Know-how for Horticulture™

Integrating lettuce aphid into integrated pest management strategies

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DPIWE, Tasmania

Project Number: VG04067

VG04067

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Final Report for project VG04067 (completion date 31 January 2006)

Project Title: **Integrating lettuce aphid into IPM for lettuce: a commercial trial.**

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Research Providers:

Department of Primary Industries, Water and Environment, Tasmania

IPM Technologies P/L

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VG04067

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Purpose:

Following the arrival of currant lettuce aphid in Australia this project sought to teach Tasmanian lettuce growers how to integrate control of all pests in commercial-scale lettuce crops; to demonstrate this (Integrated Pest Management) to a broader audience and to demonstrate that seedling insecticidal drenches, although effective against aphids, do not integrate with management of other pests.

Funding:

This project was supported by $75,000 from the National Vegetable Levy, a loan of planting equipment from Bovill Brothers, access to the Forthside Research and Demonstration Farm belonging to DPIWE, Tasmania, and access to Bovill Brothers' farms.

Date of report: 17 January 2006.

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Executive Summary

1. This project was initiated because of the arrival of a new pest, currant lettuce aphid, in Australia. The pest arrived in Tasmania, and not on the mainland, in February 2004.
2. The only approach officially sanctioned and recognised has been the use of high rates of Confidor on seedlings.
3. The Confidor treated seedlings have so far controlled lettuce aphid, but have killed predators of aphids and so an IPM approach using native predators is incompatible.
4. This project assessed for the first time in Australia the potential for a non-pesticide based control method for lettuce aphid.
5. This project has demonstrated to growers and entomologists that there is a viable alternative to high rates of Confidor drenching on seedlings to control lettuce aphid in Australia.
6. The aphid reached Victoria by May 2005 and further assessment of the potential for IPM to control lettuce aphid is happening in Tasmania and Victoria.
7. The assessment at this stage is that there is every expectation that an IPM approach to dealing with this pest will be effective.
8. The project fast-tracked field testing and adoption of IPM in a novel pest-crop combination with modest expenditure.

Media Summary

Common predators of farmland controlled currant lettuce aphid, a new pest in Tasmanian lettuce crops. The predators entered lettuce hearts, eliminated aphids and vanished before harvest. Insecticides sprayed on lettuce failed because this pest lives inside lettuces unlike other aphids.

A few systemic insecticides will travel up the sap of lettuce if drenched around the roots. They control the new aphid but not caterpillars. It is feared that their use will not integrate with selective management of caterpillars. Caterpillars and aphids share natural predators that die if they eat poisoned aphids - control of one pest does not integrate with control of another. Ignoring integration leads to complex, expensive, repetitive spray schedules or failure.

The aphid first arrived in Tasmania in February 2004, spread to Victoria by May 2005 and will spread to other states. Complete crop losses occurred in Tasmania when insecticides were used inappropriately. Interstate trade remains disrupted in early 2006.

The national vegetable levy funded this project to test whether Integrated Pest Management (IPM) is appropriate for lettuce. Predators and parasites of many pests in lettuce crops were fostered by providing an unbroken sequence of crops managed only with selective pesticides. They were used only when observation suggested a deteriorating balance between predators and pests.

Lettuces were grown in nine, sequential, adjoining plantings from spring to autumn. Growers learned technical skills of IPM at five small-group field days. Growers and wholesalers repeatedly rated the lettuce as clean at maturity and fit for market. Thousands of IPM lettuces were sold without complaint from consumers.

Control failed in autumn when larger areas of lettuce that had been root-drenched with systemic insecticides were planted adjacently to smaller areas of IPM lettuce.

Brown lacewings, transverse ladybirds, 11-spotted ladybirds and hoverflies provided excellent control in the first seven plantings. They complemented 1-2 applications of bacterial or fungal insecticides for control of caterpillars. A range of spiders and parasitic microwasps supplemented control.

Pilot IPM crops are being grown by two major Tasmanian growers in the 2005-6 season. Many large commercial IPM crops have already been successfully grown in Victoria by January 2006 under supervision of IPM Technologies P/L.

Technical Summary

Nine crops of lettuce were planted at fortnightly intervals through spring, summer and autumn in a vegetable production district near Devonport, Tasmania where currant lettuce aphid is a new pest.

The total trial area was one hectare but only one third grew lettuce at any one time while the remainder was fallow. It was surrounded by crops of onions, broccoli, potatoes, barley, canola and pasture. Each crop or 'planting' had 5,500 lettuces and occupied 0.1 ha. Crop layout, irrigation and nutrition followed commercial practice. The edges of the trial area and two internal vehicle lanes grew pasture. One 0.1 ha planting of rocket, a salad brassica (*Eruca vesicaria*), preceded the first lettuce by 10 days.

A combination of susceptible (⅔) and *Nasonovia*-resistant cultivars (⅓) was grown in each planting up to the sixth after which only susceptible cultivars were grown. The resistant lettuces sustain other aphids and other pests for which Integrated Pest Management (IPM) is also relevant but the term IPM is mostly restricted in this report to the susceptible lettuce treatment.

Choice of insecticides was determined by their impact on beneficial species, their cost and their efficacy against pests. Xentari with Mobait, DiPel and Success were used occasionally to control caterpillars. Initially, a calendar program of three fungicides was adopted on professional, commercial advice but was progressively abandoned so that no fungicides were used in later plantings.

In several plantings, 5-19% of lettuce received Chess ™ or Confidor ™ drenches or foliar sprays of Pirimor ™ or Dominex 100EC ™ as ancillary investigations. Control of aphids in IPM lettuce succeeded in these plantings.

In the last two plantings 66% of seedlings were root-drenched with Chess or Confidor and 33% not drenched. Control of aphids in the undrenched (IPM) lettuce failed in these two plantings.

A laboratory experiment investigated the impact of Actara ™ and Confidor drenches on brown lacewings eating potato aphids on drenched lettuce. Such diets were highly toxic to brown lacewing for 4-5 weeks and to aphids for 6 weeks.

A series of five field days designed for small groups of growers or agronomists to learn IPM skills were held. Two larger open days made the project familiar to a broader audience.

Experienced Tasmanian agronomists and growers said at an early field day that the current level of lettuce aphid in immature lettuce would result in unacceptable contamination at harvest. A fortnight later they were surprised at the downward trend in aphids as crops aged but still expected rejection of the first crop. Another fortnight later growers assessed the mature first planting in the field. All present assessed the crop as meeting their standards.

By six weeks later, on 19 January 2005, the fourth planting was mature. It confirmed a continuing pattern in each planting of noticeable infestation during the first 3-5 weeks of each crop followed by progressive elimination of aphids and insignificant contamination by aphid residues or predators. Contamination at maturity by live aphids was no greater than in drenched lettuce. It averaged 1-3 aphids per lettuce, which were 'invisible' to all growers and supermarket agents. Drenched lettuce had most contamination by caterpillars. Resistant lettuce had least contamination by aphids but were comparable to IPM lettuce in contamination by caterpillars. Drenched and resistant lettuce also received benefits of predators from adjacent IPM lettuce but not vice versa.

Additional measures of marketability of undrenched aphid-susceptible IPM lettuce were obtained by selling 550 dozen. The state buyers for Woolworths and Coles also assessed several cartons of undrenched susceptible IPM lettuce. Neither the marketplace nor the supermarket buyers rejected the lettuce.

Caterpillar pests included both *Helicoverpa* (heliothis) species, green loopers, true cutworms, chevron cutworm, green cutworms and occasional leafrollers. Heliothis caterpillars were usually more abundant in drenched (both Chess and Confidor) than undrenched lettuce. Heliothis caterpillars were equally or more abundant in undrenched *N*-resistant plantings than in undrenched susceptible plantings.

Other pests were Rutherglen bug, yellow leafhopper, brown leafhopper, potato bug, thrips and slugs.

Beneficial insects included brown lacewing, 11-spotted ladybird, transverse ladybird, *Melangyna* hoverfly, damsel bug, spiders, microhymenoptera, predatory mites and *Aeolothrips* thrips.

IPM is viable for managing Tasmanian lettuce pests including currant lettuce aphid. It failed in autumn when attempted adjacent to larger areas of drenched lettuce. The sequence of plantings and the areas that can support populations of beneficial species are critical in an IPM strategy. Indirect poisoning of lacewings by ingestion of poisoned aphids persisted for several weeks at low rates of imidacloprid drench.

Confidor and Chess seedling drenches, including a low rate of Confidor, were associated with the highest *Helicoverpa* caterpillar populations and did not reduce cutworm problems. However the low rate (5.5 g) of imidacloprid produced marketable lettuce.

The broad spectrum insecticide, Dominex exacerbated lettuce aphid infestations. Pirimicarb may have temporarily disrupted natural control of lettuce aphids.

Introduction

There are several major lettuce growing regions in Australia, including the Lockyer Valley in southern Queensland, the Riverina of NSW, Werribee in southern Victoria, the Adelaide Hills of South Australia and northern Tasmania. Despite the differences in climate and growing seasons between these regions, there are several common insect pests that damage crops. These include native budworm, corn earworm*,* western flower thrips and several species of aphids. (Scientific names in Appendix 5).

In recent years, control strategies for these pests shifted away from routine applications of broad-spectrum insecticides. More growers are now aware of integrated pest management and they integrate applications of selective or 'soft' insecticides with cultural and biological control methods.

Biological control usually relies on the build-up of natural populations of beneficial species, which includes brown lacewing, damsel bug, transverse ladybird and *Aphidius colemani* (aphid parasite). The use of selective insecticides which impair only the target pest are critical in fostering populations of the beneficial species. Brown lacewing is the major predator of aphids in lettuce and other crops using IPM in southern Australia (Horne, unpublished data; and Horne, Ridland and New, 2001). Insecticides impair insects, including predators, not only by killing them but by sublethal effects such as infertility. This can happen when predators eat poisoned prey.

During the growing season of 2003/04 a new aphid was found in lettuce crops in Tasmania. This was the first record in Australia. This aphid is a pest of lettuce in New Zealand, North America and Europe. It has been responsible for large yield losses because it lives deep inside the head of maturing lettuces secure from foliar insecticides. It is not secure from systemic insecticides or predators such as brown lacewing, ladybirds and hoverflies.

The Australian vegetable industry is greatly concerned about the impact that this pest may have on lettuce crops. Their strategic plan to help combat the perceived impact of this pest included development of resistant lettuce varieties and high rates of imidacloprid insecticide as a seedling drench. Many growers have adopted the practice of drenching seedlings just prior to planting with imidacloprid. Imidacloprid is toxic to a broad range of insects (Koppert 1998) but not caterpillars which are a major pest of lettuce. If predators are impaired after eating poisoned aphids they are not available to complement the soft insecticides that are increasingly used for caterpillar control or to restrain other pests for which no selective insecticides are available.

This project sought:

- to teach Tasmanian lettuce growers how to integrate control of several pests in commercially realistic lettuce crops;
- to demonstrate this (Integrated Pest Management) to a broader audience;
- to demonstrate that seedling insecticidal drenches, although effective against aphids, probably will not integrate with management of caterpillars and perhaps other pests;
- to examine some related issues such as the performance of *Nasonovia*-resistant lettuce and low drench rates.

Material & Methods

Terminology

The term IPM lettuce is restricted in this report to undrenched, *Nasonovia*-susceptible lettuce although *Nasonovia*-resistant lettuce may also sustain IPM.

The abbreviations P1, P2 … P9 are used for plantings 1 to 9. The term outer leaf refers to the outer 6-8 leaves and inner leaf to the remainder such that inner leaves include both the tight head and several, loose, 'wrapper' leaves.

Lettuce aphid is used as shorthand for currant lettuce aphid, *Nasonovia ribisnigri*. Heliothis is used as an indeterminate common name for both native budworm and corn earworm.

Scientific names of insects and allied organisms are given in Appendix 5.

Technology transfer (Extension)

In a series of five field lessons IPM advisors with commercial experience and extension entomologists met growers and/or their advisory agronomists on 4, 17 and 18 November, 2 December 2004 and 19 January 2005. Agronomists from the private sector services, which are substantial and very influential in Tasmania, were given by various communications the opportunity to attend field days. About 15 Tasmanian lettuce growers and several senior private agronomists received personal written invitations to each of four field days. A series of progressive reports on a local ABC Radio rural program further advertised the series of field days. Some interstate attendance, including ad hoc tour groups, were achieved through the industry network. Most major stakeholders were well aware of the project.

Growers and agronomists inspected sequential plantings of lettuce at various ages, observed how the balance of pest and beneficial insects could be rapidly assessed, discussed the selectivity of pesticides and discussed the management options at several stages of several plantings.

The initial intention was to hold group size near a dozen to ensure growers or agronomists had ready access to tutors. However the success of IPM in the first two plantings generated a larger audience at the later field days.

A field day for the general public on 9 January 2005 provided another opportunity to publicise the project to visitors such as leading broccoli and Brussells sprouts growers interested in attempting IPM in brassica crops.

Agronomy

Lettuces were grown following local commercial practice as much as possible but the pesticide program was modified on advice from Dr Paul Horne of IPM Technologies P/L. The trial demonstrated and taught IPM and did not investigate processes experimentally. Controls and replication were a secondary consideration because crop-scale (treatment plot size) was as large as financially possible.

A calendar program of three fungicides, adopted on commercial advice, was progressively abandoned because one fungicide appeared injurious to transverse ladybirds and another was deregistered during the trial.

Most of the project was conducted at Forthside Research and Demonstration Farm, 10 km west of Devonport in north-western Tasmania. Some complementary field observations were made in commercial lettuce crops adjacent to Devonport. A simple laboratory in Devonport provided facilities for sorting, counting and identifying insects. A substantial complementary bioassay to determine the impact of root-drench insecticides on brown lacewing was conducted in the laboratory of IPM Technologies P/L in Melbourne, Victoria.

Paddock 6 at Forthside Research and Demonstration Farm was used for the 1 ha demonstration crop and Paddock 13, about 300 m to the north, for a few beds of lettuce that were treated with the unselective insecticide, alphacypermethrin, 1-4 times to reveal the potential for aphid multiplication in the absence of predators.

Paddock 6 was on the southwestern side of the farm (map in Appendix 2). To the south side was Kings Lane and a commercial organic farm sown mostly to pasture. The other sides of paddock 6 adjoined diverse, small crops of broccoli, potatoes, onions and barley. About 200 m to the east was an experimental crop of lettuce grown for the companion project, VG04068, in which seedling drenches and systemic foliar insecticides were applied in small, replicated plots (Appendix 2, Paddock 3).

Paddock 6 contained broccoli, onions, potatoes and rye corn in the previous season. It was ploughed on 21 July 2004 and left fallow as a stale seedbed until 22 September when it was cultivated. A 3x3 grid of plots, each 30 x 34 m, to accommodate one planting of rocket and nine adjoining plantings each of 5,500 lettuces were pegged out and grass planted in laneways and headlands in late September. The rocket preceded the first lettuce by 10 days. The fourth and ninth lettuce plantings occupied the same ground (the central plot) but each of the other plantings occupied new ground. The residues of each planting were cultivated into the soil about a fortnight after maturity. At any one time there were about three, contiguous plantings present surrounded by clean or weedy fallow plots.

The nine plots were planted at 2-3 week intervals and crops matured as detailed in Table 1. Durations from planting to maturity ranged from 48 (Planting 5) to 77 (Planting 9) days with a mean of 62 days or 8.8 weeks.

Table 1. Planting and maturity dates of the nine plantings of lettuce and one of rocket in paddock 6, Forthside Research and Demonstration Farm.

