2
Methomyl Lannate® 1A						✓x2
Dimethoate 1B					✓x2	✓x2
alpha-cypermethrin Fastac® 3A					✓	✓
Imidacloprid Confidor® 4A						(✓)
Spinosad Success® Entrust® 5A	✓	✓x2	✓		✓	✓x2
Emamectin benzoate Proclaim® 6A			✓		✓x2	✓
Pymetrozine Chess® 9A			✓	✓		✓x2
Bt Dipel® Xentari® 11C	✓		✓x4	✓x2		✓x4
Indoxacarb Avatar® 22A		✓	✓	(✓)	✓	✓x2
Heliothis npv Gemstar®		✓				
Hort Oil				✓x7		
FUNGICIDES						
Iprodione Rovral® B				✓		
Procymidone Sumislex® B		✓				
Metalaxyl Ridomil® D					✓x2	✓x2
Metalaxyl + mancozeb RidomilMZ® DY				✓x2		
Boscalid Filan® G			✓	(✓)		✓
Copper Y			✓			✓x2
Chlorothalonil Bravo® Y			✓			
Phos-acid Throwdown® Y				✓		
Propineb & oxadixyl Rebound® YD				(✓)		
Mancozeb Dithane® Y			✓		✓x2	✓x2
Dimethomorph Acrobat® X		✓		✓x2		
HERBICIDES						
Chlorthal Dacthal® D			✓			
Propachlor Ramrod® K						✓
Propyzamide Kerb® K		✓	✓	✓	✓	✓
Metham Metham Sodium®						✓

(✓) nominated using at times but not in an 'average' crop

The bulk of the Victorian lettuce production is over summer, whereas the NSW growers from the Central West grow for the 'shoulder season' i.e. spring and autumn harvests. All the growers nominated heliothis (*Helicoverpa spp.)* as their main pest and the two IPM growers in Victoria also nominated aphids (Table S3.3). Rutherglen bug (*Nysius vinitor)*(RGB) was nominated as a major pest for the non IPM and minor pest for the IPM growers in Victoria. All but one of the NSW growers nominated downey mildew as the major disease.

Table S3.3 Summary Major and Minor pests and diseases 2006 by interviewed growers

	IPM Growers				**Non IPM Growers**	
INSECTS & MITES	NSW	NSW	VIC	VIC	NSW	VIC
Heliothis *Helicoverpa spp.*	✓	✓	✓	✓	✓	✓
Aphids *Aphidae*	✓	✓			✓	
Aphids – CLA *Nasonovia ribisnigri*			✓	✓		
Aphids – BSA *Uroleucon sonchi*			✓			
Rutherglen bugs *Nysius vinitor*			✓	✓		✓
Thrips *Thripidae*		✓				
Leafhoppers *Cicadellidae*		✓				
Weevils *Curculionidae*			✓			
Leafminer *Agromizidae*				✓		
Earwigs *Dermptera*				✓		
Redlegged earth mites *Halotydeus destructor*				✓		
DISEASES						
Downey Mildew *Bremia lactucae*	✓		✓	✓	✓	✓
Sclerotinia *Sclerotinia minor* or *S.sclerotiorum*		✓	✓	✓		
Tip burn		✓	✓	✓		
Anthracnose *Microdochium panattonianum*			✓			✓
Varnish spot *Pseudomonas* spp.			✓		✓	
Rust				✓		

Weed species were virtually unique to each grower with the only overlap in nominations of their 'main' weed problems being nettles, capeweed and marshmallow weed for the two Victorian IPM growers. Species nominated included: winter grass (*Poa annua*), rye grass (*Lolium* spp.), barnyard grass (*Echinochloa* spp.), black oats (*Avena* spp.), Datura (*Datura* spp.), milk thistle (*Sonchus oleraceus*), amaranth (*Amaranthus spinosus*), pig face (*Carpobrotus glaucescens*), barnyard grass (*Echinochloa* spp.), groundsel (*Senecio* spp.), nettles (*Urtica* spp.), capeweed (*Arctotheca calendula*), wireweed (*Polygonum aviculare*) and marshmallow weed (*Malva parviflora*).

When asked why they adopted IPM three of IPM growers included a financial driver. Their answers included: "more profitable"; "save of cost and time"; "save costs, better heliothis control and easier system to manage" and "pest control crisis and health concerns".

When the non IPM growers were asked about IPM both said that they had adopted many strategies included in an IPM system but that they wanted or needed to include broad-spectrum insecticides. Both were happy with the strategy they have adopted and one responded with "why change" and the other said he had tried an IPM strategy but had crop failures when an infrequent pest devastated his crops. The growers were asked to define IPM and a summary of their answers is included in Table S3.4. The Victorian IPM growers took a more wholistic approach and included farm design and using non-crop plants as hosts for beneficials.

Table S3.4 Components of an IPM strategy

IPM Components	IPM Growers				Non IPM Growers	
	NSW	NSW	VIC	VIC	NSW	VIC
Monitoring	✓	✓	✓	✓	✓	✓
Timing sprays		✓	✓	✓	✓	✓
Soft chemistry	✓	✓	✓	✓	✓	✓
Biologicals	✓	✓	✓	✓	✓	✓
Farm design			✓	✓		
Nursery crops for beneficials			✓	✓		
Native plants for beneficials				✓		

The IPM growers were asked to nominate what were the key supports or drivers for them to adopt IPM. The only support all the IPM growers nominated as 'very important' or 'essential' for their IPM adoption was '1 on 1 technical support' (Table S3.5). All the other reasons varied with the individual growers.

Table S3.5 Ratings of Drivers or Supports for IPM Adoption

Driver or Support for IPM Adoption	Not important	Somewhat important	Important	Very important	Essential
1-on-1 technical support				✓	✓✓✓
IPM group support	✓		✓		✓
Industry culture			✓✓	✓	
Crisis (pest control failure)	✓			✓	✓
Environmental impact	✓✓				✓
Health impact	✓			✓✓	✓
Market push	✓		✓	✓	✓
Regulations	✓		✓	✓	✓
QA			✓✓	✓	✓

When asked what they thought were the 'barriers to IPM adoption' for non-IPM growers adopting an IPM strategy. The IPM growers all thought concerns of the control of 'secondary pests' was a very important barrier to adoption (Table S3.6). That was the main barrier for one of the non-IPM growers and that 'current control was adequate' was the main barrier for the other non-IPM grower.

Table S3.6 Ratings of Barriers to IPM Adoption

Barriers to adopt IPM	IPM Growers					Non IPM Growers				
	Not important	Somewhat important	Important	Very important	Essential	Not important	Somewhat important	Important	Very important	Essential
Current control adequate	✓			✓	✓	✓				✓
Cost of adoption too high	✓✓		✓	✓		✓✓				
No available consultants	✓✓		✓		✓	✓✓				
Consultants not supportive of IPM	✓		✓	✓		✓✓				
Too few 'soft' options available	✓	✓		✓✓		✓✓				
Availability of cleanup chemicals	✓✓			✓		✓				
Secondary pests				✓✓✓✓		✓				✓
Quality poorer	✓		✓	✓		✓			✓	
Market requirements	✓			✓		✓✓				
Too complicated	✓		✓		✓✓	✓✓				
Too risky	✓			✓	✓✓	✓✓				
No (perceived) advantage			✓	✓		✓✓				

The IPM growers were asked how IPM adoption and changed some aspects of their farm management (Table S3.7). They either nominated they reduced the number of sprays they applied or that it didn't change. They all increased their usage of 'soft or biological' sprays and reduced usage of 'broad spectrum' sprays. The nonIPM growers were asked whether they thought IPM would increase or decrease costs, as well as yield, quality, OH& S or residue risks (Table S3.7).

Table S3.7 When compared to a conventional pest management strategy IPM adoption leads to an increase/decrease or equivalent

IPM adoption leads to:	IPM Growers			Non IPM Growers		
	↑	↓	=	↑	↓	=
Number of sprays		✓✓	✓✓	-	-	-
Types sprays soft or biologicals	✓✓✓✓			-	-	-
Broad spectrum chemicals		✓✓✓✓		-	-	-
Chemical costs	✓	✓✓✓		✓	✓	
Diesel costs		✓	✓✓✓		✓✓	
Labour costs	✓		✓✓✓			✓✓
Marketable yield	✓H ✓	✓	✓			✓✓
Quality	✓	✓✓	✓	✓		✓
OH&S risk		✓✓✓✓			✓✓	
Residues		✓✓✓✓			✓✓	
Insects	✓	✓✓	✓	-	-	-
Diseases	✓	✓	✓✓	-	-	-
Damage predictability	✓✓✓	✓		-	-	-
Saleability	✓✓		✓✓	-	-	-
Crop rejections at market		✓H	✓✓✓	-	-	-

H = when Heliothis pressure is high

The non-IPM growers expected adopting IPM would reduce diesel cost but increase labour costs. Three of the IPM growers thought diesel and labour costs were no different but that chemical costs had gone down. In each case one of the IPM growers thought costs had changed. There was not agreement with the IPM growers about changes in marketable yield or product quality although three of the growers did say that they probably have increased in-field rejections although not market rejections. There was broad agreement that IPM reduced OH&S and residue risks. Again there was not much agreement about whether insect and disease levels increased or decreased but three of the IPM growers felt it increased the damage predictability. The fourth thought hotspots within the crops meant that damage predictability had gone down slightly. For two IPM growers adopting IPM has meant their crops are more saleable but the other two didn't think it had changed. Crop rejections at market had stayed the same or in one case when heliothis pressue is high they felt the IPM strategy resulted in fewer market rejections.

The growers were all asked to rate the relative importance of a range of IPM tools (Table S3.8). Opinions were variable, however most (5/6) agreed experimentally derived thresholds were not important but that new chemistry, biologicals, *Nas* and downey mildew resistant varieties were very important to essential. Other resistant varieties were not rated important.

Table S3.8 Ratings of the relative importance of various IPM tools

Tool	Not important	Somewhat important	Important	Very important	Essential
Best bet thresholds	✓		✓✓	✓✓✓	
Experimentally derived thresholds	✓✓✓✓✓			✓	
New chemistry e.g Success, Avatar,				✓✓✓	✓✓✓
Biological insecticides e.g. virus, Bts				✓✓	✓✓✓✓
Crop scouting protocol	✓✓			✓✓	✓✓
Resistant Varieties Nas				✓✓✓	✓✓✓
Downy				✓✓	✓✓✓✓
Corky root	✓✓✓✓		✓		✓
Black root rot	✓✓✓✓		✓		
Bigvein	✓✓✓	✓	✓✓		
Endemic beneficials Nabids (Damsel bugs)	✓✓✓✓	✓		✓	
Ladybirds			✓	✓	✓✓✓✓
Lacewing			✓	✓	✓✓✓✓
Hover flies	✓✓			✓✓	✓✓
Parasitic wasps	✓		✓	✓✓	✓✓
Cultural controls Rouging diseased crops		✓✓✓	✓	✓	✓
Weed management within crop			✓	✓✓	✓✓✓
Weed management around crop				✓✓✓✓	✓✓
Planting time	✓		✓		
Nutritional management			✓✓	✓✓✓	✓
Water management			✓✓	✓✓✓	✓
Post harvest cultivation	✓		✓✓✓	✓✓	
Crop rotation			✓	✓✓✓	✓✓
Cover crops	✓		✓✓	✓✓	✓

Ladybeetles and lacewings were rated very important to essential but the other beneficials were not rated quite so consistently high. Weed management in and around crops were cultural controls considered important but rouging was 'somewhat important'. The other cultural controls were important to essential for most growers. There was no discernable difference between what the practicing IPM and non IPM growers responded.

Gross margins were constructed and were very variable in all facets of crop production (Table S3.9). Planting density varied between 30,000 to 84,000 plants/ha, tractor costs at 2006 diesel prices were not very expensive but were nevertheless variable ranging from $54-$257/ha. Irrigation cost similarly varied from $75 -$355/ha. Fertilizer costs varied from $0 (carry-over from other crops) to $6,951/ha (includes $3,450 in gypsum). Insecticide costs including crop monitoring costs varied from $217-$1,368/ha; fungicides from $0-$1,686 (includes fumigation); and herbicides varied from $0-$1,263/ha. Harvest costs were the single largest variable cost in producing lettuce and included pickers, cartons, and cooling. They varied from $12,521-$30,945/ha of lettuce. The main variable in the harvest cost was the grower estimate of time to harvest a hectare of lettuce with estimates ranging from 10-62 hours. Freight varied between growers ranging from $1,992-$7,651/ha of lettuce. The total variable costs varied from $18,130 to $46,946. The gross margin is based on a price of $15/carton for the organic lettuce ('low' lettuce price average for 2006) and $8.90/carton (average of the 'low' lettuce price in the Sydney and Melbourne markets for 2006) for the non-organic lettuce.

Table S3.9 Summary of farm gross margins

	IPM Growers				Non IPM Growers	
	NSW*	NSW	VIC	VIC	NSW	VIC
Planting density plants/ha	30000	60000	58800	84000	60000	48600
Yield boxes/ha	1875	4500	4165	5950	4500	3645
Tractor $/ha	183	168	172	54	207	257
Irrigation $/ha	355	161	202	75	172	255
Fertilizer $/ha	265	251	346		808	6,951
Insecticides $/ha	217	844	1,064	404	476	1,368
Fungicides $/ha		132	185	337	230	1,686
Herbicides $/ha		355	1,263	18	188	369
Harvest $/ha	13,518	21,470	20,521	30,945	23,589	12,521
Freight $/ha	1,992	4,781	7,651	3,719	4,219	2,170
Total variable $/ha	18,130	31,159	34,050	46,946	37,207	28,493
Gross margin $/ha	9,995*	8,891	3,019	6,009	2,843	3,948

* organic lettuce

Discussion

Most Australian lettuce growers have adopted some IPM management practices for dealing with their pests and diseases but adoption of biologically based IPM systems for lettuce production has been slow. To assist in understanding more about why some growers adopt the biologically based IPM strategy and some don't a series of case studies were undertaken. These case studies have gone into more detail than previous lettuce grower surveys. Given financial drivers are strong drivers we wanted to see whether a gross margin would highlight financial drivers or barriers for IPM adoption.

