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# *Integrated Pest and Disease Management (IPM) for outdoor lettuce – Final Report*

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# Contents

# 1 Project background and introduction

In 2002, the lettuce industry initiated a 3-year project to develop and implement an integrated pest management (IPM) programme for the control of insect pests and plant diseases in outdoor lettuce to counter concerns about unsustainable crop protection practices, and to control the new insect pest, lettuce aphid (LA), *Nasonovia ribisnigri*.

The project team included grower groups from the two major lettuce-producing regions, Pukekohe and Gisborne, and other key industry partners. These parties worked closely with Crop & Food Research to research and develop environmentally compatible control strategies and best grower practices for outdoor lettuce production. The goal was to maximise non-pesticide controls while maintaining the efficacy of available and new pesticides. Vegfed, the agrichemical industry and other industry partners all supported this MAF Sustainable Farming Fund project.

The IPM project involved a large number of replicated field trials at Pukekohe Research Centre (PRC), validation trials in grower fields in the final year, seasonal regional surveys to assess the insect fauna and incidence of virus diseases in different regions, field trials in LeaderBrand crops in Gisborne, field days based at Pukekohe; seasonal insect trials in Christchurch and other field and laboratory studies in Auckland and Canterbury.

After completion of the 3-year project, funding for a 2-year "implementation phase" of the project was approved by Vegfed and MAF SFF (grant number 05/059) and began in July 2005. An outdoor lettuce 'Information Guide' manual has been developed as a training resource and will be further developed into an IPM manual in the implementation phase.

## 1.1 *IPM project objectives by milestone*

These objectives are taken from the initial project design documentation.

**Milestone 1: Planning**

A meeting of all stakeholders will be held to decide priorities, trial protocols, responsibilities and timeframes for all activities. Project activities will be publicised in the *Grower*, the commercial magazine published for Vegfed growers and the vegetable industry.

**Milestone 2: Insect pest control**

Field trials in grower crops in Gisborne and Pukekohe will test different monitoring systems (including pheromone trapping and crop scouting) and will test economic action thresholds for the key pest aphids, thrips and looper species. Trials in years 1 and 2 will include the assessment of different insecticides to include these products into compatible control strategies, which maximise the impacts of natural enemies. In year 3, trials will validate the monitoring systems and action thresholds. Articles in the *Grower* magazine will update growers on progress.

**Milestone 3: Plant disease control**

Field trials in grower crops in Gisborne and Pukekohe will assess the efficacy of different fungicide spray programmes and treatment regimes using new and/or presently available fungicides for key fungal diseases. Trials in years 1 and 2 will assess best treatment regimes and in year 3 trials will validate best practice techniques for disease management. Yearly reports in the *Grower* magazine will update progress.

**Milestone 4: Virus diseases**

Surveys in both regions will determine the incidence and importance of virus diseases including alternative host plants and important insect vectors. Yearly reports in the *Grower* magazine will update progress and management strategies will be incorporated into the IPM programme.

**Milestone 5: Pesticide resistance**

To develop pesticide resistance management strategies for the key insect pests and plant diseases. The strategies will be incorporated into the IPM programme and reported in *Grower* articles.

**Milestone 6: Looper monitoring**

To study the looper populations in both districts to determine the pest status of the two main species. Investigate the use of pheromone trapping for monitoring looper moth movement into crops. Incorporate as appropriate into the IPM programme and publicise in the *Grower.*

**Milestone 7: Biological control**

To assess the importance of natural enemies of the key insect pests during the field trials and emphasise the use of selective pesticides to maximise the impact of biological control agents. Incorporate the identification and use of natural enemies into the IPM programme (to be completed by June 2007).

**Milestone 8: Tech transfer**

Demonstration trials, grower field days and training of scouts in IPM crops in grower fields, Pukekohe and Gisborne (to be completed by May 2007).

**Milestone 9: IPM manual**

Production of an IPM manual incorporating management techniques for all the key pests and diseases, including monitoring techniques, use of proven action thresholds and pesticide resistance management strategies. Present seminars in all the major lettuce-growing regions to promote the IPM programme for lettuce. Survey of uptake by growers of the IPM programme (to be completed by June 2007).

# 2 Changes to project

- The project team agreed that regional surveys should be extended beyond just the two main growing regions of Pukekohe and Gisborne. Therefore insect and virus surveys were undertaken in other regions, particularly in Canterbury, Nelson, Manawatu/Horowhenua and Hawke's Bay.
- Milestone 6: A pheromone lure for soybean looper (*Thysanoplusia orichalcea*) was not obtained until January 2005. Therefore most of the research in the first 2 years was aimed at developing control strategies for looper caterpillars in the replicated summer and autumn field trials at PRC.
- Researchers: Sohail Qureshi resigned in 2004 and was replaced by Carol Curtis. Marlon Stufkens retired in late May 2005.

# 3 Summary of project outcomes (by milestones)

## 3.1 Milestone 1: Planning

- Regular project team meetings were held, mainly at Pukekohe.
- The project team agreed that the Information Guide would initially be produced in a folder format (similar to the vegetable brassica IPM manual), and as a limited edition draft distributed to obtain comment and feedback prior to revision. It should not include current agronomic practices, weed identification or pesticide application techniques.

## 3.2 Milestone 2: Insect pest control

### Aphids

### Surveys and monitoring

- Surveys showed that LA spread to all lettuce-growing regions within 12 months of first being recorded in New Zealand. Transportation of lettuces and seedlings played an important role in the spread of LA.
- A 7.5 m suction trap was constructed at PRC, and monitoring of flights of aphids and thrips began in October 2003.
- Flights of LA were continuously monitored by three to five suction traps at Canterbury, Hastings and Pukekohe. LA flight information was continuously updated (usually every week) on www.aphidwatch.com.
- Populations of LA infesting untreated susceptible crops at PRC declined dramatically (by about a factor of 10) over the 3 years, probably mainly due to the activity of natural enemies adapting to this new host. Aphid-infecting (entomopathogenic) fungi are very important in reducing LA populations at Pukekohe over winter.
- An aphid identification key was produced and a number of workshops held to train industry personnel on its use.

### Field trials

- 18 seasonal replicated insect field trials were undertaken; 13 at Pukekohe, four in Canterbury and one in Gisborne. Most trials were undertaken at PRC and focused on testing sampling systems and control strategies for LA and natural enemies. Appendix 1 contains a summary of replicated trials and results testing biological controls for aphid pests. Many trials included also treatments trialled for control of caterpillar pests (particularly soybean looper in summer and autumn trials), and of thrips (summer trials).
- The 10 seasonal trials completed at PRC (weekly sampling in spring, summer and autumn; fortnightly in winter) had four to eight treatments per trial. Treatments included testing foliar insecticides, insecticidal drenches and biocontrols for control of LA and other aphid species. Results included:
  - LA infestations must be determined by destructive sampling. Visual (non-destructive) examination is not accurate enough to determine the infestation levels, or even the presence of LA.
  - LA was controlled in three consecutive spring trials at PRC by natural enemies, particularly by Tasmanian brown lacewing.
  - An epizootic of *Erynia neoaphidis* (a naturally occurring insect-infecting fungus) controlled LA in the winter trial in 2003 and in the autumn trial in 2004 at PRC, but LA populations were not controlled by natural enemies in the autumn 2003 trial or the winter 2004 trial.
  - LA can be controlled by drenching seedlings with 20 to 30 mL of imidacloprid per 1000 plants applied 24 hours before transplanting.

- In the third year, it was demonstrated that Tasmanian brown lacewing controlled LA in three spring trials in commercial crops in the South Auckland region.
- Research trials in Gisborne showed potential control of LA by natural enemies but control was not achieved in a replicated spring trial.
- Research in Canterbury showed that natural enemies controlled LA infestations in two consecutive summer trials (2004 and 2005) and in a spring trial in 2003.

## Caterpillar pests

- Soybean looper (*Thyanoplusia orichalcea*) is the only looper species recovered from lettuce during this study period. Green looper (*Chrysodeixis eriosoma*) has not been recovered. Therefore, pheromone trapping for soybean looper may well be a useful monitoring tool. Results to date suggest that pheromone trapping in spring and early summer crops will forewarn of egg and larval infestations of soybean looper.
- Where imidacloprid drenching or LA-resistant cultivars are used, soybean looper is the major insect pest in summer and autumn lettuce crops at Pukekohe.
- An action threshold of 0.5 larvae per plant, along with thresholds of 15% and 30% of plants infested, gave good control of caterpillar pests in small plot trials. However, these thresholds should be used with care because they have not been validated over a number of seasons and years.
- Large soybean looper caterpillars are not well controlled by natural enemies, although a small nuclear polyhedrosis (NPV) virus commonly infects this species in late summer and autumn.
- Heliothis (*Helicoverpa armigera*), tomato fruitworm, was rare in Pukekohe but can heavily infest crops in late summer and autumn in Gisborne.
- A new caterpillar pest was recovered in New Zeaalnd for the first time. *Agrotis infusa*, called Bogong moth in Australia where it is a major cutworm pest, was found to be infesting the summer trial at PRC. Although captured in light trapping in the 1980s and 1990s by DSIR, this is the first known recovery of this pest in its immature stages in New Zealand. Biosecurity NZ was alerted and a pest incursion investigation is underway. Preliminary attempts at eradication have involved triple ploughing of the trial site to kill any overwintering pupae.
- Pheromone technology already developed for use in process tomatoes for monitoring Heliothis (*Helicoverpa armigera*) may be applicable for use in lettuce to monitor for damaging generations of Heliothis moths.

## Thrips

- Western flower thrips (*Frankliniella occidentalis,* WFT) and Intonsa flower thrips (*Frankliniella intonsa*) were identified infesting crops in Pukekohe. WFT was also occasionally recovered from Christchurch outdoor crops, but only in association with infested seedlings (the infestation originated from a nursery).

- Western flower thrips and Intonsa flower thrips are effective vectors of *tomato spotted wilt virus* (TSWV) but no symptoms of this virus were seen in these trials.
- Thrips species, including onion thrips (*Thrips tabaci*) do not normally require insecticidal controls in outdoor lettuce.
- Methamidophos can give good control of thrips in lettuce but disrupts biological control of other pests.
- Biological control of thrips by natural enemies appears to to be poor in lettuce. Hoverfly larvae and a predatory thrips, *Aeolothrips fasciatum,* attack pest thrips but their impact is unknown.

Control strategies for insect pests and plant diseases are outlined in Appendix II: Preliminary control strategies by season for pests and diseases of lettuce – Pukekohe region.

**Laboratory trials**

- Laboratory assays were undertaken at Lincoln to study the non-target effects of selective aphicides on lacewings. Results showed that imidacloprid was very harmful, pirimicarb was slightly harmful, and pymetrozine was harmless to lacewing larvae feeding on imidacloprid-intoxicated LA.

## 3.3 *Milestone 3: Plant disease control*

- Field trials demonstrated that iprodione, dichloran, and trifloxystrobin control grey mould (*Botrytis cinerea*) of lettuce.
- Field trials demonstrated efficacy of fosetyl-aluminium and azoxystrobin for control of lettuce downy mildew (*Bremia lactucae*).
- Laboratory bioassays demonstrated that carbendazim was the only fungicide that killed sclerotia of *Sclerotinia minor* and *S. sclerotiorum*.
- Laboratory bioassays also demonstrated that low concentrations (5-10 ppm) of procymidone and tebuconazole inhibited germination of sclerotia and mycelial growth of *S. minor* and *S. sclerotiorum*.
- Field trials demonstrated that the biocontrol agents Serenade™ (*Bacillus subtilis*), Contans™ (*Coniothyrium minitans*), and Trichodry and Trichoflow-6S (*Trichoderma harzianum*) provided only limited control of *S. minor* in artificially inoculated soil.
- More research is required to develop an integrated disease control program for lettuce diseases using combinations of various controls and management practices.

## 3.4 *Milestone 4: Virus diseases*

- The status of virus diseases in lettuce in the major growing regions is now well defined:
  - Lettuce big-vein disease (LBVD), caused by *lettuce big-vein variscosa virus* (LBVV) and *Mirafiori lettuce big-vein virus* (MLBVV), was the most widespread virus disease.

- Prevalence was high under cool winter conditions and sometimes under spring and summer conditions (in Hawke's Bay and Kapiti Coast).
- Other viruses do occur, often as mixed infections, but don't cause significant crop losses.
- TSWV, *Arabis mosaic virus* (ArMV) and *Tobacco necrosis virus* (TNV) were not detected in these surveys.

▪ Chemical control of *Olpidium brassicae*, the vector for LBVD, is possible, and is a useful alternative control strategy. In summary:

  - Chemical treatment for control of *O. brassicae* over winter/spring using selected fungicides can increase yield of lettuce plants.
  - Carbendazim, propamocarb and thiabendazole maintained or increased lettuce yield.
  - Chemicals such as fluazinam and quintozene were phytotoxic, but further work on application might improve their efficacy.

## 3.5 Milestone 5: Pesticide resistance

- Early testing for resistance to standard insecticides showed that the LA strain present in New Zealand is partially resistant to acephate and methomyl.
- A resistance management strategy for LA has been prepared and publicised to the lettuce industry in New Zealand.
- The use of low rates of imidacloprid as a seedling drench is not recommended because of the threat of resistance build-up.

## 3.6 Milestone 6: Looper monitoring

- A soybean looper lure was located in January 2005 and pheromone trapping studies commenced in late January. Moth catches around the Pukekohe area were consistently very high throughout the monitoring period, from late January to mid-March.
- Scentry (Heliothis) traps were found to be very efficient for monitoring soybean looper male moths.

## 3.7 Milestone 7: Biological control

- Tasmanian brown lacewing (*Micromus tasmaniae*), hoverfly larvae (*Melanostoma fasciatum*), spiders and harvestmen are considered important natural enemies of insect pests in lettuce at Pukekohe.
- Lacewings were the dominant aphid predator in Pukekohe, Gisborne and Christchurch.
- Regional surveys showed that 11-spot ladybirds are important aphid predators in spring in regions other than South Auckland.