Planting	Planted	Final visual assessment near crop maturity
Rocket	23 September 2004	-
1	30 September 2004	30-Nov-04
2	13 October 2004	20-Dec-04
3	10 November 2004	4-Jan-05
4	24 November 2004	20-Jan-05
5	15 December 2004	1-Feb-05
6	7 January 2005	28-Feb-05
7	27 January 2005	22-Mar-05
8	16 February 2005	20-Apr-05
9	8 March 2005	10-May-05

A day or two prior to planting each plot received predrilled fertiliser (13-14-13 + trace, 375 kg/ha), was cultivated by roterra and rolled. Pre-emergent herbicide (Kerb) was applied by boom spray one day after planting. Seedlings were planted using a tractor-drawn, three-row transplanter. Beds were 1.6 m wide, not raised and lettuces were 35.56 cm (14-inch) apart. Each planting was 30 m long and 34 m wide so that it had 21 beds. Supplementary fertiliser was applied after planting as detailed in Table 2. Plantings were weeded by manual hoeing at fortnightly intervals.

Irrigation was applied by solid-set sprinklers on a 9x12 m grid. These rows of sprinklers divided each planting into three bays with seven beds per bay.

In each of P1-P6 the northern bay contained seven beds of resistant cultivars while the other two bays each contained seven beds of susceptible, undrenched cultivars managed by IPM except that 1-2 (but six in P3) beds of the 14 susceptible beds were used for exploratory treatments of pirimicarb (P1 and P2), alpha-cypermethrin (P4) or pymetrozine and imidacloprid (P3, P5 and P6) (See plan, Appendix 3). In P3 two rates of imidacloprid were included but in P5 and P6 only a low rate was applied. See Table 3 for common and trade names of pesticides and Table 4 for details of exploratory treatments.

Two beds of Cos lettuce were included in the seven beds of resistant cultivars in P1-5 but not in P6.

Resistant cultivars were included in P1-6 because a major grower who we sought to influence did not expect IPM with susceptible cultivars to succeed but wanted to evaluate resistant cultivars. This greatly increased sampling work reduced the scale of susceptible IPM demonstration and perhaps diminished predator abundance adjacent to the susceptible plants.

In P7 resistant cultivars were not planted so that all 21 beds were susceptible lettuces managed by IPM except that four beds were used for pymetrozine and low-rate imidacloprid drenches.

In P8 and P9 all lettuce were susceptible but the relative area of drenched plantings was increased because it was felt that the influx of predators from adjacent IPM beds in earlier plantings masked the effects of the drenches and that IPM using undrenched, susceptible lettuce had already proven viable in seven plantings. Two-thirds of P8 and P9 were drenched and one-third were undrenched susceptible lettuces. This proved to be a poor decision in that it took the focus away from IPM but was driven by a desire to find IPM-friendly drench rates or active ingredients.

The chronological pesticide regime for susceptible, IPM-lettuce and *Nasonovia*-resistant lettuce in each planting is listed in Table 5. A few other beds received additional pesticides as described above and summarised in Table 4. Bt (*Bacillus thuringiensis*), spinosad and fungicides were applied by a tractor-mounted, 12-metre boom-spray fitted with size-16 cone nozzles operating at 5 Bar pressure. However, alpha-cypermethrin and pirimor were applied by back-pack 1-metre boom in paddocks 6 and 13. Pirimor was applied to P1 and P2 at 1 kg/ha in 250L/ha of water at 1500 hours at 23ºC.

In paddock 13 three small plantings (80-200 each) of undrenched, susceptible lettuce were grown at 4-weekly intervals and sprayed with alpha-cypermethrin 1-4 times. Initially we intended to withhold insecticides here in order to assess the response of caterpillars and other pests while selective, soft insecticides would be used for caterpillars in paddock 6 on comparable lettuce as necessary. However, comments at field days that IPM was succeeding only because lettuce aphid pressure was lower than the previous season prompted us to use the lettuce in paddock 13 to induce infestations by applying a broad-spectrum insecticide to disrupt natural control and demonstrate that pest pressure was substantial.

For the purpose of deciding on pesticide interventions the population trends of pests and beneficials were assessed by visual examination of several lettuces in the field. Population trends of pests and beneficial insects, mites and spiders were also assessed by vacuuming lettuces during early weeks of crop growth. Initially vacuuming was performed from week 1 to 7 but eventually restricted to weeks 2, 3 and 4 after planting. Table 6 shows the schedule. Vacuum samples took a few days to process for seven treatments and many taxa and, in reality, were secondary to the in-field visual checks in decision making. However, vacuuming can be useful in commercial practice if only key pests and predators are counted in the field.

Table 2: Fertiliser regime in lettuce plantings.

Before planting	13-14-13 + trace, 375 kg/ha
1 day after planting	GRO-CAL MGB
week 3 after planting	Nitrophoska®
week 5	Balance Foliar (P1-P5) or Wuxal Liquid® (P6-P9)
week 6	Balance Foliar or Wuxal Liquid
week 7	Balance Foliar or Wuxall Liquid

Table 3. Insecticides and fungicides used in the field during project

Bacillus thuringiensis or Bt, XenTari®
Bacillus thuringiensis or Bt, DiPel ® DF
Food flavourings Mobait (feeding attractant)
spinosad Success ™
pymetrozine Chess ™
imidacloprid Confidor ™
pirimicarb Pirimor®
alpha-cypermethrin Dominex 100EC ™
procymidone Sumisclex 500™
procymidone Fortress 500 ™
mancozeb Penncozeb 750DF ™
Copper hydroxide Kocide Liquid Blue®

Table 4. Summary of ancillary field treatments.

Active	Trade Name	Rate	Planting
alpha-cypermethrin	Dominex	250 ml / ha	P4 and paddock 13
pirimicarb	Pirimor	1 kg / ha	P1 and P2
imidacloprid	Confidor	55 g / 1000 seedlings	P3
imidacloprid	Confidor	5.5 g / 1000 seedlings	P3, P5-P9
pymetrozine	Chess 250 WP	30g /1000 seedlings	P3, P5-P9

Table 5. The pesticide (including Kerb herbicide) regime for the nine plantings of *Nasonovia*-susceptible IPM lettuce.

Rocket	23/09/2004	Planted
Planting 1	30/09/2004	Planted
	1/10/2004	Kerb
	1/10/2004	Sumisclex 500
	8/10/2004	Kocide Liquid Blue
	15/10/2004	Sumisclex 500
	15/10/2004	Penncozeb 750 DF
	22/10/2004	Fortress 500
	22/10/2004	Penncozeb 750 DF
	28/10/2004	Penncozeb 750 DF
	28/10/2004	Sumisclex 500
	4/11/2004	Penncozeb 750 DF
	4/11/2004	Fortress 500
	8/11/2004	Mobait
	8/11/2004	Activator
	8/11/2004	Xen Tari
	9/11/2004	Two beds got Pirimor at 1kh/ha
	12/11/2004	Fortress 500
	12/11/2004	Penncozeb 750 DF
	17/11/2004	Fortress 500
	17/11/2004	Penncozeb 750 DF
Planting 2	13/10/2004	Planted
	15/10/2004	Sumisclex 500
	15/10/2004	Kerb
	22/10/2004	Kocide Liquid Blue
	28/10/2004	Sumisclex 500
	28/10/2004	Penncozeb 750 DF
	4/11/2004	Penncozeb 750 DF
	4/11/2004	Fortress 500
	8/11/2004	Activator
	8/11/2004	Mobait
	8/11/2004	Xentari
	9/11/2004	Two beds got Pirimor at 1 kg.ha
	12/11/2004	Fortress 500
	12/11/2004	Penncozeb 750 DF
	17/11/2004	Penncozeb 750 DF
	17/11/2004	Fortress 500
	25/11/2004	Success
Planting 3	10/11/2004	Planted
	12/11/2004	Fortress 500
	12/11/2004	Kerb
	17/11/2004	Kocide Liquid Blue
	25/11/2004	Success
Planting 4	24/11/2004	Planted
	25/11/2004	Success
	25/11/2004	Kerb
Planting 5	15/12/2004	Planted
	17/12/2004	Kerb (& Success preplant 25 Nov)
	22/12/2004	Kocide Liquid Blue
Planting 6	7/01/2005	Planted
	11/01/2005	Kerb
	14/01/2005	Kocide Liquid Blue
Planting 7	27/01/2005	Planted
	28/01/2005	Kerb
	4/03/2005	Dipel
Planting 8	16/02/2005	Planted
	18/03/2005	Kerb
	4/03/2005	Dipel
Planting 9	8/03/2005	Planted
	8/03/2005	Kerb

For P1 and P2, 100 plants were vacuumed on each date but thereafter one row (86 plants) was vacuumed at walking pace. A different row was used on each occasion. Edge rows were avoided. The intake duct of the vacuum machine was a 25 cm diameter truncated cone of fine metal mesh. By stopping the vacuum motor the vacuumed insects were emptied down a large funnel into a 50 ml vial containing ethanol and taken to a laboratory for microscopic counting of several taxa including aphids, predators, parasites and common higher taxa such as Brachyceran and Nematoceran Diptera (gnats, midges and flies).

Table 6. Schedule of vacuum samples expressed as days after planting (DAP).

DAP	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Planting 1	8	15	21	28	34	40	46
Planting 2	7	15	21	27	33	40	
Planting 3			20	27			
Planting 4		13	19	26			
Planting 5	9		20	27			
Planting 6		10	17	24			
Planting 7		11	18	25			
Planting 8		12	19	27			
Planting 9		13	25	30			

Destructive samples of lettuce were taken a fortnight before maturity and at maturity for detailed visual examination. Table 7 shows the schedule of these samples. Sample sizes ranged from 20 to 40 lettuces per treatment. Different cultivars of susceptible IPM or resistant lettuce represented different treatments so that up to seven treatments were assessed in each planting. As with vacuuming, the resistant cultivars (up to three per planting), pirimicarb and alpha-cypermethrin treatments, and drench treatments (up to three per planting) multiplied sampling effort and distracted from documenting trends in the undrenched, susceptible IPM lettuce.

Lettuces in destructive samples were inspected on a bench in a shed, leaf by leaf, by a team of four observers using eyes and occasional hand lens. Each lettuce required about 10 minutes for dissection. The fauna on the outer six leaves was scored separately from the remainder. The lettuces were initially cut at ground level so that all leaves were taken for visual observation but data collected for outer leaves is not analysed in this report.

Table 7. Schedule of destructive visual samples of lettuce expressed as days after planting (DAP).

DAP	First	Second	Third	Maturity in weeks	Date of final Assessment
Planting 1	57	62	-	9	30-Nov-04
Planting 2	58	62	68	9	20-Dec-04
Planting 3	40	55	-	8	4-Jan-05
Planting 4	43/48	57	-	8	20-Jan-05
Planting 5	48		-	8	1-Feb-05
Planting 6	48	62	-	9	28-Feb-05
Planting 7	39	54	62	9	22-Mar-05
Planting 8	49	63	-	10	20-Apr-05
Planting 9	60	77	-	11	10-May-05

One water trap (300 x 400 x 70 mm yellow tray) was placed on a fence at the northern edge of paddock 6 at 1.2 m height. The catch was collected at 1or 2-weekly intervals during the project.

Data from a 160-Watt mercury vapour light trap of Rothamsted-pattern operated at Devonport for 10-12 years was also available for brown lacewing, *Melangyna* hoverfly, damsel bug and the noctuid pests relevant to this project.

Pheromone traps for noctuid pests such as native budworm and corn earworm were not operated for this project.

Results

Pests and beneficial species encountered

The common beneficial insects were brown lacewing, 11-spotted ladybird, transverse ladybird, *Melangyna* hoverflies, several spider species, damsel bugs, many microwasp parasites, predatory mites and predatory *Aeolothrips* thrips. The first four were regularly seen inside lettuce a fortnight before harvest but were rare at harvest.

The major pests were aphids and six species of noctuid caterpillars but leafhopper, Rutherglen bugs and thrips were also present as detailed below.

Notable absences from the fauna of lettuces in paddock 6 as determined by vacuum and visual inspections of lettuce were the pests vegetable leafhopper, western flower thrips, cluster caterpillar, lucerne leafroller and silverleaf whitefly and the predators common spotted ladybird, white-collared ladybird, minute pirate bug, bigeyed bug, assassin bug, predatory shield bug and the caterpillar egg parasitoids *Telenomus* sp. and *Trichogramma* sp.

Overview of results with IPM (*N*-susceptible, undrenched) lettuce

Integrated pest management using susceptible lettuce produced successful crops in all plantings (1-7) where IPM was not compromised by the proximity of hostile habitats. Two peaks of aphid flights occurred in this period (Fig. 1). It failed in plantings 8 and 9. These differed from preceding plantings in being one half the area of adjoining drenched (imidacloprid and pymetrozine) lettuce rather than several times larger. One peak of aphid flight activity occurred in this period. Currant lettuce aphid contaminated P8. It and sow thistle aphid caused gross contamination of P9. Most (over 80%) aphids present in undrenched lettuce of P9 at maturity were dead from fungal infection at assessment (Table 8).

Table 8. Whole mean numbers (rounded up) of aphids, all species, and other notable insects vacuumed per 100 lettuce plants at weeks 3 and 4 after planting or seen in lettuce near (around 6-8 weeks after planting) and at maturity (8-11 weeks). The first of two values for planting 8 is for lettuce furthest from - and the second for lettuce closest to - adjacent drenched lettuce. * Two sampling dates in 6-8 week bracket yielding 448 aphids at 39 days and 8 at 54 days.

Planting	1	2	3	4	5	6	7	8	9
Winged aphids	20	16	1	2	29	22	3	5	26
Wingless aphids	7	11	1	3	18	8	1	5	59
lacewing adults	0	2	1	1	7	4	7	0	0
ladybird beetles	0	1	4	2	2	6	2	0	0
ladybird grubs	0	0	0	0	2	0	0	0	0
microwasps	3	5	8	10	39	27	5	12	37
spiders	6	0	9	6	26	14	13	16	28
6-8 weeks, visual, all aphids	100	55	25	135	-	33	448/8*	194	22600
8-11 weeks, visual, all aphids	295	160	18	160	73	40	33	7250	3500
Adult lacewing at maturity	10	5	13	0	3	3	3	3/0	23
Immature lacewings at maturity	15	10	28	20	5	0	3	13/20	23
Hoverfly larvae at maturity	0	10	3	0	15	3	3	50/40	73
All ladybird stages at maturity	0	0	0	0	0	0	0	0	0
Predatory mites at maturity	5	5	0	0	0	3	0	0/3	0
Adult rove beetles at maturity	5	0	10	0	3	18	0	0/3	0
Spiders at maturity	0	0	0	0	3	8	0	0/0	0
Predatory *Aeolothrips* at maturity	0	0	0	0	0	0	0	0	0

Several hundred dozen of IPM-lettuce from plantings 1-7 were sold in local shops without complaint. Growers and buyers who inspected IPM lettuce rated them fit for market. Lettuce from P8 and P9 from the low-rate imidacloprid treatment were also sold without complaint from buyers.

A summary of insecticide applications to IPM-lettuce is given in column 2, Table 13. A chronological history appears in Table 5. In summary, IPM lettuce of P5, P6 and P9 received no foliar insecticides while P1, P2, P7 and P8 received foliar Bt, and P2-P4 received foliar spinosad. Weeds in the plot used for P5 received spinosad against cutworm 20 days before lettuce were planted. Caterpillars were the targets of all foliar applications. In particular, numerous second instar common cutworms were vacuumed from the early plantings and were seen as a threat. Subsequently the presence of some heliothis caterpillars and finally the appearance of chevron cutworm and green cutworm caterpillars caused concern.

Other pests such as leafhoppers, thrips, potato bug and Rutherglen bug were present but never proliferated sufficiently to cause concern. The application of spinosad to P2-P4 on 25 November 2004 when these sequential plantings were at very different stages of growth probably had little influence on this result.