There are not many lettuce growers that manage their pests that are on the biological intensive end of the IPM spectrum so we were limited with where we could sample. Two regions, Cranbourne and Central Western NSW were selected and four IPM growers and two conventional growers were interviewed. The growers were asked about their general production methods as well as their opinions and beliefs about using a biologically based IPM strategy.

The sample size is very small and is therefore not necessarily representative of all ‘non IPM’ or all ‘IPM’ growers. We see from these growers huge variability in what they do in the aspects of their farm management we collected information on, as well as their perspectives on IPM. The average ‘non IPM’ grower in 1998 was unlikely to have monitored their lettuce, nor had the option for soft chemistries or biologicals. Choices available to growers are changing frequently with new registrations and permits, old chemistries being withdrawn or use restricted, new varieties and new pest and disease problems.

As would be expected many aspects of the production systems were similar and all made pest management decisions based on crop monitoring. We would expect growers in a particular region would have similar pests. All the growers nominated heliothis and aphids as their major lettuce pests and downy mildew as the major disease. All the growers primarily relied on Kerb® for weed management and used some of the new softer or biological insecticides. All the growers defined IPM as including crop monitoring, soft chemistry, spray timing and biologicals.

The major differences were that the non-IPM growers also used broader spectrum chemistries i.e. Lannate® (methomyl), Fastac® (alpha-cypermethrin), and Dimethoate® (dimethoate) for pest management which would knockout their beneficial insect populations from the crop as well. An IPM strategy tries to conserve their pest’s natural enemies or ‘beneficials’.

The biggest differences in pesticides use was between the regions with the ‘average’ crop in Cranbourne having almost twice as many sprays (both insecticides and fungicides) as the average Central Western crop which presumably relates to higher pest pressure in summer. Rutherglen bugs were named as a major or minor pest by all the Victorian growers but not the NSW growers. IPM growers in each area applied half the number of sprays to the non-IPM grower in each area however we are comparing a single non-IPM grower to two IPM growers so they may not be representative of other nonIPM or IPM growers. The Cranbourne non-IPM grower used a greater range and number of fungicide applications than the other growers and one of the IPM growers in the Central West is certified organic so relies on using downy mildew resistant varieties rather than using fungicides. This grower also plants at almost half the density (30,000 plants/ha) of the other growers which may allow for better airflow and reduce disease transmission. This grower would not be profitable if he had to sell at the non-organic prices but with the 100% premium it makes his lettuce the most profitable per hectare based on the information we had from their ‘average’ crop in 2006.

Perhaps the biggest surprise was the variability that was illustrated by the construction of gross margins, in all aspects there are large differences from the number of tractor passes, levels of fertilizer added, quantities of pesticides, estimates of labour hours for harvest, to transport costs. This may reflect what the growers have in their mind as an ‘average’ crop. Ideally we would have actual data for all plantings over a number of years. This may also suggest that growers could learn a lot from benchmarking type studies such as has been done with rice crops and the NSW DPI ‘Rice-Check’ program.

Acknowledgements

Thankyou to the collaborating growers, and to Tony Napier and Kathryn Bechaz for conducting the interviews. Adelle Dunn summarized the growers comments and followed up the information for the gross margins.

Industry Communication

A significant component of this project is directed at industry communication. Lettuce growers and allied industry people have had 10 issues of the Lettuce leaf newsletter, had two presentations at the national vegetable conference, 16 information days/nights, 4 field days, and electronic reports/fact sheets/video available via the web.

Lettuce Leaf Newsletter (Issues 22-32)

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 months lettuce researchers, the Vegetable Industry Development Officers (VIDOs) for each state 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. For states other than NSW the VIDO network is used. Electronic versions are e-mailed to interested parties and are available from both the NSW DPI and AUSVEG websites.

1st Lettuce Leaf newsletter (issue 22) – Summary of VG01028 and introduction to VG05044.

Victorian special edition of the lettuce leaf was distributed in January after one of the IPM growers lost a planting due to varnish spot and rumours were circulating that it was due to CLA

2nd Lettuce leaf newsletter (issue 23) CLA in NSW, Vic IPM update, Nas lettuce trials Hay, Tas IPM update, APVMA permit updates for lettuce

3rd Lettuce Leaf newsletter (issue 24): Tas IPM trials, Soil mites, CLA into SA, Gaucho trial results, Foxglove aphid

4th Lettuce leaf newsletter (issue 25) Lettuce IPM project summary 05/06 season, Lettuce pest and disease posters, Part 1 Effect of growing conditions on yield and shelf-life

5th Lettuce Leaf newsletter (issue 26): State roundups, Sydney basin IPM, Downey Mildew, Crop management for shelf-life training project reports to download

6th Lettuce Leaf newsletter (issue 27): Methomyl gone, NZ, Vic, Qld, NSW & WA roundup, WA CLA resistant variety trials, Part 2 Effect of growing conditions on yield and shelf-life, Using Confidor

7th Lettuce leaf newsletter (issue 28) Biological Control using Mites, Methomyl on Field-Grown Lettuce, 2,4-D Herbicide Periodic Ban, State Roundups, Reducing the Disease & Insect Load, and Applied Horticultural Research Training Days

8th Lettuce Leaf newsletter (issue 29): Revegetation by Design, Student Projects, New Permit, IPM Case Studies Cranbourne

9th Lettuce leaf newsletter (issue 30 – 4 pages) AHR training days, CLA strain breaks nas resistance, State Roundups, Freshwise DVD, WFT management, New projects, Pest Management in Central west, IPM vs non IPM Opinions & beliefs.

10th Lettuce Leaf newsletter (issue 31): special issue on managing root diseases in hydroponic lettuce

11th Lettuce Leaf newsletter (issue 32): State roundups, pesticide residues in hydro lettuce, host suitability for CLA, potential beneficial nursuries,, VG05044 lettuce IPM

Grower information sessions

This project team were the principal organisers of meetings of lettuce growers when CLA was first detected in the area, to give further information to growers and industry about the situation and management options. The meetings, particularly with the initial CLA incursion were well attended (Table 1). Meetings that were not tied in with a perceived crisis were not so well attended.

Table 1. Lettuce IPM Project Meetings/Workshops

Date	Location	Topic	Attendance*
Feb 2006	Penrith, NSW	CLA arrival & management	~80
April 2006	Gosford, NSW	IPM & CLA management for consultants	12
April 2006	Hay, NSW	CLA arrival & management	5
May 2006	Hay, NSW	CLA arrival & management	5
May 2006	Werribee, VIC	CLA	10
May 2006	Virginia, SA	CLA arrival & management	20
June 2006	Richmond, NSW	Hydro lettuce IPM	70+
Nov 2006	Applethorpe, QLD	CLA	~12
Dec 2006	Waneroo, WA	CLA arrival & management	50+
Feb 2007	Richmond, NSW	Hydro – WFT & TSWV	~50
June 2007	Virginia, SA	Project report & consult	4
Nov 2007	Richmond, NSW	Lettuce IPM symposium & workshop	~50
Apr 2008	Virginia, SA	Project report & consult	10
Apr 2008	Wanneroo, WA	Project report & consult	12
Apr 2008	Gatton, QLD	SLW, Project report & consult	~50 (~5 lettuce growers & 2 consultants)
Apr 2008	Richmond, NSW	Project report & consult	4

*including growers, consultants and industry people but not including presenters or organisers

Project reports were also made at the two Australian Vegetable Industry Conferences in Brisbane (2006) and Sydney (2007) by the project leader.

In November 2007 a full day of lettuce crop protection/IPM related activities was held in Richmond. The morning had a series of talks from NSW DPI staff working on lettuce including: Len Tesoriero (VG04012 *Effective management of root diseases in hydroponic lettuce* and the NSW DPI funded *Cleanfresh* project) , Leigh Pilkington (VG03098 *Regional extension strategy for managing western flower thrips and tomato spotted wilt virus in the Sydney Region* and VG0593 *IPM for greenhouse vegetables-research to industry)*, Grant Herron (VG06010 *The sustainable use of pesticides (especially spinosad) against WFT in vegetables)* as well as Sandra McDougall and Tanya Shaw from this project. The afternoon had a series of hands-on workshop activities covering some IPM basics including what is IPM (Leanne Forsyth and Silvia Jelinek), insecticide resistance (Grant Herron, Tanya Shaw and Jeremy Badgery Parker), lettuce diseases (Len Tesoriero), lettuce aphid quiz (Sandra McDougall), WFT & weeds (Leigh Pilkington and Virginia Brunton). The growers rated the afternoon session (4.5/5) more highly than the morning session (3.8/5)]. Whereas "industry" people preferred the morning session (3.9/5) compared to the afternoon session (3.6/5).

Field days

Field days associated with IPM demonstrations were intended to be a key extension tool for this project after their success in raising awareness of the potential of an IPM strategy relying on beneficials for managing CLA in VG04067, a one year project funded after CLA was found in Tasmania. Given the Tasmanian growers had followed a series of IPM managed lettuce plantings the initial focus was to be in Victoria, the only mainland state where CLA was found. Victoria also had a number of IPM lettuce growers, most of whom were using IPM Technologies, a project collaborator to monitor their crops and provide IPM advice. After the arrival of CLA three of these IPM growers decided not to use imidacloprid treated seedlings. On two farms additional data was collected to demonstrate the effectiveness of an IPM strategy for managing CLA but neither were keen for other growers to visit their farms hence field days were not possible. A third IPM farm was happy for a field day and in February 2006 one was organised by Paul Horne and Jessica Page from IPM Technologies. The field day was held at a time when CLA was present in Victoria but not other mainland states and the interstate trading restrictions for lettuce were stipulating that lettuce had to either be Nas resistant varieties or have been grown from imidacloprid treated seedlings. Growers with Nas susceptible lettuce and managing CLA populations via beneficial insects and foliar sprays were unable to sell their lettuce interstate. And given most of the summer lettuce consumed in Australia is grown in Victoria these trade barriers were forcing the larger IPM growers to use imidacloprid hence abandon their IPM management strategy. Regulatory officers were invited from each state but only Victorian regulatory officers attended the field day. Brad Wells from HAL and the lettuce project leader, Sandra McDougall NSW DPI, a local agronomist, three local growers, and the Victorian VIDO Patrick Ulloa attended. The growers, Peter Schreurs and Sons, and Paul Horne spoke about managing CLA through the previous spring and summer season. Patrick Ulloa made a video from the event and it was distributed to state Regulatory officers, VIDOs and the lettuce project team. It is also available via the web.

An article in Good Fruit & Vegetables was subsequently produced.

Three field days for growers and consultants were held at the IPM trial/demonstration at Eddie Galea's in Sydney. They were held on the 12th and 26th October and 9th November 2006. The first field day 8 local growers, 3 agronomists, the NSW VIDO and DPI staff along with Paul Horne and the grower Eddie Galea gathered to inspect CLA infested lettuce and the beneficials feeding on them. Those present also heard about the difficulties that Eddie and his crop consultant, Andy Ryland had been having managing CLA over the winter months without many beneficial insects to assist. The second and third field days attracted 6-8 growers, although not the same growers, so didn't have quite the impact anticipated. To see a young lettuce crop that is heavily infested with CLA, observe a few beneficials that multiply and then to see a mature crop with hardly a CLA or beneficial to be found is very dramatic.

Other resources

Other resources that have been produced by the project include:

1. two regionally specific editions of the Lettuce Leaf newsletter.
2. Nas resistant varieties handout
3. IPM Lettuce update CDrom and followup video clip available via the web
4. draft CLA host poster
5. project reports

In November 2005 rumours were circulating the Victorian lettuce production areas that one of the IPM growers had had to plough in lettuce because of CLA infestation. In one instance a Nas resistant head lettuce variety did not meet market specifications and in two other instances plantings had varnish spot. Varnish spot is a bacterial disease that causes brown lesions around the midrib on lettuce leaves quite commonly under outside leaves which show no symptoms. Varnish spot of lettuce is caused by *Pseudomonas cichorii*. It appears that varnish spot can affect lettuce sporadically or totally wipe out a planting. How the disease is spread and can affect whole plantings but not neighbouring plantings is not well understood (Watson 2005). An update on the Victorian IPM growers was produced and distributed to Victorian lettuce growers – a truncated version was also included in the Lettuce leaf newsletter No. 23 in March 2006.

After CLA was detected in Hay in November 2007 a special edition was compiled on request from the growers of their management options.

Given the importance and desirability of having *Nas* resistant varieties a handout has been produced and updated each year on what varieties are available, In the last 2 editions downey mildew resistance status has also been included. The handout has been available at meetings and via the web. The most recent version was updated and distributed in Feb 2008.

In April 2006 Paul Horne and Jessica Page organised a field day at Peter Schreurs and Sons farm in Cranbourne. The Schreurs were one of the IPM farms that Paul and Jessica monitored and one which the growers were happy for other growers to visit.