- Insect-infecting (entomopathogenic) fungi, particularly *Erynia neoaphidis,* are important natural enemies of LA in autumn and winter at Pukekohe.
- Parasitic hymenoptera are only rarely found in lettuce. Only four specimens of lettuce aphid were found to be parasitised by *Aphidius* spp. in all the trials at PRC.
- Syrphid larvae were observed feeding on thrips in the laboratory but their impact on thrips populations in the field is unknown. Syrphid larvae will also feed on aphids, caterpillars, and various eggs.
- Predators are important natural enemies for control of soybean looper eggs and small larvae, but are ineffective against large caterpillars.
- A small NPV virus was the the only natural enemy found to be commonly infecting large soybean looper larvae.
- Parasitism of soybean looper larvae was low, with *Cotesia ruficrus*, *Copidosoma floridanum* and *Meteorus pulchricornis* only occasionally reared from collected caterpillars.
- Laboratory studies were completed on the biology (development rate, feeding ability and fecundity) of brown lacewing developing at two temperatures feeding on LA.

## 3.8 Milestone 8: Tech transfer

- Four field days were held at PRC, attended by 30-55 people. A field day in Christchurch was attended by 30 people.
- For a list of oral presentations, scientific papers and *Grower* articles, see the publications section (4.8).

## 3.9 Milestone 9: IPM manual

- An information guide for outdoor head lettuce has been produced as a limited edition draft to obtain comment and feedback prior to revision and development into an IPM manual by the end of June 2007.

# 4 Results in detail (by milestones)

## 4.1 Planning

- An application to Vegfed and MAF SFF for an extension of the project into years 4 and 5 – the implementation phase – was approved and the new phase began in July 2005.
- PhD student Gabriella Lankin (ex Crop & Food Research, Lincoln), who is attached to Adelaide University, is planning to undertake her field trials at Pukekohe. Her research is in defining the feeding habits of generalist predators in brassicas and leafy vegetables, and will help ascertain to what degree generalist predators prey on other beneficial insects, compared with feeding on pest species.

## 4.2 Insect pest control

### 4.2.1 Insecticide efficacy testing

- A number of trials was undertaken at PRC for residue and efficacy testing of imidacloprid at various rates, being requirements for the registration of Confidor® (imidacloprid). Rates of 10, 20 and 30 mL per 1000 seedlings were tested in replicated trials. The 10 mL rate failed to adequately control LA.
- Success® (spinosad) failed to control thrips populations in summer trials at PRC.
- Steward® (indoxacarb) gave good control of caterpillar pests in most trials at PRC. However, under extreme pest pressure in summer crops, where we had constant reinvasion by soybean looper (intensive, continuous egg-laying), weekly sprays failed to control looper caterpillars to an adequate level. Further research is required to improve timing of sprays. Crop scouting more regularly than weekly may be required in high-risk periods.

### 4.2.2 Lettuce aphid monitoring

- Flights of LA have been monitored continuously from three to five suction traps in Canterbury, Hastings and Pukekohe. This information is updated regularly (usually weekly) and available on the internet site: www.aphidwatch.com.
- LA spread to all surveyed regions by the winter of 2003.
- Sexual forms of LA have been found in all regions.
- LA can be found in large numbers on the flowers and buds of a number of common weeds, e.g. *Crepis* spp., *Hieracium* spp. and *Cichorium* sp.

### 4.2.3 Population dynamics of LA

- Populations of LA infesting untreated susceptible crops at PRC declined dramatically (by about a factor of 10) over the 3 years, probably due to the activity of natural enemies adapting to this new host. Aphid-infecting (entomopathogenic) fungi are probably very important in reducing LA populations at Pukekohe over winter.
- In other regions, population increases appear to be related to seasonal flights and activity of natural enemies. For example, population increases in Canterbury in spring crops in 2003 were controlled by natural enemies, while in the spring of 2004 they were not controlled. The loss of control of LA in the latter season is attributed to the absence of the 11-spot ladybird, due possibly to an unusually cool spring.

### 4.2.4 Field trials (control strategies for insect pests)

18 seasonal replicated insect field trials were undertaken; 13 at Pukekohe, four in Canterbury and one in Gisborne. Most trials were undertaken at PRC and focused on testing sampling systems and control strategies for LA. Many of these trials also included treatments for control of caterpillar pests

(particularly soybean looper in summer and autumn trials) and thrips in summer trials.

- The focus of all spring trials was on testing control strategies for LA and control of other aphid species.
- Trials in summer were targeted against all the major pests: LA, other aphid species, caterpillar pests and thrips.
- Trials in autumn were targeted against LA and caterpillar pests, both soybean looper and Heliothis.
- Winter trials were exclusively targeted against LA, being the only significant pest present during this season.

For more details, see Appendix I: Seasonal insect trials assessing biological control (untreated) for aphid pests – 2002-2005.

### *4.2.5 Field trials*

**Aphids**

The 10 seasonal trials completed at PRC had four to eight treatments per trial. Treatments included testing foliar insecticides, different rates of insecticidal drenches and biocontrols for control of LA and other aphid species. Results included:

- LA infestations must be determined by destructive sampling. Visual (non-destructive) examination is not accurate enough to determine the infestation levels or even the presence of LA.
- LA can only be controlled reliably by foliar-applied insecticides in winter crops, when its incidence is very low.
- LA was controlled in three consecutive spring trials at PRC by natural enemies, particularly by Tasmanian brown lacewing.
- An epizootic (disease outbreak) of *Erynia neoaphidis* controlled LA in the winter trial in 2003 at PRC, but populations were not controlled in subsequent winter trials.
- LA can be controlled by drenching seedlings with 20 to 30 mL of imidacloprid per 1000 plants, applied 24 hours before transplanting.
- In the third year, it was demonstrated that Tasmanian brown lacewing controlled LA in three spring trials in commercial crops in the South Auckland region.

**An action threshold for aphid control**

Provisional analysis of all the aphid trials showed that at a certain level, key predators controlled aphid populations. This has led to the development of a provisional aphid/predator action threshold for the Pukekohe region.

Table 1 shows the successful biological control of LA in three consecutive spring trials and the failure of biological control in three consecutive summer trials. Note that no insecticides were applied even if action thresholds were exceeded in these trials.

*Table 1: Mean total number of aphids and predators (lacewings and syrphids) per plant and aphid/predator ratios in three spring and three summer lettuce trials at Pukekohe, 2002-2004.*

| **Spring 2002** | | | | | |
|---|---|---|---|---|---|
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 22.10.02 | 0.25 | 0.06 | 0.00 | 0.06 | 4.0 |
| 29.10.02 | 0.78 | 0.06 | 0.00 | 0.06 | 12.5 |
| 5.11.02 | 2.84 | 0.44 | 0.00 | 0.44 | 6.5 |
| 12.11.02 | 13.94 | 3.03 | 0.00 | 3.03 | 4.6 |
| 19.11.02 | 32.81 | 2.63 | 0.00 | 2.63 | 12.5 |
| 26.11.02 | 38.47 | 3.56 | 0.44 | 4.00 | 9.6 |
| 3.12.02 | 40.69 | 4.63 | 0.97 | 5.59 | 7.3 |
| 10.12.02 | 5.88 | 4.59 | 0.59 | 5.19 | 1.1 |
| 17.12.02 | 3.47 | 0.66 | 0.72 | 1.38 | 2.5 |
| **Spring 2003** | | | | | |
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 28.10.03 | 1.00 | 0.1† | 0.00 | 0.10 | 10.0 |
| 4.10.03 | 0.59 | 0.1† | 0.00 | 0.10 | 5.9 |
| 11.11.03 | 1.13 | 0.03 | 0.13 | 0.16 | 7.2 |
| 18.11.03 | 1.59 | 0.22 | 0.00 | 0.22 | 7.3 |
| 25.11.03 | 6.94 | 1.50 | 0.00 | 1.50 | 4.6 |
| 2.12.03 | 1.50 | 3.63 | 0.28 | 3.91 | 0.4 |
| 9.12.03 | 0.59 | 2.59 | 1.00 | 3.59 | 0.2 |
| 16.12.03 | 0.22 | 0.25 | 0.44 | 0.69 | 0.3 |
| 23.12.03 | 0.41 | 0.22 | 0.19 | 0.41 | 1.0 |
| **Spring 2004** | | | | | |
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 9.11.04 | 0.23 | 0.1† | 0.00 | 0.10 | 2.3 |
| 23.11.04 | 0.79 | 0.18 | 0.80 | 0.98 | 0.8 |
| 7.12.04 | 0.27 | 0.93 | 0.60 | 1.53 | 0.2 |
| 21.12.04 | 0.30 | 0.91 | 0.48 | 1.39 | 0.2 |

| Summer 2003 | | | | | |
|---|---|---|---|---|---|
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 28.01.03 | 7.06 | 0.1† | 0.00 | 0.10 | 70.6 |
| 4.02.03 | 35.47 | 0.69 | 0.63 | 1.31 | 27.0 |
| 11.02.03 | 109.28 | 1.28 | 2.22 | 3.50 | 31.2 |
| 18.02.03 | 532.41 | 1.72 | 2.03 | 3.75 | 142.0 |
| 25.02.03 | 1060.09 | 0.50 | 2.59 | 3.09 | 342.7 |
| 4.03.03 | 656.34 | 0.34 | 2.81 | 3.16 | 208.0 |
| 11.03.03 | 905.31 | 0.13 | 0.38 | 0.50 | 1810.6 |
| **Summer 2004** | | | | | |
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 27.01.04 | 0.66 | 0.00 | 0.06 | 0.06 | 10.5 |
| 30.02.04 | 2.44 | 0.00 | 0.16 | 0.16 | 15.6 |
| 10.02.04 | 10.75 | 0.19 | 0.88 | 1.06 | 10.1 |
| 17.02.04 | 17.91 | 1.06 | 0.28 | 1.34 | 13.3 |
| 24.02.04 | 34.81 | 2.88 | 0.44 | 3.31 | 10.5 |
| 2.03.04 | 86.25 | 1.34 | 0.72 | 2.06 | 41.8 |
| 9.02.04 | 121.09 | 2.28 | 0.25 | 2.53 | 47.8 |
| **Summer 2005** | | | | | |
| Date | Aphids/ plant | Lacewings/ plant | Syrphids/ plant | Total predators/plant | Aphid/predator ratio* |
| 1.02.05 | 3.16 | 0.09 | 0.00 | 0.09 | 33.67 |
| 8.02.05 | 28.50 | 0.75 | 0.13 | 0.88 | 32.57 |
| 15.02.05 | 61.59 | 2.78 | 1.09 | 3.88 | 15.90 |
| 22.02.05 | 154.28 | 1.66 | 2.41 | 4.06 | 37.98 |
| 1.03.05 | 93.28 | 3.72 | 1.09 | 4.81 | 19.38 |
| 8.03.05 | 94.41 | 1.69 | 1.53 | 3.22 | 29.33 |

* Figures are numbers of aphids per predator.
† No predators present, so default value of 0.1 used.

## Preliminary action thresholds for lettuce aphid using biological controls

At this stage of our research, total counts of aphids and predators per plant are required. In the future it is hoped that a presence/absence approach may be developed. These are only preliminary guidelines. Further analysis of the data is required to validate this action threshold and further research is required for other regions. The general scouting method recommended in the draft Information Guide (see publications) can be used to collect the required information. The aphid/predator ratio is:

Aphid/predator ratio = Total number of aphids/Total number of predators

- If no predators are present or if the mean number is below 0.1 a default value of 0.1 is used for predator numbers (this compensates for periods early in the crop growing cycle when predator numbers are very low or absent).
- The recommended action threshold is based on an aphid/predator ratio of 10:1 (see below).

*Table 2: Aphid/predator ratio and action required.*

| Aphid/predator ratio | Action | Monitoring |
|---|---|---|
| <10:1 | No action | Scout in 7 days |
| Close to 10:1 | No action | Scout in 3-4 days |
| >10:1 | Apply insecticide, preferably a selective aphicide | Scout in 7 days |

**Canterbury field trials – aphids**

- Research in Canterbury showed that natural enemies control LA infestations in summer crops, and to varying degrees in spring. Consecutive summer trials in 2004 and 2005 had no LA at harvest. In the spring of 2003, predators controlled LA populations.
- The lack of control of LA in the spring trial in 2004 is attributed to an unusually cool spring. Predator numbers were comparatively low, with 11-spot ladybird beetles notable for their absence.
- Results from the summer trial in 2005 include: LA populations reached up to more than 100 per plant at the pre-capping stage, causing the plants to start hearting early with smaller leaves. This resulted in plants on average 80 g lighter than imidacloprid-treated plants and reaching harvest stage 10 days earlier than imidacloprid-treated plants.
- During the early stage of hearting most aphids had gone from the untreated plants, either due to emigration or predation.
- High numbers of aphids on seedling lettuce may deleteriously affect the subsequent development of the lettuce plants.

**Gisborne trials – aphids**

Research trials in Gisborne showed potential control of LA by natural enemies but control was not achieved in a replicated spring trial (see Appendix 1 for details).

**Caterpillar pests**

Replicated field trials were undertaken in summer and autumn at PRC to develop and assess different control strategies for caterpillar pests, particularly soybean looper. Treatments included action thresholds using the number of caterpillars per plant, and the percentage of plants infested, the use of broad-spectrum and selective foliar-applied insecticides, and trialling a newly developed potential biopesticide, *Beauveria bassiana*. Results included:

- Indoxacarb (Steward®), newly registered for use on lettuce, and spinosad (Success®) gave good control of caterpillars in most trials and appeared to have a minimal effect on biological control of other pests.
- Crop assessment and foliar-applied controls were unable to give complete control of caterpillar infestations during periods of extreme pest pressure.
- Spraying with selective insecticides at a nominal caterpillar threshold of 0.5 small caterpillars per lettuce kept caterpillar populations below two small larvae per plant under extreme pest pressure, and there was minimal damage at harvest.
- Use of simple thresholds based on presence or absence of caterpillars showed that 15 and 30% infestation of plants also kept populations below two per plant under high pest pressure.
- Sprays containing known amounts of conidia of a soybean looper-infecting strain of *B. bassiana* failed to adequately control caterpillar infestations.
- Crop scouting may need to be undertaken more frequently than weekly during very high-risk periods for caterpillar pests.