The first two plantings each included 4-5 applications of mancozeb fungicide, which was suspected on the second field day (18 November) of reducing the immature transverse ladybird population that was apparent on the first field day (4 November) in P1 and P2. Eleven-spotted ladybird was apparent in P1 and P2 on 18 November and is the species detected by vacuuming as shown in Table 22 for P2. Vacuum data in Table 22 does not fully reflect these field visual observations by experienced IPM consultants. Mancozeb was not used in later plantings and no significant losses to fungi followed. The other two fungicides were progressively abandoned as can been seen in Table 5. Later plantings supplied lettuce to local shops when two commercial growers in the district using heavy fungicide programs were unable to do so because of fungal or bacterial infections.

Aphid identities and disease

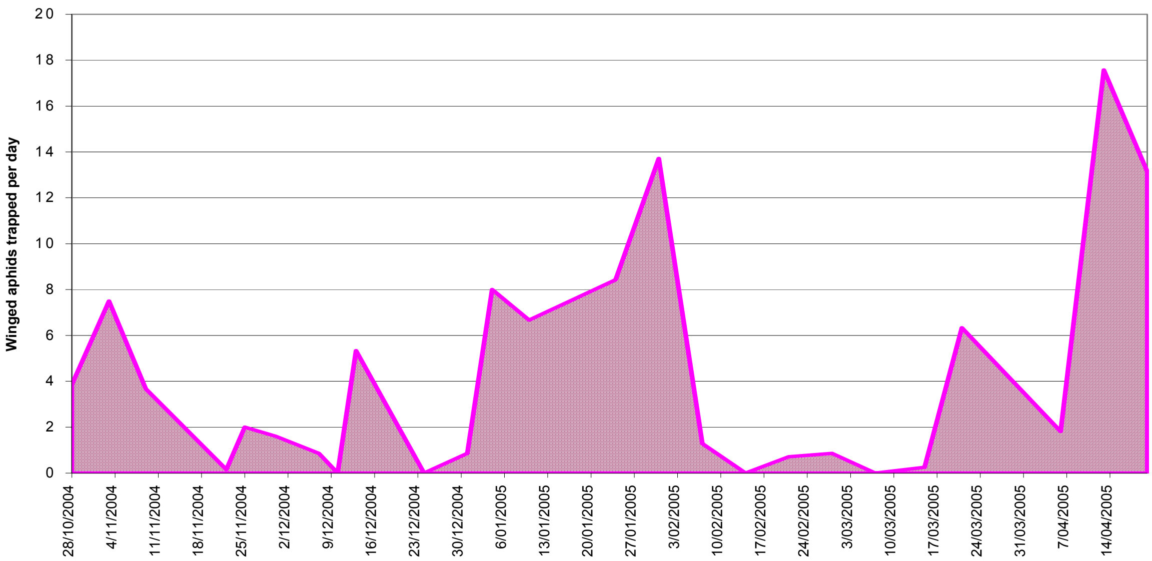
The dominant winged aphids vacuumed from lettuce are listed in Table 9. Weeds contiguous with vacuumed lettuce may account for a few records.

Table 9. Species of aphids that were vacuumed from lettuce beds by walking with a vacuum machine intake immediately above lettuce.

Species of aphid	winged	wingless
Aphis gossypi, cotton aphid	yes	yes
Brachycaudus sp.	yes	rare
Nasonovia ribis-nigri, currant lettuce aphid	yes	yes
Macrosiphum euphorbiae, potato aphid	yes	yes
Aulacorthum solani, foxglove aphid	yes	yes
Myzus persicae, green peach aphid	yes	yes
Rhopalosiphinus sp.	yes	no
Hyperomyzus lactucae, blackcurrant-sowthistle aphid	yes	no
Uroleucon sonchi, sow thistle aphid	yes	yes
Brevicoryne brassicae, cabbage grey aphid	yes	no
Other	yes	yes

The flight peaks for all species of winged aphids indicated by the yellow water tray are shown in Figure 1 and Appendix 4. Figure 1 indicates three major flights - one each in spring, summer and autumn. Many species, such as cotton, green peach, sow thistle and foxglove aphids were trapped in the yellow tray but not counted separately. The proportion of currant lettuce aphid in each catch is not known but they were present in all peaks.

Figure 1. Catch rate of all species of winged aphids in a yellow water tray trap in paddock 6 from October 2004 to May 2005 which spans the period of P1-P9.



Wingless lettuce aphids were vacuumed from all plantings. Their numbers followed a similar trend of three peaks as occurred in the yellow water trap (Table 10). Winged lettuce aphids dominated vacuum samples for late summer whereas other species predominated in spring and autumn. Cotton, green peach, foxglove and potato aphids predominated in vacuum samples in late October while these plus *Brachycaudus* sp., currant lettuce aphid and sowthistle dominated in November 2004. Cotton, green peach and *Brachycaudus* aphids flew again in autumn. Potato, sow thistle and green peach aphids dominated the wingless portion of vacuum catches on most dates.

Fungal disease was present in the aphid population in lettuce in November infecting up to 30% of the aphids counted in one visual examination of 10 lettuces. Through summer and early autumn such fungus was rarely seen. It proliferated in the high populations of currant lettuce and sow thistle aphids in P9 infecting about 80% of the aphids seen during the visual examination at maturity. This fungus was not identified. Preceding this trial the fungus *Erynia* was identified (by R. Milner) infecting aphids on potted *Crepis* plants in a glasshouse in Devonport.

IPM and aphids

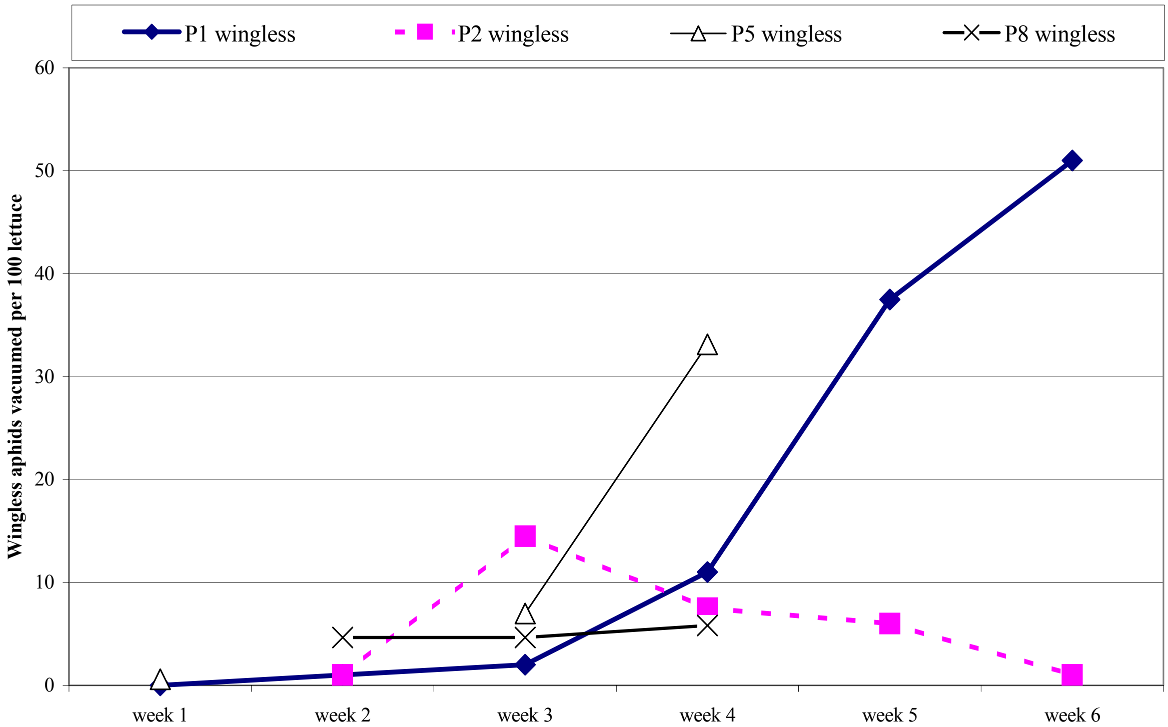
The most doubtful planting for aphid control was the first (Fig. 2). This is typically the case when relying on predators to establish in a sequence of crops. Nevertheless, the first planting succeeded. Brown lacewing adults were present in the adjoining crop of rocket at least by late October and abundant, along with diamondback moth caterpillars, by mid November. A vacuum sample revealed lacewing adults, hoverfly larvae and aphids in the grass verges three weeks after planting P1 lettuce. It is not known whether the crop of rocket planted ten days before lettuce was essential to fast establishment of predators or whether the grass verges were sufficient.

Vacuum data as shown in Table 10 suggests there were three peaks of aphid activity which follows the trend in catches of all aphids in a nearby yellow water trap (Fig. 1). Lettuce aphid was present in all peaks.

In P1-7, aphid numbers, principally lettuce aphid on inner leaves, typically rose a little or a lot before falling to negligible levels. The peak varied from week 3 to week 6. In P1 the rise (as measured by vacuuming) continued until week 6 at which time 51 wingless aphids were vacuumed per 100 plants. This was the highest number and latest date for the peak. Observers at the second field day for growers (week 7 of P1) noted the decline since the first field day (week 5 of P1).

In P2 wingless aphids peaked by week 3. In P5, which was grown during the middle peak of aphid activity, wingless aphids reached 33 per 100 plants at week 4 while in other successful IPM plantings wingless aphids peaked at lower levels. Vacuum counts were not made beyond week 4 in later plantings but general visual observations confirmed the preceding trends.

Figure 2. Vacuum sample data for three successful plantings of IPM lettuce with relatively high or late abundance of wingless aphids and for P8 where control failed by maturity despite low initial numbers in vacuum samples. See Table 10 for all plantings.



The closest to a synchronous comparison of vacuum and visual counts is data for P1 in which 0.51 wingless aphids were vacuumed per plant at 40DAP, which was probably near the peak population, compared to a visual count of one wingless aphid per lettuce at 57DAP, probably during the subsequent decline. However the two values for visual assessment of P7 at 54DAP and 62 DAP suggest that rapid declines occur during one week (Table 10).

A comparison of vacuum counts for weeks 3 and 4, for all plantings is given in Table 10 along with visual aphid-counts at maturity. Although vacuum and visual counts are not directly comparable those for P1-7 indicate a large range in the size of the peak population during growth of lettuce but a consistently low final count. This suggests that threshold values based solely on counts of vacuumed-aphids (and ignoring predation) are not appropriate as triggers for the 'remedial' application of insecticides, which in head lettuce would need to be applied before week 4 to have any chance of achieving effective coverage.

Table 10. Aphids of all species vacuumed per 100 lettuce at 1-6 weeks after planting as whole numbers and the number of aphids per 100 lettuce counted by complete visual assessment near and at maturity. wd indicates alatae or winged aphids; ws indicates apterae or wingless aphids; nd, no data. For P7 at 6-8 weeks the first value is for a sample at 54DAP and the second at 62DAP.

	P1	P1	P2	P2	P3	P3	P4	P4	P5	P5	P6	P6	P7	P7	P8	P8	P9	P9
After planting	wd	ws	wd	ws	wd	ws	wd	ws	wd	ws	wd	ws	wd	ws	wd	ws	wd	ws
week 1	2	0	nd	nd	nd	nd	nd	nd	1	1	nd	nd	nd	nd	nd	nd	nd	nd
week 2	2	1	20	1	nd	ndf	2	1	nd	nd	2	0	0	0	2	5	7	2
week 3	2	2	30	15	0	0	1	1	17	7	28	6	0	0	2	5	30	43
week 4	39	11	3	8	2	2	3	4	45	33	16	10	7	1	8	6	21	75
week 5	25	38	0	6	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
week 6	10	51	1	1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
6-8 weeks, visual, all	100		55		25		135		-		33		448/8		194		22600	
8-11 weeks, visual, all	295		160		18		160		73		40		33		7250		3500	

It is also notable that the control failure in P8 was not forecast by the low vacuum counts at weeks 2, 3 and 4 but may have been predicted by comparing these with the absence of lacewings and ladybirds in the same samples (Table 21) (although lacewings subsequently appeared in numbers by maturity, Table 8)

Table 11 shows that the highest level of aphid infestation in IPM susceptible lettuce at maturity was three per plant. These plants were assessed as clean and marketable by industry participants in field days not only because of the 'absence' of aphids but for the rarity of all insect species, dead or alive, including predators and parasitoids. It should be noted that for P3 both the high and low rates of imidacloprid drenching, which also benefited by predators immigrating from larger areas of adjoining IPM lettuce, were no more effective in reducing the final count of live aphids on susceptible lettuce than the IPM treatment. For P5-P7 the low rate of imidacloprid drench was comparable to IPM (and no high rate was tested).

Table 12 gives more detail of the proportion of susceptible IPM and *Nasonovia*-resistant lettuce with high or low infestations of aphids.

Table 11. Summary of the number of aphids (all species, winged and wingless) per lettuce at maturity in each treatment of each planting in paddock 6, Forthside farm. Rounded mean values based on destructive visual inspection of 20, 30 or 40 lettuce per treatment are given. The outer six leaves are excluded from this assessment. The parentheses indicate data from plantings in paddock 13, not 6, at Forthside farm. The two values for IPM susceptible lettuce in planting 8 are for samples adjacent to (72) or remote from (42) adjoining treatments of drenched lettuce. Dashes indicate absence of a treatment in a planting.

Planting	IPM susceptible	IPM resistant	IPM resistant Cos	5.5 ml Confidor drenched	55 ml Confidor drenched	Rate Chess drenched	Repeated Dominex susceptible
1	3	0.3	0.2	-	-	-	-
2	1.5	0.1	0.1	-	-	-	(54)
3	0.2	0.03	0	0.3	0.3	0.3	(30)
4	1.5	0.1	0.8	-	-	-	11
5	0.7	0.3	1	1.3	-	0.9	(39)
6	0.4	0.03	-	0.1	-	0.5	(36)
7	0.3	-	-	0.2	-	0.8	(45)
8	72 & 42	-	-	2.4	-	19	-
9	35	-	-	3	-	97	-

Table 12. Summary of aphid infestation levels in IPM *Nasonovia*-susceptible and *Nasonovia*-resistant iceberg lettuce as assessed by destructive visual counts at two dates (days after planting, DAP) for each planting with the second date being at maturity. The near and far values for IPM susceptible lettuce in planting 8 are for samples adjacent to or remote from adjoining treatments of drenched lettuce. Dashes indicate absence of a treatment in a planting. The classification of lettuce into those with more or less than five aphids is arbitrary but less than five aphids is certainly invisible to commerce.

		Susceptible undrenched (IPM) lettuce			Resistant undrenched lettuce		
	DAP	aphids per plant	% Lettuce with 1-5 aphids	% Lettuce with >5 aphids	aphids per plant	% Lettuce with 1-5 aphids	% Lettuce with >5 aphids
Planting 1	57	1	45	5	0.15	15	0
Planting 1	62	2.95	10	20	0.3	0	5
Planting 2	58	0.55	35	0	0	0	0
Planting 2	68	1.6	10	10	0	0	0
Planting 3	40	0.25	20	0	0.1	10	0
Planting 3	55	0.175	15	0	0.025	2.5	0
Planting 4	43	1.35	52.5	2.5	0.375	22.5	2.5
Planting 4	57	1.6	35	7.5	0.1	10	0
Planting 5	-	nd	nd	nd	nd	nd	nd
Planting 5	48	0.725	42.5	0	0.275	27.5	0
Planting 6	48	0.325	22.5	0	0.15	7.5	0
Planting 6	62	0.4	17.5	0	0.025	2.5	0
Planting 7	39	4.48	48	8	-	-	-
Planting 7	54	0.075	7.5	0	-	-	-
Planting 7	62	0.33	21.2	0	-	-	-
Planting 8	49	19.43	30	33	-	-	-
Planting 8 far	63	41.8	6.7	76.7	-	-	-
Planting 8 near	63	72.52	25.8	70.97	-	-	-
Planting 9	60	225.7	0	100	-	-	-
Planting 9	77	35	10	90	-	-	-

Bugs (Hemiptera) other than aphids

Aphids are a type of sap-sucking bug. Other bugs infest lettuce. Very few juvenile leafhoppers were detected in vacuum and visual inspections. The vacuum samples regularly contained adults of brown leafhopper and yellow leafhopper. Otherwise, only two adults of the grass leafhopper and the leafhopper, *Arawa novella* (Metcalf) were vacuumed. Adult leafhoppers were rarely encountered on inner leaves during visual inspections. Green or vegetable leafhopper was not encountered. Juveniles possibly of the yellow leafhopper were common in vacuum samples from the pasture verges that surrounded the lettuce.