Patrick Ulloa, the then Victorian Vegetable Industry Development Officer (IDO) produced a video from talks and interviews at the field day, he then produced a CD rom that was distributed to the invited regulatory officers, other state IDOs and the project team. In April 2008 the new IDO, Craig Murdoch was requested to make a followup video with Peter and Darren Schreurs and Paul Horne to talk about lettuce IPM and managing CLA 2 years on. Both videos was uploaded to YouTube and can be found from the web:

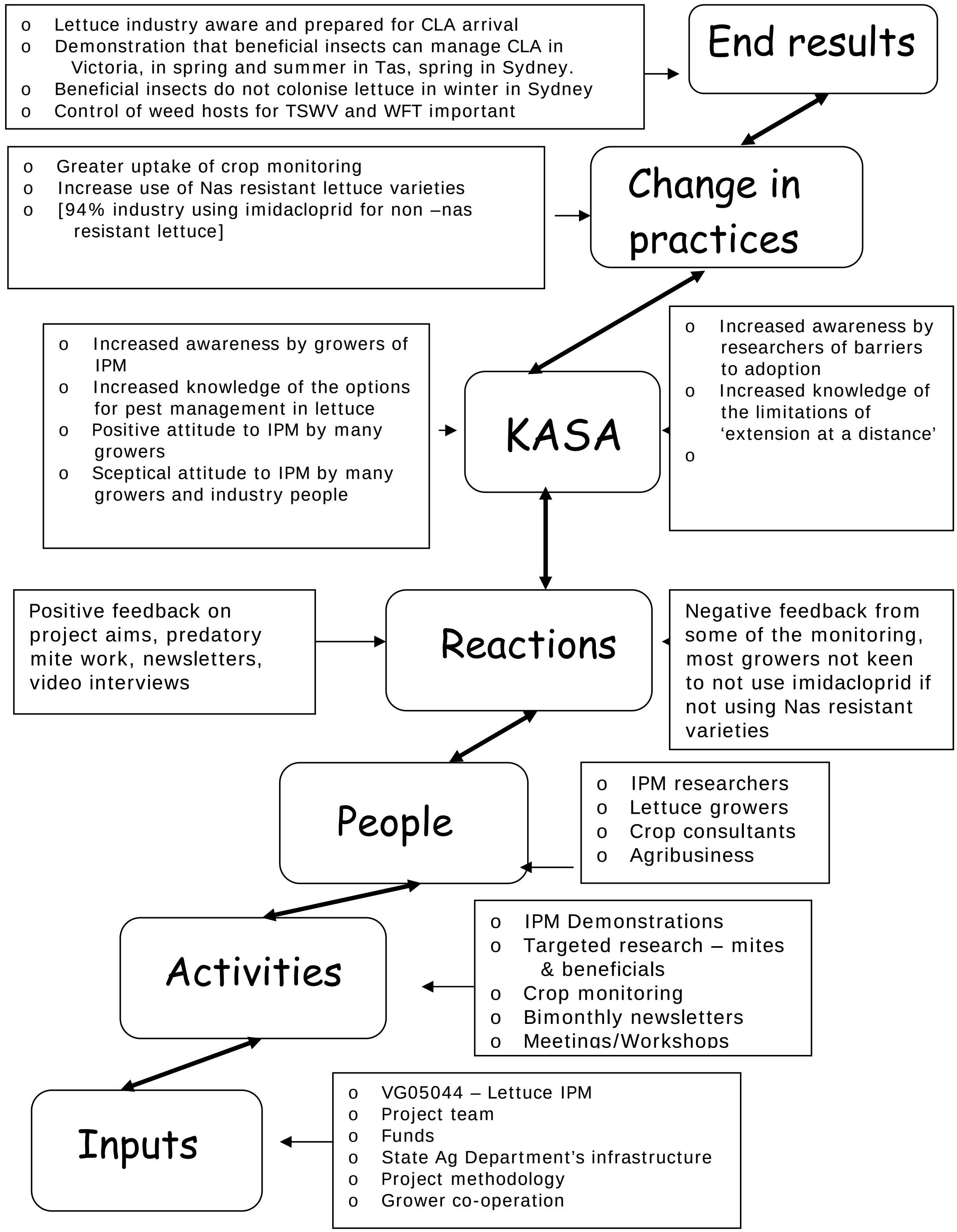
http://www.youtube.com/watch?v=ovg0in86kXU (Feb 2006 Part 1)
http://www.youtube.com/watch?v=tMnaPd_ccUQ (Feb 2006 Part 2)
http://www.youtube.com/watch?v=hzIP6hkwLP0 (Feb 2006 Part 3)
http://www.youtube.com/watch?v=TKO_lfj0ork (Apr 2008)

or searching google video or YouTube for “Lettuce IPM”

A draft poster on CLA hosts was made by Sonia Broughton with some assistance from Sandra McDougall but was put on hold when field monitoring of weeds rarely found CLA on any other hosts other than the commercially produced lettuce, endive and radicchio. And unless monitoring does find CLA on a regular basis on non-crop hosts then the poster serves no useful purpose.

Project reports including the IPM surveys of growers (2006) and Survey of lettuce consultants (2006), and the Tasmanian 2005/6 IPM demonstration trial report have been available electronically via NSW DPI’s and AUSVEG’s website.

Figure 1. Bennett's hierarchy for "improving lettuce pest management"



KASA- Knowledge, aspirations, skills and attitudes

An evaluation survey conducted in April 08 of lettuce growers indicated that growers saw IPM as an aspiration but that they will still use imidacloprid while it is available and works if they don't have suitable nas resistant varieties. There is an understanding that IPM involves crop monitoring and priority to use of selective chemistry, some understanding of the role of beneficial insects but less recognition of the importance of cultural contol methods.

Only the growers who were working with experienced IPM consultants or were organic growers, used beneficial insects as the main control method for CLA, the rest of the industry used either imidacloprid or Nas resistant varieties. In the past two years we have seen consultants with IPM experience start to service the lettuce industry in the northern Perth production areas, in Hay and the Sydney basin in NSW. An increasing proportion of the lettuce industry are using consulting services to monitor their crops. Although most of the growers are still using imidacloprid for CLA control they have moved away from a calendar spray program for WFT.

The researchers on the project have recognized that when water is scarce and input costs increasing that growers are even less inclined to change management practices that are essentially working. Attendance at meetings, workshops and field days has been lower than in previous projects indicating pest management issues are currently a low priority for most growers.

Changes in practice

At the beginning of this project growers were asked to participate in a formal survey and it will not be repeated until 2010 so a direct comparison is not possible. The growers that participated in monitoring in the Sydney basis were surveyed before the monitoring and again 8 months latter and reported some increase in monitoring and decrease in chemical usage. In Western Australia none of the lettuce growers were using a consultant to monitor their crops and now the majority of the acreage is monitored.

A smaller survey specific to the project directions was circulated to all lettuce growers and only 25 responded most of those were met face to face.

End results

This project contributed to the lettuce industry being prepared for the arrival of currant lettuce aphid into their production area. It has provided them with information on management options for CLA and other pests. It has demonstrated that in some areas and for some windows CLA can be effectively managed by beneficial insects. It has also documented that beneficial insects numbers do not increase in response to CLA population increases over the cooler months. We have a number of potential but yet unproven options for increasing beneficial insect populations. Western flower thrips are still the priority pest of many growers, particularly hydroponic growers but that weed management and roguing diseased plants is not given the priority it probably needs.

This project has continued to inform lettuce growers and the lettuce industry about pest management issues and management options, as well as results from research trials as the information is available and of relevant industry information such as when new permits are granted or chemicals are restricted.

There continues to be relatively few growers using biointensive IPM, although a much larger number of growers identifying as IPM growers, using crop monitoring to inform chemical timing and choice. Broad spectrum insecticides are being used to manage an apparently growing Rutherglen bug problem and WFT management is relying on one or two chemicals.

Recommendations

1. Demonstrations of IPM in lettuce production areas in WA, QLD, SA and Riverina NSW.
2. Monitor *Nas*-susceptible untreated lettuce in major production areas to monitor CLA population movements or use suction trap data where available to monitor CLA population dynamics.
3. Research and demonstrate the potential of roguing and weed management to reduce WFT and TSWV.
4. Research and demonstrate the potential for non-crop plants to reduce WFT and TSWV habitat, e.g. trial plantings of the species identified as suitable in the 'reveg by design' project and assessing analogous species in the key lettuce production areas.
5. 1 on 1 technical support available in all major lettuce production areas
6. Develop IPM training/ professional development options for agronomists and crop consultants
7. Research into IPM options for Rutherglen bugs and western flower thrips
8. Research into improving efficacy of biological insecticides, for example sunscreens for Bts
9. Research methods for increasing or enhancing beneficial populations within cropping areas.
10. Production of resource materials on maximising efficacy of biological insecticides, on impact of pesticides on beneficials and residue periods.
11. Identify the attitudes of processors and the market sectors have towards IPM and identify ways to collaborate.
12. Review the various quality management guidelines and identify where improvements can be codified that support IPM and identify areas of potential conflict.

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Appendix 1: Key to scientific names used in this report

Common name	Abbreviations	Scientific name
ant spiders		Zodaraiidae
aphid parasite		*Aphidius colemani*
Assassin bug		*Pristhesancus* sp.
Bigeyed bug		*Orius* sp.
Brown sowthistle aphid	BSA	*Uroleucon sonchi*
Brown lacewing	BLW	*Micromus tasmaniae*
brown lacewing parasitoid		*Anacharis* sp.
Cluster caterpillar		*Spodoptera litura*
Common brown earwig		*Labidura truncata*
Common brown leafhopper		*Orosius argentatus*
Common spotted ladybird		*Harmonia conformis*
Corn earworm		*Helicoverpa armigera*
Currant lettuce aphid	CLA	*Nasonovia ribisnigri*
Cutworm		*Agrotis spp.*
Damsel bug		*Nabis kinbergi*
Eleven spotted ladybird		*Coccinella undecimpunctata*
European earwig		*Forficula auriculata*
Foxglove aphid		*Aulacorthum solani*
Glossy shield bug		*Cermatulus nasalis*
Green lacewings		Chrysopidae
Green looper		*Chrysodeixis argentifera*
Green peach aphid	GPA	*Myzus persicae*
Green vegetable bug		*Nezera viridula*
Grey garden slug		*Derocera reticulatum*
Hoverflies		Syrphidae
hoverfly parasitoid		*Diplazon laeletorius*
Jumping spiders		Salticidae
Melangyna hoverfly		*Melangyna sp.*
Minute pirate bug		*Geocoris* sp.
Native budworm		*Helicoverpa punctigera*
Onion thrips		*Thrips tabaci*
Plague thrips		*Thrips imaginis*
Potato aphid	PA	*Macrosiphum euphorbiae*
Potato bug		*Calocoris norvegicus*
predatory mites		*Athasiella relata*
predatory mites		*Dendrolealaps* sp
predatory mites		*Hypoaspis* spp
predatory mites		*Machrochelidae* spp
predatory mites		*Pachylaelaps* sp
predatory mites		*Pergamasus* sp
predatory mites		*Protogamasellus mica*
Predatory shield bug		*Oechalia schellenbergi*
predatory thrips		*Aeolothrips* sp.
Red and blue beetle		*Dicranolaius bellulus*
Red legged earth mite	RLEM	*Halotydeus destructor*
Rutherglen bug	RGB	*Nysius vinitor*
Silverleaf whitefly	SLW	*Bemesia tabaci*
Spiraea aphid		*Aphis spiraecola*
Spotted amber ladybeetle		*Hippodamia variegata*
Soldier beetle		*Chauliognathus* sp.
Southern ladybird		*Cleobora mellyi*
Sowthistle aphid	SA	*Hyperomyzus lactucae*
Striped ladybird		*Micraspis frenata*
Tomato thrips		*Frankliniella schultzei*
Transverse ladybird		*Coccinella transversalis*
Two striped slug		*Lehmannia nyctelia*
Two-spotted ladybird		*Diomus notescens*

Vegetable leafhopper		*Austroasca viridigrisea*
Vegetable weevil		*Listroderes difficilis*
Western flower thrips	WFT	*Frankliniella occidentalis*
White-collared ladybird		*Hippodamia variegata*
Wolf spiders		Lycosidae
Yellow leafhopper		*Zygina zealandica* (Myers)

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Appendices A1.1-A1.9 Tasmanian Demonstration Data

Appendix A1.1. *Destructive visual assessments of 30 mature iceberg lettuce per planting from P1-P6 at Brownwood Farm, Campania.*

P1, 8 March 06	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	SUM	MEAN	ST DEV
Currant lettuce aphids	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	0	0	0	10	0.33	1.32
Brown sowthistle aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0.07	0.26
other aphids	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	0.07	0.19
TOTAL aphids	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7	0	0	1	1	0	1	0	0	14	0.47	1.33
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
plant-feeding thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	20	0.67	3.71
brown lacewing larvae	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	1	0	0	4	0	0	2	0	0	0	0	0	18	0.60	1.66
brown lacewing adults	0	0	1	2	1	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	9	0.30	0.60
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0.03	0.19
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	2	0	0	1	0	0	0	0	0	0	0	0	6	0.20	0.56
spiders	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	6	0.20	0.49
predatory mites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
predatory thrips	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0.10	0.31
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00

P2, 29 March06	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	SUM	MEAN	ST DEV
Currant lettuce aphids	50	20	1	0	0	0	5	25	0	0	15	0	16	30	8	0	0	0	0	0	6	5	40	0	25	0	2	6	2	0	256	8.53	10.96
Brown sowthistle aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
other aphids	3	0	0	2	0	0	0	0	0	0	1	0	0	0	2	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	12	0.40	0.76
TOTAL aphids	53	20	1	2	0	0	5	25	0	0	16	0	16	30	10	0	0	0	1	0	6	5	40	0	28	0	2	6	2	0	268	8.93	11.12
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
plant-feeding thrips	1	5	0	1	1	3	2	0	0	2	1	0	1	0	0	1	10	0	2	1	2	1	3	4	0	0	0	0	1	1	43	1.43	2.10
brown lacewing larvae	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	4	0.13	0.31
brown lacewing adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0.07	0.37
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0.07	0.26
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
spiders	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	5	0.17	0.35
predatory mites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	2	0.07	0.26
predatory thrips	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	6	0.20	0.49
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00

Appendix A1.1 continued

P3, 12 April 06	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	SUM	MEAN	ST DEV
Currant lettuce aphids	1	1	2	0	1	0	0	13	20	0	50	0	24	0	0	67	82	10	1	205	5	81	10	5	20	40	10	30	0	100	778	25.93	44.67
Brown sowthistle aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	5	0.17	0.76
other aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
TOTAL aphids	1	1	2	0	1	0	0	13	20	0	50	0	24	0	0	67	86	10	1	205	5	81	10	5	20	40	10	31	0	100	783	26.10	44.86
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
plant-feeding thrips	2	0	0	0	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	9	0.30	0.51
brown lacewing larvae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.03	0.19
brown lacewing adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.03	0.19
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
spiders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	4	0.13	0.35
predatory mites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
predatory thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00

P4, 14 May 06	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	SUM	MEAN	ST DEV
Currant lettuce aphids	0	1	2	0	0	1	2	7	0	5	1	3	61	39	0	0	0	0	0	1	0	13	0	3	0	0	3	7	2	0	151	5.03	5.21
Brown sowthistle aphids	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0.13	0.14
other aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.03	0.03
TOTAL aphids	0	1	3	0	0	1	2	7	1	5	1	3	61	39	0	1	0	0	1	1	0	13	1	3	0	0	3	7	2	0	156	5.20	5.38
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
plant-feeding thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
brown lacewing larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
brown lacewing adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.03	0.03
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
spiders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
predatory mites	0	1	0	0	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0.27	0.28
predatory thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00

Appendix A1.1 continued

P5, 5 July 2006	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	SUM	MEAN	ST DEV
Currant lettuce aphids	5	2	10	0	5	131	10	3	0	0	0	0	0	0	0	1	3	2	64	11	41	105	30	100	2	5	5	20	5	0	560	19	34.9
Brown sowthistle aphids	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0.3
other aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TOTAL aphids	5	2	10	0	5	132	10	3	0	0	0	0	0	0	0	1	3	2	64	11	42	105	30	100	2	5	5	20	5	0	562	19	35.0
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
plant-feeding thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
brown lacewing larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
brown lacewing adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
spiders	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3	0	0.3
predatory mites	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0.3
predatory thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0.2
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0

P6, 5 July 2006	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	SUM	MEAN	SD
Currant lettuce aphids	0	116	21	11	15	50	0	0	1	44	2	10	5	1	0	0	2	2	2	4	1	1	1	70	3	2	2	0	0	0	366	12	25.8
Brown sowthistle aphids	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.3
other aphids	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
TOTAL aphids	0	116	21	12	16	50	0	0	1	44	2	10	5	1	0	0	2	2	2	4	1	1	1	70	3	2	2	0	0	0	368	12	25.8
caterpillars	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
plant-feeding thrips	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0.4
brown lacewing larvae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
brown lacewing adults	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0.2
hoverfly larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ladybird larvae & pupae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ladybird adults	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
spiders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0.4
predatory mites	0	0	3	1	0	1	1	0	1	1	1	0	2	1	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	16	1	0.8
predatory thrips	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
ladybird eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0

Appendix A1.2

Destructive visual assessments of mature lettuce for major insect groups at Houstons Farm, Richmond.