**Thrips**

Trials to assess the pest status and controls for thrips pests were undertaken as part of larger insect pest summer trials at PRC and in a trial in Gisborne. Various foliar-applied insecticides and drenching with imidacloprid were compared with untreated controls. Results include:

- Onion thrips (*Thrips tabaci*) are common in summer crops at Pukekohe and Gisborne but do not normally cause any major damage.
- Western flower thrips and Intonsa flower thrips were identified infesting crops in Pukekohe.
- Western flower thrips was often the dominant thrips species in lettuce at PRC.
- Western flower thrips and Intonsa flower thrips are known to be effective vectors of TSWV but no symptoms of this virus were found in these trials.
- Thrips species, including onion thrips, do not normally require insecticidal controls in outdoor lettuce.
- Methamidophos can give good control of thrips in lettuce but disrupts biological control of other pests.
- Spinosad did not reduce thrips populations in trials at PRC.
- There was no evidence of control of thrips by drenching seedlings with imidacloprid.
- Surveys at Pukekohe showed that flower thrips are infesting plants while they are in the field, and not being transported on infested seedlings from nurseries.

- *Thrips nigropilosus* (chrysanthemum thrips) was identified from lettuce for the first time in the summer trials at PRC in 2005 and was the most common species recorded at harvest.
- Thrips numbers were often highest in the first few weeks of the trial and then declined. It is not known whether this decline was caused by predation (possibly by syrphids), nutritional changes in the lettuce, or low reproduction of thrips in lettuce.

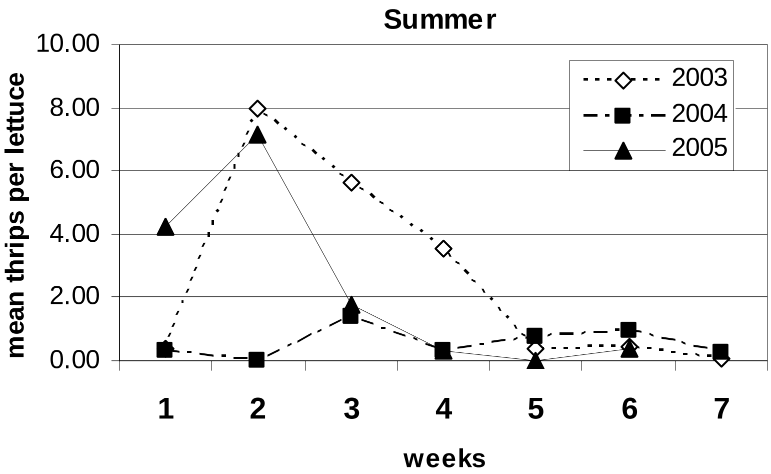


*Figure 1: Thrips populations in three summer trials at PRC from 2003-2005.*

## 4.2.6 *Other insect work*

**Regional insect surveys**

Surveys of lettuces were undertaken throughout New Zealand for 3 years, recording grower practices and incidence of insect pests and predators. Results include:

**Monitoring the spread and impact of LA throughout New Zealand**

- Transportation of lettuces and seedlings played an important role in the spread of LA.
- LA spread throughout the entire country within 12 months of its first incursion.
- Many growers throughout the country had to destroy lettuce crops due to large infestations of lettuce aphids. Some growers gave up growing lettuces due to the larger costs involved in controlling lettuce aphid.
- Growers used a large range of insecticides, including mixes, to try to control LA.
- The use of imidacloprid (Confidor®) gave varying results. Most control failures were attributed to:

1. Use of a low dose of imidacloprid (aphids colonising the lettuces in the last weeks before harvest);
2. Poor imidacloprid application to seedlings pre-transplanting.

- Looking for the presence of live, wingless aphids was considered the most important aspect of crop monitoring of imidacloprid-treated lettuces.
- Lettuce aphid infestations were often spread from infested older crops in close proximity.
- Lettuce aphids were commonly found in large numbers (up to 70+/bud) on the flowers and buds of hawksbeard and chicory in all lettuce-growing regions during the late spring to autumn months. This period of infestation was extended into the winter in the North Island. These weeds were often found in the fence lines close to lettuce crops.

**Other insects and predators**

- There were regional differences in the incidence and species of aphid predators in lettuce crops.
- In the Auckland/Pukekohe region ladybirds were rare in late spring, whereas they were common in most other regions.
- During the late spring/early summer season the most common predators were brown lacewings and ladybirds while in the late summer/autumn they were brown lacewings and syrphids.
- 11-spot ladybird was the most common ladybird species, with adult beetles common rather than larval stages. Adult ladybirds were flying in to feed before their summer aestivation period.
- Many dead adult lacewings and ladybirds were observed in crops treated with broad-spectrum insecticides (synthetic pyrethroids and organophosphates).
- Other common general predators were rove beetles and spiders, while earwigs, centipedes, nabids and harvestmen were occasionally located.
- Other common insects were springtails, thrips, red soil mites, leafhoppers and small flies. A number of different bugs were found (*Nysius huttoni*, *Sidnia kinbergi*, *Calocoris norvegicus*) as well as weevils, two-spotted mite, various caterpillar species, and book lice.
- From the Hawke's Bay through to Nelson, a small ladybird, *Veronicobius hirtalis,* was often found in lettuce plants. It has been shown to feed on aphids.
- In three glasshouse lettuce crops (Christchurch, Levin and Palmerston North) the ragwort leaf miner *Chromatomyia syngenesiae* caused major damage to the outer leaves of leafy lettuces. This species was seldom found damaging outdoor lettuce crops.
- In one commercial lettuce crop in Christchurch, Western flower thrips severely damaged and stunted young plants. The crop was replanted. Some damage by thrips was observed in field-grown lettuces, mainly to the outer leaves but not enough to prevent sale of the product.

- Growers trialled aphid-resistant varieties of lettuce. Lettuce aphid was rarely found infesting these varieties. Aphid species found infesting LA-resistant cultivars included brown sowthistle aphid, potato aphid, greenpeach aphid, and foxglove aphid. These were found mainly on the outer leaves.
- Most of the common insects found on LA-resistant cultivars were the same species common on susceptible varieties, but populations were lower.
- Many growers were found to be drenching their LA-resistant cultivars with imidacloprid. This practice is now considered to be unnecessary.
- Very few parasitoid aphid 'mummies' were found on lettuces. Most parasitised aphids were identified as not being lettuce aphid.
- Aphids infected with fungi (entomopathogens) were found in most districts, mainly after a few days of rain or during wet autumn periods.

### Laboratory studies – Mt Albert Research Centre

- A colony of LA was maintained for laboratory studies. The development rate and feeding behaviour of Tasmanian lacewing (Micromus tasmaniae) was studied at two temperatures reared on LA.

### Laboratory studies – Lincoln Research Centre

- The development rate of LA was assessed at seven different constant temperatures. Winged aphids were only produced at temperatures of 20°C and above.
- Laboratory assays were undertaken at Lincoln to study the non-target effects of selective aphicides, imidacloprid, pirimicarb and pymetrozine on lacewings. Results include:
  - Imidacloprid at 5.25 and 10.5 g/1000 transplants killed all 1st instar larvae feeding on imidacloprid-intoxicated aphids placed on plants 48 hours after treatment.
  - Pirimicarb was slightly harmful to lacewing larvae.
  - Pymetrozine was harmless to lacewing larvae.

## PRELIMINARY CONTROL STRATEGIES FOR INSECT PESTS

### Control strategies for lettuce aphid

In response to the arrival of LA, four grower practices have been developed for growing outdoor lettuces. Each of these practices favours different pest complexes and requires different monitoring frequencies, action thresholds and control strategies. Some of these control strategies are more appropriate than others for certain seasons. Overuse of control strategies based on insecticidal controls may lead to insecticide resistance. The growing systems use combinations of susceptible or resistant cultivars, insecticide drenches and foliar insecticides, and rely to differing extents on natural enemies.

The crop-growing practices combine control strategies to provide four options that have been investigated for control of LA:

**(1) Foliar-applied insecticides and cultivars susceptible to LA**

This method should only be used when LA populations in an area are very low because it is difficult to control LA with foliar insecticides, particularly on large plants. Regular crop monitoring is essential. This should be at least once a week during the warmer part of the year but may be required only fortnightly during winter and the cooler months.

Rotate the use of foliar insecticides. Use of the same active ingredient should be restricted to no more than three applications. If further foliar-applied insecticides are required, choose from another chemical group. The choice of insecticide will be determined not only by what pest species are present, but also by what natural enemy complex is present in the crop. If aphids are the only pests present, use of a selective aphicide would be appropriate. However, if aphids and other pests (such as caterpillars or large numbers of thrips) are present and exceed action thresholds, choose an insecticide that will target all pest species.

Insect-attacking fungal pathogens that attack aphids often significantly reduce LA populations in autumn and winter and may reduce the need for insecticide applications in these seasons.

**(2) Imidacloprid-drenched transplants and cultivars susceptible to LA**

This is a very effective method for controlling LA but continual use and over-dependence on imidacloprid may lead to resistance. It is recommended that growers allocate imidacloprid-free periods when other practices for controlling LA are used. To prevent resistance developing, imidacloprid should be applied at the full, recommended rate. Using imidacloprid at lower rates will encourage the development of resistant strains of LA. Imidacloprid will control all aphid species that attack lettuce. However it will not control other pests such as caterpillars and thrips.

Monitoring will be required to detect other pests and to confirm that the imidacloprid treatment is effective. It is important to apply a precise imidacloprid drench treatment evenly to all seedlings, and crops therefore should be scouted to provide assurance that the drenching has been effective. Crop scouting will be required weekly over summer and autumn to monitor, in particular, caterpillar infestations, but during the winter and spring, crop scouting may only be required every 2 weeks.

**(3) Cultivars resistant to LA**

A range of cultivars resistant to LA is now available and suitable selections can be made for growing in all seasons except for winter. Advice is available from seed companies on the appropriate cultivars for each season and region. Growers should trial a range of resistant cultivars to determine which perform best under their growing conditions.

The resistant cultivars are only resistant to LA. Control measures may be required for other aphid species. Most other aphid species are controlled by natural enemies, but if foliar applications are required, selective insecticides (aphicides) will help preserve natural enemies.

Crop scouting is required in cultivars resistant to LA to monitor other aphid species and other pests. It is important to record breeding colonies of aphids rather than single winged adults, because winged adult aphids may have just arrived in the crop and may not survive or reproduce.

Varieties resistant to LA should be scouted weekly in summer and autumn but may only need scouting every 2 weeks in spring. This is because other important pests, including caterpillars and thrips, do not reach pest status in spring. The application of broad-spectrum insecticides should be minimised to increase the impact of natural enemies. There is a range of selective insecticides available for the control of aphids and caterpillars.

**(4) Biological control with susceptible cultivars and no insecticides**

Several effective aphid predators and aphid-infecting fungal pathogens can give effective control of LA in certain seasons and regions, thereby avoiding the need for insecticides. Aphids have been successfully controlled in spring at Pukekohe using biological control for 3 consecutive years in small plot trials. In addition, in trials conducted in spring 2004 on three commercial properties in the Pukekohe area, the total numbers of aphids did not exceed a mean of one per plant. In summary, all our research studies show that insecticide applications are not normally required in spring crops at Pukekohe.

Fungal infections (epizootics) have occasionally controlled LA in autumn and winter trials in Pukekohe.

Biological controls have failed to control LA in summer crops at Pukekohe, but have controlled it in Canterbury.

Weekly crop scouting is required when using biological controls, and scouts require a good knowledge of aphid and predator identification.

Growers should consider using trials in small areas to gain confidence in this method before implementing a wide-ranging biological control strategy in their growing areas.

Growing crops at Pukekohe using biological control should be successful during the periods of planting from mid-September through to about the third week in November (harvesting before the end of December).

Any spray decisions should be based on action thresholds derived from the aphid/predator ratio in a crop, assessed by crop scouting.

**Control strategies for other aphid species**

There are 12 aphid species that can breed on lettuce and additional species that are present but cannot reproduce on lettuce. When scouting lettuce it is not usually necessary to identify individual species – recommended thresholds are based on total aphid counts.

Aphid predators normally control all other aphid species on lettuce at Pukekohe, so foliar-applied insecticides are not normally required.

If foliar sprays are required, the use of selective aphicides is recommended to maximise the impact of natural enemies.

Imidacloprid treatment for control of LA is also effective against all other aphid species.

Cultivars resistant to LA do not control other aphid species. Therefore you should monitor them for any outbreaks of other aphid species, especially foxglove aphid in spring and brown sow thistle aphid in summer.

If there has been a history of *lettuce necrotic yellows virus* (LNYV), crops should be closely monitored for the vectoring sowthistle aphid, *Hyperomyzus lactucae* (not to be confused with the brown sowthistle aphid, *Uroleucon sonchi*). *H. lactucae* is similar in appearance to LA but can be distinguished by its swollen siphunculi. If sowthistle aphid is identified in a crop, additional control measures may be required.

**Preliminary control strategies for caterpillar pests**

Soybean looper and tomato fruitworm were the major caterpillar pests found in lettuce. Other moth species, such as Geometrids, do not require control, or would be controlled by strategies instigated against the major pest species.

**Preliminary control strategies for soybean looper**

Soybean looper was the dominant caterpillar found in the Pukekohe trials.

Scouting for noctuid eggs and small caterpillars should begin in mid-December or earlier if large numbers of soybean looper moths are being captured in pheromone traps. Crops should be scouted weekly in summer and autumn (see the scouting method in the Information Guide). Our recent trials at Pukekohe indicate that spring crops are normally free from damaging populations of caterpillars, with eggs and larvae present only occasionally. Geometrid eggs may be commonly sighted in spring but they only develop into very small caterpillars that cause very little damage. Although quite large numbers of Geometrid eggs can occur in crops, Geometrid caterpillars are rarely seen, probably because of predation.