The most common heteropteran bug encountered on lettuce was potato bug. It appeared mostly as juveniles until late December after which some adults were vacuumed or observed in the lettuce. However, one adult was found on lettuce on 25 November 2004. This sap-sucking mirid species is absent from the mainland but commonly occurs on Tasmanian vegetable crops as a minor pest that distorts terminal growth of plants when feeding is intense.

Rutherglen bugs were vacuumed but never reached high levels. They were most abundant in April and, to a lesser extent May, as is typical in most years on other vegetation in this district. However adults were present at low levels in the pasture verges in mid January 2005. Early, migratory influxes of Rutherglen bug occur rarely in spring as on 3 November 2005 in this district .

Damsel bug, a predator of caterpillars, was absent from early plantings despite the abundance of young cutworms. It was first observed as adults in P5 in mid December which coincided with mean catches of the bug in a nearby light-trap during the preceding five years (Fig. 3). Adults were detected in the pasture verges in mid January but such sampling was cursory. The abundance of damsel bug may depend on immigration. In the following growing season a rare, early influx of damsel bug appeared in this district on 3 November 2005, along with Rutherglen bug and several other known migratory insects, six weeks ahead of the mean date for sizeable catches of damsel bugs in the Devonport light trap.

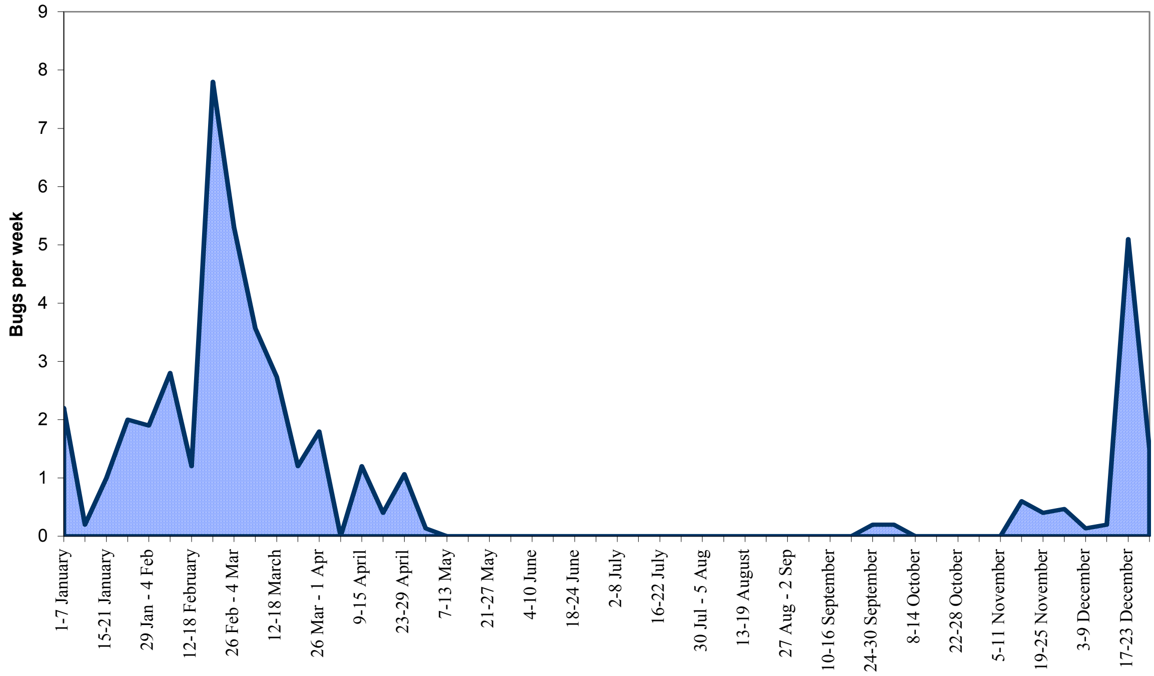
The predacious glossy, shield bug (*Cermatulus*) was not seen in lettuce until late January (P4 at maturity) and continued to be seen through February and March. In P5 it was detected as frequently as one adult per 10 plants in some visual assessments. Occasional clusters of bug eggs seen in lettuce near maturity in February probably belong to this species.

Predatory shield bug (*Oechalia)* was not encountered in lettuce but does occur in this district. Assassin bug, big-eyed bug and minute pirate bug also were not detected in lettuce although juvenile assassin bugs occurred in the pasture verges and an unidentified species of pirate bug occurs in tomato glasshouses a few kilometres away.

Green vegetable bug was first noted in the crop in early March and seen again in early April but was always rare.

Adults of a ground bug (Cydnidae) were found uncommonly on inner and outer leaves by visual inspection in December and January. They were also occasionally vacuumed from lettuce.

Figure 3. Damsel bug seasonal flight profile as measured by weekly catches in a light trap at Devonport over five years 2000-2004.



Caterpillars

Six species of noctuid caterpillars were found on lettuce in addition to occasional leafrollers. They were common cutworm, corn earworm, native budworm, chevron cutworm, green cutworm and green looper.

Young cutworm caterpillars from P1 and P2 were reared to adult stage to confirm identification as common cutworm.

Flights of moths of native budworm and common cutworm, as measured by a light trap at Devonport, were above the decade-average during the trial. The same trap detects very few or no corn earworm in most years and the same occurred during this project suggesting that they were not highly abundant. Native budworm moths were reared from caterpillars collected in P1, P6 and P8. Corn earworm was reared from P6 and P7. These are the first Tasmanian records of corn earworm from a crop other than sweet corn.

Green looper, green cutworm and chevron cutworm were the predominant caterpillars on lettuce in late summer and autumn but corn earworm also appeared late in the season. Young chevron cutworm and older heliothis caterpillars were observed on inner leaves of P7 in late March. Moths of green looper were reared from caterpillars collected in P6 and caterpillars were observed in late May on P9. Moths of green cutworm were reared from P6-8 and moths of chevron cutworm from P6 and P7 to confirm identifications. Green cutworm caterpillars up to fifth instar were found on inner leaves. Chevron cutworms at third and fourth instars occurred in inner leaves of P9 on 11 May. Eggs of chevron cutworm were seen on inner and outer leaves from late March to late April.

Wasp parasitoids occurred in several species of caterpillars and a bristle fly (Tachinidae) parasitoid was reared from chevron cutworm.

A leafroller moth reared from a caterpillar collected in inner leaves of lettuce in late March was possibly *Epiphyas* and probably not lucerne leafroller. Clustered leafroller eggs typical of the latter were never observed.

One brown looper (Geometridae), possibly *Ciampa* sp. was found on inner leaves in late February.

IPM and caterpillars

Prior to the arrival of currant lettuce aphid, caterpillars, particularly *Helicoverpa* species, were the main pest of lettuce for which reliable control through IPM was sought. Resistance to many insecticides in corn earworm primarily drove that levy-funded research.

The only undrenched, susceptible planting that had caterpillar contamination at harvest was P9 which was compromised by adjoining larger areas of drenched lettuce. These caterpillars were green cutworm and green looper. The former is best known as a minor pest of forage brassicas in Tasmania and not well known on the mainland. Common cutworm was the most common caterpillar in early season, heliothis in mid season and green cutworm in late season but see Table 13 for details.

The susceptible IPM treatments usually had less infestation by caterpillars than all other iceberg treatments, including *Nasonovia*-resistant lettuce as indicated in Table 13.

Table 13. Number of caterpillars per 100 lettuce at maturity in each treatment of each planting in paddock 6, Forthside farm. Values based on destructive visual inspection of 20, 30 or 40 lettuce per treatment are given. The outer six leaves are excluded from this assessment. Caterpillar species include native budworm and corn earworm (*Helicoverpa*), common cutworm (*Agrotis*), chevron cutworm (*Diarsia*), green cutworm (*Neumichtis*) and green looper (*Chrysodeixis*). S for *Nasonovia* susceptible; R for *Nasonovia* resistant

Plant-ing	Insecticide history	Caterpillar species	S-IPM Iceberg	R-IPM Iceberg	R-IPM Cos	5.5 ml Confid or drench	55 ml Confid or drench	Chess drench
1	1 Bt 39DAP	88% Agrotis + 12% Helicoverpa	5	10	0	-	-	-
2	1 Bt 27DAP& 1 Success 43DAP	100% Agrotis	5	0	0	-	-	-
3	1 Success 15DAP	100% Agrotis	0	10	0	0	10	0
4	1 Success 1DAP	100% Helicoverpa	0	5	5	-	-	-
5	1 Success 20DBP	55% Helicoverpa + 45% Agrotis	0	5	10	5	-	5
6	None	88% Helicoverpa + 12% Agrotis	0	8	-	5	-	5
7	1 Bt 37DAP	53% Diarsia, 40% Helicoverpa + 7% Agrotis	0	-	-	12	-	44
8	1 Bt 16DAP	50-100% Helicoverpa	0	-	-	7	-	3
9	None	57% Neumichtis, 29% Chrysodeixis + Helicoverpa	23	-	-	0	-	-

Very young common cutworm caterpillars were vacuumed from lettuce of P1-5 (spring and summer) although the abundance of adults indicated by a light trap at Devonport was more narrowly peaked within spring. Older cutworm caterpillars avoid light and are not likely to be vacuumed by day. Common cutworm caterpillars at instars 2-4 were encountered in visual inspections mostly on the outer six leaves from November to mid January and occasionally on inner leaves in late November and mid December. Destructive samples of lettuce taken from crops around weeks 5 and 7 after planting revealed a few caterpillars up to instar 4 but no older caterpillars entering the heads of lettuce.

In four of the six plantings for which a comparison is available, heliothis caterpillars were more abundant in drenched (both Chess and Confidor) than undrenched IPM plantings while in the other two they were nil in all such treatments. If P8 and P9 are excluded, then IPM lettuce performed better in three of four comparisons (Table 14). For other species of caterpillars differences were obscure (Table 15). No comparisons were available in P1 and P2 when cutworm pressure was greatest. However, the result for lettuce treated with a high rate of imidacloprid in P3 (Tables 13 & 15), when common cutworm pressure was still evident, warrants further investigation as it relates to the fundamental flaw in a seedling-drench strategy for lettuce aphid.

In three of the six plantings for which a comparison is available, heliothis caterpillars were more abundant in undrenched *Nasonovia*-resistant plantings than in undrenched, susceptible plantings while in two comparisons they were nil and in the other they were less abundant. For other species of caterpillars there was no clear trend. However, the high count for resistant lettuce in P1 and P3, when common cutworm pressure was greatest, warrants consideration.

Table 14. Number of heliothis caterpillars per 100 lettuce at maturity by destructive, visual inspection

Treatment	IPM	N-resistant	Low Confidor	High Confidor	Chess drench
P1	5	0	-	-	
P2	0	0	-	-	
P3	0	0	0	0	0
P4	0	5	-	-	-
P5	0	5	5	-	5
P6	0	8	5	-	5
P7	0	-	8	-	16
P8	0	-	7	-	3
P9	0	-	0	-	0

Table 15. Number of noctuid caterpillars other than heliothis per 100 lettuce at maturity by destructive visual inspection

Treatment	IPM	N-resistant	Low Confidor	High Confidor	Chess drench
P1	0	10	-	-	
P2	5	0	-	-	
P3	0	10	0	10	0
P4	0	0	-	-	-
P5	0	0	0	-	0
P6	3	0	0	-	0
P7	0	-	4	-	4
P8	0	-	0	-	0
P9	23	-	0	-	0

Thrips

No western flower thrips were encountered.

Thrips were rare in vacuum samples from early plantings but became noticeable in mid January when P5 was 4-weeks old (Table 6). At this time the general environment at Forthside was drying off whereas it had dried off much earlier in southern Tasmania where transmission of TSWV by onion thrips is historically more frequently reported as a pest issue in lettuce.

The species commonly encountered on lettuce in mid to late season was plague thrips – starting mid January. Earlier the black grass thrips predominated but was never abundant in lettuce although it was abundant in the grass verges.

Some predatory *Aeolothrips* appeared in early January in P4, became more common in mid January in P5 and remained present in P6-8 (although not detected in vacuum samples for P8) from February to early April 2005 (Table 8). A few black tubuliferan thrips were also seen in lettuce.

Table 16. Phytophagous terebrantian thrips (mostly *Limothrips* and *Thrips*) vacuumed per 100 lettuce at weeks 3 and 4 (mean) after planting.

Treatment	IPM	*N*-resistant	Low Confidor	High Confidor	Chess drench
P1	0	0	-	-	-
P2	0	0	-	-	-
P3	0.25	3	2	2	2
P4	0*	1.16	-	-	-
P5	20.3 (1.375)	15.37 (0.29)	8.7 (0)	-	18.56 (0)
P6	28.71 (some)	72.6 (some)	16.82 (some)	-	29.58 (some)
P7	26.1 (1.16)	-	4.46 (0)	-	23.78 (1.16)
P8	71.92	-	22.04	-	25.52
P9	48.72**	-	24.36	-	33.64

A dash indicates no such treatment in a particular planting. Additional *Aeolothrips* in parentheses. * Dominex treatment in P4 had 0.87 terebrantian thrips. ** 31.3% juveniles

Table 17. Phytophagous terebrantian thrips (mostly *Limothrips* and *Thrips*) seen per 100 lettuce at crop maturity.

Treatment	IPM	*N*-resistant	Low Confidor	High Confidor	Chess
P1	0	0	-	-	-
P2	15	0	-	-	-
P3	0	0	0	0	0
P4	8	8	-	-	-
P5	0	300	0	-	0
P6	3	1	8	-	0
P7	136	-	132	-	72
P8	65	-	17	-	10
P9	0	-	0	-	0

A dash indicates no such treatment in a particular planting.

Table 18. ***Aeolothrips*** **per 100 lettuce about two weeks before maturity by visual count (They were rarer by crop maturity).**

Treatment	IPM	N-resistant	Low Confidor	High Confidor	Chess
P1	0	0	-	-	-
P2	0	0	-	-	-
P3	0	0	0		0
P4	5	0	-	-	-
P5	-	-	-	-	-
P6	10	8	2	-	0
P7	5	-	0	-	4
P8	3	-	3	-	0
P9	0	-	0	-	0

A dash indicates no such treatment in a particular planting or no prematurity sample for P5.

Microhymenoptera

Small parasitoid wasps of diverse species were abundant in vacuum samples. The other two groups that were numerous in vacuum samples were spiders and flies. The wasps were sporadically encountered on inner leaves during visual inspections.

Wasps, probably *Aphidius*, were reared from a dozen potato aphids on lettuce but only one parasitoid microwasp, not Aphididae, was reared from currant lettuce aphid. A similar wasp was also reared from sow thistle aphid. However such rearing was conducted cursorily so that lettuce aphids were not intensively sampled.