Currant lettuce aphid		**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
	Date of planting	**4-Nov**	**18-Nov**	**1-Dec**	**15-Dec**	**29-Dec**	**18-Jan**	**17-Feb**	**23-Feb**	**8-Mar**	**22-Mar**	**5-Apr**
	Date of assessment	**16-Dec**	**5-Jan**	**12-Jan**	**18-Jan**	**2-Feb**	**1-Mar**	**12-Apr**	**5-May**	**17-May**	**8-Jun**	**20-Jul**
	Days old at assessment	42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	1.7	0.2	19.1	20.1	0.0	0.1	826.7	271.0	797.0	5.7	11.1
Virjile	**Green coral**	4.1	10.7	38.3	na	5.3	1.3	413.3	82.7	593.0	8.9	38.5
Jamai	**Red oak**	0.0	7.1	35.0	26.8	2.3	9.5	366.7	720.0	687.0	35.6	174.4
Lagon	**Red coral**	4.1	5.6	30.5	24.1	0.1	1.5	747.0	540.0	847.0	18.6	95.9
Tarragona	**Green frilly**	2.1	0.2	28.1	na	na	na	na	na	na	na	na
	Mean lettuce aphids per plant at maturity:	**2**	**5**	**30**	**24**	**2**	**3**	**588**	**403**	**731**	**17**	**80**
Deltona	**Green oak & pirimicarb**	na	na	na	22.0	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	0.1	1.4	0.5	0.0	na	na	na	na	na	na	na
Obregon	**Nr red coral**	0.1	0.0	ns	na	na	na	na	na	na	na	na
	Planting interval in days:	na	14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	15

na not applicable, no such treatment

ns no sample taken

Nr means Nasonovia resistant

Appendix A1.2 continued

All aphids		**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
Date of planting		4-Nov	18-Nov	1-Dec	15-Dec	29-Dec	18-Jan	17-Feb	23-Feb	8-Mar	22-Mar	5-Apr
Date of harvest		16-Dec	5-Jan	12-Jan	18-Jan	2-Feb	1-Mar	12-Apr	5-May	17-May	8-Jun	20-Jul
Days old at assessment		42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	5.5	0.3	24.3	21.2	0.0	0.2	826.7	272.0	798.0	5.8	11.1
Virjile	**Green coral**	8.3	17.1	38.9	na	5.3	1.5	413.3	82.7	593.0	9.1	38.5
Jamai	**Red oak**	0.1	8.3	35.9	27.0	2.4	9.5	366.8	720.0	687.0	36.3	174.4
Lagon	**Red coral**	6.8	9.5	31.0	25.3	0.1	1.7	747.0	540.0	848.0	18.9	95.9
Tarragona	**Green frilly**	3.3	0.8	28.1	na	na	na	na	na	na	na	na
	Mean for all aphids per plant at maturity:	**4.8**	**7.2**	**31.6**	**24.5**	**2.0**	**3.2**	**588.5**	**403.7**	**731.5**	**17.5**	**80.0**
Deltona	**Pirimor sprayed**	na	na	na	22.4	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	0.5	3.6	0.5	0.5	na	na	na	na	na	na	na
Obregon	**Nr red coral**	1.1	1.9	ns	na	na	na	na	na	na	na	na
	Planting interval in days	na	14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	0

na not applicable, no such treatment
ns no sample taken
Nr means Nasonovia resistant

Appendix A1.2 continued

Lacewing adults & larvae		**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
Date of planting		**4-Nov**	**18-Nov**	**1-Dec**	**15-Dec**	**29-Dec**	**18-Jan**	**17-Feb**	**23-Feb**	**8-Mar**	**22-Mar**	**5-Apr**
Date of harvest		**16-Dec**	**5-Jan**	**12-Jan**	**18-Jan**	**2-Feb**	**1-Mar**	**12-Apr**	**5-May**	**17-May**	**8-Jun**	**20-Jul**
Days old at assessment		42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	2.3	0.6	1.5	0.1	0.6	0.3	2.8	0.1	0.4	0.1	0.1
Virjile	**Green coral**	0.3	0.6	0.2	na	0.9	1.3	0.3	0.0	0.0	0.6	0.1
Jamai	**Red oak**	0.1	0.4	0.4	0.4	1.1	1.5	1.2	0.3	0.1	0.0	0.4
Lagon	**Red coral**	0.5	0.8	0.2	0.2	0.4	0.5	3.2	0.2	0.8	0.2	0.0
Tarragona	**Green frilly**	0.2	0.3	0.2	na	na	na	na	na	na	na	na
	Mean lacewing adults and larvae per plant:	**0.7**	**0.5**	**0.5**	**0.2**	**0.7**	**0.9**	**1.9**	**0.2**	**0.3**	**0.2**	**0.2**
Deltona	**Pirimor sprayed**	na	na	na	0.1	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	0.9	1.0	0.1	0.1	na	na	na	na	na	na	na
Obregon	**Nr red coral**	0.0	0.2	ns	na	na	na	na	na	na	na	na
	Planting interval in days	na	14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	0

na not applicable, no such treatment
ns no sample taken
Nr means Nasonovia resistant

Appendix A1.2 continued

Hoverfly larvae and pupae		**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**
Date of planting		**4-Nov**	**18-Nov**	**1-Dec**	**15-Dec**	**29-Dec**	**18-Jan**	**17-Feb**	**23-Feb**	**8-Mar**	**22-Mar**	**5-Apr**
Date of harvest		**16-Dec**	**5-Jan**	**12-Jan**	**18-Jan**	**2-Feb**	**1-Mar**	**12-Apr**	**5-May**	**17-May**	**8-Jun**	**20-Jul**
Days old at assessment		42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	0.3	0.3	0.8	0.1	1.5	0.4	1.1	1.3	1.1	0.0	0.0
Virjile	**Green coral**	0.1	1.5	0.5	na	0.8	2.1	0.6	0.8	0.4	0.0	0.0
Jamai	**Red oak**	0.1	0.2	0.2	0.1	1.8	2.1	0.3	0.0	0.2	0.0	0.1
Lagon	**Red coral**	0.1	0.3	0.1	0.2	0.9	0.2	0.3	0.9	0.4	0.0	0.1
Tarragona	**Green frilly**	0.0	0.7	0.3	na	na	na	na	na	na	na	na
	Mean hoverfly larvae and pupae per plant:	**0.1**	**0.6**	**0.4**	**0.1**	**1.3**	**1.2**	**0.6**	**0.8**	**0.5**	**0.0**	**0.1**
Deltona	**Pirimor sprayed**	na	na	na	0.1	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	0.0	0.0	0.0	0.0	na	na	na	na	na	na	na
Obregon	**Nr red coral**	0.0	0.0	ns	na	na	na	na	na	na	na	na
	Planting interval in days		14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	0

na not applicable, no such sample
ns no sample
Nr means Nasonovia resistant

Appendix A1.2 continued

Ladybird larvae, pupae and adults		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Date of planting		4-Nov	18-Nov	1-Dec	15-Dec	29-Dec	18-Jan	17-Feb	23-Feb	8-Mar	22-Mar	5-Apr
Date of harvest		16-Dec	5-Jan	12-Jan	18-Jan	2-Feb	1-Mar	12-Apr	5-May	17-May	8-Jun	20-Jul
Days old at assessment		42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	0.1	0.4	0.4	0.1	0.2	0.1	0.5	0.1	0.1	0.0	0.0
Virjile	**Green coral**	0.1	0.2	0.2	na	0.3	0.3	0.5	0.0	0.1	0.0	0.0
Jamai	**Red oak**	0.1	0.1	0.2	0.1	0.5	0.7	0.6	0.0	0.0	0.0	0.0
Lagon	**Red coral**	0.1	0.3	0.3	0.0	0.4	0.0	1.2	0.1	0.0	0.0	0.0
Tarragona	**Green frilly**	0.4	0.1	0.3	na	na	na	na	na	na	na	na
	Mean ladybirds per plant:	**0.2**	**0.2**	**0.3**	**0.1**	**0.4**	**0.3**	**0.7**	**0.1**	**0.1**	**0.0**	**0.0**
Deltona	**Pirimor sprayed**	na	na	na	0.0	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	0.0	0.2	0.1	0.0	na	na	na	na	na	na	na
Obregon	**Nr red coral**	0.0	0.2	ns	na	na	na	na	na	na	na	na
	Planting interval in days		14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	0

na not applicable, no such sample
ns no sample
Nr means Nasonovia resistant

Appendix A1.2 continued

Ladybird eggs		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Date of planting		4-Nov	18-Nov	1-Dec	15-Dec	29-Dec	18-Jan	17-Feb	23-Feb	8-Mar	22-Mar	5-Apr
Date of harvest		16-Dec	5-Jan	12-Jan	18-Jan	2-Feb	1-Mar	12-Apr	5-May	17-May	8-Jun	20-Jul
Days old at assessment		42	48	42	34	35	42	54	71	70	78	106
Cultivar	***Lettuce class***											
Deltona	**Green oak**	0.1	0.1	0.0	0.3	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Virjile	**Green coral**	0.0	0.0	0.0	ns	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jamai	**Red oak**	0.0	0.0	0.0	0.0	0.7	0.0	0.9	0.0	0.0	0.0	0.0
Lagon	**Red coral**	0.0	0.6	0.0	0.0	0.1	0.0	1.1	0.0	0.0	0.0	0.0
Tarragona	**Green frilly**	0.0	0.0	0.0	na	na	na	na	na	na	na	na
	Mean lady bird eggs per plant:	**0.0**	**0.1**	**0.0**	**0.1**	**0.2**	**0.0**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**
Deltona	**Pirimor sprayed**	na	na	na	0.0	na	na	na	na	na	na	na
Sirmai	**Nr red oak**	1.7	0.0	0.0	0.0	na	na	na	na	na	na	na
Obregon	**Nr red coral**	0.1	0.0	ns	na	na	na	na	na	na	na	na
	Planting interval in days	na	14	13	14	14	20	30	6	13	14	14
	Sample size per cultivar:	15	15	15	15	15	15	30	15	15	15	0

na not applicable, no such sample
ns no sample
Nr means Nasonovia resistant

Appendix A1.3

Destructive visual assessments of mature lettuce for all insects counted, at Houstons Farm, Richmond.

P1, 16 Dec 2005	Del	Vir	Jam	Lag	Tar	Sir	Obr	Susceptible MEAN
Currant lettuce aphids	1.70	4.10	0.00	4.10	2.10	0.10	0.10	2.40
Brown sowthistle aphids	1.10	0.60	0.00	1.30	1.00	0.30	0.40	0.80
other aphids	2.70	3.60	0.10	1.50	0.20	0.30	0.70	1.62
TOTAL aphids	5.50	8.30	0.10	6.80	3.30	0.70	1.10	4.80
caterpillars	0.00	0.00	0.00	0.10	0.00	0.00	0.10	0.02
plant-feeding thrips	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brown lacewing larvae	0.90	0.10	0.10	0.20	0.10	0.50	0.00	0.28
brown lacewing adults	1.40	0.20	0.00	0.30	0.10	0.40	0.00	0.40
hoverfly larvae & pupae	0.30	0.10	0.10	0.10	0.00	0.00	0.00	0.12
ladybird larvae & pupae	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.02
ladybird adults	0.10	0.10	0.10	0.10	0.30	0.00	0.00	0.14
spiders	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
predatory mites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
predatory thrips	0.10	0.00	0.10	0.20	0.00	0.30	0.00	0.08
ladybird eggs	0.10	0.00	0.00	0.00	0.00	1.70	0.10	0.02

P2, 5 Jan 2006	Del	Vir	Jam	Lag	Tar	Sir	Obr	Susceptible MEAN
Currant lettuce aphids	0.20	10.7	7.10	5.60	0.20	1.40	0.00	4.76
Brown sowthistle aphids	0.00	1.50	0.60	2.00	0.00	0.90	0.00	0.82
other aphids	0.10	12.4	0.50	1.90	0.60	1.30	0.00	3.10
TOTAL aphids	0.30	17.1	8.30	9.50	0.80	3.60	0.00	7.20
caterpillars	0.10	0.10	0.10	0.10	0.00	0.10	0.10	0.08
plant-feeding thrips	0.10	0.00	0.00	15.00	0.00	0.60	0.00	3.02
brown lacewing larvae	0.50	0.50	0.10	0.50	0.20	0.50	0.00	0.36
brown lacewing adults	0.10	0.10	0.30	0.30	0.10	0.50	0.10	0.18
hoverfly larvae & pupae	0.30	1.50	0.20	0.30	0.70	0.00	0.00	0.60
ladybird larvae & pupae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ladybird adults	0.40	0.20	0.10	0.30	0.10	0.20	0.20	0.22
spiders	1.00	0.30	0.50	0.30	0.10	0.50	0.00	0.44
predatory mites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
predatory thrips	0.30	0.30	0.10	0.30	0.70	0.10	0.00	0.34
ladybird eggs	0.10	0.00	0.00	0.60	0.00	0.00	0.00	0.14