When summer and autumn crops have looper egg infestations of more than 0.2 per plant, this is a good indicator that caterpillar infestations of greater than one per plant will occur 2 weeks later. Soybean looper eggs deposited once lettuce has hearted will not normally lead to economic damage and should not need treatment. This is because the crop will be harvested before any large caterpillars have time to develop, and small larvae and eggs will be removed along with the outer and wrapper leaves at harvest.

Crops heavily infested with small caterpillars should be sprayed with a selective insecticide, such as indoxacarb. Spraying with selective insecticides at a nominal caterpillar threshold of 0.5 small caterpillars per lettuce has been shown to keep caterpillar populations below two small larvae per plant even under extreme pest pressure (larval numbers reached 12.5 per plant in unsprayed plots) and plants were suitable for sale. This research was undertaken only in small plot trials and further research is required to validate these caterpillar action thresholds. Growers should use this threshold with caution. If in doubt we recommend scouting crops more frequently than weekly during high-risk periods. (Note: simpler thresholds based on presence or absence of caterpillars show that insecticide applications at 15 and 30% infestation of plants also keeps populations below two small larvae per plant.)

Insecticides should be applied to control any significant infestations of large caterpillars, using selective insecticides for the control of caterpillars to maximise the impact of natural enemies. Large infestations of eggs and larvae often produce minimal numbers of large larvae because of the activity of predators, particularly hoverfly larvae and spiders.

**Control strategies for tomato fruitworm**

In the Pukekohe trials tomato fruitworm was a minor component of the caterpillar population but did occur in larger numbers in other regions, particularly in Gisborne. Infestations of tomato fruitworm eggs and larvae can be detected during routine scouting. Pheromone trapping or temperature data can also alert scouts to high-risk periods when the second or third generation of moths is present. Foliar applications should be timed to coincide with the presence of hatching eggs or small larvae as the caterpillars burrow into the heart of lettuce soon after hatching, where they are difficult to control with topically applied insecticides. Selective insecticides including indoxacarb and Bt (*Bacillus thuringiensis*) sprays should be used to maximise the impact of the beneficial predator and parasitoid complexes that can attack tomato fruitworm.

**Preliminary control strategies for thrips**

In New Zealand, three thrips species can vector TSWV, but despite this TSWV rarely occurs in lettuce. In other countries TSWV is an important disease in lettuce crops, and neonicotinoid insecticide drenches such as imidacloprid have proven effective in suppressing the spread of TSWV. However, the mechanism for this control is unknown because trials in New Zealand indicate there is no marked reduction in thrips populations in seedlings drenched with imidacloprid. The lettuce industry needs to be vigilant in reporting any increase of incidence of this disease in New Zealand.

**Seedling lettuce**

If there has been any incidence of TSWV in the area, the imidacloprid drench option should be considered during summer and autumn. If there has been no TSWV, no action is required unless the mean number of thrips per lettuce exceeds about 10. This is a nominal threshold that has not been validated in field trials. If the mean number of thrips exceeds 10 per plant, a decision needs to be made whether to apply an insecticide because feeding damage may be deleterious to plant growth.

There are no selective insecticides registered for thrips on lettuce. Diazinon is the only insecticide registered for thrips control in lettuce. However, acephate and methomyl, registered for use on lettuce for the control of aphids and caterpillars, should also be effective for controlling thrips.

**Hearting lettuce**

Thrips can live and breed in the inner leaves of the lettuce so they are very difficult to control with topically applied insecticides. Thrips populations should be reduced to low levels prior to hearting. In most cases no special intervention should be required for thrips control in lettuce.

For more information, see also Appendix 2: Preliminary control strategies by season for pests and diseases of lettuce – Pukekohe region.

## 4.3 *Plant disease control*

### 4.3.1 *July 2002 to June 2003*

Two disease field trials were established at the Pukekohe Research Centre. One trial, planted on 3 April 2003, investigated the efficacy of six fungicides and three biological control agents on diseases caused by *Sclerotinia* spp. and *Botrytis* spp. The other trial, planted on 29 May 2003, investigated the efficacy of 12 fungicides on downy mildew, anthracnose, and bacterial diseases of lettuce. The results of these trials are given in the next section.

### 4.3.2 *July 2003 to June 2004*

#### 4.3.2.1 *Evaluation of fungicides for control of* Sclerotinia *spp. and* Botrytis *spp.*

**Introduction**

Sclerotinia leaf drop, caused by *Sclerotinia minor* and *S. sclerotiorum*, is an economically important disease of lettuce in New Zealand and worldwide. Grey mould, caused by *Botrytis cinerea*, is usually regarded as a minor disease of lettuce. Both fungi survive as sclerotia on infected crop debris or in the soil. Carbendazim is currently the only fungicide registered in New Zealand for control of Sclerotinia leaf drop of lettuce. No fungicides are currently registered in this country for control of grey mould of lettuce. Chemical control of Sclerotinia leaf drop has not always been effective, especially under wet conditions in fields where disease pressure is high. Sumisclex is widely used in Australia for control of *Sclerotinia*. The aim of this experiment was to evaluate the efficacy of different chemicals for control of Sclerotinia leaf drop and grey mould of lettuce. Chemicals that are currently registered for lettuce and those that may be registered in the near future were investigated.

**Method**

Lettuce seedlings cv. ‘Winguard’, established as cell plants, were transplanted by hand on 3 April 2003 in nine four-row beds, each 65 m long x 1.5 m wide, at the Crop & Food Research Centre at Pukekohe. The soil type was a Patumahoe mottled clay loam. Fertilisers, irrigation and the control of weeds and insect pests during the growing season were managed using local commercial practice. For control of downy mildew and anthracnose, mancozeb (200 g/100 L of water) was applied at 7-10 day intervals after transplanting.

The experiment was laid out in randomised blocks with four treatment replications. The plot size was 5 m long x 1.5 m wide. Treatments were randomly allocated to plots, which were separated by buffer zones of 1.2 m. Each plot contained 48 lettuce plants – 12 plants spaced 0.4 m apart in four rows. Each datum bed was flanked on both sides by a non-sprayed guard bed.

**Treatments**

1. Control (no fungicide).
2. Carbendazim (Bavisin®DF) at 2 kg product/ha.
3. Dichloran (Botran®75 WP) at 1 kg product/ha.
4. Iprodione (Rovral®Flo) at 3 L product/ha.
5. Procymidone (Sumisclex®500) at 1.7 L product/ha.
6. Trifloxystrobin (Flint®) at 375g product/ha.
7. Tebuconazole (Folicur®430 SC) at 1 L product/ha.
8. *Bacillus subtilis* (Serenade™) at 6 kg product/ha.
9. *Pythium oligandrum* (Polyversum™) at 0.05% pre-plant tray dip and post-plant at 0.01g/$m^2$ 0, 1, 3, 5 weeks after planting.

With the exception of Polyversum™, treatments were applied immediately after transplanting and 1 and 3 weeks later using an Oxford precision sprayer. All applications were at a water rate of 1000 L per hectare.

Disease assessments for Sclerotinia leaf drop and grey mould were made at 2-weekly intervals until crop harvest. On 2 July 2003, the lettuces were harvested and assessed for disease incidence. Crop yields and produce quality were also assessed.

**Results**

Levels of Sclerotinia leaf drop caused by *S. minor* and *S. sclerotiorum* were low in the trial (<3% infected plants). The highest incidence of plants with symptoms of grey mould caused by *B. cinerea* was in the control (no fungicide) treatment (53% infected plants, Figure 2). Iprodione provided the best control of grey mould (30% infected plants). Mean lettuce head weights ranged from 0.83 kg (dichloran) to 0.65 kg (trifloxystrobin). Some tebuconazole-sprayed plants showed symptoms of phytotoxicity (early stunting, yellowing).

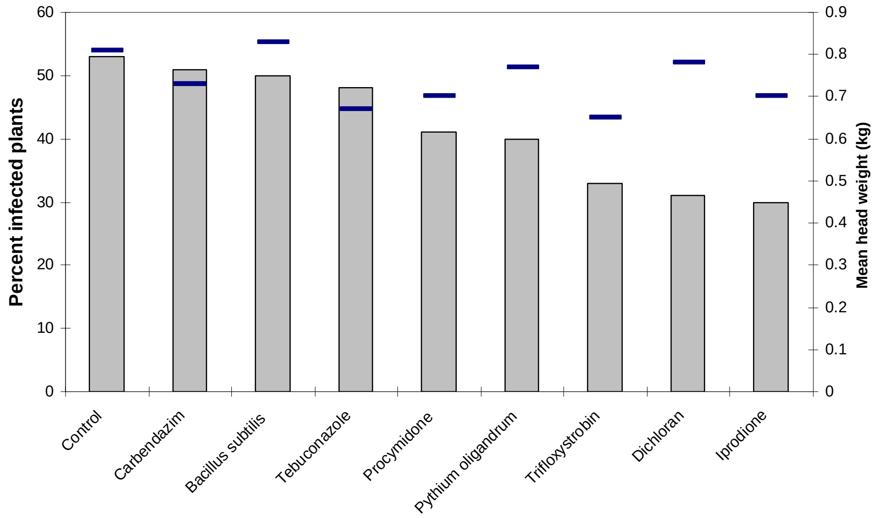


*Figure 2: Effects of fungicide treatments on incidence of grey mould of lettuce and mean head weights on 2 July 2003.*

**Conclusions**

Because of the low levels of Sclerotinia infection in the trial, the fungicides and biocontrol agents could not be evaluated for efficacy against Sclerotinia lettuce drop. In future experiments, sclerotia of both Sclerotinia species, produced in the laboratory, will be added to experimental plots. Based on the results of this experiment, iprodione, dichloran and trifloxystrobin show promise for control of grey mould of lettuce.

*4.3.2.2 Evaluation of fungicides for control of downy mildew, anthracnose, and bacterial diseases of lettuce*

**Introduction**

Downy mildew (*Bremia lactucae*), anthracnose (*Microdochium panattonianum*), and bacterial rots (*Pseudomonas* spp.) are three important diseases of lettuce in New Zealand. At present, there is a limited number of chemicals registered in this country for control of these diseases. Copper hydroxide, dimethomorph and mancozeb are registered for control of lettuce downy mildew, chlorothalonil for anthracnose, and nothing is registered for bacterial disease control. The aim of this experiment was to evaluate the efficacy of different chemicals for control of downy mildew, anthracnose, and bacterial rots of lettuce. Chemicals that are currently registered for lettuce and those that may be registered in the near future were investigated.

**Method**

Lettuce seedlings cv. 'Winguard', established as cell plants, were transplanted by hand on 29 May 2003. Experimental design, plot size and layout, and crop management was similar to the *Sclerotinia/Botrytis* trial (above). For control of Sclerotinia leaf drop, Bavistin®DF (carbendazim, 2 kg in 700 L water/ha) was applied immediately after transplanting and another application was done three weeks later. Treatments were applied using an Oxford precision sprayer at a water rate of 500 L of water per hectare.

**Treatments**

1. No chemical.
2. Azoxystrobin (Amistar®WG) at 220 g product/ha.[2]
3. Chlorothalonil (Daconil®720 EC) at 1.25 L product/ha.[1+4]
4. Copper hydroxide (Kocide®2000) at 750 g product/ha.[1]
5. Difenoconazole (Score®250 EC) at 500 mL product/ha.[3]
6. Dimethomorph + mancozeb (Acrobat®MZ 690) at 2 kg product/ha.*[2]
7. Fenamidone + mancozeb (Sereno®) at 1.5 kg product/ha.*[2]
8. Fosetyl-aluminium (Aliette®WG) at 1.25 L product/ha.*[2]
9. Iprovalicarb + propineb (Melody Duo) at 2 kg product/ha.* [1]
10. Mancozeb (Manzate®200 DF) at 1 kg product/ha.* [1]
11. Prochloraz (Sportak®) at 1 L product/ha.*[3]
12. Propineb (Antracol®) at 2 kg product/ha.* [1]

* Multifilm Extra at 25 mL/100 L water was added to spray tank.

1 Applied at 7-10 day intervals from transplanting to harvest.

2 Applied at onset of disease (10 July) and 7 days later (17 July), then again when disease pressure was high (1 September) and 7 days later (8 September). Mancozeb was applied at weekly intervals between the paired applications.

3 Applied at onset of disease and 7 days later (timing as above), then when disease pressure high evident and 7 days later (times as above). Aliette WG (1.25 L/ha) was applied on four occasions to control downy mildew.

4 Aliette WG (1.25 L/ha) was applied on four occasions to control downy mildew.

Disease assessments were made weekly until 23 September 2003 when 20 plants in the centre two rows of each plot were harvested and assessed for downy mildew using a scale of 0-5 where 1 = 1-5%; 2 = 6-10%; 3 = 11-25%; 4 = 26-50%; 5 = >51% of basal area affected. Crop yields and produce quality were also assessed.

**Results**

Levels of anthracnose and bacterial rots were low (<3%) for the duration of the trial. However, downy mildew was present throughout. Lettuces sprayed with fosetyl-aluminium, azoxystrobin, difenoconazole and prochloraz had lower levels of downy mildew than those in the other treatments (Figure 3). Control and mancozeb treatments had significantly higher ($P$ <0.05) incidence of downy mildew than the other treatments. Lettuce head weights were significantly lower ($P$ <0.05) in control plants, but head weights were not significantly different ($P$ <0.05) between the other chemical treatments.