Parasitism detected as mummified aphids in destructive visual inspections of lettuce was generally low, being 3% in November, nil in summer and 15% in March. The numbers of microwasps vacuumed from lettuce were substantial (Table 19). They correlated broadly with vacuumed aphid counts and also with catches of aphids in a yellow water trap nearby.

A braconid/ichneumonid parasitoid emerged from a cocoon under one adult 11-spotted ladybird.

An apparently polyembryonic parasitoid emerged from one green cutworm and another polyembryonic species from two green looper caterpillars.

A parasitoid of *Melangyna* hoverflies, probably *Diplazon laeletorius*, emerged from several hoverfly puparia and had been previously recorded from this district.

A parasitoid of brown lacewing, probably *Anacharis* was reared from a brown lacewing pupa on lettuce and had been previously recorded from this district.

Several treatments followed similar broad trends as shown in Table 19. Microwasps were not abundant in P1-2 and abundant in P6-7 when IPM succeeded under aphid pressure (see aphid data in Table 8) and were abundant in P8-9 when IPM failed under pressure. In contrast, lacewing numbers crashed at the same time that IPM crashed in P8 and P9.

Microwasps number increased steadily from P1 to P6 although aphids slumped in the middle of this period, which is during P3-4. A simple correlation between numbers of microwasps and all aphids vacuumed at mid growth of each planting is 0.78, which is similar to spiders and aphids (0.68) and different to lacewings and aphids (-0.03). The correlation between wasp and spider numbers for nine plantings is 0.87.

Table 19. The mean number of microwasps vacuumed per 100 lettuce at weeks 3 and 4 after planting.

Planting & treatment	Undrenched susceptible	Undrenched N-resistant	low rate Confidor drench	Chess drench	high rate Confidor drench
P1	3	4	nd	nd	nd
P2	5	1	nd	nd	nd
P3	8	5	4	18	7
P4	10	10	nd	nd	nd
P5	39	26	29	23	nd
P6	27	35	37	46	nd
P7	5	nd	9	9	nd
P8	12	nd	13	8	nd
P9	37	nd	25	29	nd

nd indicates no data because there was no such treatment.

Spiders

Spiders were numerous in vacuum samples. As for wasps, there were few spiders during the P1-2 aphid peak but many during the P5-6 peak when IPM succeeded and many spiders during the P8-9 aphid peak when IPM failed. Although spiders (vacuumed at weeks 3-4 of each planting) correlate with all aphids at 0.68 there is little slump in spider numbers before or after the mid season aphid peak. Spider eggs sacs (possibly lynx spiders) and spiders were frequently encountered on the outer six leaves during destructive visual inspections.

Table 20. The mean number of spiders vacuumed per 100 lettuce at weeks 3 and 4 after planting.

Planting & treatment	Undrenched susceptible	Undrenched N-resistant	low rate of Confidor drench	Chess drench	high rate of Confidor drench
P1	6	1	nd	nd	nd
P2	0	2	nd	nd	nd
P3	9	6	10	13	1
P4	6	6	nd	nd	nd
P5	26	19	16	16	nd
P6	14	9	8	11	nd
P7	13	nd	6	28	nd
P8	16	nd	13	11	nd
P9	28	nd	22	37	nd

nd indicates no data because there was no such treatment.

Lacewings

Brown lacewing was the only lacewing encountered in lettuce. Eggs, larvae, pupae and pupal cocoons were encountered but were never conspicuous enough at lettuce-maturity to cause concern to growers, wholesalers, retailers or consumers.

A simple correlation between lacewing adults and all aphids vacuumed at midgrowth of each planting is near zero (-0.03). However lacewings followed aphid trends until plantings 8 and 9 in contrast to microwasps and spiders (Table 21). However lacewing adults and larvae were visually abundant in IPM lettuce by the time of maturity in P8 and P9 (Table 8).

A microwasp parasitoid, probably *Anacharis* sp. was reared from an immature brown lacewing. It has been suggested that this parasitoid contributed to failure of IPM in New Zealand lettuce in summer and autumn (G. Walker, personal communication).

Table 21. The mean number of adult lacewings vacuumed per 100 lettuce at weeks 3 and 4 after planting.

Planting & treatment	Undrenched susceptible	Undrenched resistant	low rate of Confidor drench	Chess drench	high rate of Confidor drench
P1	0	0	nd	nd	nd
P2	2	1	nd	nd	nd
P3	1	1	0	1	0
P4	1	1	nd	nd	nd
P5	7	5	1	7	nd
P6	4	4	3	5	nd
P7	6	nd	2	3	nd
P8	0	nd	1	1	nd
P9	0	nd	1	2	nd

nd indicates no data because there was no such treatment.

Beetles

Only two species of ladybirds (Coccinellidae) were encountered. These, 11-spotted ladybird and transverse ladybird, are the dominant ladybirds on other vegetable crops in north-west Tasmania. Adults of both species and larvae of at least one were seen but not vacuumed in P1 three weeks after planting and may have been present earlier. A microwasp parasitoid emerged from one adult 11-spotted ladybird collected from lettuce. Table 22 shows trends for numbers of adult ladybirds in lettuce at midgrowth. Simple correlations of ladybird adults vacuumed at mid growth are negative with all aphids (-0.25), zero with spiders, low with wasps (0.17) and highest with lacewings (0.43). As for lacewings, ladybirds were low at mid growth in the last two plantings in which IPM failed.

Numbers in resistant lettuce and imidacloprid drenched lettuce were generally at lower levels than in undrenched, susceptible IPM lettuce.

Table 22. The mean number of adult ladybirds vacuumed per 100 lettuce at weeks 3 and 4 after planting. nd indicates no data because there was no such treatent.

Planting & treatment	Undrenched susceptible	Undrenched resistant	low rate of Confidor drench	Chess drench	high rate of Confidor drench
P1	0	0	nd	nd	nd
P2	1	0	nd	nd	nd
P3	4	1	1	0	2
P4	2	0	nd	nd	nd
P5	2	1	1	0	nd
P6	6	1	2	4	nd
P7	3	nd	4	4	nd
P8	1	nd	0	0	nd
P9	1	nd	0	0	nd

nd indicates no data because there was no such treatent.

White-collared ladybird was first detected in Tasmania at several sites near Devonport in late 2002 and early 2003. It was not detected during this lettuce trial but appeared abundantly in the following season in December 2005 in an IPM-lettuce crop near Hobart. Common spotted ladybird, southern ladybird, striped ladybird and two-spotted ladybird were also not encountered in Forthside lettuce.

Adult rove beetles (Staphylinidae) were the most common beetle found in vacuum and whole plant destructive samples. Larvae were rarely seen in lettuce and only adults were vacuumed from lettuce. Table 23 shows no consistent differences between treatments.

Table 23. The mean number of adult rove beetles (Staphylinidae) vacuumed per 100 lettuce at weeks 3 and 4 after planting.

Planting & treatment	Undrenched susceptible	Undrenched resistant	low rate Confidor drench	Chess	high rate Confidor drench
P1	0	0	nd	nd	nd
P2	2.5	0	nd	nd	nd
P3	3.3	0.8	1	3	3
P4	0*	0	nd	nd	nd
P5	2	2.3	1.2	0	nd
P6	3.2	3.5	4.6	1.7	nd
P7	0.58	nd	0.58	1.2	nd
P8	0	nd	0	0.58	nd
P9	0.58	nd	4.1	1.2	nd

nd indicates no data because there was no such treatment. * 0.58 in Dominex treated beds of P4.

Adult mould beetles (Lathridiidae) were the second most abundant beetle family found in vacuum samples and visual inspections. They occurred on both inner and outer leaves. The same species are common on the foliage of vegetable crops in this district. Their grubs were not common on foliage. Their eggs are superficially like those of brown lacewing.

Few ground beetles (Carabidae) were encountered in lettuce. Adults of the strawberry beetle were occasionally found in lettuce. This species is suspected of eating onion seedlings and damaging strawberry fruit but may also be predacious.

Only one vegetable weevil larva was encountered during all sampling. Adult click beetles were rarely encountered in lettuce. The predacious red and blue beetle was never encountered and is probably absent from Tasmania. Soldier beetle was not encountered on lettuce but is present in this district. Adult flea beetles (Halticinae) were occasionally encountered on outer leaves during visual inspections.

Flies

Diverse flies (Nematocera and Brachycera) were the most numerous item in vacuum samples (Tables 24 and 25). Fungus gnats (Sciaridae) were common in spring and some carried phoretic, predatory mites. Very few fly larvae were encountered during destructive visual inspections. Adult fungus gnats, usually dead, were the most frequently encountered species in visual inspection, both on inner and outer leaves. Flies are an important cosmetic-pest. Complaints from supermarket agents about flies flying out of lettuce cartons drives growers to the application of broad spectrum synthetic pyrethroid insecticides to Tasmanian lettuce and is an impediment to the adoption of Integrated Pest Management.

Eggs of the two-stripe fly were often seen on lettuce in visual inspections. These are superficially similar to eggs of hoverflies and, to a lesser extent, brown lacewing. Dead adults were rarely encountered on outer leaves. This species is common on vegetable crops in this district. It lays eggs on a wide variety of vegetables and the larvae appear to browse particles on foliage and contain red soil particles in their guts.

Several small tachinid flies emerged from one chevron cutworm caterpillar.

Table 24. The mean number of adult nematoceran flies (Diptera, gnats and midges) vacuumed per 100 lettuce at weeks 3 and 4 after planting. nd indicates no data because there was no such treatment. Nc not counted but sample retained. * Dominex 2

Planting & treatment	Undrenched susceptible	Undrenched resistant	low rate Confidor drench	Chess	high rate Confidor drench
P1	30	12	nd	nd	nd
P2	12	5	nd	nd	nd
P3	7	4	15	4	17
P4*	3	4	nd	nd	nd
P5	8	6	4	15	nd
P6	nc	nc	nc	nc	nd
P7	nc	nd	nc	nc	nd
P8	nc	nd	nc	nc	nd
P9	nc	nd	nc	nc	nd

Table 25. The mean number of adult brachyceran flies (Diptera) vacuumed per 100 lettuce at weeks 3 and 4 after planting. nd indicates no data because there was no such treatment. Nc not counted but sample retained. *Dominex 17

Planting & treatment	Undrenched susceptible	Undrenched resistant	low rate Confidor drench	Chess	high rate Confidor drench
P1	11	18	nd	nd	nd
P2	14	8	nd	nd	nd
P3	54	39	87	106	59
P4*	47	15	nd	nd	nd
P5	102	25	83	34	nd
P6	nc	nc	nc	nc	nd
P7	nc	nd	nc	nc	nd
P8	nc	nd	nc	nc	nd
P9	nc	nd	nc	nc	nd

Earwigs

Adult and juvenile European earwig were found in mature lettuce on the outer six leaves in late November, mid December and late February.

The predacious common brown earwig was found in lettuce of P7 and P9. This is the first record of the species occurring in north-western Tasmania.

Psocoptera

Psocids were occasionally encountered on outer leaves during visual inspections.

Mites

Snout mites, *Neomolgus* sp. were frequently vacuumed from early plantings along with lucerne flea, which are probably their staple prey. These mites were previously observed by the author eating young potato moth caterpillars. Other predatory mites, including Phytoseiidae and Anystidae, were repeatedly encountered in low numbers during visual inspections of lettuce at maturity (Table 8).

Slugs

Grey garden slug and two-stripe slug occasionally occurred on inner leaves in visual inspections in November, December, January and February.

Other fauna in lettuce

One dragonfly, one earthworm, one centipede and several slaters were encountered during all visual inspections.

IPM with *Nasonovia* resistant lettuce

As can be seen from Tables 11 and 12, above the resistant lettuce, including the Cos cultivar, consistently had the lowest levels of aphid infestation of all treatments. The difference between resistant and susceptible lettuce also indicates the likely proportion of lettuce aphid amongst all aphids in the *Nasonovia*-susceptible lettuce because the latter are not resistant to other aphids.

However the resistant iceberg lettuce had more caterpillars than *Nasonovia*-susceptible, IPM lettuce in five of six comparisons (Table 3). No comparison is available for P9 in which many caterpillars occurred on susceptible lettuce. For resistant Cos there was no trend for more or less caterpillars than in susceptible, undrenched iceberg lettuce. No susceptible Cos were grown.

Impacts of Confidor in IPM – lab bioassay

A complementary project investigated the impact of Actara and Confidor drenches on brown lacewings that were eating potato aphids on drenched lettuce. This was done in a laboratory by IPM Technologies P/L. Confidor, at the 55g per 1000 seedlings rate and Actara at 2g per 1000 seedlings were highly toxic to brown lacewing eating poisoned aphids for 4-5 weeks and killed all aphids for 6 weeks. A 5.5g per 1000 seedlings rate of Confidor drench caused moderate toxicity to lacewings for three weeks and killed aphids for three weeks. See Appendix 1 for details of where to view this report.

Do aphids occur in 'Confidor-lettuce'

In P3, two beds of lettuce drenched with the high rate (55 g per 1000 seedlings) of Confidor and two beds drenched with the 5.5 g rate were assessed by destructive, visual inspection at 7 and 8 weeks after planting. Infestation by aphids was comparable with eight beds of adjacent IPM lettuce. A high proportion of wingless individuals comprised the counts in drenched lettuce (Table 26).

That is, the drenched lettuce that also received the benefit of predators from larger areas of adjoining IPM lettuce were no less infested by aphids than IPM lettuce. Both classes of lettuce were fully marketable. Initial interstate quarantine protocols adopted in 2005 assumed that drenched lettuce are much less likely to carry aphids than IPM lettuce. This assumption is questionable in commercial field practice. Table 26 details aphid infestation in P3 at maturity and two weeks earlier.

Table 26. Number of live, dead or parasitised winged and wingless aphids of all species per lettuce in eight treatments of lettuce of P3. Drenches applied to seedling trays immediately prior to planting. N-r is Nasonovia or CLA-resistant.

	Aphids Or lettuce	IPM Toronto	IPM Brisbane	N-r Cos RZ4141	N-r RZ4582	N-r Eldorado	Toronto 55 ml Confid.	Toronto 5.5 ml Confid.	Toronto rate of Chess
40 DAP	Wingless	1d	4	0	0	4	4	5	1, 4d
	Winged	0	1	0	0	1	2	0	0
	Parasitised	0	0	0	0	0	0	1	0
	Total aphids	**1**	**5**	**0**	**0**	**5**	**6**	**6**	**5**
	Infested lettuce	1	4	0	0	3	5	2	2
55 DAP	Wingless	1d	2	0	1	0	5	4	1d
	Winged	1	3	0	0	0	1	2	2
	Parasitised	0	0	0	0	0	0	0	0
	Total aphids	**2**	**5**	**0**	**1**	**0**	**6**	**6**	**3**
	Infested lettuce	2	3	0	1	0	3	3	3

DAP indicates days after planting; d indicates a dead aphid, cause unknown, including possibly squashed during handling of lettuce.

In P5-P7 no high rate (55 g) of imidacloprid drenching was tested but the low rate (5.5 g) produced lettuce comparable with IPM lettuce in aphid infestation (Table 11). Both types were marketable. As with P3, the drenched lettuce probably received benefit from predators fostered by larger areas of adjacent IPM lettuce.

Impacts of Confidor and Chess in IPM – field observations

In P8 and P9 the presence of large areas of drenched lettuce coincided with a failure of aphid and caterpillar control in adjacent IPM lettuce as mentioned and tabulated above.

In P3 and P5-P7, where comparisons are available, imidacloprid-drenched lettuce (low rate, 5.5 g) tended to carry comparable numbers of aphids but more heliothis caterpillars than IPM lettuce at maturity. At mid growth fewer pest thrips and beneficial lacewings, marginally fewer spiders and comparable numbers of beneficial microwasps were vacuumed from imidacloprid-drenched lettuce than IPM lettuce.

