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Improving lettuce insect pest management - Victoria

Robert Dimsey
VIC Department of Primary Industries

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Improving Lettuce Insect Pest Management – Victoria

Final Report for HAL Project VG 01038
(November 2004)

R Dimsey et al.
Department of Primary Industries - Victoria

Improving Lettuce Insect Pest Management–Victoria
Final report for HAL project VG01038

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Scope of the Report

This report presents the key findings and a summary of the work conducted in Victoria from July 2001 to June 2004 by the Project team. The results and summary presented are as complete as possible but more detail is presented in the seasonal milestone reports which report on the trial design and results in greater detail. Copies of these more detailed reports can be obtained from the authors.

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Victoria The Place To Be

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1. Media Summary

An Integrated Pest Management (IPM) program has been developed for the lettuce industry, with a focus on the insect pest *Helicoverpa* spp. (corn earworm or native budworm). The project, was conducted by the Victorian Department of Primary Industries and supported by the lettuce industry through Horticulture Australia Limited.

Victoria is a major producer of lettuce, for fresh head and for minimally processed product, producing around 33% of the national production and a GVP of $20.7M. Around 10% of plantings were lost in the 1999/2000 season to *Helicoverpa* damage. Control of *Helicoverpa* is complicated by its resistance to a wide range of chemical groups and, at the time of commencement of the project, limited registrations of chemicals for its control.

Project work was carried out at Werribee, Cranbourne and East Gippsland since these are the principal summer production areas in southern Victoria. The project evaluated new biological and "selective" insecticides for control of *Helicoverpa* in lettuce and their timing for use in an IPM program ("selective" pesticides have a low impact on beneficial species such as spiders and other predatory insects).

The selective and biological insecticides were effective against *Helicoverpa* and since the project began, some of these have been registered for use on lettuce. The biological pesticide Nuclear Polyhedrosis Virus (NPV) can be successfully applied through overhead irrigation.

Crops were monitored and reports provided to growers on a weekly basis on moth counts, pests in crops and incidence of beneficials. Careful crop monitoring is critical under an IPM system. From this project, it was concluded that endemic populations of parasitic wasps are unlikely to provide significant control of *Helicoverpa* eggs in southern Victoria.

Current industry pest control practices were assessed, to compare the impact of growers using IPM practices with those using more broad-spectrum insecticides. While there has been a significant increase in the use of IPM systems there needs to be a better understanding of resistance management and the use of IPM and selective pesticides by the industry.

Information was extended to industry on improving tipburn management and assistance was provided to facilitate an industry response lettuce aphid, which is currently the major threat to the industry.

The impact of lettuce aphid on IPM systems needs to be assessed and strategies for control of thrips in a lettuce IPM system need to be developed.

2. Technical Summary

The aim of this project was to develop an Integrated Pest Management program for lettuce with a focus on *Helicoverpa* spp. (corn earworm and native budworm). This project builds on a previous project VG98082, "Best management production practices to meet market requirements of consistent product quality and shelf life". The previous project focussed on the development of better management practices for tipburn control in lettuce crops and disease monitoring and included some initial monitoring for the pest *Helicoverpa* spp.

This pest became a major issue for the industry, particularly in the season 1999/00 when around 10% of plantings were lost to *Helicoverpa armigera*. Control of *Helicoverpa armigera*, is complicated by resistance to a wide range of chemical groups and at the time of commencement of the project, there were limited registrations and new insecticides available.

The project:

- Evaluated a range of new and existing pesticides for *Helicoverpa* control in the first season.
- Biological pesticides Nuclear Polyhedrosis Virus (NPV) and *Bacillus thuringiensis* (Bt) were evaluated for use from early transplanting and selective pesticides emamectin, methoxyfenozide and Sumitomo 1812 were evaluated from pre-hearting to harvest in the second and third seasons.
- Monitored moth numbers in a network of pheromone traps, informed industry on pest pressure and monitored field crops to assess the incidence and diversity of pests and beneficial arthropods.
- Assessed the potential to apply the biological pesticide NPV through overhead irrigation.
- Monitored current industry practices for *Helicoverpa* control to compare the impact of growers using IPM practices with those using a more preventative control program with broad-spectrum insecticides.
- Extended information to industry on practices to improve IPM of *Helicoverpa*.
- Extended information to industry on practices to improve tipburn management.

Pest pressure for the duration of the project was relatively low and did not reach pest levels recorded even prior to 1999/00. Nevertheless some significant results were achieved in the field and to compensate for the low pest pressure, bioassays were used on treated crop samples from the field, using laboratory reared *H. armigera* populations. Since the project began, emamectin has been registered for lettuce and Sumitomo is moving towards registration of its product Sumitomo 1812.

The industry now has a number of biological and selective pesticides it can use in an effective IPM program. These include: spinosad, indoxacarb, emamectin, Bt and NPV.