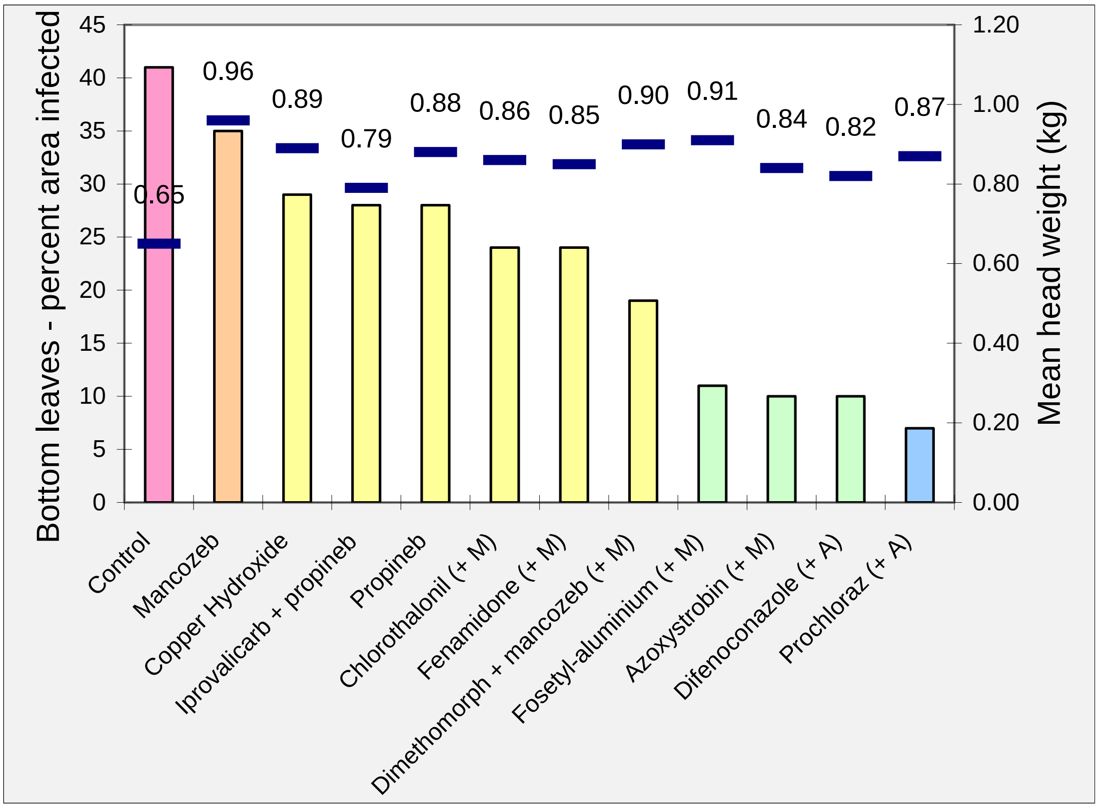


*Figure 3: Effects of fungicide treatments on downy mildew infection and on lettuce head weights. Additional applications of mancozeb (M) and Aliette (A) were part of some fungicide treatments.*

**Conclusions**

The low levels of downy mildew in the difenoconazole and prochloraz treatments were probably attributed to the additional fosetyl-aluminium applications. Based on the results of this experiment, fosetyl-aluminium and azoxystrobin show promise for control of lettuce downy mildew.

### 4.3.3 *July 2004 to June 2005*

#### 4.3.3.1 *Differential activity of fungicides on germination of sclerotia and mycelial growth of* Sclerotinia minor *and* S. sclerotiorum

**Introduction**

Because the 2003-04 *Sclerotinia* field trial produced low levels of infection, laboratory evaluations of activity of fungicides from different fungicide class groups on both *Sclerotinia* species were made in 2004-05. Six fungicides were tested for activity against germination of sclerotia, and mycelial growth of *S. minor* and *S. sclerotiorum*. The fungicides were: carbendazim (Bavistin®DF), dichloran (Botran®75WP), trifloxystrobin (Flint®), tebuconazole (Folicur®430SC), iprodione (Rovral Flo®), and procymidone (Sumisclex®500). Of these fungicides, carbendazim is the only one currently registered for control of Sclerotinia leaf drop of lettuce.

## Test 1: Germination of sclerotia after immersion in fungicide

### Method

Twenty *S. minor* sclerotia and 20 *S. sclerotiorum* sclerotia were immersed in suspensions (500, 50, 5, 1 and 0.5 ppm) of each fungicide for 4 days at 18°C. The sclerotia were removed from the fungicide suspensions, thoroughly washed with distilled water, surface sterilised for 5 min in sodium hypochlorite containing 1% available chlorine, rinsed with sterile distilled water, and plated on PDA (potato dextrose agar). 10 sclerotia were placed in each petri dish. Germination of sclerotia was recorded after 7 days at 18°C.

### Results

After they had been immersed for 4 days in 500 ppm carbendazim, sclerotia of *S. minor* did not germinate on PDA (Table 3). No *S. sclerotiorum* sclerotia germinated after a 4-day immersion in 5 ppm carbendazim (Table 4). All sclerotia of both *Sclerotinia* species germinated following immersion in dichloran, iprodione and procymidone.

*Table 3: Percent germination of* Sclerotinia minor *on PDA after 7 days, following a 4-day immersion in fungicide solutions.*

| Fungicide | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| | 0.5 | 1 | 5 | 50 | 500 |
| Carbendazim | 96 | 92 | 90 | 22 | 0 |
| Dichloran | 100 | 100 | 100 | 100 | 100 |
| Trifloxystrobin | 100 | 100 | 100 | 78 | 80 |
| Tebuconazole | 100 | 100 | 100 | 84 | 76 |
| Iprodione | 100 | 100 | 100 | 100 | 100 |
| Procymidone | 100 | 100 | 100 | 100 | 100 |

*Table 4: Percent germination of* Sclerotinia sclerotiorum *on PDA after 7 days, following a 4-day immersion in fungicide solutions.*

| Fungicide | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| | 0.5 | 1 | 5 | 50 | 500 |
| Carbendazim | 100 | 100 | 0 | 0 | 0 |
| Dichloran | 100 | 100 | 100 | 100 | 100 |
| Trifloxystrobin | 100 | 100 | 100 | 100 | 100 |
| Tebuconazole | 100 | 100 | 100 | 76 | 14 |
| Iprodione | 100 | 100 | 100 | 100 | 100 |
| Procymidone | 100 | 100 | 100 | 100 | 100 |

## Test 2: Germination of sclerotia on agar medium containing fungicide

### Method

Twenty surface-sterilised *S. minor* sclerotia and 20 *S. sclerotiorum* sclerotia were imbedded in 20 mL PDA containing different concentrations (500, 50, 5, 1 and 0.5 ppm) of each fungicide. Ten sclerotia were placed in each petri dish. Germination of sclerotia was recorded after incubation at 18$^{o}$C for 7 days.

### Results

No *S. minor* sclerotia germinated on PDA containing 5 ppm procymidone, 5 ppm tebuconazole, 50 ppm carbendazim, 50 ppm dichloran, and 50 ppm iprodione (Table 5). No *S. sclerotiorum* sclerotia germinated on PDA containing 5 ppm carbendazim. 5 ppm procymidone, 5 ppm tebuconazole, or 50 ppm iprodione (Table 6). Trifloxystrobin was not effective against either *Sclerotinia* species.

*Table 5: Percent germination of* Sclerotinia minor *after 7 days on PDA containing different concentrations of fungicides.*

| | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| Fungicide | 0.5 | 1 | 5 | 50 | 500 |
| Carbendazim | 28 | 16 | 16 | 0 | 0 |
| Dichloran | 100 | 100 | 62 | 0 | 0 |
| Trifloxystrobin | 100 | 100 | 100 | 100 | 82 |
| Tebuconazole | 62 | 16 | 0 | 0 | 0 |
| Iprodione | 100 | 58 | 16 | 0 | 0 |
| Procymidone | 46 | 10 | 0 | 0 | 0 |

*Table 6: Percent germination of* Sclerotinia sclerotiorum *after 7 days on PDA containing different concentrations of fungicides.*

| | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| Fungicide | 0.5 | 1 | 5 | 50 | 500 |
| Carbendazim | 52 | 16 | 0 | 0 | 0 |
| Dichloran | 100 | 100 | 100 | 24 | 18 |
| Trifloxystrobin | 100 | 100 | 100 | 100 | 100 |
| Tebuconazole | 100 | 70 | 0 | 0 | 0 |
| Iprodione | 100 | 100 | 32 | 0 | 0 |
| Procymidone | 100 | 96 | 0 | 0 | 0 |

## Test 3: Mycelial growth on agar medium containing fungicide

### Method

Glass bottles, each containing a standard volume of PDA medium (100 mL) and a magnetic stir bar, were autoclaved and allowed to cool to 55°C. Appropriate volumes of stock fungicide suspensions were added to the media to give final concentrations of 0.1, 0.5, 1, 5, and 10 ppm of each fungicide. Additional flasks without fungicides were used as controls. Media were dispensed into standard disposable petri dishes with 20 mL of medium in each dish. Agar plugs (5 mm diameter) from the leading edges of 2-day old *S. minor* and *S. sclerotiorum* cultures were placed in the centre of petri dishes containing fungicide-amended medium. Cultures were incubated at 20°C in the dark for 5 days. Each day, mycelial growth was measured along a radius from the edge of the agar plug to the colony margin.

### Results

The most effective fungicides, causing at least 90% inhibition of mycelial growth of *S. minor,* were iprodione (0.5 ppm), procymidone (0.5 ppm), followed by tebuconazole (5 ppm), carbendazim (5 ppm), and dichloran (5 ppm, Table 7). Fungicides that caused more than 90% inhibition of mycelial growth of *S. sclerotiorum* were procymidone (0.5 ppm), tebuconazole (1 ppm), carbendazim (1 ppm), iprodione (1 ppm), and dichloran (5 ppm, Table 8). Trifloxystrobin was much less effective against mycelial growth of both *S. minor* and *S. sclerotiorum*.

*Table 7: Mean daily radial growth (mm) of* Sclerotinia minor *mycelium on fungicide-amended PDA.*

| | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| Fungicide | 0.1 | 0.5 | 1 | 5 | 10 |
| Carbendazim | 13.9 | 3.5 | 3.0 | 0.4 | 0.2 |
| Dichloran | 17.0 | 8.6 | 4.3 | 0.1 | 0.1 |
| Trifloxystrobin | 9.5 | 9.0 | 8.1 | 7.0 | 7.6 |
| Tebuconazole | 4.9 | 2.9 | 2.9 | 0.1 | 0.1 |
| Iprodione | 3.8 | 0.7 | 0.2 | 0 | 0 |
| Procymidone | 10.2 | 0.6 | 0.1 | 0 | 0 |
| Control | 17.1 | | | | |

*Table 8: Mean daily radial growth (mm) of* Sclerotinia sclerotiorum *mycelium on fungicide-amended PDA.*

| | Fungicide concentration (ppm) | | | | |
|---|---|---|---|---|---|
| Fungicide | 0.1 | 0.5 | 1 | 5 | 10 |
| Carbendazim | 8.5 | 2.4 | 1.5 | 0.1 | 0 |
| Dichloran | 15.0 | 9.7 | 7.4 | 0.9 | 0.1 |
| Trifloxystrobin | 7.2 | 6.3 | 5.1 | 4.8 | 3.9 |
| Tebuconazole | 9.2 | 1.8 | 1.0 | 0.3 | 0.1 |
| Iprodione | 8.5 | 3.5 | 0.3 | 0.1 | 0 |
| Procymidone | 5.5 | 0.6 | 0.2 | 0 | 0 |
| Control | 16.1 | | | | |

**Conclusions**

Germination of sclerotia to produce mycelia, and the growth of mycelia from infected areas on a plant are two important stages in the disease life cycle. Carbendazim was the only fungicide that killed sclerotia of both species of *Sclerotinia* that had been immersed in the fungicide for 4 days. Procymidone inhibited both the germination of sclerotia and the mycelial growth of both fungi at low concentrations (5 ppm). Tebuconazole also inhibited both germination of sclerotia and mycelial growth of both fungi at low concentrations (5-10 ppm). Both of these fungicides show promise for control of Sclerotinia leaf drop of lettuce. Ascospores are generally regarded as the major primary inocula for *S. sclerotiorum*. Research is in progress to determine the effectiveness of fungicides against ascospores of *S. sclerotiorum*.

*4.3.3.2 Effects of fungicides, biocontrol agents, and lettuce varieties on Sclerotinia leaf drop*

**Introduction**

Current management strategies for Sclerotinia leaf drop are heavily reliant upon the sole currently registered agrochemical, carbendazim. It is difficult to target soil-borne pathogens such as *Sclerotinia*, and the hard, over-wintering structures (sclerotia) persist in the soil for many years. Biocontrol agents for control of sclerotial pathogens, including *Sclerotinia*, have been developed overseas and in New Zealand. Although no lettuce cultivars are immune to infection by *Sclerotinia* spp., several cultivars appear to be less susceptible than others. Many of these cultivars show architectural features that may promote avoidance or escape from infection, such as upright growth. The aim of this experiment was to evaluate three fungicides, three biocontrol agents, and five lettuce cultivars for control of Sclerotinia leaf drop of lettuce.

**Method**

Three experiments were done to determine the effects of (1) fungicides, (2) biological control agents, and (3) cultivar on incidence of Sclerotinia leaf drop of lettuce caused by *S. minor*. Each experiment was done twice, with lettuce plantings on 1 April and 14 July 2004 at Pukekohe on a mottled clay loam soil (pH 6.5). The cultivar 'Greenway' was used, except in the cultivar experiment, where four other cultivars were also grown. One day before planting, sclerotia of *S. minor*, produced in the laboratory on inoculated potato tuber pieces, were distributed evenly on the surface of experimental plots and raked into the soil (1 g sclerotia/$m^2$ of bed). The three experiments were each laid out in randomised blocks with five treatment replications along five rows. Each plot was 5 m long x 1.5 m wide, and contained 24 lettuce plants (six plants spaced 0.4 m apart along four rows). Fungicide and biocontrol agent treatments are shown in Tables 9 and 10. An Oxford precision sprayer, calibrated to 1000 L of water per hectare, was used to apply the fungicides and biocontrol agents. The number of dead plants, caused by *Sclerotinia* infection, per plot were recorded at plant maturity (6 June and 7 October).

*Table 9: Fungicide experiment treatments.*

| Chemical | Trade name | Rate |
|---|---|---|
| None | | |
| Carbendazim | Bavistin®DF | 2 kg/ha[1] |
| Tebuconazole | Folicur®430 SC | 1 L/ha[1] |
| Procymidone | Sumisclex®500 | 1.7 L/ha[1] |

[1] Applied after planting and 1 and 3 weeks later.