In P3 and P5-P7 pymetrozine-drenched lettuce were never less infested by aphids than IPM lettuce and tended to carry more heliothis caterpillars at maturity. At mid growth comparable numbers of pest thrips, beneficial lacewings, microwasps and spiders were vacuumed from IPM and pymetrozine-drenched lettuce.

Lettuce drenched with a low rate of imidacloprid (5.5 g per 1000 seedlings) had low aphid infestations when grown adjacent to larger or smaller areas of IPM lettuce. Such lettuce from several plantings were marketable provided care was taken to minimise harvest of caterpillar infested lettuce.

Lettuce drenched with the highest rate (55 g per 1000 seedlings) were not entirely free of aphids and no cleaner than IPM lettuce in the one comparison available (P3).

Impact of Pirimor in IPM – field observations

Pirimor may have interrupted predatory control of aphids in P1. On 9 November 2005 pirimicarb was applied to one bed of each of two susceptible cultivars in each of P1 and P2 (there being three susceptible cultivars in P1 and two in P2).

Vacuum sampling one week later showed that the pirimicarb beds in P1 and P2 had fewer aphids, fewer adult lacewings but more adult flies (excluding hoverflies) than the unsprayed beds. Table 27 gives the data. Some idea of the variability in suction counts can be gained from the two pretreatment samples for each planting.

However, visual counts in P1 two weeks after treatment (15 DAT) showed the pirimicarb beds (both cultivars) had more aphids, more larval lacewings and more larval hoverfly than untreated beds (this ignores the untreated bed of cultivar Target in P1 which had a high aphid count but for which there is no treated comparison). By the time of maturity (20 DAT) the pirimicarb beds had fewer aphids and larval lacewings than unsprayed lettuce.

In P2 the visual counts were done relatively late (31 and 41 DAT) and followed a foliar application of spinosad but notably high aphid counts occurred in Sheeba pirimicarb beds on both dates.

These 'anomalies' may reflect sampling error derived from a small sample and highly clumped distribution, or a deleterious effect of an insecticide widely regarded as selective. Given that flies drive use of broad spectrum sprays the increase in flies following use of pirimicarb is notable.

Table 27: Number of various insects vacuumed per 100 susceptible, undrenched, IPM, iceberg lettuce on 9 and 15 November 2004 from P1 at 40 and 46 DAP and the adjacent P2 at 33 and 40 DAP.

Planting & Cultivar	Wing-ed aphids	Wing less aphids	Cater-pillars	Adult lace-wings	Spiders	Adult lady birds	Larval lady birds	Micro wasps	Predat ory mites	Pest thrips	Pest bugs	flies
P1 Brisbane C 0 DAT	7	59	3	15	7	0	2	12	6	0	5	22
P1 Brisbane P 0 DAT	7	45	5	9	2	0	1	4	0	0	4	20
P1 Brisbane P 6 DAT	**14**	**14**	**6**	**2**	**3**	**2**	**0**	**13**	**0**	**0**	**9**	**46**
P1 Oxley C 0 DAT	12	43	1	19	5	0	2	16	7	0	2	30
P1 Oxley P 0 DAT	5	46	5	18	5	0	3	10	16	0	8	21
P1 Oxley P 6 DAT	**9**	**2**	**2**	**0**	**1**	**0**	**0**	**17**	**5**	**0**	**8**	**55**
P2 Brisbane C 0 DAT	5	10	4	1	0	0	0	6	0	0	3	7
P2 Brisbane P 0 DAT	1	4	0	0	0	1	0	0	0	0	2	0
P2 Brisbane C 6 DAT	0	5	1	1	2	1	0	0	1	0	2	4
P2 Brisbane P 6 DAT	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**8**
P2 Sheeba C 0 DAT	0	5	1	1	1	1	0	1	1	0	5	3
P2 Sheeba P 0 DAT	0	0	1	1	1	0	0	0	1	0	2	3
P2 Sheeba C 6 DAT	0	7	2	3	0	0	0	3	0	0	4	12
P2 Sheeba P 6 DAT	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**2**	**2**	**0**	**5**	**22**

DAT indicates days after treatment, DAP, days after planting; C, untreated; P, pirimicarb treated. Brisbane, Oxley and Sheeba are susceptible cultivar (Appendix 7).

Table 28: Number of various insects seen in lettuce (n = 10 per cultivar per treatment per date) of P1 before and at maturity and later than vacuum samples detailed in preceding table. Counts include some dead hoverfly larvae. BT applied to all beds on 8 November 2004; Pirimor was applied to 2 beds of each susceptible cultivar on 9 November. DAT indicates days after treatment, DAP, days after planting.

	Cos CLA-Resistant	CLA-Resistant iceberg		CLA-Susceptible iceberg				
56 DAP, 15 DAT 24/11/04	Cos RZ4141	RZ4598	Eldorado	Target	Brisbane without Pirimor	Brisbane with Pirimor	Oxley without Pirimor	Oxley with Pirimor
Live aphids	4	3	0	63	6	54	0	49
Dead aphids & mummies	6	1	0	4	7	22	7	0
caterpillars	0	1	2	0	2	2	2	2
lacewing grubs	11	15	2	16	12	20	4	15
hoverfly grubs	1	8	1	22	2	32	3	7
60-61 DAP, 20 DAT 2/12/04	Cos	RZ4598	Eldorado	Target	Brisbane without Pirimor	Brisbane with Pirimor	Oxley without Pirimor	Oxley with Pirimor
Live aphids	2	6	0	2	13	1	35	5
Dead aphids	1	0	0	4	8	3	3	11
caterpillars	0	2	3	1	1	1	1	0
lacewing grubs	6	3	0	3	10	0	21	6
hoverfly grubs	0	2	1	1	1	1	10	4

Table 29: P2 Number of various insects seen in lettuce (n = 10 per cultivar per treatment per date) of P2 before and at maturity and later than vacuum samples detailed in Table X on 9 and 15 November 2004. BT applied to all beds on 8 November; Pirimor was applied to two beds of each susceptible on 9 November; Success applied to all beds on 25 November. DAT indicates days after treatment, DAP, days after planting.

	Cos CLA-Resistant	CLA-Resistant iceberg		CLA-Susceptible iceberg			
58 DAP 10 December 2004	Cos RZ4141	RZ4560	RZ4582	Brisbane	Brisbane 31 DAT with Pirimor	Sheeba	Sheeba 31 DAT with Pirimor
Live aphids	1	0	0	2	2	6	68
Dead aphids & mummies	2	1	1	3	1	0	4
caterpillars	0	0	0	0	1	1	0
lacewing grubs	0	0	1	1	2	6	5
hoverfly grubs	1	0	2	0	0	1	3
62 or 68 DAP 14 or 20 December 2004	Cos RZ4141	RZ4560 (62 days)	RZ4582 (62 days)	Brisbane	Brisbane 41 DAT with Pirimor	Sheeba	Sheeba 41 DAT with Pirimor
Live aphids	0	0	1	21	0	11	50
Dead aphids	1	0	0	0	0	0	0
caterpillars	0	1	0	0	0	1	0
lacewing grubs	9	0	0	1	1	1	0
hoverfly grubs	0	0	0	1	2	1	2

Impact of Dominex in IPM – field observations

Alpha-cypermethrin (Dominex®) exacerbated aphid infestations. It was used in the companion project (VG04068) to build aphid populations sufficiently high to allow other insecticides to be tested without interference from beneficial insects.

Alpha-cypermethrin clearly exacerbated aphid infestation in two beds of P4, despite adjacent populations of predators in IPM beds. It exacerbated aphids to a greater extent in several beds planted 500 m to the north in a fallow paddock (paddock 13) adjacent to pasture.

Table 30. Number of aphids in susceptible, undrenched lettuce (excluding six outer leaves) managed with IPM at maturity and in similar lettuce sprayed 1-4 times with Dominex®. P8 and P9 adjoined large areas of drenched lettuce (Chess and Confidor). (13) indicates paddock 13, other treatments were in paddock 6.

Susceptible lettuce	Dominex spray dates	Visual assessment dates	aphids per plant (rounded up)
Planting 1	-	30 November 2004	3
Planting 2	-	20 December 2004	2
Planting 3	-	4 January 2005	0
Planting 4	-	20 January 2005	2
Planting 4 Dominex	10 December 2004	20 January 2005	11
Planting 5	-	1 February 2005	1
2 Dominex sprays (13)	14 & 25 January	1 February 2005	54
Planting 6	-	28 February 2005	0
1 Dominex spray (13)	10 February	7 March 2005	30
Planting 7	-	22 March 2005	0
2 Dominex sprays (13)	10 Feb, 11 March	22 March 2005	40
3 Dominex sprays (13)	10 Feb, 11 & 22 March	6 April 2005	36
Planting 8 far or near seedling-drenched bays	-	20 April 2005	42 (far) or 73 (near)
4 Dominex sprays (13)	10 Feb, 11 & 22 March, 18 April	22 April 2005	45
Planting 9	-	10 May 2005	35

Discussion

Defining a 'clean' lettuce

Planting 1 was assessed at maturity (64 days after planting) in the field by six growers during the third field day which was on 2 December 2004. All said the IPM susceptible lettuces were clean and marketable. At 62 days after planting a destructive visual inspection of 20 lettuces contained an average of 2.95 aphids each (winged, wingless, dead, alive or parasitized). This assessment excluded the outer 6-8 leaves. Ten percent of plants had 1-5 aphids and 20% had more than five aphids. The average was strongly influenced by one plant containing 33 aphids. The outer leaves averaged nil live aphids but 0.15 per plant were parasitised or had been killed by a fungus.

A similar destructive inspection of 20 lettuces from P1 five days earlier revealed an average of 1 aphid per lettuce, 45% of plants with 1-5 aphids and 5% with more than five aphids. Another 0.4 aphids, apparently healthy, occurred on the outer six leaves of each lettuce.

Planting 4 was assessed at maturity (55 days after planting) in the field by several growers and interstate visitors during the fifth field day (19 January 2005). All said the IPM susceptible lettuces were clean and marketable. At 56 days after planting a destructive visual inspection of 40 lettuces, excluding the outer 6-8 leaves, revealed an average of 1.6 aphids each (winged, wingless, dead, alive or parasitized). At this time, 35% of plants had 1-5 aphids and 7.5% had more than five aphids. A similar inspection 14 days earlier revealed similar levels of infestation – or cleanliness.

Several dozen lettuce from planting 4 were also submitted in cartons of one dozen to the state buyers of vegetables for Woolworths and Costa Coles on 20 January. The two buyers for Costa Coles said the lettuce were acceptable while the two buyers for Woolworths did not give a clear decision but did not reject the lettuce.

Around 600 dozen lettuce, from all plantings, were sold on the local market through several greengrocers. No complaints about insect contaminants arose from buyers, yet the IPM lettuce averaged between 0.18 and 3.95 aphids per lettuce across plantings 1-7.

In summary, the public, growers, greengrocers and supermarket agents repeatedly assessed lettuce as clean despite them containing several aphids per plant.

IPM is viable for managing Tasmanian lettuce pests including currant lettuce aphid. It failed in autumn when attempted adjacent to larger areas of drenched lettuce. The sequence of plantings and the areas that can support populations of beneficial species are critical in an IPM strategy. The laboratory bioassay confirmed that indirect poisoning of lacewings by ingestion of poisoned aphids persisted for several weeks at low rates of Confidor drench.

Confidor and Chess seedling drenches, including a low rate of Confidor, were associated with the highest *Helicoverpa* caterpillar populations and did not reduce cutworm problems. However the low rate of Confidor produced marketable lettuce.

The broad spectrum insecticide Dominex exacerbated lettuce aphid infestations. Pirimor may have temporarily disrupted natural control of lettuce aphids.

The very disruptive effects of broad spectrum insecticides such as Dominex are well known by some mainland growers but was poorly recognised in practice by Tasmanian agronomists and growers. Some continue to recommend mixes of cheap broad spectrum insecticides with expensive selective insecticides.

The impact of Pirimor in IPM deserves more detailed examination under commercial conditions (as opposed to laboratory bioassays) so that its use can be optimised.

Technology Transfer

The commercial scale demonstration of IPM in lettuce at Forthside led, after some hesitancy and discussion, to two of the three major Tasmanian growers planting pilot IPM crops of both open-hearted and iceberg lettuce in 2005-6 with assistance in the form of seedlings, weekly monitoring and access to advice from IPM Technologies P/L.

This rate of adoption within Tasmania is better than achieved in the last decade in other national vegetable levy pest projects and suggests that first hand experience with a commercial scale IPM crop is very persuasive, even given the impediments outlined below. This outcome is pursued in the Recommendations.

Field days

Eleven field events, including five lessons, based at the IPM lettuce crop were completed. Appendix 6 provides a summary of attendance excluding project staff and DPIWE personnel. Interstate participants were strongly represented at two field lessons, although the size of these groups restricted one-to-one tuition. The events, additional to the field lessons for growers and agronomists were tours for a leading iceberg grower, supermarket produce buyers, two groups led by Bayer, two student vocational groups and a general open day covering all projects at Forthside Research and Demonstration Farm.

The first seven of nine lettuce crops successfully demonstrated IPM. Emphasis was put on group assessment by participants at field days rather than on presentation of detailed numerical data to demonstrate 'success'. About 600 cartons of lettuce were sold through vegetable shops as further proof of success and progressively reported back at field days. Market share limited further sales. Growers, agronomists, supermarket buyers and others were given a brief explanation of IPM, shown the crops, shown monitoring and decision making actions and encouraged to cut and inspect lettuce in the field.

In addition the supermarket buyers inspected IPM lettuce in cartons. Sampling of lettuce in cartons by the buyers was initially minimal and both groups explained that they varied sample size according to the reliability of suppliers. In order to get more detailed feedback for the research team the buyers were encouraged to sample more lettuce and comment on various contaminants. They explained their specifications and did not find fault, although no lettuce were marketed through the major supermarkets

Field Day 1, on 4 November 2004, revealed high levels of lettuce aphid and high levels of ladybird and lacewing adults in P1-3. The expectation from seven experienced Tasmanian agronomists and growers was that this level of lettuce aphid would result in unacceptable contamination at harvest.

Field Day 2, on 17 November 2005, was held exclusively for six agronomists from the dominant agronomy/pesticide reseller company in Tasmania. It commenced with a quiz to stimulate interest in and assess knowledge of beneficial insect identification followed by a guided tour of the project crop. Fast monitoring methods were demonstrated and insect identification taught in the field.

Field Day 3, on 18 November 2004, revealed much lower levels of aphids and much higher levels of brown lacewings and other beneficial insects in P1 but continued aphid pressure in planting 3. The growers and agronomists that had attended the first field day expressed surprise at the high degree of control of lettuce aphid that had been achieved in P1 then seven weeks old. They were particularly interested in the *decrease* in lettuce aphid numbers per lettuce rather than the level of control. They still expected rejection despite the downward trend.

Field Day 4, on 2 December 2004, was extremely interesting. Growers were invited to assess the level of lettuce aphid by cutting lettuce in the field and to offer advice as to whether the crop would meet, or not meet, their own commercial standards for insect contamination. All growers present assessed lettuce from P1, then nine weeks old, as meeting their standards.

At the Forthside whole-farm open day on 9 December two groups each of 20-30 people visited the IPM crop and received a 15-minute explanation. On the same day seven interviews were given to the media, namely ABC TV, WIN TV, Southern Cross TV, *The Examiner*, *The Mercury*, *The Advocate* and *Tasmanian Country* newspapers.

Field Day 5 was on 19 January 2005, by which time P4 was mature. Many interstate participants attended. It revealed a recurring pattern of infestation by lettuce aphid during the first few weeks of each crop followed by progressive and satisfactory elimination of aphids by beneficial insects with inconspicuous final contamination by aphids or beneficial insects.