P3, 12 Jan 2006	Del	Vir	Jam	Lag	Tar	Sir	Obr	Susceptible MEAN
Currant lettuce aphids	19.1	38.2	35.0	30.5	28.1	0.47	n. d.	30.18
Brown sowthistle aphids	1.30	0.70	0.70	0.20	0.00	0.07	n. d.	0.58
other aphids	1.70	0.10	0.30	0.30	0.00	0.00	n. d.	0.48
TOTAL aphids	24.3	38.9	35.9	31.0	28.1	0.53	n. d.	31.64
caterpillars	0.00	0.00	0.00	0.00	0.00	0.07	n. d.	0.00
plant-feeding thrips	20.0	20.0	20.0	20.0	20.0	19.3	n. d.	20.00
brown lacewing larvae	0.80	0.20	0.10	0.00	0.10	0.03	n. d.	0.24
brown lacewing adults	0.70	0.00	0.30	0.20	0.10	0.13	n. d.	0.26
hoverfly larvae & pupae	0.80	0.50	0.20	0.10	0.30	0.00	n. d.	0.38
ladybird larvae & pupae	0.00	0.00	0.10	0.10	0.00	0.00	n. d.	0.04
ladybird adults	0.40	0.20	0.10	0.20	0.30	0.13	n. d.	0.24
spiders	0.10	0.30	0.60	0.50	0.30	0.67	n. d.	0.36
predatory mites	0.00	0.00	0.00	0.00	0.00	0.00	n. d.	0.00
predatory thrips	0.30	0.30	0.00	0.10	0.30	0.13	n. d.	0.20
ladybird eggs	0.00	0.00	0.00	0.00	0.00	0.00	n. d.	0.00

Appendix A1.3 continued

P4, 18 Jan 2006	Del		Jam	Lag		Sir	Del pir	Susceptible MEAN
Currant lettuce aphids	20.1		26.8	24.1		0.00	22.00	23.67
Brown sowthistle aphids	0.40		0.20	0.80		0.50	0.40	0.47
other aphids	0.70		0.00	0.40		0.00	0.00	0.37
TOTAL aphids	21.2		27.0	25.3		0.50	22.40	24.50
caterpillars	0.00		0.00	0.00		0.00	0.00	0.00
plant-feeding thrips	8.10		13.3	2.70		5.50	2.70	8.03
brown lacewing larvae	0.00		0.00	0.10		0.00	0.00	0.03
brown lacewing adults	0.10		0.40	0.10		0.10	0.10	0.20
hoverfly larvae & pupae	0.10		0.10	0.20		0.00	0.10	0.13
ladybird larvae & pupae	0.00		0.00	0.00		0.00	0.00	0.00
ladybird adults	0.10		0.10	0.00		0.00	0.00	0.07
spiders	0.10		0.20	0.30		0.30	0.30	0.20
predatory mites	0.00		0.00	0.00		0.00	0.00	0.00
predatory thrips	0.50		0.00	0.10		0.10	0.20	0.20
ladybird eggs	0.30		0.00	0.00		0.00	0.00	0.10

P5, 2 Feb 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	0.00	5.30	2.30	0.10				1.93
Brown sowthistle aphids	0.00	0.00	0.00	0.00				0.00
other aphids	0.00	0.00	0.10	0.00				0.03
TOTAL aphids	0.00	5.30	2.40	0.10				1.95
caterpillars	0.00	0.00	0.00	0.00				0.00
plant-feeding thrips	4.30	8.00	6.70	12.0				7.75
brown lacewing larvae	0.20	0.30	0.00	0.10				0.15
brown lacewing adults	0.40	0.60	1.10	0.30				0.60
hoverfly larvae & pupae	1.50	0.80	1.80	0.90				1.25
ladybird larvae & pupae	0.00	0.00	0.10	0.00				0.03
ladybird adults	0.20	0.30	0.40	0.40				0.33
spiders	0.50	0.50	0.70	0.50				0.55
predatory mites	0.00	0.00	0.00	0.00				0.00
predatory thrips	0.40	0.50	0.00	0.00				0.23
ladybird eggs	0.00	0.00	0.70	0.10				0.20

P6, 1 Mar 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	0.10	1.30	9.5	1.45				3.09
Brown sowthistle aphids	0.10	0.10	0.00	0.20				0.10
other aphids	0.00	0.05	0.00	0.00				0.01
TOTAL aphids	0.20	1.45	9.5	1.65				3.20
caterpillars	0.10	0.00	0.00	0.00				0.03
plant-feeding thrips	2.25	8.80	5.30	5.75				5.53
brown lacewing larvae	0.20	0.75	1.40	0.45				0.70
brown lacewing adults	0.10	0.50	0.10	0.05				0.19
hoverfly larvae & pupae	0.40	2.10	2.10	0.20				1.20
ladybird larvae & pupae	0.00	0.05	0.40	0.00				0.11
ladybird adults	0.10	0.25	0.30	0.00				0.16
spiders	0.20	0.25	1.10	0.40				0.49
predatory mites	0.05	0.00	0.10	0.00				0.04
predatory thrips	0.10	0.05	0.00	0.05				0.05
ladybird eggs	0.00	0.00	0.00	0.00				0.00

Appendix A1.3 continued

P7, 12 Apr 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	827	413	367	747				588.35
Brown sowthistle aphids	0.00	0.00	0.10	0.00				0.03
other aphids	0.00	0.00	0.00	0.00				0.00
TOTAL aphids	827	413	367	747				588.38
caterpillars	0.00	0.00	0.10	0.10				0.05
plant-feeding thrips	0.00	0.10	0.10	0.00				0.05
brown lacewing larvae	2.70	0.30	1.20	3.10				1.83
brown lacewing adults	0.10	0.00	0.00	0.10				0.05
hoverfly larvae & pupae	1.10	0.60	0.30	0.30				0.58
ladybird larvae & pupae	0.10	0.00	0.50	0.70				0.33
ladybird adults	0.40	0.50	0.10	0.50				0.38
spiders	0.20	0.50	0.40	0.30				0.35
predatory mites	0.00	0.00	0.00	0.00				0.00
predatory thrips	0.10	0.00	0.10	0.10				0.08
ladybird eggs	0.70	0.00	0.90	1.10				0.68

P8, 5 May 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	271	82.7	720	540				403.35
Brown sowthistle aphids	0.90	0.10	0.00	0.10				0.28
other aphids	0.00	0.00	0.00	0.00				0.00
TOTAL aphids	272	82.7	720	540				403.58
caterpillars	0.00	0.00	0.10	0.10				0.05
plant-feeding thrips	0.00	0.10	0.00	0.10				0.05
brown lacewing larvae	0.10	0.00	0.20	0.10				0.10
brown lacewing adults	0.00	0.00	0.10	0.10				0.05
hoverfly larvae & pupae	1.30	0.80	0.00	0.90				0.75
ladybird larvae & pupae	0.00	0.00	0.00	0.00				0.00
ladybird adults	0.10	0.00	0.00	0.10				0.05
spiders	0.50	0.10	0.30	0.30				0.30
predatory mites	0.00	0.00	0.00	0.00				0.00
predatory thrips	0.00	0.00	0.00	0.10				0.03
ladybird eggs	0.00	0.00	0.00	0.00				0.00

P9, 17 May 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	797	593	687	847				730.85
Brown sowthistle aphids	1.10	0.00	0.00	1.20				0.58
other aphids	0.00	0.00	0.00	0.00				0.00
TOTAL aphids	798	593	687	848				731.43
caterpillars	0.00	0.00	0.10	0.10				0.05
plant-feeding thrips	0.00	0.10	0.00	0.00				0.03
brown lacewing larvae	0.30	0.00	0.10	0.80				0.30
brown lacewing adults	0.10	0.00	0.00	0.00				0.03
hoverfly larvae & pupae	1.10	0.40	0.20	0.40				0.53
ladybird larvae & pupae	0.00	0.00	0.00	0.00				0.00
ladybird adults	0.10	0.10	0.00	0.00				0.05
spiders	0.30	0.30	0.10	0.30				0.25
predatory mites	0.00	0.10	0.00	0.10				0.05
predatory thrips	0.00	0.00	0.00	0.00				0.00
ladybird eggs	0.00	0.00	0.00	0.00				0.00

Appendix A1.3 continued

P10, 8 Jun 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	5.70	8.90	35.6	18.6				17.20
Brown sowthistle aphids	0.10	0.20	0.70	0.30				0.33
other aphids	0.00	0.00	0.00	0.00				0.00
TOTAL aphids	5.80	9.10	36.3	18.9				17.53
caterpillars	0.00	0.00	0.00	0.00				0.00
plant-feeding thrips	0.00	0.00	0.00	0.00				0.00
brown lacewing larvae	0.10	0.40	0.00	0.10				0.15
brown lacewing adults	0.00	0.20	0.00	0.10				0.08
hoverfly larvae & pupae	0.00	0.00	0.00	0.00				0.00
ladybird larvae & pupae	0.00	0.00	0.00	0.00				0.00
ladybird adults	0.00	0.00	0.00	0.00				0.00
spiders	0.30	0.00	0.00	0.20				0.13
predatory mites	0.00	0.00	0.10	0.70				0.20
predatory thrips	0.00	0.00	0.00	0.00				0.00
ladybird eggs	0.00	0.00	0.00	0.00				0.00

P11, 20 Jul 2006	Del	Vir	Jam	Lag				Susceptible MEAN
Currant lettuce aphids	11.1	38.5	174.4	95.9				79.98
Brown sowthistle aphids	0.00	0.00	0.00	0.00				0.00
other aphids	0.00	0.00	0.00	0.00				0.00
TOTAL aphids	11.1	38.5	174.4	95.9				79.98
caterpillars	0.00	0.00	0.00	0.00				0.00
plant-feeding thrips	0.00	0.00	0.00	0.00				0.00
brown lacewing larvae	0.10	0.00	0.40	0.00				0.13
brown lacewing adults	0.00	0.10	0.00	0.00				0.03
hoverfly larvae & pupae	0.00	0.00	0.10	0.10				0.05
ladybird larvae & pupae	0.00	0.00	0.00	0.00				0.00
ladybird adults	0.00	0.00	0.00	0.00				0.00
spiders	0.10	0.50	0.20	0.50				0.33
predatory mites	0.00	0.00	0.00	0.00				0.00
predatory thrips	0.00	0.00	0.00	0.00				0.00
ladybird eggs	0.00	0.00	0.00	0.00				0.00

Cultivar abbreviations:
Del – Deltona susceptyible green oak
Vir – Virjile susceptible green coral
Jam – Jamai susceptible red oak RZ83-48
Lag – lagon susceptible red coral
Tar – Tarragona susceptible green frilly
Sir – Sirmai Nasonovia resistant red oak RZ83-57
Obr – Obregon Nasonovia resistant red coral RZ79-79
Del pir – Deltona sprayed with pirimicarb.

Appendix A1.4

Richmond, Premature and mature comparisons for Plantings 2 and 6. Richmond Planting 2 at 15 days before and at maturity.

P2, 21/12/2005	**Del**	**Vir**	**Jam**	**Lag**	**Tar**	**Sir**	**Obr**	Susceptible MEAN
Currant lettuce aphids	2.50	14.10	2.10	0.10	7.50	0.00	0.00	5.26
Brown sowthistle aphids	5.10	2.90	0.10	1.10	1.70	0.70	1.10	2.18
other aphids	5.70	3.30	0.30	0.70	0.70	0.10	0.80	2.14
TOTAL aphids	13.30	20.1	2.50	1.90	9.90	0.90	1.90	9.54
caterpillars	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
plant-feeding thrips	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brown lacewing larvae	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.06
brown lacewing adults	0.40	0.10	0.00	0.30	0.50	0.10	0.20	0.26
hoverfly larvae & pupae	0.10	0.00	0.40	0.00	0.50	0.00	0.00	0.20
ladybird larvae & pupae	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
ladybird adults	0.00	0.70	0.10	0.10	0.10	0.10	0.00	0.20
spiders	0.50	0.40	0.30	0.50	0.80	0.10	0.30	0.50
predatory mites	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.02
predatory thrips	0.00	0.00	0.10	0.00	0.30	0.30	0.10	0.08
ladybird eggs	0.00	0.40	0.00	0.00	1.70	0.00	0.40	0.42

P2, 5/01/2006	**Del**	**Vir**	**Jam**	**Lag**	**Tar**	**Sir**	**Obr**	Susceptible MEAN
Currant lettuce aphids	0.20	10.70	7.10	5.60	0.20	1.40	0.00	4.76
Brown sowthistle aphids	0.00	1.50	0.60	2.00	0.00	0.90	0.00	0.82
other aphids	0.10	12.40	0.50	1.90	0.60	1.30	0.00	3.10
TOTAL aphids	0.30	17.1	8.30	9.50	0.80	3.60	0.00	7.20
caterpillars	0.10	0.10	0.10	0.10	0.00	0.10	0.10	0.08
plant-feeding thrips	0.10	0.00	0.00	15.00	0.00	0.60	0.00	3.02
brown lacewing larvae	0.50	0.50	0.10	0.50	0.20	0.50	0.00	0.36
brown lacewing adults	0.10	0.10	0.30	0.30	0.10	0.50	0.10	0.18
hoverfly larvae & pupae	0.30	1.50	0.20	0.30	0.70	0.00	0.00	0.60
ladybird larvae & pupae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ladybird adults	0.40	0.20	0.10	0.30	0.10	0.20	0.20	0.22
spiders	1.00	0.30	0.50	0.30	0.10	0.50	0.00	0.44
predatory mites	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
predatory thrips	0.30	0.30	0.10	0.30	0.70	0.10	0.00	0.34
ladybird eggs	0.10	0.00	0.00	0.60	0.00	0.00	0.00	0.14

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Appendix A1.4 continued
Richmond, Planting 6 assessments at 9 days before and at maturity.