*Table 10: Biocontrol experiment treatments.*

| Product | Biocontrol agent |
|---|---|
| None | |
| [1]Serenade™ | *Bacillus subtilis* |
| [1]Contans™ | *Coniothyrium minitans* |
| [2]Lettucemate™ | *Trichoderma hamatum* |

[1] 4 kg/ha applied at planting and 1 and 3 weeks later.
[2] In potting mix, before planting, and 3 and 6 weeks after planting.

**Results**

Results are shown in Figures 4, 5 and 6. In all but one case, levels of Sclerotinia leaf drop were higher in the lettuces planted on 14 July than in those planted on 1 April.

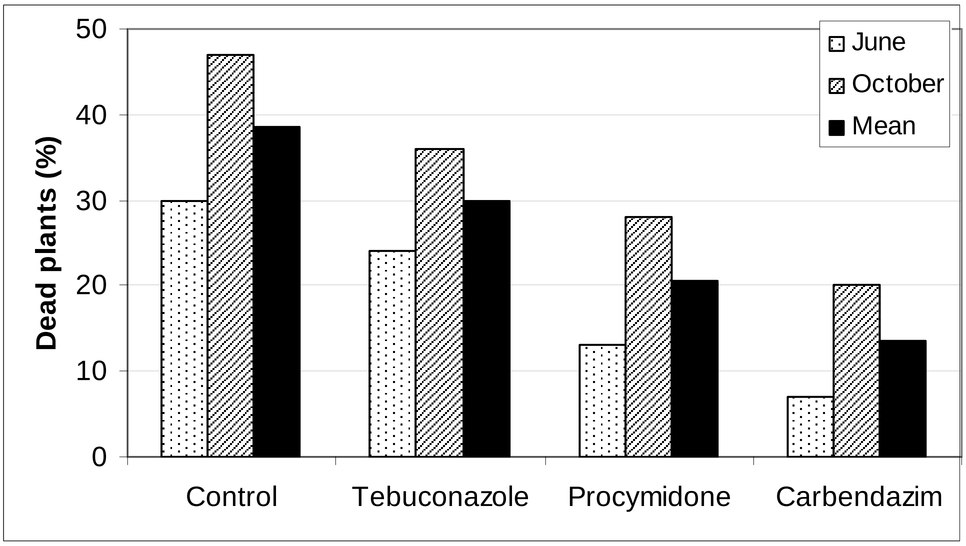


*Figure 4: Effects of fungicides on Sclerotinia leaf drop incidence at plant maturity.*

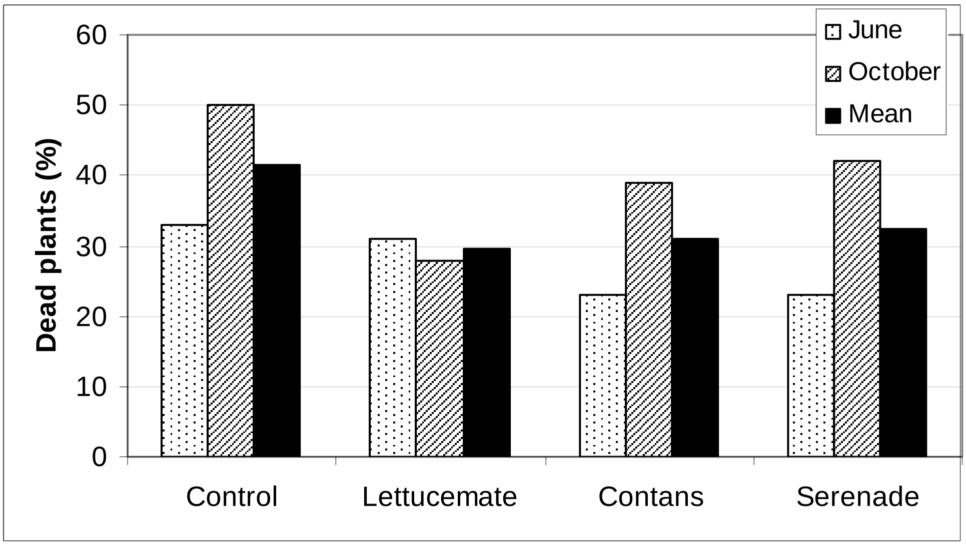


*Figure 5: Effects of biological control agents on Sclerotinia leaf drop incidence at plant maturity.*

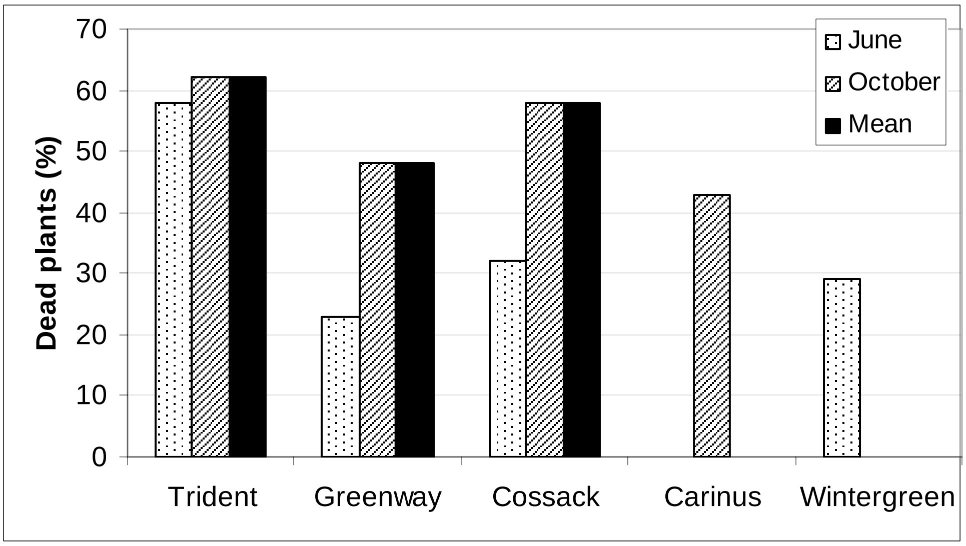


*Figure 6: Effects of cultivar on Sclerotinia leaf drop incidence at plant maturity.*

**Conclusions**

Addition of sclerotia to the experimental plots resulted in a high level of disease. Carbendazim clearly provided the most effective control of Sclerotinia leaf drop, with procymidone also reducing the incidence of the disease. The biocontrol agents all provided some measure of disease control. For valid comparisons of products for control of Sclerotinia leaf drop of lettuce, it is important that the results of several field experiments from different geographic locations are compared. Future research aims at developing an integrated disease control program for Sclerotinia leaf drop using combinations of various controls and management practices.

### *4.3.3.3 Effects of combinations of biocontrol agents and a “biocontrol-compatible” fungicide on Sclerotinia leaf drop*

**Introduction**

Procymidone was reported by McLean et al. (2001) to be compatible with the biocontrol agent *Trichoderma harzianum* C52. The aim of this experiment was to determine any synergy between three biocontrol agents for control of Sclerotinia leaf drop caused by *S. minor*, and to determine if procymidone is compatible with the biocontrol agents.

**Method**

Lettuce seedlings cv. ‘Greenway’, established as cell plants, were transplanted by hand on 14 July 2004 in nine four-row beds, each 40 m long x 1.5 m wide. Immediately before transplanting, 2 g of *S. minor* sclerotia (0.67 g/m$^2$) was distributed evenly on the surface of each plot and raked in to c. 2-3 cm. Plot size was 2 m long x 1.5 m wide, and plots were separated by buffer zones of 1 m. Each treatment was replicated four times, and each plot contained 24 lettuce plants (six plants spaced 0.4 m apart along each of four rows per bed). Treatments consisted of combinations of applications of

Lettucemate™ (*Trichoderma*), Contans™, Serenade™, and procymidone at the same rates as the previous experiment. An Oxford precision sprayer, calibrated to 1000 L water per hectare, was used to apply the fungicides and biocontrol agents. The number of dead plants, resulting from *Sclerotinia* infection, per plot were recorded at plant maturity (7 October 2004).

**Results**

Procymidone had the greatest effect on levels of Sclerotinia leaf drop (19-24% dead plants). Without the addition of procymidone, the biocontrol agents Lettucemate™, Contans™ and Serenade™, either alone or in combination with each other (26-39% dead plants), did not reduce the incidence of diseased plants compared with the control (no biocontrol agent) treatment (33% dead plants).

*Table 11: Effects of Lettucemate™, Contans™, Serenade™, and procymidone applications on incidence of Sclerotinia leaf drop at plant maturity (7 October 2004).*

| Treatment number | Trichoderma | Contans | Serenade | Fungicide | Dead plants (%) |
|---|---|---|---|---|---|
| 1 | - | - | - | - | 33 |
| 2 | - | - | + | - | 31 |
| 3 | - | + | - | - | 26 |
| 4 | - | + | + | | 33 |
| 5 | + | - | - | - | 38 |
| 6 | + | - | + | - | 28 |
| 7 | + | + | - | - | 39 |
| 8 | + | + | + | - | 28 |
| 9 | - | - | - | Procymidone | 22 |
| 10 | - | | + | Procymidone | 19 |
| 11 | - | + | - | Procymidone | 19 |
| 12 | - | + | + | Procymidone | 19 |
| 13 | + | - | - | Procymidone | 23 |
| 14 | + | - | + | Procymidone | 21 |
| 15 | + | + | - | Procymidone | 24 |
| 16 | + | + | + | Procymidone | 23 |

**Conclusions**

The addition of laboratory-grown sclerotia to the plots resulted in higher levels of disease than perhaps would normally occur in a naturally infected field. This experiment indicated that biocontrol agents may be more effective where levels of *Sclerotinia* inoculum are low to moderate.

## 4.4 *Surveys and controls for virus diseases*

**Virus disease surveys**

Virus diseases recorded on outdoor lettuces in New Zealand include *Arabis mosaic virus* (ArMV), *Beet western yellows virus* (BWYV), *Cucumber mosaic virus* (CMV), *Lettuce big-vein virus* (LBVV), *Lettuce mosaic virus* (LMV), *Lettuce necrotic yellows virus* (LNYV), *Tobacco necrosis virus* (TNV), *Tomato spotted wilt virus* (TSWV) and *Turnip mosaic virus* (TuMV). No virus disease surveys had been published since the 1950s so it was important that we confirmed which viruses were currently a problem in field-grown lettuces.

- Surveys took place during 2002-2004 over the spring/summer and autumn/winter periods.
- Primary focus in Pukekohe & Gisborne.
- Also around Hastings, Kapiti Coast, Christchurch and Nelson.
- Virus incidence was estimated visually from symptoms e.g. plant stunting and yellowing, leaf mottle/mosaic/necrosis and big-vein.
- Representative leaf and plant specimens were collected for analysis.

Results are summarised in Table 12.

*Table 12: Prevalence (% crops within each region) of lettuce crops affected with viruses and range of incidence within crops (% – in parentheses) in four surveys in 2002-2004.*

| | LBVD | LNYV | CMV | BWYV | LMV | TuMV |
|---|---|---|---|---|---|---|
| Spring/summer 2002 | | | | | | |
| Pukekohe | 66 (0-2) | 0 | 33† | 0 | 11 | 0 |
| Gisborne | 42 (10-50) | 0 | 14 | 0 | 28 | 0 |
| Christchurch | 10 (0-1) | 0 | 0 | 10 | 0 | 10 |
| Winter 2003 | | | | | | |
| Pukekohe | 41 (8-50) | 58 (1-8) | 17 | 41 (2-20) | 0 | 0 |
| Gisborne | 20 (1-20) | 0 | 0 | 0 | 10 | 0 |
| Christchurch | 20 (10-30) | 0 | 0 | 0 | 0 | 0 |
| Spring/summer 2003 | | | | | | |
| Gisborne | 10 (0-40) | 20 | 0 | 0 | 20 | 0 |
| Hawke's Bay | 50 (5-25) | 20 | 0 | 0 | 20 | 0 |
| Kapiti Coast | 66 (10-20) | 0 | 0 | 0 | 0 | 0 |
| Nelson | 20 (1-10) | 0 | 0 | 0 | 0 | 0 |
| Spring/summer 2004 | | | | | | |
| Auckland* | 59 (4-25) | 0 | 0 | 27 | 0 | 0 |
| Gisborne | 23 (1-50) | 20 | 8 | 8 | 54 | 0 |
| Hawke's Bay | 60 (5-30) | 10 | 30 | 0 | 10 | 0 |

*Pukekohe, Bombay and Mangere.
†Where no range is given incidence within the crops was scattered.

In summary:

- LBVD caused by LBVV and *Mirafiori lettuce big-vein virus* (MLBVV) was the most widespread virus disease.
- Prevalence was high under cool winter conditions and sometimes under spring and summer conditions (Hawke's Bay and Kapiti Coast).
- Other viruses occur, often as mixed infections, but do not cause significant crop losses.
- TSWV, ArMV and TNV were not detected in these surveys.

**Fungicide trials**

Lettuce big-vein disease (LBVD) is caused by MLBVV often in combination with LBVV.

The soil fungus *Olpidium brassicae* transmits LBVD – motile zoospores carry LBVD infection through the field soil from infected roots of lettuces and weeds to healthy lettuce roots. We explored the potential use of fungicides to control *Olpidium* and thereby limit virus spread and effect.

- Spring, autumn, and winter trials were established in a LBVD-affected block at Gisborne.
- 20-plant replicated plots were planted with transplant cells drenched in fungicide. In the soil band, fungicide was applied after transplanting.
- Individual plants were assessed at harvest for LBVD symptoms and lettuce heads were weighed.
- Results were analysed with a binomial generalised linear model (McCullagh & Nelder 1989).