Subsequently two field days were held to host groups organised by Bayer and Boomaroo Nursery and two field days for student vocational groups. The former groups also visited the VG04068 project site (insecticidal efficacy and residue studies for lettuce aphid) nearby.

Reports to groups

A project workshop was held in Devonport with IPM Technologies and growers on 7 July 2004 to teach and discuss the theory of IPM prior to the project commencing.

A talk was given at the National Lettuce Industry Conference at Werribee in May 2005 to an audience of 200 or so; another to an industry group of 40 persons at the DPI Knoxfield offices, Melbourne on 23 June 2005 and another to a group of 30 at the Tasmanian Agricultural Research Advisory Committee annual seminar in Devonport on 27 July 2005.

Mass media

ABC regional radio (Rural News) covered all field days. ABC TV news, ABC Country Hour radio and two commercial TV journalists covered one field day. Progress reports appeared in the national industry newsletter *Lettuce Leaf*. Reports also appeared in the state IDO newsletter *Getting Results*. A handful of reports appeared in Tasmanian newspapers and one in the national *Weekly Times*. Many photographs were obtained to facilitate future communications.

On 30 October 2005 ABC Landline televised a story about lettuce aphid including mention of the project. This arose from a request from AUSVEG for a film to assist promotion of national vegetable levy projects. This screening was repeated on 2 January 2006.

Printed media items:

Adamson, K., *The Weekly Times* 9 March 2005, Insect plan to save lettuces,

Anonymous, *Advocate* 26 January 2005, Pest test success.

Cole, D., *Advocate* 10 December 2004, Lettuce pest trial shows promising results.

Creek, A. *Lettuce Leaf* No 19 (sic), April 2005, Tasmanian Lettuce Update.

Grube, K., *Tasmanian Country*, 14 January 2005, Getting lettuce aphids to bug off.

Hill, L. and Creek, A., *Lettuce Leaf* No 17, August 2004, Lettuce aphid weed survey, Lettuce aphid projects and How are growers coping with the aphid.

Hill, L. and Creek, A., *Lettuce Leaf* No 18, December 2004, Lettuce aphid project.

Kempton, H., *Examiner*, 10 December 2004, Lettuce growers not bugged.

McDougall, S., *Lettuce Leaf* No 19, February 2005, Beneficials continue to clean up Lettuce Aphid.

Vegetable IDOs, *Good Fruit and Vegetables*, June 2005, Latest on lettuce aphid.

Vegetable IDOs, *Good Fruit and Vegetables*, June 2005, IPM controls lettuce aphid in Tasmania.

Welsh, S., *Getting Results*, December 2004, Research puts pressure on the lettuce aphid.

Discussion of impediments to transfer of IPM technology

Among growers

During discussions at field days growers acknowledged that there was effective control of pests in the IPM lettuce and expressed interest in trying IPM for lettuce in part of their production but were not ready to embark wholeheartedly. This was a substantial step forward because there was low expectation of success from most of this group before the trial commenced.

Indeed the trial was modified at a late stage of planning to include several *Nasonovia*-resistant cultivars because these were regarded as the only likely 'IPM' alternative to the seedling drench. Another late change was the repeated application of alpha-cypermethrin to some plantings to reveal the true potential for lettuce aphid multiplication. This was done because of comments received at field days that IPM worked only because aphid pressure was low during the trial. These two attitudes reflected a general reluctance to consider IPM with susceptible lettuce as a serious option.

At field days, the focus was on the efficacy of IPM for aphid control rather than comparisons to imidacloprid drenches. Comparative data from P3, P5-P9, showing that drenched lettuce contained aphids, were incomplete at that time and were not highlighted in order to avoid the distraction of adversarial debate such as whether IPM was 'better or worse' than drenching.

The main concern that the IPM team wished to examine in regard to imidacloprid-drenching was not its efficacy for aphids but the likelihood of it disrupting (or not integrating with) management of other pests, especially caterpillars. At the time of the field days comparative data for caterpillar infestation were incomplete and not strongly promoted. In addition, northern Tasmanian growers felt that caterpillars were minor pests locally and hence any advantages of IPM over the seedling drench strategy for overall pest control were irrelevant. Southern Tasmanian growers felt that transmission of Tomato Spotted Wilt Virus by onion thrips was a major issue in their region and not addressed in the Forthside plantings because, historically, such a problem rarely occurs in the northwestern region of the state.

The owner of one small, hydroponic lettuce farm attended all four field lessons available to him. One small fresh market grower attended three field lessons and assisted greatly with the sale of IPM lettuce. Other growers attended only one or two field days. Their concerns about IPM could not be addressed in convincing detail. Fortunately, all three major growers subsequently agreed to try pilot crops of IPM lettuce, although one was prevented by adverse weather in the following season.

Organic growers never attended. A couple said they were not interested in IPM and preferred to rely upon pyrethrum insecticide or, for open lettuce, post-harvest washing. They missed opportunities such as learning about spinosad (Table 3) as a selective insecticide for caterpillars and thrips that is also available in an organic formulation.

Among agronomists

Impediments to IPM are greater among agronomists than growers.

Tasmanian vegetable growers typically run diverse farms with many crops. They are heavily serviced by private sector agronomy companies who monitor crop health including pests. Their staff, with telling exceptions, do not actively seek to learn and recommend IPM to a high level of competency whether or not their business also involves reselling pesticides.

There are 20 or so agronomists in a handful of companies compared to two public entomologists, no public vegetable IPM extension officer and one levy-funded Industry Development Officer. Many private agronomists are graduate agricultural scientists but a minority lack tertiary training in agriculture. Growers are usually preoccupied with farm management at a broad level and rely heavily upon the agronomists for specific pest management advice. In this project, there was poor attendance by the private agronomy sector. This made it difficult to identify and address their doubts about IPM. The poor attendance occurred despite a high level of technical success, awareness and media attention the project achieved during its life (Appendix 6). It was evident from interactions at field days that few graduate agronomists have effective working knowledge of selective pesticides or familiarity with key pests, predators and parasitoids. Previous projects and activities suggest that less than a handful actively pursue opportunities to learn these details to a high level although most have a fragmentary familiarity with some components of IPM. This suggests that most do not understand IPM in practice.

One agronomist was paid for advice on lettuce agronomy and disease management during the project. He attended four field days. However, most agronomists attended only once, mostly at an exclusive field day arranged for one company early in the project and before results became clear. Personal, written invitations to many agronomists during the project yielded little extra attendance. Perhaps most agronomists do not deal with lettuce growers and failed to see that the core of IPM knowledge can be extrapolated to a range of vegetable crops. Perhaps some did not see how this project differed from disjointed 'one-off' presentations of IPM information offered in previous levy-funded projects.

Many Tasmanian agronomists say they are too busy to attend IPM seminars in the warmer months. While it is sometimes possible to schedule certain types of IPM workshops to winter it is not possible to do so for demonstration crops.

Most agronomists seem not to understand vegetable-IPM as it has evolved commercially in the last decade in Victoria and New South Wales. That is, there are a few common factors, selective pesticides and beneficial species shared among vegetable crops. This facilitates extrapolation of IPM from crop to crop. Perhaps previous technology transfer has overemphasized crop specific knowledge, pest-specific parasitoids and sampling techniques.

A principal agronomist remarked, after a presentation by IPM Technologies P/L in July 2004, that monitoring for pests had been tried by his company but was not economic in Tasmania. Factors such as greater topographic complexity requiring larger sampling effort and 'zero' tolerances for contaminants in processing vegetables were cited as reasons. These misconceptions perhaps derive from previous attempts to extend formal, dynamic, sequential sampling plans to the brassica industry, wilful disredgard of progress towards finite and flexible tolerances (specifications) in processing factories (for example, 10-20% for caterpillars in processing broccoli) and perhaps some lack of attention during the presentation in question. Notably, this agronomist and others (as well as some of the national research community) rarely if ever refer to a more valid difference (for IPM) between Tasmanian processing crops and mainland fresh market crops inherent in large, isolated plantings versus small, sequential, adjacent plantings.

Many other agronomists also say that supermarkets and vegetable processors have nil tolerance for 'bugs' and that routine use of insecticides insures this at a small financial premium paid by the grower ('insurance spraying'). Exacerbation of pest levels by inappropriate insecticide use is never considered a possibility. Insecticides (unlike herbicides), either their use or their selection, are rarely blamed for crop damage (via pests) but the absence of a recommendation for insecticide is likely to be regarded as negligent advice.

At a brassica-IPM field day held during the period of this lettuce-IPM project, another agronomist remarked that IPM was good in theory but that she could not afford to count bugs in crops. She was unaware that the IPM consultant to whom she was talking was fully commercial (despite him being introduced as such). This may indicate a common misconception arising from most IPM extension work in the past being done by non commercial IPM advisors. It may also indicate a tendency to use 'commercial necessity' as a convenient excuse to avoid learning new skills for IPM.

It appears that many Tasmanian vegetable agronomists are unaware that a few private sector IPM consultants have not only been making a living but also reducing their clients' costs and chemical exposure without unacceptable financial risks for a decade in the south-eastern Australian vegetable industry. A prime objective of the series of field days was to teach quick assessment of the pest/predator balance and trends in a crop. Agronomists may not have realised that the methods used in this project are simpler and more intuitive than some complex pest sampling systems (or decision-trees) they may have encountered through other recent projects. The IPM system used in this project had no simple 'threshold' number that acts as a trigger for spraying. It also paid great attention to a few general predators that were neglected in recent brassica-IPM decision systems.

Indeed, the decision system taught in this project is similar to what many agronomists seem to do in practice (in small sample size, integration of observations from several plantings in a sequence, integration of crop history and farm history) but are underpinned with a greater recognition of key predators and parasites and knowledge of selective chemistry.

Another principal of a major agronomy company never attended field lessons, nor did his several graduate staff. In response to the acronym IPM he repeatedly expounds the KILL strategy. This anecdote suggests that many agronomists transfer risks and costs from themselves to their clients by recommending programs of multiple, prophylactic pesticides driven by the calender or low-thresholds for sightings of pests. He continues to recommend mixtures of selective and broad-spectrum insecticides contrary not only to the basics principles of IPM but also the profits of his clients. Such advice does not require graduate agricultural science training but continues to be offered at professional rates.

BT sprays are important components of IPM. Many Tasmanian vegetable agronomists have no confidence in BT insecticides (*Bacillus thuringiensis*) citing lower temperatures or higher ultraviolet degradation as possible causes for poorer performance here than on the mainland. Very few recommend BT sprays. There was never funding within recent national levy projects to test or rebuff these regional concerns by conducting regional demonstrations using best practice in the application of BT such as high volume application at dusk. These reservations about BT may begin to diminish following recent successes by influential broccoli contractors who are conducting their own technology transfer to their growers. This in turn is placing pressure on commercial agronomists to reconsider the use of BT.

In summary, although the private agronomy sector drives pest management in Tasmania, it has proven resistant to adopting IPM, as taught by non commercial exponents, and it may be more productive to use commercially proven IPM exponents to demonstrate IPM directly to influential growers, who, in turn, will insist that their agronomists ‘get up to speed’ with recent progress in commercial IPM.

Recommendations

Emphasise commercial demonstration cropping.

The commercial scale demonstration of IPM in lettuce at Forthside led, after some discussion, to two of the three major Tasmanian growers agreeing to plant pilot IPM crops of open or iceberg lettuce in 2005-6 with assistance in the form of free seedlings, assistance with weekly monitoring and access to advice from IPM Technologies P/L.

This rate of adoption within Tasmania is better than achieved in the last decade in other national vegetable-levy projects and suggests that first hand experience with a commercial scale IPM crop is very persuasive, even given the deficiencies mentioned above in the Technology Transfer section.

Currant lettuce aphid was a new pest for which no local research outputs were available. The pest and beneficial insect fauna were rather different to the mainland Yet IPM succeeded on first attempt when supervised by an experienced, commercial IPM consultant who extrapolated key principles from other crops. This suggests that levy funds should first be directed to pilot implementation of IPM in commercial crops in the manner of IPM Technologies P/L and followed, only when intractable problems arise, by experimental research. This implies many regionalised demonstrations to test and adapt core principles.

Target growers in demonstration crops.

During the last two decades it seemed more productive to persuade a few agronomists who advise many clients to promote IPM in Tasmania. However this project suggests that a few pilot, commercial IPM crops, witnessed by growers, will force agronomists to follow their clients' interest in IPM with greater enthusiasm.

Harness existing IPM practical experience.

The project harnessed a decade of commercial-scale, well-informed and experienced empirical research by IPM Technologies P/L and took it directly to a commercial demonstration of IPM in a novel crop-pest combination. There is a valuable pool of knowledge in IPM Technologies P/L which is not yet fully recognised by the IPM research community in Australia. For instance, the methods of bug counting, the emphasis on the needs of a few widespread generalist predators in a variety of vegetable crop and philosophy of insecticide resistance management differ subtly but significantly from many recent outputs of the R&D community.

Reduce costs by selling demonstration crops.

With better marketing arrangements to seek cooperation with and avoid competition with levy-paying growers the project had the potential to recover substantial costs.

Safety net for demonstration growers

Alternatively, IPM commercial-scale projects are potentially cheap if conducted entirely commercially but with subsidised supervision by practising IPM consultants and a mechanism for partial or whole compensation. Compensation would not need to be drawn upon for all demonstration projects because many are likely to succeed.

Traineeships in IPM

Experienced commercial IPM advisors are rare and take time to train. Perhaps the levy could be used to place trainees with proven IPM advisors or to assist mainstrean agronomists to take 'sabbaticals' with proven IPM consultants.

Acknowledgements

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

The national vegetable levy provided funds for crop production, technical staff and travel for professional staff for this project.

The Department of Primary Industries, Water and Environment, Tasmania provided professional staff in kind, housed technical staff and provided the facilities and staff of the Forthside Vegetable Research and Demonstration Farm at normal research rates.

The NSW Department of Primary Industries provided professional staff (Dr Sandra McDougall) for project design and field events and access to the *Lettuce Leaf* newsletter.

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Horne, P. A., Ridland, P. R. and New, T. R., Chapter 18, *Micromus tasmaniae*: a key predator on aphids in field crops in Australasia? In Lacewings in the Crop Environment, Edited by Peter K. McEwen, Tim R. New and Andrew E. Whittington, Cambridge University Press June 2001, pp 388-394.

Koppert, 1998, http://www.koppert.nl - Toxicity of imidacloprid to various insects.