Key Outcomes and Conclusions

- NPV was successfully applied through overhead irrigation systems.
- The new selective insecticides were effective against *Helicoverpa*.
- NPV achieved best results within 24 hours after application but larvae were still killed when exposed to material sprayed 6 days earlier.

- It is unlikely that endemic populations of parasitic wasps will provide significant control of *Helicoverpa* eggs in southern Victoria.
- There needs to be a better understanding of resistance management and the use of IPM and selective pesticides by industry.
- Careful crop monitoring is critical under an IPM system.
- The appropriate timing for the use of biological insecticides such as NPV or Bt is from transplant to pre-hearting and the targeted selective insecticides should be used from pre-hearting to harvest unless pest pressure is high.

Industry practices have changed significantly in the last 5 years with 92% of growers using new insecticides. There is increased use of IPM strategies, a reduction in the number of growers using calender sprays and more than 50% have changed other management practices such as irrigation.

The project also participated in the establishment of a Lettuce Aphid Steering Committee when the aphid outbreak occurred in NZ and facilitated industry meetings when the incursion occurred in Tasmania.

Recommendations for Future Work

- Further studies on impact of spinosad on syrphid and lacewing larvae are warranted.
- There is a need to develop IPM strategies for the control of thrips in an IPM system.
- Lettuce aphid is the major threat to the Victorian industry and its impact on IPM systems and the use of various control methods need to be assessed.
- The development of user friendly software for forecasting emergence of local moth and egg hatch times of *Helicoverpa* spp based on near real time temperature to allow better targeted pesticide application.
- More detailed observations of activity of egg parasitoids are required for *Helicoverpa* spp.

3. Introduction

Victoria is a major producer of lettuce both for fresh head production and for minimally processed product, producing around 33% of the national production of 36,557 tonne with a Gross Value of Production (GVP) of $20.7M. Lettuce is produced in Werribee and Cranbourne around Melbourne, East Gippsland and the North West however the major production area is Southern Victoria with summer lettuce. This is the major summer production area for Australia and consequently there are specific regional issues. This project has worked in collaboration with a similar project in NSW and Queensland (Integrated pest management in lettuce 2).

This project builds on a previous project VG98082, "Best management production practices to meet market requirements of consistent product quality and shelf life". The previous project focussed on the development of better management practices for tipburn control in lettuce crops and disease monitoring and included some initial monitoring for the pest *Helicoverpa* (corn earworm and native budworm) as this became a major issue for the industry during the period of this project. The project focussed on the development of an Integrated Pest Management for *Helicoverpa* on lettuce. *Helicoverpa armigera* caused significant crop loss in lettuce particularly in the season 1999/00 when around 10% of plantings were lost to the pest. Crop losses had also been reported in the preceding two seasons.

Control of *Helicoverpa armigera* is complicated by, resistance to a wide range of chemical groups. Options for control when the project began were limited and the new insecticide groups becoming available may not necessarily be registered and *H. armigera* was potentially the most significant pest for lettuce. Sustainable integrated pest management strategies need to be developed for the lettuce industry and will help prevent development of resistance, protect the new pesticide groups and improve options for control.

The major focus of the project is control of *Helicoverpa* spp., which had become a critical problem in recent years due to favourable weather conditions, increased pest activity and the development of significant chemical resistance. The project will evaluate new biological and soft pesticides in conjunction with the potential for using other biological controls such as parasitoid wasps and their use in lettuce, to develop an improved control strategy and an integrated pest management program. Information from the trials will also assist in the registration of new pesticides. The potential for application of Nuclear Polyhedrosis Virus through overhead irrigation has been evaluated as an effective method of applying this biological insecticide. Comparison of a range of grower practices for pest control have also been compared to look at the impact of growers using an IPM strategy with those using broad-spectrum insecticide and calender spray approach.

This project was complementary to work in NSW (S McDougall) and Qld (J Duff). Pesticides need to be evaluated in a number of areas to assist in registration and Southern Victoria is primarily a summer production area with different issues to the winter production areas of NSW and Qld.

Because the project was building on a previous project one aim of this project was to continue to extend the key issues identified for improved management practices for lettuce production to the wider lettuce industry. This included information on management practices for tipburn such as nutrition, pests, irrigation management and cultivars improve quality and develop better management practices.

Outputs of the project have included: a) a lettuce newsletter produced in conjunction with NSW and Queensland, which reported progress to growers in all 3 states, b) pest monitoring and scouting with regular bulletins issued to growers and the wider industry, c) information sheets have been provided to all stakeholders on tipburn control, *Helicoverpa,* thrips control strategies and on scouting protocols. Field trials of different rates of the new chemical Sumitomo 1812 were also carried out for residue analysis to assist in registration.