P6, 22 Feb 2006	**Del**	**Vir**	**Jam**	**Lag**	Susceptible MEAN
Currant lettuce aphids			39.8		39.8
Brown sowthistle aphids			0.03		0.0
other aphids			0.03		0.0
TOTAL aphids			39.9		39.9
caterpillars			0.00		0.0
plant-feeding thrips			1.37		1.4
brown lacewing larvae			0.67		0.7
brown lacewing adults			0.90		0.9
hoverfly larvae & pupae			2.67		2.7
ladybird larvae & pupae			0.00		0.0
ladybird adults			0.53		0.5
spiders			0.40		0.4
predatory mites			0.00		0.0
predatory thrips			0.00		0.0
ladybird eggs			2.87		2.9

P6, 1 Mar 2006	**Del**	**Vir**	**Jam**	**Lag**	Susceptible MEAN
Currant lettuce aphids	0.10	1.30	9.5	1.45	3.1
Brown sowthistle aphids	0.10	0.10	0.00	0.20	0.1
other aphids	0.00	0.05	0.00	0.00	0.0
TOTAL aphids	0.20	1.45	9.5	1.65	3.2
caterpillars	0.10	0.00	0.00	0.00	0.0
plant-feeding thrips	2.25	8.80	5.30	5.75	5.5
brown lacewing larvae	0.20	0.75	1.40	0.45	0.7
brown lacewing adults	0.10	0.50	0.10	0.05	0.2
hoverfly larvae & pupae	0.40	2.10	2.10	0.20	1.2
ladybird larvae & pupae	0.00	0.05	0.40	0.00	0.1
ladybird adults	0.10	0.25	0.30	0.00	0.2
spiders	0.20	0.25	1.10	0.40	0.5
predatory mites	0.05	0.00	0.10	0.00	0.0
predatory thrips	0.10	0.05	0.00	0.05	0.1
ladybird eggs	0.00	0.00	0.00	0.00	0.0

Cultivar abbreviations:
Del – Deltona susceptyible green oak
Vir – Virjile susceptible green coral
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Appendix A1.5.

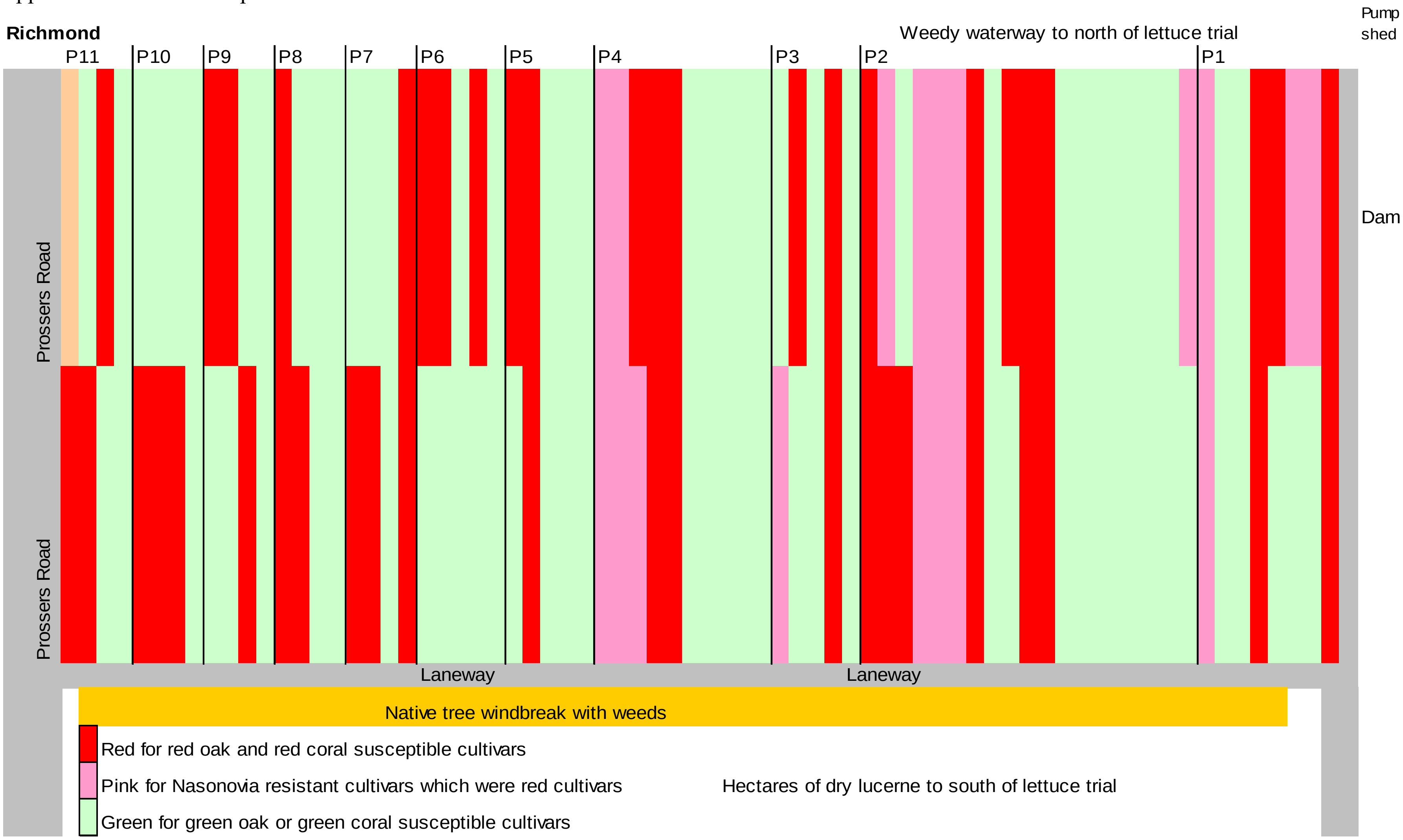
Physical layout of beds of loose-leaf lettuce at Richmond.

Rocket and P12-P13 superimposed on P1-2. North to top of page, East to right.

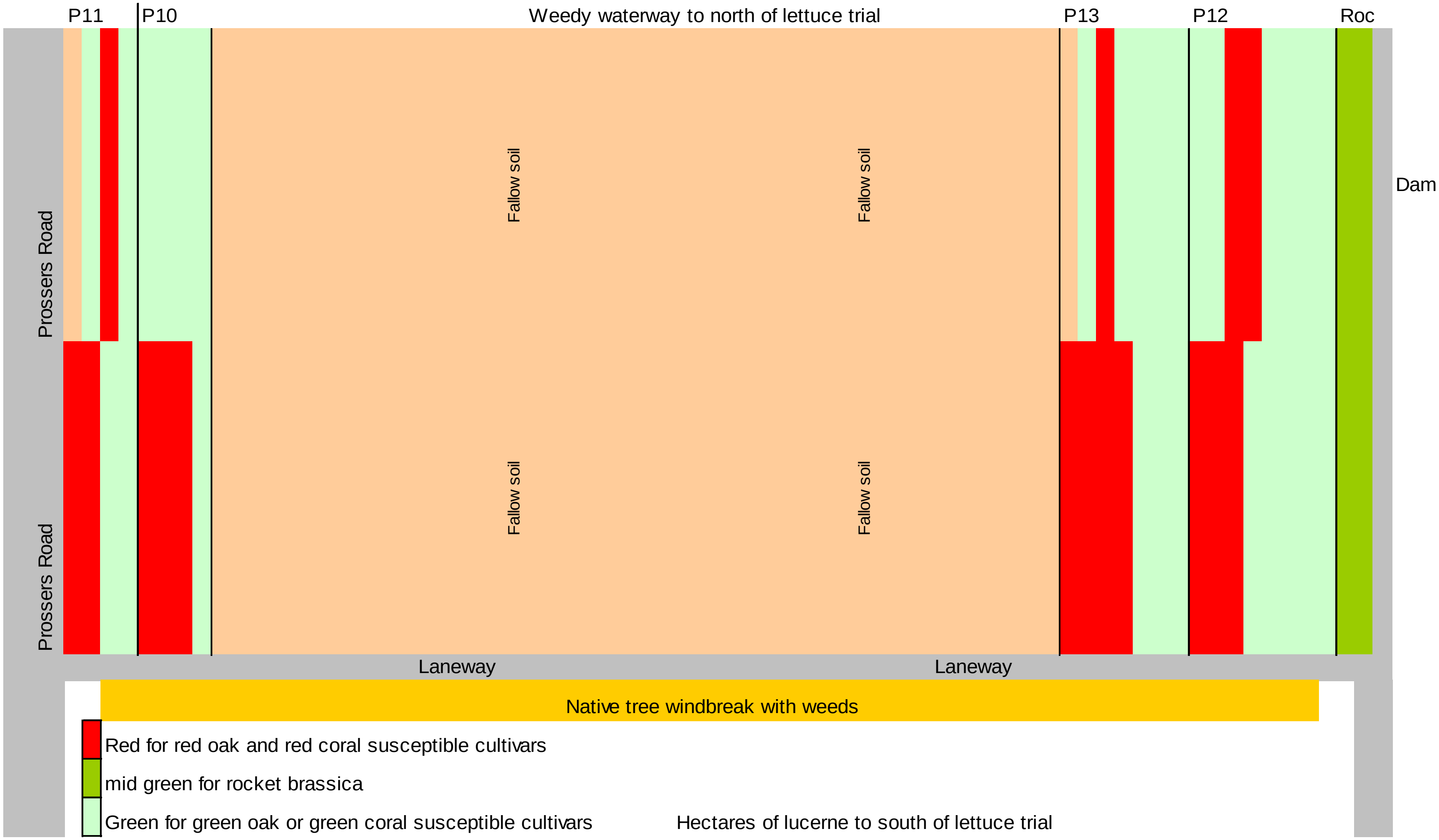
Planting:	P11	P10	P9	P8	P7	P6	P5	P4	P3	P2	P1
	4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	3 cultivars red oak, red coral, green oak	5 cultivars incl. 1 red Nr and Pirimor green oak No Virjile green coral	7 cultivars incl. 2 red Nr (Obregon & Sirmai)	7 cultivars including 2 red Nr (Obregon & Sirmai)	7 cultivars including 2 red Nr (Obregon & Sirmai)
Planted:	5/04/2006	22/03/2006	8/03/2006	23/02/2006	17/02/2006	18/01/2006	29/12/2005	15/12/2005	1/12/2005	18/11/2005	4/11/2005
Matured:	28/07/2006	8/06/2006	17/05/2006	5/05/2006	12/04/2006	1/03/2006	2/02/2006	18/01/2006	12/01/2006	5/01/2006	16/12/2005
Destroyed:		30/07/2006	7/07/2006	8/06/2006	14/05/2006	14/05/2006	29/03/2006	17/02/2006	17/02/2006	30/01/2006	11/01/2006
Beds:	4	4	4	4	4	5	5	10	5	18	9

Planting:	P11	P10	P9	P8					P13	P12	rocket
									4 cultivars red oak, red coral, green oak, green coral	4 cultivars red oak, red coral, green oak, green coral	rocket brassica
Planted:	5/04/2006	22/03/2006	8/03/2006	23/02/2006					31/05/2006	26/04/2006	5/04/2006
Matured:	28/07/2006	8/06/2006	17/05/2006	5/05/2006							
Destroyed:		30/07/2006	7/07/2006	8/06/2006							27/07/2006
Beds:	4	4	4	4					7	8	2

Appendix A1.6 Colour plan Richmond loose-leaf lettuce.

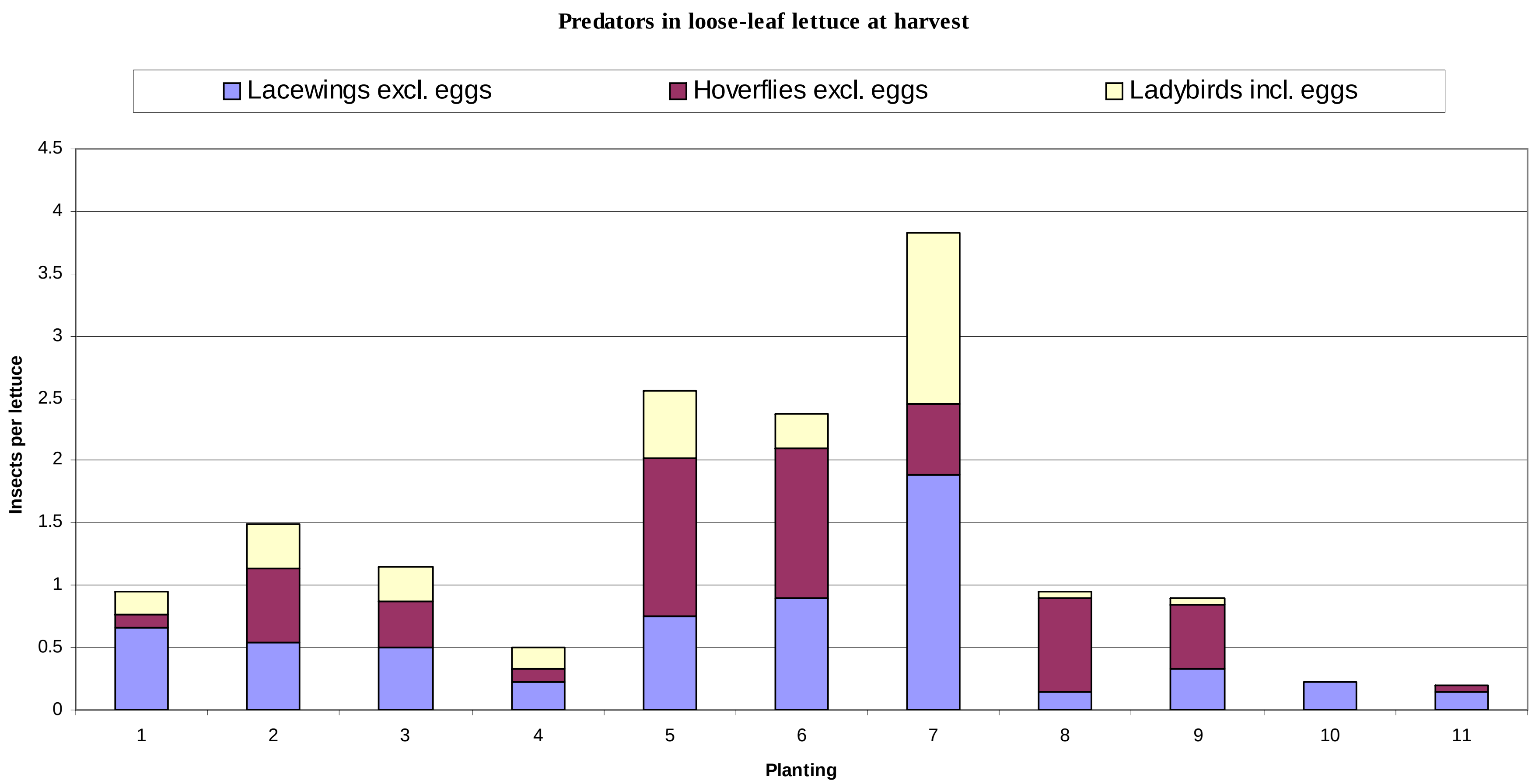


Appendix A1.6 continued.