*Table 13: Chemical treatments used to control* O. brassicae*.*

| Fungicide | Trade name/active ingredient | Application | Rate | Action |
|---|---|---|---|---|
| Carbendazim | Prolific 500 g/kg | cell transplant drench | 20 g/L | systemic (acropetally) |
| Propamocarb | Previcur 600 g/L | cell transplant drench | 1.5 mL/L | protectant systemic (acropetally) |
| Thiabendazole | Tecto 450 g/L | cell transplant drench | 10 mL/L | systemic (acropetally) |
| Fluazinam | Shirlan 500 g/L | soil band application | 12 mL/L | protectant, some systemic |
| Flusulfamide | Nebijin 50 g/L | soil band application | 3 mL/L | spore germination inhibitor |
| Quintozene | Terrachlor 750 g/L | soil band application | 2 g/L | contact fungicide |

Results from the spring trial are summarised below.

*Table 14: Yield of lettuces (kg/plot) and mean lettuce head weight (g) from different fungicide treatments to control* O. brassicae *in spring/summer (November) 2003.*

| | | | Mean lettuce head weight (g) | | | |
|---|---|---|---|---|---|---|
| Treatment | % lettuces infected | Yield of healthy lettuces | All plants | Healthy plants | Plants with LBVD | Reduction (Healthy-LBVD) |
| Control | 26 | 11 | 702 | 730 | 621 | 109 |
| Carbendazim | 24 | 11 | 710 | 734 | 638 | 96 |
| Propamocarb | 21 | 12 | 734 | 764 | 616 | 148 |
| Thiabendazole | 20 | 11 | 683 | 701 | 610 | 91 |
| Fluazinam | 31 | 9 | 633 | 662 | 568 | 94 |
| Flusulfamide | 21 | 12 | 757 | 783 | 660 | 122 |
| Quintozene | 24 | 11 | 704 | 743 | 580 | 163 |
| LSD (*P*=0.05, df=24) | | 1.8 | 75 | 91[1] | | 95[1] |

[1]Each comparison of two means has a different LSD because the numbers of lettuces vary. This is the mean all of the LSDs.

In the spring trial there were no significant differences in mean head weight between treatments and no significant differences in the mean yield of healthy plants between treatment and control. We found that fluazinam and thiabendazole had lower head weights whereas the rest had higher mean weights than the control.

However, for all treatments, lettuce plants infected with LBVD were significantly lighter than healthy/uninfected lettuces – a reduction of 16%.

Results for the autumn trial are presented below.

*Table 15: Yield of lettuces (kg/plot) and mean lettuce head weight (g) from different fungicide treatments to control* O.brassicae *in autumn/winter (March) 2004.*

| | | | Mean lettuce head weight (g) | | | |
|---|---|---|---|---|---|---|
| Treatment | % lettuces infected | Yield of healthy lettuces | All plants | Healthy plants | Plants with LBVD | Reduction (Healthy-LBVD) |
| Control | 83 | 1.4 | 441 | 419 | 445 | -26 |
| Carbendazim | 83 | 1.4 | 435 | 444 | 433 | 11 |
| Propamocarb | 85 | 1.4 | 499 | 472 | 503 | -31 |
| Thiabendazole | 92 | 0.75 | 510 | 501 | 512 | -10 |
| Fluazinam | 99 | 0.1 | 192 | 317 | 190 | 126 |
| Flusulfamide | 89 | 1.1 | 468 | 478 | 466 | 12 |
| Quintozene | 99 | 0.08 | 444 | 294 | 446 | -152 |
| LSD (*P*=0.05, df=18) | | 1.4 | 56 | 116[1] | | 146[1] |

[1]Each comparison of two means has a different LSD because the numbers of lettuces vary. This is the mean all of the LSDs.

In the autumn trial fluazinam treatment significantly reduced the mean head weight of all plants whereas propamocarb and thiabendazole treatments significantly increased the mean lettuce weight. However, the proportion of infected lettuces was noticeably greater for fluazinam and quintozene than for the control; all other treatments had similar infection levels to the control. There were no significant differences between the weights of LBVD-infected and uninfected lettuces.

Results for the winter trial are presented below.

*Table 16: Mean lettuce head weight (g/plant) from different fungicide treatments to control* O. brassicae *in winter (June) 2004. There was 100% infection in all plots.*

| Treatment | Mean lettuce head weight (g) | Difference from control (g) |
|---|---|---|
| Control | 494 | 0 |
| Carbendazim | 456 | -38 |
| Propamocarb | 504 | 10 |
| Thiabendazole | 520 | 25 |
| Fluazinam | 138 | -357 |
| Flusulfamide | 499 | 4 |
| Quintozene | 413 | -81 |
| LSD ($P$=0.05, df=24) | 66.7 | |

In the winter trial in June, 100% infection was recorded in all plots, so healthy/LBVD yield comparisons could not be made. Overall, mean head weight for fluazinam and quintozene were significantly lower ($P$<0.05) than for other treatments.

In conclusion:

- Chemical treatment for control *O. brassicae* over winter/spring using selected fungicides can increase yield of lettuce plants.
- Carbendazim, propamocarb and thiabendazole maintained or increased lettuce yield.
- Chemicals such as fluazinam and quintozene were phytotoxic, but further work on application might improve their efficacy.

## *4.5 Pesticide resistance management*

- Early testing for resistance to standard insecticides showed that the LA strain present in New Zealand is partially resistant to acephate and methomyl.
- A resistance-management strategy for LA has been prepared and publicised to the lettuce industry in New Zealand.
- The lettuce industry supports a resistance-management strategy that imidacloprid should only be registered as a seedling drench, and not used as a foliar-applied insecticide.

- The use of low rates of imidacloprid as a seedling drench is not recommended because of the threat of resistance build-up.
- Steward® (indoxacarb) has been registered for use against caterpillar pests on lettuce and presents an opportunity for growers to use a selective larvicide. This can give good control of caterpillar pests while conserving natural enemies of other pests, which should lead to a reduction in overall insecticide use.

## *4.6 Looper monitoring*

**Pheromone trapping for soybean looper**

A supplier for the male lure for soybean looper moths was not located until late 2004. Research then began to develop pheromone trapping as a crop-monitoring tool for control of soybean looper. Results to date show that crops in the north of the North Island are at continual risk from soybean looper caterpillar infestations from early January until late autumn. Large numbers of moths are caught throughout this period using Scentry (Heliothis) traps baited with a male lure. Results from our first season of intensive monitoring with Scentry traps indicate very large numbers of moths flying from mid-February to mid-April (approximately 100 male moths caught per trap per night over this period).

Egg and caterpillar infestations can be assessed during routine crop scouting for other pests.

## *4.7 Biological control*

- Tasmanian brown lacewing (*Micromus tasmaniae*), hoverfly larvae (*Melanostoma fasciatum*), spiders and harvestmen (*Phalangium opilio*) are considered important natural enemies of insect pests in lettuce at Pukekohe.
- These natural enemies and 11-spot ladybirds are important predators in other regions.
- Insect-infecting (entomopathogenic) fungi, particularly *Erynia neoaphidis,* are important natural enemies of LA in autumn and winter at Pukekohe.
- Control of aphids by parasitic hymenoptera in lettuce is poor.
- The status of biological controls for thrips in lettuce is basically unknown.
- Predators are important natural enemies for control of looper eggs and small larvae, but are ineffective against large caterpillars.
- The impact of biological control agents on the immature stages of soybean looper is relatively poorly understood. Therefore, to assess the natural enemy complex (apart from predators) attacking soybean looper eggs and larvae in trials at PRC, sub-samples of more than 30 representative larvae were collected regularly from untreated plots and also from *Beauveria*-treated plots in trials in summer and autumn. Also, large number of looper eggs were occasionally also collected and reared to fate. Results include:
  - Egg parasitoids were not recovered.

- Soybean looper larvae were occasionally parasitised by three species of parasitic hymenoptera; *Cotesia ruficrus*, *Copidosoma floridanum* and *Meteorus pulchricornis*.
- A small NPV virus was commonly found to be infecting soybean looper larvae in summer and autumn crops at PRC.

- Three parasitoids attack important predators of insect pests in all regions. The lacewing pupal parasitoid *Anacharis zealandica*, the syrphid parasitoid *Diplazaon laetatorius,* and *Dinocampus coccinellae,* which attacks adult 11-spot ladybirds, are all natural enemies with a negative impact on predator populations in spring, summer and autumn.
- A survey of ground predators, their identification and abundance was undertaken in spring (2003) and summer (2004) lettuce crops at PRC. Results show that three common species are present; sheetweb spiders (Linypphiidae), wolf spiders (Lycosidae) and harvestmen (*Phalangium opilio*). Seven other families of spiders have been identified (by Grace Hall, Landcare).
- A second entomopathogenic fungus that attacks LA at Pukekohe was identified. This species, *Zoophthora phalloides*, prefers cool conditions and is known to attack other aphid species in New Zealand (Dr Travis Glare, AgResearch, personal comment).

## 4.8 Technology transfer and IPM information guide

**IPM information guide**

A draft ‘Information Guide for outdoor lettuce’ has been prepared, and a small number of copies is available. This is a working document and will be updated periodically as new information is gained.

**Team meetings**

- There were numerous presentations given at team planning meetings.
- Dr Sandra McDougall (Team Leader, IPM for Lettuce, NSW Agriculture) attended project team meetings in Gisborne and Pukekohe.

**Grower field days:**

- Four grower field days were held at Pukekohe Research Station attended by 30-55 growers and industry personnel. Field days consisted of a series of Powerpoint presentations by Dr Davis and key Crop & Food researchers on recent progress in the project, and then a field walk to look at ongoing trials at the research station.
- A grower field day held in Christchurch was attended by 30 industry personnel.

**Other presentations:**

- A key for identification of aphid species on lettuce was completed and aphid identification workshops were held in Pukekohe, Gisborne and Levin in autumn 2003.

- A number of oral paper and poster presentations was made in August (2004 and 2005) at NZ Plant Protection conferences. See publications for details.
- Davis, S. 2004: Integrated pest and disease management for outdoor lettuce. Oral presentation in 'IPM and Beyond'. Sustainable Farming Fund Workshop. 9 August 2004.
- Davis, S.; Walker, G.P.; Wright, P. 2005. Progress report on MAF SFF/Vegfed project, IPM for outdoor lettuce. Oral presentations at meeting of the Vegfed fresh sector grower regional representatives, Palmerston North, 7 March 2005.
- Walker, G.P. 2004. History, status and control of lettuce aphid in New Zealand. A series of Powerpoint presentations given in Australia; Melbourne, Sydney, Hobart, 6-8 April, 2004.
- Walker, G.P. 2005. Current and past vegetable IPM programmes in New Zealand'. Oral presentation at the Vegfed-sponsored strategy workshop on IPM in vegetables, Waipuna Lodge, Auckland, 27 January 2005.
- Stuart Davis (IPM for lettuce aphid in New Zealand) and John Fletcher (lettuce viruses in New Zealand) gave oral presentations at the 3rd Australian Lettuce Industry Conference in Werribee, Victoria, 5-6 May 2005.

**Publications**


Anon. 2003: Progress made in battle to defeat lettuce aphid. *Horticulture News*, July 2003: 15.

Cameron, P.J. 2004: Review of lettuce IPM. Report to IPM for Outdoor Lettuce Project Team, 41 pp.

Cameron, P.J. (Editor) 2005: Integrated Pest Management in Lettuce: a draft information guide for outdoor head lettuce. Crop & Food Research. In press.

Curtis, C.; Workman, P.W. Biology of Tasmanian lacewing (*Micromus tasmaniae*) reared at two temperatures on *Nasonovia ribisnigri*. In prep.

Fletcher, J.; France, C.; Butler, R.C. 2004: Control and management of lettuce big vein disease. Poster abstract in *New Zealand Plant Protection 57*: 344.

Fletcher, J.D.; France, C.; Butler, R.C. 2004: Control and management of lettuce big-vein disease. Poster paper for 3rd Australian Lettuce Industry Conference at Werribee, 5-6 May 2005.

Fletcher, J.D.; Lister, R.A. 2005: Reports to IWGVV & IWLV combined Newsletter on our vegetable virus research projects.

Fletcher, J.D.; France, C.; Butler, R.C. 2005: Virus surveys of lettuce crops and management of lettuce big-vein disease in North Island, New Zealand. *New Zealand Plant Protection 58*: 239-244.

Fletcher, J.D. 2005: Lettuce viruses. www.aphidwatch.com

Stufkens, M.A.W.; Moore, M.S.; Hagerty, G.C. 2003: Preliminary advice on minimising insecticide resistance in lettuce aphids. Crop & Food Report. www.aphidwatch.com

Stufkens, M.A.W.; Wallace, A.R. 2004: Effectiveness and persistence of six insecticides for control of lettuce aphid on field lettuce in Canterbury, New Zealand. *New Zealand Plant Protection 57*: 233-238.

Stufkens, M.A.W.; Workman, P.J. 2004: Lettuce aphid (*Nasonovia ribisnigri*) resistance to insecticides. Crop & Food Research. www.aphidwatch.com

Stufkens, M.A.W.; Nichol, S.E.; Bulman, S.R.; Drayton, G.M. 2004: The incursion of the lettuce aphid into Tasmania – could it have blown over from New Zealand? Poster abstract in New Zealand Plant Protection 57: 340. www.aphidwatch.com

Stufkens, M.A.W.; Teulon, D.A.J. 2003: Distribution, host range and flight pattern of the lettuce aphid in New Zealand. New Zealand Plant Protection 56: 27-32.

Walker, G.P.; Workman, P.J.; Stufkens, M.A.W.; Wright, P.J.; Fletcher, J.D.; Qureshi, M.S.; Curtis, C.; MacDonald, F.; Winkler, S. Integrated pest management (IPM) for lettuce (3 monthly progress reports for MAF Sustainable Farming Fund and Vegfed. Crop & Food Research Confidential Reports: at 6, 9, 12, 15, 18, 21, 24, 27, 30, 33 months.

Walker, G.P.; Workman, P.J.; Stufkens, M.A.W.; Wright, P.J.; Fletcher, J.D.; Qureshi, M.S.; Davis, S.I. 2003: Integrated pest and disease management (IPM) for outdoor lettuce. Poster Abstract. Proc. 56th New Zealand Plant Protection Conf. 269.