Appendix 1

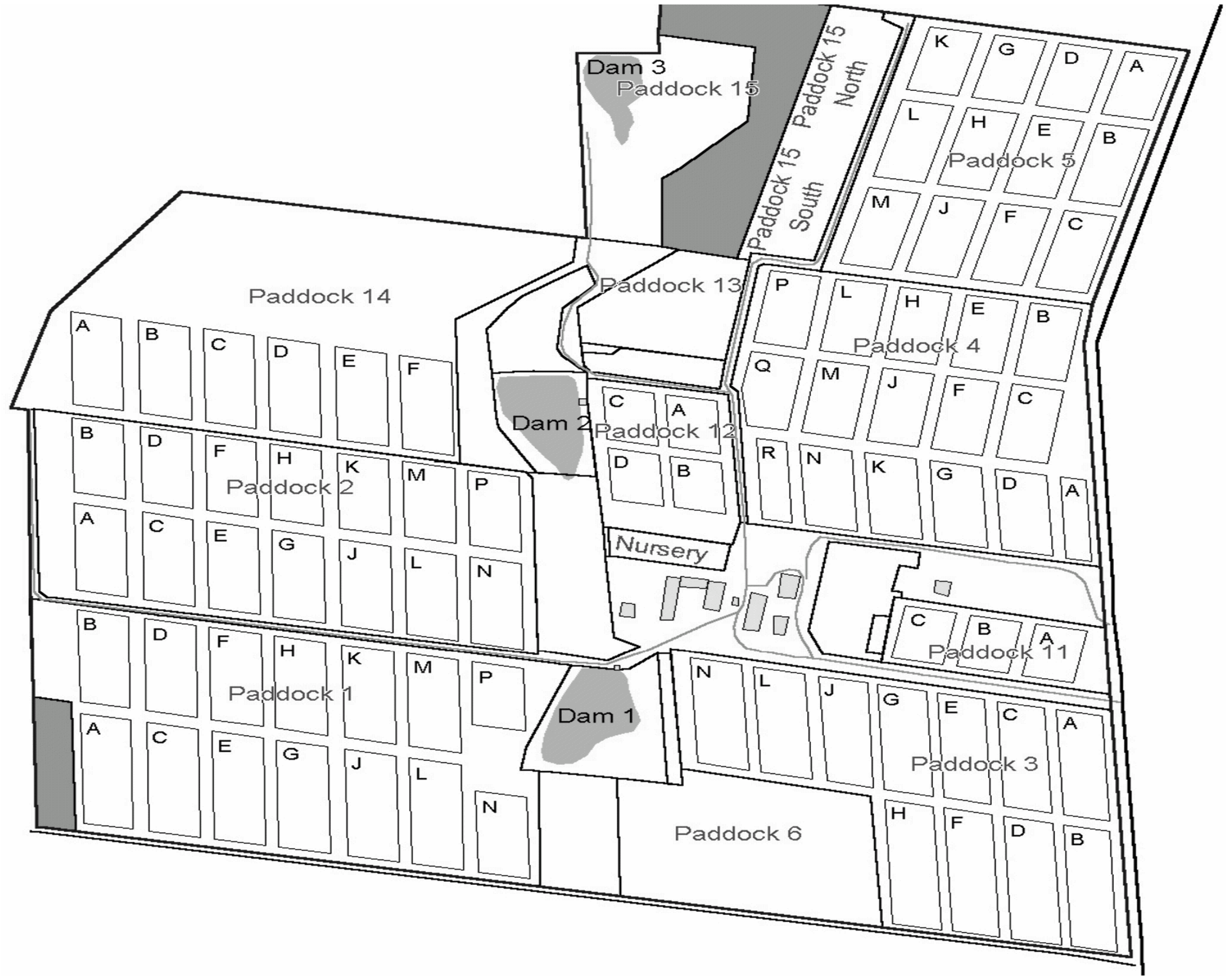
Report to Ausveg and HAL on "The impact of aphicide drenches on *Micromus tasmaniae* (Walker) (Neuroptera: Hemerobiidae) and the implications for pest control in lettuce crops by Paul A. Horne and Peter G. Cole, February 2005.

A manuscript detailing this bioassay has been submitted to the Journal of the Australian entomological Society and accepted for publication subject to revision. The revised manuscript was resubmitted to the Journal in January 2006.

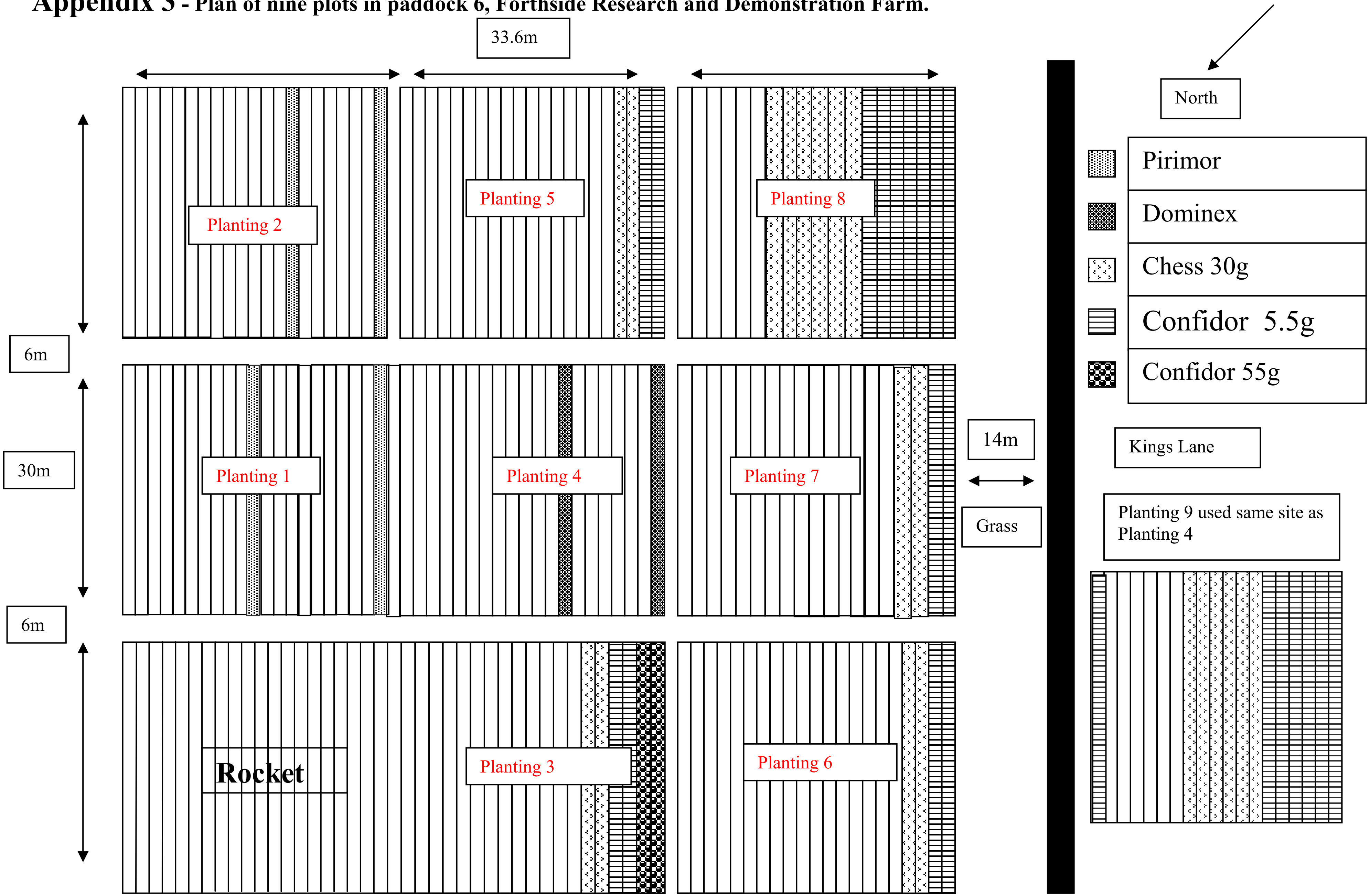
The essential results are given above in the Results section.

Appendix 2

Map of Forthside Research and Demonstration farm.



Appendix 3 - Plan of nine plots in paddock 6, Forthside Research and Demonstration Farm.



Appendix 4

Table 1: Aphids, common or predatory insects, expressed as catch of individuals per day, caught in yellow water tray near lettuce crop.

Period ending	Drone fly *Eristalis tenax*	*Melangyna* hoverfly	winged aphids	Bumble bee *Bombus terrestris*	Honeybee *Apis mellifera*	Brown lacewing	11-spotted ladybird
28-Oct-04	0	0	3.9	0.1	0	0	0
03-Nov-04	0	0.2	7.5	0	0	0.3	0
09-Nov-04	0	0.3	3.7	0.7	2.5	0	0
22-Nov-04	0.3	1.8	0.2	0.2	0	0	0
25-Nov-04	0	10.0	2.0	0.7	0.7	0	0
30-Nov-04	0	7.0	1.6	0.2	0	0.4	0
07-Dec-04	0.4	2.0	0.9	0	0	0	0
10-Dec-04	1.7	3.7	0	0	0	0	0
13-Dec-04	0	0.3	5.3	0	0	0.3	0
24-Dec-04	0	0.1	0	0	0	0	0
31-Dec-04	0	0	0.9	0	0	0	0
04-Jan-05	0.5	0.3	8.0	0.3	0	0	0
10-Jan-05	0	0.2	6.7	0.2	0	0	0
24-Jan-05	0.3	0.3	8.4	0.2	0	0	0
31-Jan-05	0.9	1.0	13.7	1.0	0.4	0.4	0
07-Feb-05	7.6	0.4	1.3	0.9	0.4	0.1	0
14-Feb-05	2.7	0.3	0	0.7	1.1	0	0
21-Feb-05	0.6	0	0.7	1.0	1.6	0.1	0.3
28-Feb-05	0.3	0.4	0.9	0.9	1.3	0	0.4
07-Mar-05	1.0	0.4	0	1.6	4.6	0	0
15-Mar-05	0.3	0	0.3	2.6	5.8	0	0
21-Mar-05	1.5	0	6.3	1.2	2.0	0	0
06-Apr-05	0.3	0	1.8	0.2	0.1	0	0
13-Apr-05	1.6	0.1	17.6	0	0.7	0	0
20-Apr-05	0.6	0.1	13.1	0.6	1.0	0.3	0

Appendix 5

Table 1: Key to scientific names used in this report

Aphid parasite	*Aphidius colemani*
Assassin bug	*Pristhesancus* sp.
Bigeyed bug	*Orius* sp.
Black grass thrips	*Limothrips cerealium*
Blackcurrant-sowthistle aphid	*Hyperomyzus lactucae*
Brown lacewing	*Micromus tasmaniae*
Brown lacewing parasitoid	*Anacharis* sp.
Bumble bee	*Bombus terrestris*
Cabbage grey aphid	*Brevicoryne brassicae*
Caterpillar egg parasitoid	*Telenomus* sp.
Caterpillar egg parasitoid	*Trichogramma* sp.
Chevron cutworm	*Diarsia intermixta*
Cluster caterpillar	*Spodoptera litura*
Common brown earwig	*Labidura truncata*
Common cutworm	*Agrotis infusa*
Common spotted ladybird	*Harmonia conformis*
Corn earworm	*Helicoverpa armigera*
Cotton aphid	*Aphis gossypi*
Currant lettuce aphid	*Nasonovia ribisnigri*
Damsel bug	*Nabis kinbergi*
Drone fly	*Eristalis tenax*
Eleven spotted ladybird	*Coccinella undecimpunctata*
European earwig	*Forficula auriculata*
Foxglove aphid	*Aulacorthum solani*
Glossy shield bug	*Cermatulus nasalis*
Green cutworm	*Neumichtis nigerrima*
Grass leafhopper	*Nesoclutha phryne* (Kirkaldy)
Green looper	*Chrysodeixis argentifera*
Green peach aphid	*Myzus persicae*
Green vegetable bug	*Nezera viridula*
Grey garden slug	*Derocera reticulatum*
Honey bee	*Apis mellifera*
Hoverfly parasitoid	*Diplazon laeletorius*
Lucerne flea	*Sminthuridis viridis*
Lucerne leafroller	*Merophyas divulsana*
Melangyna hoverfly	*Melangyna sp.*
Minute pirate bug	*Geocoris* sp.
Native budworm	*Helicoverpa punctigera*
Onion thrips	*Thrips tabaci*
Plague thrips	*Thrips imaginis*
Potato aphid	*Macrosiphum euphorbiae*
Potato bug	*Calocoris norvegicus*
Predatory shield bug	*Oechalia schellenbergi*
Predatory thrips	*Aeolothrips* sp.
Red and blue beetle	*Dicranolaius bellulus*
Rutherglen bug	*Nysius vinitor*
Silverleaf whitefly	*Bemesia tabaci*
Soldier beetle	*Chauliognathus* sp.
Southern ladybird	*Cleobora mellyi*
Sowthistle aphid	*Uroleucon sonchi*
Strawberry beetle	*Clivina* sp.
Striped ladybird	*Micraspis frenata*
Tranverse ladybird	*Coccinella transversalis*
Two striped slug	*Lehmannia nyctelia*

Two-spotted ladybird	*Diomus notescens*
Two-stripe fly	*Poeciloheteraeus* sp.
Vegetable leafhopper	*Austroasca viridigrisea*
Western flower thrips	*Frankliniella occidentalis*
White-collared ladybird	*Hippodamus varigata*
Yellow leafhopper	*Zygina zealandica* (Myers)

Appendix 6

Table 1: Summary of participants at various field events extending the results of the IPM lettuce trial. VG indicates a researcher connected with other national vegetable levy projects.

Classification of individuals	Grower tour, 20/9/04	Field day 1, 4/11/2004	Field day 2, 17/11/04	Field day 3, 18/11/04	Field day 4, 2/12/04	Forthside open day, 9/12/04	Field day 5, 19/1/05	Supermarket buyer tour, 20/1/05	Field day 6, 16/3/05	Univ. student tour, 17/3/05	Sec. student tour 23/3/05	Researchers tour, 2/5/05
ABC Radio		y		y	y	y	y					
Other TV, radio & print media						y						
agronomist 1, Serve-Ag			y									
agronomist 2, Serve-Ag			y									
agronomist 3, Serve-Ag		y	y	y			y					
agronomist 4, Serve-Ag			y									
agronomist 5, Serve-Ag			y									
agronomist 6, Serve-Ag				y	y							
agronomist 7, Serve-Ag			y									
agronomist, brassica		y										
agronomist, Muirs Vic							y					
agronomist, Muirs Vic									y			
agronomist, private Tas		y					y					
Ausveg committee					y		y					
Ausveg committee							y					
Ausveg committee					y							
Ausveg committee					y							
Ausveg CEO							y					
Ausveg IDM							y					
Ausveg IDO Qld							y					
Ausveg IDO Tasmania		y			y		y					
TFGA chairman							y					
Bayer									y			y
Bayer									y			
Bayer							y		y			y
Bayer									y			
Grower, lettuce	y						y					
Grower, lettuce		y		y	y							
Grower, lettuce							y					
Grower, lettuce		y		y	y		y					
Grower, lettuce					y							
Grower, lettuce					y							
Grower, lettuce					y							
Grower, lettuce									y			
Grower, lettuce									y			
Grower, lettuce					y							
Grower, brassica												
GSF Australia							y					
Harvest Fresh Cut							y					
Supermarket buyers								y				
Nursery lettuce									y			

Nursery lettuce							y					
Nursery lettuce							y					
Nursery lettuce									y			
Nursery lettuce									y			
Nursery lettuce									y			
Nursery lettuce							y		y			
Research extension., SARDI					y		y					
Researcher VG04068, Serve-Ag												y
Researcher VG04068, Serve-Ag		y			y							
Researcher VG04068, Serve-Ag							y					
Researcher, Agronico				y			y					
Researcher, SARDI							y					
Senator, Parl. Agric. Sec.							y					
Senator's staff							y					
Senator's staff							y					
Victorian DPI							y					
Victorian quarantine							y					
Victorian quarantine							y					
Attendance	1	7	6	5	13	40	30	4	12	15	15	3

Appendix 7

Table 1: Cultivars used in paddock 6, Forthside Research and Demonstration Farm.

Planting	Susceptible cultivars	Resistant cultivars	Resistant Cos
1	Oxley, Target, Brisbane	RZ45-98, Eldorado	RZ 41-41
2	Sheeba, Brisbane	RZ45-82, RZ45-62	RZ 41-42
3	Brisbane, Toronto	RZ45-82, Eldorado	RZ 41-43
4	Brisbane, Toronto	RZ45-82, Eldorado	RZ 41-44
5	Sheeba, Toronto	RZ45-82, Eldorado	RZ 41-45
6	Sheeba, Toronto	RZ45-82, Eldorado	
7	Toronto		
8	Toronto		
9	Toronto		

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