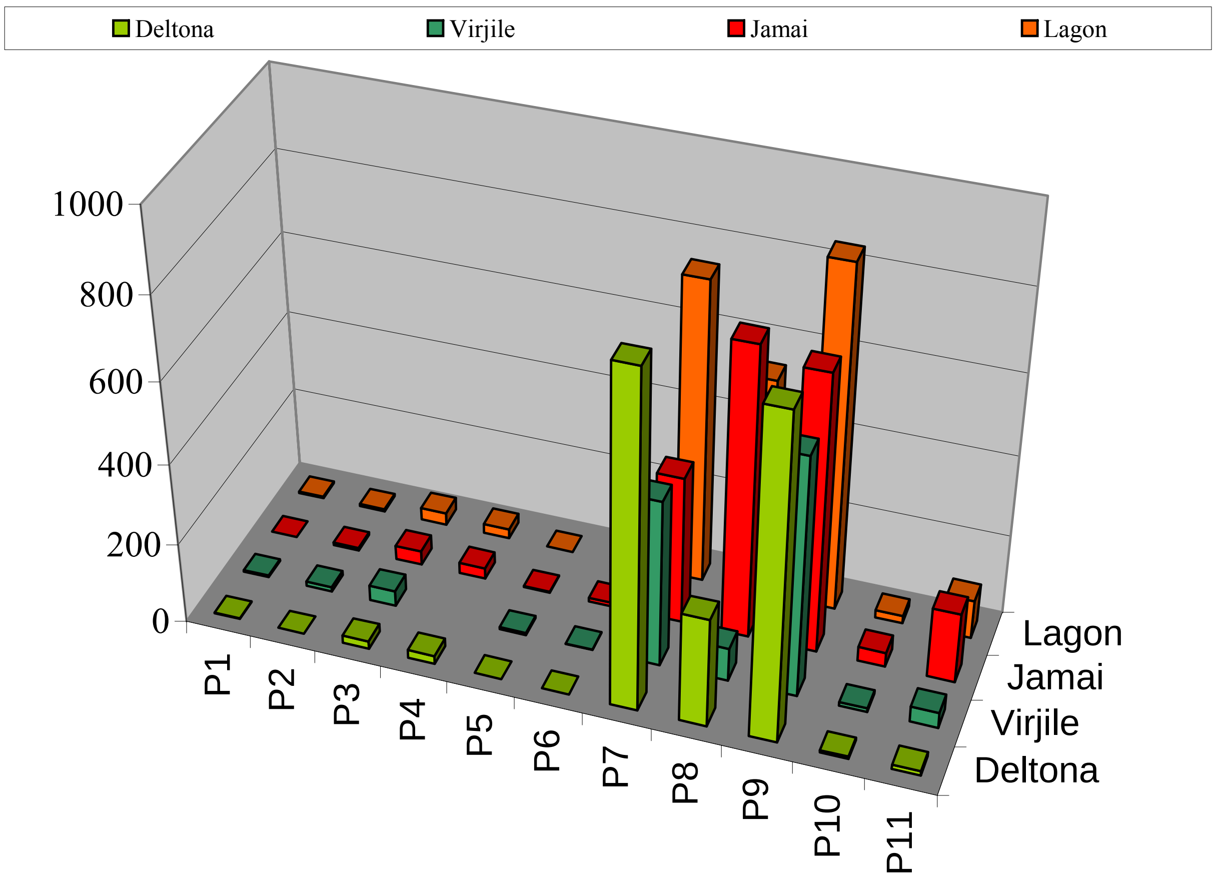


Appendix A1.7.

Graphical comparison of abundance of predators at harvest in loose-leaf lettuce.

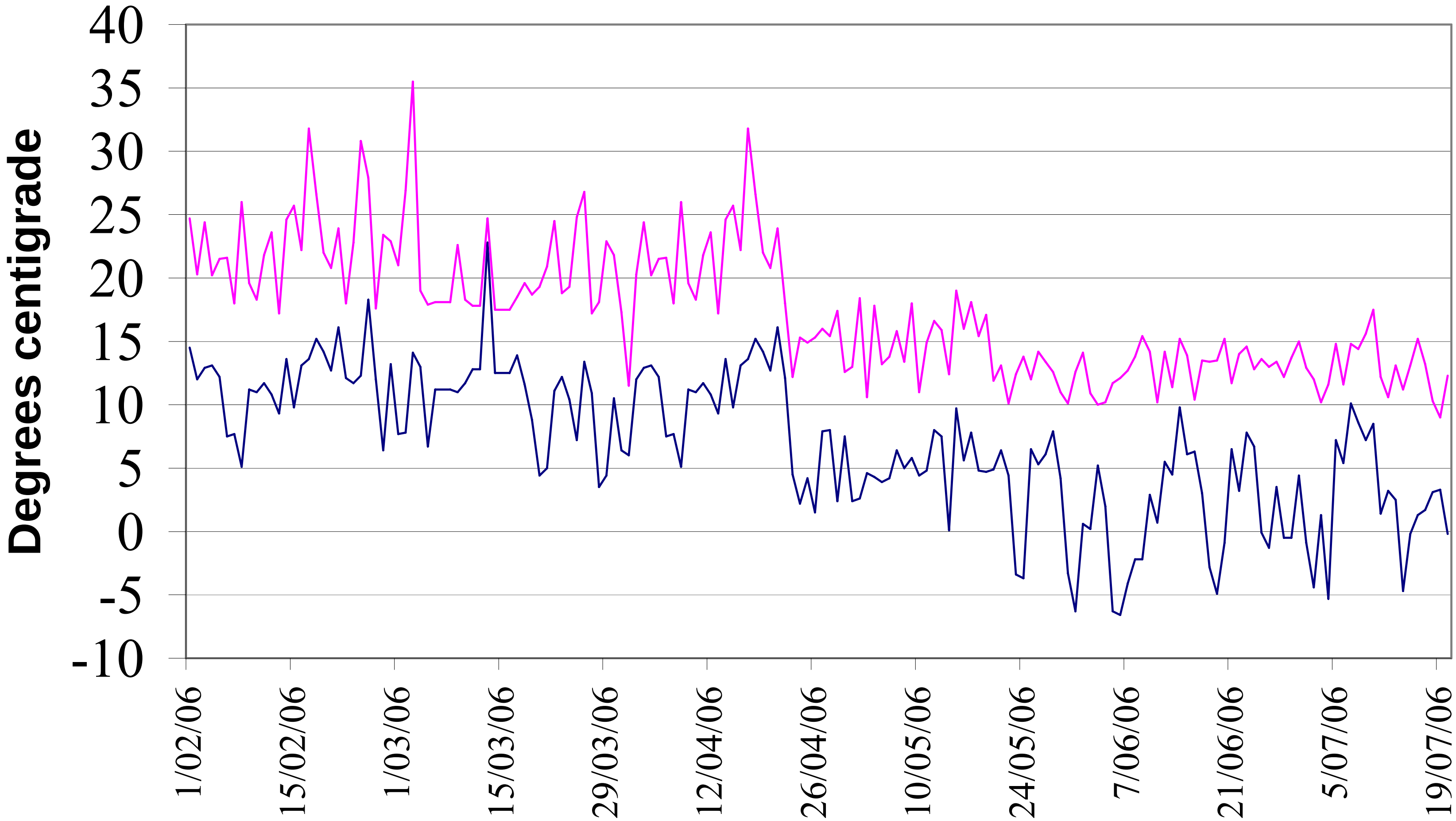


Appendix A1.8:
Numbers of currant lettuce aphids on four major N-susceptible loose-leaf cultivars at Richmond



Appendix A1.9:

Maxima and minima air screen temperatures at Richmond IPM trial site from 1 February 2006 to 20 July 2006.



Appendix A3.1 Summary of Visual sampling data per lettuce

Planting	DAP	Sample date	CLA	BSA	Other aphid	Hoverfly Eggs	Hoverfly Larvae	BLW eggs	BLW Larvae	BLW adults	Ladybird Eggs	L,bird Larvae	Ladybird adult	total aphid pred	Spider	PredatoryThrips	Predatory Earwig	Staphylinid Beetle	Damsel bug	Acceptable^
P1	49	20/07/2006	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	1.0
P1	62	2/08/2006	5.6	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.9
P1	70	10/08/2006	6.7	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.7
P1	77	17/08/2006	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
P1	88	28/08/2006	19.6+*	0.0	0.0	0.0	0.4	1.3	0.6	0.1	0.0	0.0	0.0	2.3	0.3	0.0	0.0	0.2	0.2	0.3
P2	49	20/07/2006	1.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	1.0
P2	62	2/08/2006	7.9	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.3	0.5	0.1	0.0	0.0	0.0	0.9
P2	70	10/08/2006	11.9+*	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.3	0.4	0.0	0.0	0.3	0.0	0.7
P2	77	17/08/2006	19.6+*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.1	0.0	0.0	0.1
P2	91	31/08/2006	20+*	0.0	0.0	0.0	2.7	0.0	0.3	0.1	0.0	0.0	0.0	3.1	0.1	0.1	0.0	0.0	0.1	0.0
P2	98	7/09/2006	287.6	0.0	0.0	0.0	3.9	0.3	0.2	0.0	0.4	0.0	0.0	4.9	0.3	0.0	0.0	0.2	0.1	0.1
P3	49	28/09/2006	122.8	0.0	0.0	0.0	5.5	0.0	0.0	0.0	5.7	0.5	0.0	11.7	0.5	0.0	0.0	1.2	0.0	0.2
P3	57	6/10/2006	86.5	0.0	0.0	0.0	5.3	0.0	0.5	0.2	5.8	0.3	0.7	12.8	0.5	0.0	0.0	0.5	0.0	0.2
P4	28	21/09/2006	56.7	0.1	0.0	0.1	0.6	0.9	0.0	0.0	0.2	0.0	0.1	1.9	0.3	0.0	0.1	0.1	0.2	0.0
P4	35	28/09/2006	121.3	0.0	0.0	0.2	4.9	4.5	0.3	0.5	2.8	0.1	0.1	13.5	0.6	0.0	0.0	0.1	0.3	0.0
P4	42	5/10/2006	18.3	0.0	0.0	0.5	4.4	1.7	0.5	0.1	2.4	0.1	0.1	9.7	0.7	0.0	0.0	0.0	0.5	0.8
P4	49	12/10/2006	1.9	0.0	0.0	0.0	0.7	0.5	0.7	0.1	0.5	0.1	0.1	2.8	0.5	0.0	0.0	0.1	0.1	1.0
P8	28	19/10/2006	81.3	0.0	0.0	0.6	0.8	1.9	0.1	0.8	0.7	0.0	0.3	5.2	0.2	0.0	0.0	0.0	0.5	0.1
P8	36	27/10/2006	91.6	0.0	0.0	1.1	2.3	1.8	0.9	0.3	7.5	0.0	1.1	15.1	0.9	0.1	0.0	0.0	0.2	0.1
P8	42	2/11/2006	70.3	0.0	0.0	0.2	2.9	5.3	0.5	0.8	12.2	0.5	1.7	24.1	0.5	0.1	0.0	0.0	0.5	0.7
P8	49	9/11/2006	18.8	0.0	0.0	0.0	1.6	0.5	0.1	0.3	1.9	0.0	1.0	5.5	0.3	0.0	0.0	0.0	0.3	0.9

* lettuce with over 20 CLA per lettuce were noted as 20+ hence total numbers and averages cannot be accurately calculated

^ Acceptable lettuce had less than 20 CLA per head

Appendix A4.1 Sydney Basin survey of growers who's farms were monitored

Aim To evaluate the perceived benefit of having farms monitored by project staff.

Methods
Two NSW DPI extension officers, one who services the field vegetable growers and the other who services the hydroponic growers, contacted their growers to ask a series of questions to understand from the grower's perspectives whether they valued the monitoring by a Technical Officer employed on the Lettuce IPM project. Questions were also asked about whether the visits have resulted in change of practices.

Results
10 hydro growers and 6 field growers responded

Q	Questions	Hydro YES	Field YES
1	Have you had a visit from Tanya Shaw?	9/10	6/6
2	Do you know who Tanya Shaw is?	9/10	5/6
3	Have you had a visit from her in the last 12 months?	7/10	6/6

Q4. Do you know what project she is working on?

RESPONSE	Hydro	Field
No	2/10	0
WFT	5/10	0
Pest monitoring	3/10	0
Lettuce IPM	0	6/6

Q5. Did you find her visits helpful?