Walker, G.P.; Wallace, A.R.; Qureshi, M.S. 2004: Parasitism of lepidopteran larvae collected from vegetable crops and associated weeds at Pukekohe. *New Zealand Plant Protection 57*: 1-7.

Walker, G.P.; Workman, P.J.; Stufkens, M.A.W.; Wright, P.J.; Fletcher, J.D.; Qureshi, M.S.; MacDonald, F. 2003: IPM for outdoor lettuce. *Grower*. December 2003: 21-24.

Walker, G.P.; Teulon, D.A.J. 2004: Solving problems with IPM. Grower 59 (10) November: 22.

Walker, G.P.; Teulon, D.A.J. 2004: Future-proofing the vegetable industry. Crop & Food Digest newsletter 46, Spring 2004: 4.

Walker, G.P. 2005: IPM for lettuce aphid. 54th Annual Conference Entomological Society of New Zealand. Abstract of oral presentation: 12.

Walker, M.K.; Stufkens, M.A.W. Indirect effects of insecticides on Tasmanian lacewing (*Micromus tasmaniae*) through aphid feeding. In prep.

Wallace, A.R.; Stufkens, M.A.W. 2005: Modelling the persistence of insecticides to control lettuce aphid on field lettuce. Poster presented at the joint meeting of the Australasian Region of the International Biometric Society and the Australasian Genstat Users Association Inc., Thredbo, Australia, 6-11 Feb 2005.

Workman, P.J.; Stufkens, M.A.W.; Martin, N.A.; Butler, R.C. 2004. Testing for pesticide resistance in lettuce aphid. *Proceedings of the New Zealand Plant Protection Society 57*: 239-243.

Workman, P.J.; Walker, G.P; Qureshi, M.S.; MacDonald, F.H. 2004: Control of lettuce aphid by the Tasmanian lacewing in New Zealand. Poster at 22nd

International Congress of Entomology, 15-21 August 2004, Brisbane, Australia.

Workman, P.J.; Walker, G.P.; O'Neill, E. 2005: Evaluation of Imidacloprid 350 SC as a pre-transplant drench for control of aphids in outdoor lettuce. A report prepared for Bayer CropScience. Crop & Food Research Confidential Report No. 1274.

Workman, P.J.; Fletcher, J.D.; Walker, G.P.; Winkler, S. Thrips on outdoor lettuce in New Zealand. Final draft prepared.

Wright, P.J. 2004: Evaluation of fungicides for control of downy mildew, anthracnose, and bacterial rots of lettuce. Proceedings of the 57th Plant Protection Conference 347. Poster abstract.

Wright, P.J. Differential activity of fungicides on germination of sclerotia and mycelial growth of *Sclerotinia minor* and *S. sclerotiorum*. To be submitted to *New Zealand Journal of Crop and Horticultural Science*.

Wright, P.J. 2005: Control of Sclerotinia leaf drop of lettuce. Poster to be presented at the Australasian Plant Pathology Society Conference, 26-29 September 2005, Geelong, Victoria.

www.aphidwatch.com (updated weekly)

## *4.9 IPM manual and information dissemination*

Funding for the 2-year 'implementation phase' of this project (2005-2007) has been approved by Vegfed and MAF SFF (grant number 05/059). A draft IPM information guide has been produced and will be revised and developed into the IPM manual by the end of June 2007.

# Appendices

## *Appendix I Seasonal insect trials assessing biological control (untreated) for aphid pests - 2002-2005*

| | | Planting date | Harvest date | Mean number for each trial: Aphids | Predators | Diseased aphids | Proportion lacewings | Proportion syrphids | Proportion ladybirds | Aphids at harvest |
|---|---|---|---|---|---|---|---|---|---|---|
| **Spring** | | | | | | | | | | |
| Pukekohe small plot trials | Spring 2002 | 15-Oct-02 | 17-Dec-02 | 15.46 | 2.52 | 0.00 | 0.87 | 0.13 | 0 | 3.47 |
| | Spring 2003 | 23-Oct-03 | 23-Dec-03 | 1.55 | 1.16 | 0.05 | 0.81 | 0.19 | 0 | 0.41 |
| | Spring 2004 | 2-Nov-04 | 21-Dec-04 | 0.40 | 0.98 | 0.75 | 0.52 | 0.48 | 0 | 0.30 |
| Pukekohe grower trials | Pukekawa | 27-Oct-04 | 21-Dec-04 | 0.32 | 0.82 | 0 | 0.61 | 0.39 | 0 | 0.02 |
| Spring 2004 | Ramarama | 29-Oct-04 | 21-Dec-04 | 0.18 | 0.43 | 0.00 | 0.64 | 0.36 | 0 | 0.04 |
| (large fields) | Pukekohe Hill | 1-Nov-04 | 28-Dec-04 | 0.08 | 0.12 | 0.00 | 0.73 | 0.27 | 0 | 0.04 |
| Christchurch trials | Spring 2003 | 12-Nov-03 | 7-Jan-03 | 12.20 | 2.75 | 0.23 | | | | 0 |
| | Spring 2004 | 4-Nov-04 | 29-Dec-04 | 139.37 | 14.56 | 4.67 | 0.93 | 0.06 | 0.0005 | 55.47 |
| Gisborne trial | Spring 2004 | 1-Nov-04 | 28-Dec-04 | 18.28 | 2.27 | 0.00 | 0.91 | 0.03 | 0.06 | 24.22 |
| **Summer** | | | | | | | | | | |
| Pukekohe small plot trials | Summer 2003 | 21-Jan-03 | 11-Mar-03 | 472.28 | 2.09 | 1.00 | 0.32 | 0.68 | 0 | 905.31 |
| | Summer 2004 | 20-Jan-04 | 9-Mar-04 | 39.13 | 1.50 | 1.15 | 0.74 | 0.26 | 0 | 121.09 |
| | Summer 2005 | 25-Jan-05 | 8-Mar-05 | 72.54 | 2.82 | 2.81 | 0.63 | 0.37 | 0 | 94.41 |
| Christchurch trials | Summer 2004 | 6-Jan-04 | 3-Mar-04 | 115.12 | 5.17 | 4.67 | 0.79 | 0.20 | 0.01 | 0 |
| | Summer 2005 | 17-Jan-05 | 3-Mar-05 | 20.94 | 6.46 | 0.69 | 0.80 | 0.20 | 0.001 | 0 |
| **Autumn** | | | | | | | | | | |
| Pukekohe small plot trials | Autumn 2003 | 2-Apr-03 | 21-Jun-03 | 59.58 | 1.47 | 11.21 | 0.92 | 0.08 | 0 | 108.50 |
| | Autumn 2004 | 1-Apr-04 | 15-Jun-04 | 9.95 | 1.33 | 0.82 | 0.85 | 0.15 | 0 | 0.16 |
| **Winter** | | | | | | | | | | |
| Pukekohe small plot trials | Winter 2003 | 27-May-03 | 30-Sep-03 | 9.21 | 0.49 | 2.93 | 0.73 | 0.27 | 0 | 6.38 |
| | Winter 2004 | 15-Jun-04 | 5-Oct-04 | 10.98 | 0.12 | 1.12 | 0.96 | 0.04 | 0 | 43.72 |

## *Appendix II Preliminary control strategies by season for pests and diseases of lettuce – Pukekohe region*

### Summer controls

| Growing system | Aphids | Caterpillars | Thrips | Diseases | Viruses |
|---|---|---|---|---|---|
| **Imidacloprid drench, susceptible cultivars** | - Scout every 1-2 weeks (count only wingless aphids)<br>- Use selective insecticide if aphid/predator ratio exceeds 10:1 | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant<br>- Protect pre-head if thrips numbers are high | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides<br>- Careful fertiliser and irrigation management<br>- Crop rotation | -Monitor glasshouse hygiene<br>- Control weeds, rogue infected plants. Do not over irrigate<br>- Consider pre-winter soil fumigation or solarisation |
| **Resistant cultivars, selective pesticides** | - Scout every 1-2 weeks (count only wingless aphids)<br>- Use selective insecticide if aphid/predator ratio exceeds 10:1 | - Scout weekly<br>- Use selective insecticide if caterpillars exceed 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant<br>- Protect pre-head if thrips numbers are high | - Scout for diseases every 1-2 weeks<br>- Use systemic and protectant fungicides | - Control weeds, rogue infected plants<br>- Plant virus-tolerant cultivars |
| **Biological control, susceptible cultivars** | Not suitable for this period at Pukekohe because lettuce aphid populations generally too high | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant<br>- Protect pre-head if thrips numbers are high | - Scout for diseases every 1-2 weeks<br>- Use Sclerotinia biocontrol agents | - Monitor glasshouse hygiene<br>- Control weeds, rogue infected plants. Do not over-irrigate |
| **Foliar pesticides, susceptible cultivars** | Not suitable for this period as lettuce aphid populations generally too high | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant<br>- Protect pre-head if thrips numbers are high | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides | - Control weeds, rogue infected plants<br>- Consider pre-winter soil fumigation or solarisation |

*Use with care (threshold not validated over different seasons or years).

## Autumn controls

| Growing system | Aphids | Caterpillars | Thrips | Diseases | Viruses |
|---|---|---|---|---|---|
| **Imidacloprid drench, susceptible cultivars** | - Scout every 1-2 weeks<br>- Use selective insecticide if aphid/predator ratio exceeds 10:1 | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- for young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides<br>- Crop rotation | - Monitor glasshouse hygiene<br>- Control weeds, rogue infected plants |
| **Resistant cultivars, selective pesticides** | - Scout every 1-2 weeks<br>- Use selective insecticide if aphid/predator ratio exceeds 10:1 | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant | - Scout for diseases every 1-2 weeks<br>- Plant cultivars resistant to downy mildew<br>- Use systemic and protectant fungicides | - Control thrips & aphid virus vectors<br>- Choose virus-tolerant cultivars for winter planting |
| **Biological control, susceptible cultivars** | - A combination of predators & fungal pathogens may control lettuce aphid (use with care)<br>- Scout weekly<br>- Use selective insecticides if aphid/predator ratio exceeds 10:1 | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant | - Scout for diseases every 1-2 weeks<br>- Use Sclerotinia biocontrol agents | - Monitor glasshouse hygiene<br>- Control weeds, rogue infected plants<br>- Choose well-drained winter blocks with a low risk of LBVD |
| **Foliar pesticides, susceptible cultivars** | Not a suitable control option for this period because aphid numbers generally too high | - Scout weekly<br>- Apply a selective insecticide (larvicide) if small caterpillar numbers exceed a mean of 0.5 per plant*<br>- Control large caterpillars | - Scout every 1-2 weeks<br>- For young seedlings, consider using an insecticide if thrips numbers exceed 10 per plant | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides | - Control weeds, rogue infected plants |

*Use with care (threshold not validated over different seasons or years).

## Winter controls

| Growing system | Aphids | Caterpillars | Thrips | Diseases | Viruses |
|---|---|---|---|---|---|
| **Foliar pesticides, susceptible cultivars** | - Scout every 1-2 weeks<br>- Use foliar-applied insecticide if aphid/predator ratio exceeds 10:1 | Caterpillar pests are not normally present. However, after a mild autumn crops grown in early winter may be at risk.<br>- Scout weekly in early winter<br>- If required, control as for autumn period | Thrips numbers are low during this period and do not require control | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides<br>- Crop rotation | - Monitor glasshouse hygiene<br>- Sow crops in well-drained winter blocks<br>- Consider fungicide seedling drench for LBVD |
| **Imidacloprid drench, susceptible cultivars** | Aphid numbers are at their lowest during winter so this period offers an opportunity for an imidicloprid-free window | See above | See above | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides | - Monitor glasshouse hygiene<br>- Consider fungicide seedling drench for LBVD |
| **Biological control, susceptible cultivars** | Fungal pathogens have given effective aphid control during winter, but not consistently (use with caution)<br>- Scout every 1-2 weeks and apply insecticide if aphid/predator ratio exceeds 10:1 | See above | See above | - Scout for diseases every 1-2 weeks<br>- Use Sclerotinia biocontrol agents | - Monitor glasshouse hygiene<br>- Sow crops in well-drained winter blocks |
| **Resistant cultivars, selective pesticides** | Available lettuce aphid resistant cultivars do not grow well during winter | See above | See above | - Scout for diseases every 1-2 weeks<br>- Use systemic and protectant fungicides | - Plant virus-tolerant cultivars |

## Spring controls

| Growing system | Aphids | Caterpillars | Thrips | Diseases | Viruses |
|---|---|---|---|---|---|
| **Biological control, susceptible cultivars** | Natural enemies control aphids during this period<br>However, biocontrol has not been consistently successful in other regions<br>- Scout weekly<br>- Apply a selective insecticide if the aphid/predator ratio exceeds 10:1 (count only wingless aphids) | Pest species not common during this period. Other species (e.g. Geometrids) do not require control. A risk period is late spring<br>- Pheromone traps or weekly scouting will alert of increased soybean looper activity<br>- Scout weekly (control as for summer period) | Thrips numbers low during this period and do not require control | - Scout for diseases every 1-2 weeks<br>- Use Sclerotinia biocontrol agents<br>- Crop rotation | - Control weeds, rogue infected plants<br>- Plant virus-tolerant cultivars |
| **Resistant cultivars, selective pesticides** | Scout weekly and apply a selective insecticide if the aphid/predator ratio exceeds 10:1 (count only wingless aphids) | See above | See above | - Scout for diseases every 1-2 weeks<br>- Plant cultivars resistant to downy mildew<br>- Use systemic and protectant fungicides | - Control weeds, rogue infected plants |
| **Imidacloprid drench, susceptible cultivars** | Scout every 1-2 weeks to check on the effectiveness of the treatment (count only wingless aphids) | See above | See above | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides | - Control weeds, rogue infected plants<br>- Consider fungicide seedling drench for LBVD |
| **Foliar pesticides, susceptible cultivars** | Aphid populations generally too high to achieve control using this method | See above | See above | - Scout for diseases every 1-2 weeks<br>- Use recommended fungicides | - Control weeds, rogue infected plants<br>- Consider fungicide seedling drench for LBVD |