Not at all ---a lot

SCORE	1	2	3	4	5
Hydro	5/10	0	2/10	1/10	2/10
WHY?	No visits Found Stacey's visits helpful Thought Tanya was inexperienced Specific problem that project can't help		Good to have visits but not influencing practices Less sprays	Good to get feedback	Know what pests they have Confidence with monitoring Less sprays
Field	0	1/6	0	4/6	1/6
WHY?		Unhappy with scouting and follow up		Already use a crop scout Already use a natural IPM system	Knows what pests are in crop

Did the monitoring help? Not at all ---------------------------- a lot

Q	SCORE		1	2	3	4	5
6	Identify pests you didn't know you had?	Hydro	3/10	3/10	0	3/10	1/10
		Field	1/6	0	0	3/6	2/6
7	Identify beneficials you didn't know you had?	Hydro	3/10	2/10	2/10	2/10	1/10
		Field	0	0	0	4/5	1/5
8	Identify weeds as a problem?	Hydro	2/10	5/10	1/10	2/10	0
		Field	0	0	2/5	2/5	1/5
9	Did the information she provided from the monitoring change you management strategies?	Hydro	3/10	0	4/10	2/10	1/10
		Field	1/6	0	5/6	0	0

Did you change your:

Q		Hydro YES	Field YES	HOW?
10	Spray timing?	3/10	3/5	H-Yes- uses monitoring to make spray decisions H-Yes- sprays fortnightly instead of weekly H-No- still sprays every Saturday F-Yes- earlier application of Dipel F-No- already uses crop scout F-No- have to work around weather and harvest dates
11	Chemical choice?	2/10	1/5	H-Yes- uses Confidor now H-Yes- uses monitoring to decide which chemicals to use H-No- no choices available for certain pests F-Yes- rotate more F-No- already IPM
12	Weed management?	3/10	1/4	H-Yes- awareness of which weeds to manage H-Yes- now has grassed areas around the perimeter F-No- already doing F-No response- knows they're a problem but weather and time limit management
13	Spray frequency?	2/10	1/5	H-Yes- uses monitoring to reduce frequency F-No- have to spray when you have to spray F-No- timing is more important F-Yes- depends on pest pressure in crop
14	Own monitoring practices?	4/10	3/5	H-Yes- checks crop before spraying H-Yes- monitors but still manages in the same way F-Yes- if you've got good bugs, bad ones come along F-Yes- especially for Heliothis F-No- already uses crop scout

If no, what do you feel would help you change any of these things:

H: Nothing specific
H: New controls for WFT, especially new chemicals
H: Regulations to force neighbours to clean up weeds
H: Equipment/skills required to monitor crops
H: Nothing, can only spray once a week anyway
F: Nothing- need to spray to sell product
F: Nothing- already using a crop scout
F: Using a crop scout on regular basis (need to have expert advice- too much for growers to do)

Any other comments?

H Tanya's visits provide confidence when making spray decisions
H Tanya's visits aren't critical, but still valued
H Relies on Tanya's visits for monitoring data
H Would like to see an internet/fax/mobile report on regional pest numbers on a regular basis
H More field days *e.g.* every 6 months
H Rogues weekly for virus now
H On Stacey's advice cleaned up leaves from under benches and reduced TSWV incidence
H Won't change practices- still spray weekly, no real options for WFT
H Confusion between people and projects- poor integration of activities
H Poor follow up with some projects
H Tired of doing the right thing when other growers don't
H Bigger problems than pests & diseases *e.g.* pesticide residues and pricing discrepancies
H Problem is no options. Vic. growers can use pesticides off-label

F Tanya's visits aren't critical, but still valued
F Happy to have extra input on pest numbers, even if they already monitor
F Recognise the value in having a expert to do crop monitoring
F Helped with information about a disease
F The service was a good thing- she soon let me know if there as something out there.
F If you're shown something or some way better, you soon change.
F Wouldn't ever knock back a second set of eyes- they often see things you don't because they have more time to do it.

Appendices R3.1-3 Weed survey host lists

Appendix R3.1. Plant virus hosts

Plant Viruses Online: VIDE database http://image.fs.uidaho.edu/vide/refs.htm (1996)

Parrella, G., Gognalons, P., Gebre-Selassiè, K., Vovlas, C. and Marchoux, G. (2003). An update of the host range of *tomato spotted wilt virus*. Journal of Plant Pathology 85 (4, Special Issue), 227-264.

Appendix R3.2. Known hosts of currant lettuce aphid.

Blackman R L and Eastop V E, 1984, 2000. Aphids on the World's Crops: An Identification Guide. J. Wiley & Sons, London, UK. 644p.

Chicory *(Cichorium intybus)*
Endive *(Cichorium endiva)*
Hawksbeard *(Crepis* sp.)
Hawkweed *(Hieraceum* sp.*)*
Globe artichoke *(Cynara scolymus)*
Nipplewort *(Lapsana* sp.*)*
Petunia *(Petunia* sp.*)*
Speedwell *(Veronica* sp.*)*
Tobacco *(Nicotiana tabacum)*
Dandelion *(Taraxacum officinale)*

Appendix R3.3. Aphids recorded in the Sydney basin survey.

Apple aphid	*Aphis spiraecola*
Artichoke aphid	*Capitophorus elaegni* #
Black citrus aphid	*Toxoptera citricidus*
Blue-green aphid	*Acythosiphun kondoi*
Brown sowthistle aphid	*Uroleucon sonchi* #*
Coriander aphid	*Hyadaphis coriandri*
Cotton/melon aphid	*Aphis gossypii* #
Cowpea aphid	*Aphis craccivora* #
Currant lettuce aphid	*Nasonovia ribis-nigri* #*
Foxglove aphid	*Aulacorthum solani* #*
Green peach aphid	*Myzus persica* #*
Leaf curl plum aphid	*Brachycaudus helichrysi* #
Pea aphid	*Acyrthosiphum pisum* #
Poplar gall aphid	*Pemphigus bursarius* #*
Potato aphid	*Macrosiphum euphorbiae* #*
Sowthistle aphid	*Hyperomyzus lactuca* #
Turnip aphid	*Lipaphus pseudobrassicaceae* #
Wheat/oat aphid	*Rhopalosiphum padi*

Appendix R5.1 Gaucho® Trial Protocol

The trial used a Latin Square design (5 treatments, 5 replicates). Each plot was 2.5 m x 1.2 m in four rows. There were 400 plants per plot, plants were sown 2.5 cm apart in 4 rows. Trial to use 2.5 metre plots with 0.5 metre buffers between trial side and rest of the crop from the top and bottom. Five replicates and with five treatments will make 25 plots.

Control	Monaco 80	Monaco 120	Shiraz 80	Shiraz 120
Monaco 120	Shiraz 80	Shiraz 120	Control	Monaco 80
Shiraz 120	Control	Monaco 80	Monaco 120	Shiraz 80
Monaco 80	Monaco 120	Shiraz 80	Shiraz 120	Control
Shiraz 80	Shiraz 120	Control	Monaco 80	Monaco 120
Rep5	Rep4	Rep3	Rep2	Rep1

Road

Dam

Appendix S2.1 Consultant Survey Responses

Factors assisting grower adoption of IPM

Farmer education

- Having IPM explained, demonstrated and proved successful on their own farm
- Seeing results
- Getting results to growers
- Lazy growers never accept IPM
- Success proven approaches using demonstrations
- Grower understanding of IPM
- Knowledge of growers
- Reliance on agronomists for information
- Education about use of beneficials
- Lack of confidence
- Word of mouth from good farms
- Prove increase in yield or saving money
- Growers need help to change ideas about ‘grubs’ in crops

Technical Issues

- Lower costs of beneficials
- Availability of soft options
- Minimising risk
- Level of technology
- Seen as risky
- Needs good support from industry
- Increased pesticide resistance
- Proven research
- Problem driven

Market issues

- Uptake increases if chemicals not available
- Supermarket demand for high quality produce
- Demands for completely clean product
- Crisis bring on demand for alternatives
- Close support from consultants in providing answers to what do I do

Factors hindering adoption of IPM

Farmer Issues

- Level of grower sophistication
- New generation taking over has more interest in IPM
- Demand for weekly monitoring
- Time to learn about IPM
- Lower tech farmer not interested
- Frustrations with sampling
- Chemical reps don’t want growers going IPM so they are reporting to growers bad experiences with IPM
- Reps undermining grower confidence

Technical Issues
- Lack of consistency
- Unrealistic expectations
- Ease of calendar spraying
- Failures get heard about quickly
- Lack of beneficials
- Difficult to implement
- Lack of soft options

Market Issues
- Supermarkets and buyers demanding an insect free crop irrespective of whether insect is a beneficial, causing day before spraying
- State trade barriers

Suggestions of support required to increase adoption

Education and training
- Active training programs
- Single day IPM awareness raising workshops for growers
- Tours
- Workshops & demonstrations
- Books
- Identifying pests for growers
- Ute guides
- Training of crop scouts
- Training for growers on IPM
- Broaden beneficial recognition
- Training and understanding of thresholds
- Multiday IPM skills days for consultants
- Upskilling of consultants in insect identification, beneficials – no farmers at workshops

Technical support
- Entomology backup that releases consultants from developing expert entomological skills and [so leaves them to] focus on development of IPM plan
- More softer chemicals
- More info on chemicals interaction with biocontrols
- More detailed info in general
- Close back up to answer 'What do I do now?' [types of questions]
- More information on natural enemies and predators

Networking
- Better working with IPM specialists between the states
- Sharing of ideas
- More info to growers through local DPI
- Getting research information back to consultants

- Negotiating an acceptable fee for services [getting growers to accept that they have to/should pay for services]

Research
- Better understanding of cost benefits to growers – help in selling IPM

Aim: Case study of paired IPM & non IPM growers
Identify differences
Attitudes to IPM
Barriers and Drivers for

S3 Appendix 1 Case Study Survey Form

IPM Case Study & Gross Margins

Name:______________________________
Name Farm Enterprise: ____________________
Region:________________________________ IPM/ non IPM
Main Crops grown:____
Other Crops grown:____
Area under cropping:____________________Area under lettuce:____________________

Head Lettuce, Fancy, Babyleaf Field or Hydro

Main Lettuce markets: fresh, processing, domestic, export

IPM Survey questions

1. Do you routinely monitor your crops?

If yes: who does it? Self/employee consultant agronomist with reseller other

2. Do you keep crop records?

Spray records Monitoring Packout Quality notes/damage

2a. Would you be prepared to share them if business name/identifiers are kept anonymous?

[If IPM grower do you have records preIPM adoption?]

3. What are your main Lettuce insect pests, diseases and weeds?

What are your minor Lettuce insect pests and diseases?

Main insect pests	Other insect pests	Main diseases	Other diseases	Weeds

(Note seasonal variation: spring [sp], summer [s], autumn [au], winter [w], all plantings [a])

4. Lettuce Pesticide Use: Average or specific year_______

Insecticides	#/planting	Fungicides	#/planting	Herbicides	#/planting

(Note seasonal variation: spring [sp], summer [s], autumn [au], winter [w], all plantings [a])

Attitudes to IPM

5. Do you consider yourself as being an IPM grower? Yes/No **If No => to Q8**

If yes: how do you define your IPM practice?

Monitoring
Timing sprays
Soft chemistry
Biologicals
Farm design

Other….

6. In your own words, why did you adopt IPM?

7. How important were the following when you adopted IPM?

Keys to adoption (rate on scale of 1- 5; 1 = not important at all, 5 = essential)

1-on-1 support from researchers/consult	1	2	3	4	5
IPM group support	1	2	3	4	5
Industry culture	1	2	3	4	5
Crisis (pest control failure)	1	2	3	4	5
Environmental impact	1	2	3	4	5
Health impact	1	2	3	4	5
Market push	1	2	3	4	5
Regulations	1	2	3	4	5
QA	1	2	3	4	5
Other – please specify	1	2	3	4	5

Comments on keys to adoption:

8. If Not IPM: Have you ever considered following an IPM strategy for pest management? Yes/No

If yes: Why are you not currently practicing

If **no:** Are you happy with your current pest management strategy

b. Do you have any particular gripe with IPM

9. How important are the following as barriers to adoption of IPM for non IPM growers?

Barriers to adoption (rate on scale of 1- 5; 1= not important at all, 5 = essential)

Current control adequate	1	2	3	4	5
Cost of adoption too high	1	2	3	4	5
No available consultants	1	2	3	4	5
Consultants not supportive of IPM	1	2	3	4	5
Too few soft or biological options available	1	2	3	4	5
No clean up chemicals available	1	2	3	4	5
Secondary pests	1	2	3	4	5
Quality poorer	1	2	3	4	5
Market requirements	1	2	3	4	5
Too complicated	1	2	3	4	5
Too risky	1	2	3	4	5
No (perceived) advantage	1	2	3	4	5
Other – please specify	1	2	3	4	5

Comments on barriers to adoption:

10. Has the adoption of IPM changed

a). the number of sprays used? *comment*:____

b). the types of sprays used *comment*____

c). other aspects of crop management *comment*:_______________________________________

11. Has IPM/Do you think IPM would

a). cost more/less/no change in chemical *comment*:____________________________________

b). cost more/less/no change in diesel *comment*:______________________________________

c). cost more/less/no change in labour (monitoring) *comment*:_____________________________

d). cost more/less/no change in marketable yield *comment*:_______________________________

12. Has IPM/Do you think IPM would

a). Improved or diminished crop quality *comment*:_____________________________________

b). Improved or diminished OH&S concerns *comment*:__________________________________

c). Improved or diminished residue issues *comment*:___________________________________

13. With adoption of IPM

a). Do you see more/less/no change to insect damage *comment*:___________________________

b). Do you see more/less/no change in disease levels *comment*:____________________________

c). Is damage more/less/no change predictable *comment*:________________________________

d). Is your crop more/less/no change in saleability *comment*:______________________________

e). Do you have more/less/no change in crop rejections *comment*:__________________________

Importance of IPM tools available in the crop *Rate importance by ticking the appropriate box*

Tool	Not important	Somewhat important	Important	Very important	Essential	Notes/qualifications/comments
Best bet thresholds						
Experimentally derived thresholds						
New chemistry e.g Success, Avatar,						
Biological insecticides e.g. virus, Bts						
Crop scouting protocol						
Resistant Varieties Nas Downey Corky root Black root rot Bigvein						
Endemic beneficials Nabids Ladybirds Lacewing Hover flies Parasitic wasps						
Cultural controls						
Roughing diseased crops	…	…	…	…	…	
Weed management within crop	…	…	…	…	…	
Weed management around crop	…	…	…	…	…	
Planting time	…	…	…	…	…	
Nutritional management	…	…	…	…	…	
Water management	…	…	…	…	…	
Post harvest cultivation	…	…	…	…	…	
Crop rotation	…	…	…	…	…	
Cover crops	…	…	…	…	…	