Following the outbreak of Lettuce Aphid (*Nasonovia ribis-nigris*) in New Zealand, its impact and the likelihood that it would reach Australia, the project facilitated a Lettuce Aphid Advisory Group. The project also began advising industry of likely problems with Lettuce Aphid and the progress in New Zealand. Subsequent to the outbreak in Tasmania in 2004 the project helped to facilitate industry meetings and provide industry information as well as crop scouting and assisting in the deployment of aphid traps.

Literature Review

In seasons 1998 and 2000 there was significant crop damage to lettuce by *Helicoverpa* spp. and this was identified by M Titley (Inaugural Australian Lettuce Industry Conference in 2000) as a major cause of concern and led to his company having to exit export markets in those years. *Helicoverpa* is considered to be one of Australia's most economically damaging pests in a range of crops. McGahan et al. (1991) estimated the losses to horticultural crops in Queensland as $188M per year. This includes control costs and crop losses. Insecticide resistance in *Helicoverpa armigera* is a major factor contributing to management difficulties with this pest in all crops including sweet corn. Resistance to methomyl was detected in 1984 in tobacco in north Qld and the first significant spray failures in sweet corn, due to high resistance levels, were detected on the Darling Downs in 1992. Since then resistance levels ranging from 10 to 100% have been detected in major production districts in Australia (R. Gunning, pers. comm.). Victorian populations have grown steadily in resistance to synthetic pyrethroids and carbamates, since 1995 and by 2000 resistance was extremely high (P Ridland 2001). Alternatives to synthetic insecticide such as augmentation of *Trichogramma* spp. (Scholz, 1994) and (Scholz - ARRIP*)* and use of *Bacillus thuringiensis* and nuclear polyhedrosis virus (NPV) (Monsour, 1995 and 1996), have potential in managing heliothis as part of an integrated approach. McDougall (2000) and Duff (2000) identified that there were new biologicals and soft chemistry that would appear to provide some control against *Helicoverpa* spp. were softer on beneficials and that these required further testing. Victoria is predominantly a summer production area while NSW and Queensland are winter production areas. Production times overlap but the cropping cycle and production conditions for Victoria are different.

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4. Materials and Methods

General Summary

The materials and method have been broken down into the various activities carried out over the period of the project. The materials and methods for each activity are described separately.

Trials and monitoring were carried out in 3 sites over the three year period of the project:

- Somerville/Cranbourne
- Werribee
- Lindenow in East Gippsland

These sites are representative of lettuce production in southern Victoria taking into account variation in soil types, climate, production differences and are the main areas where summer lettuce is produced in Victoria.

In the first year of the project, field trials of insecticides included both biological and new insecticides, in the one field trial at the 3 locations. However, in the second year these trials were broken up into trials focusing on new selective chemistry (low impact on beneficials) and biological insecticides. The Biological trials were conducted from early transplant to hearting while the selective chemical trials were conducted from hearting to harvest. In the third year only field evaluation of biological insecticides were conducted. More detailed methods are described under each of the field trial sections.

5. Moth Monitoring

5.1 Materials and Methods

Traps were set up to monitor moth activity around lettuce crops and were set up in three regions Cranbourne, Werribee and Lindenow and monitored from early spring. Traps were checked weekly and moth numbers forwarded to growers by fax, email or text messaging.

Activity of male *Helicoverpa punctigera* and *H. armigera* moths around lettuce crops was monitored in three production areas using Scentry® pheromone traps. The Scentry® traps are net traps, which have proven more effective in trapping *Helicoverpa* than pot traps particularly with the lower moth numbers experienced in Southern Victoria. The pheromone traps attract the males and separate traps are required for each species as a different pheromone is used.

5.2 Results

Monitoring of *H. armigera* has been going on for a number of years in sweet corn crops with Scentry® trap data being recorded since 1995 and Texas Trap (another form of net trap) and pot trap data prior to that in East Gippsland. A seasonal pattern of moth activity has been established and confirmed over a number of years (Fig. 1). This pattern of moth activity has also been mirrored in other production areas such as Werribee and Cranbourne.

Moth counts have been provided to industry on a regular basis as an indicator of pest activity with advice provided on pest pressure levels. This project commenced in the summer of 2000, which was the season after extreme levels had been recorded and had resulted in significant crop loss with failure to control the pest. Some crop damage had been reported in seasons prior to 1999/00 but the impact on crops was more sporadic. It was not until 1999/00 that it was confirmed to be *H. armigera* rather than *H. punctigera,* which does not have the resistance issues. The moth counts were higher than those observed during this project.

Figs 1, 2 and 3 are graphs of the long term moth counts for each area showing *H. punctigera* and *H. armigera* daily moth counts in comparison with the *H. armigera* counts experienced in 1999/00.

The Lindenow data are averaged over 9 years compared with 6 years for the other districts but the differences between regions are evident. Cranbourne seems to have lower pressure than Werribee, which more closely resembles the trap counts for moths that are recorded from Lindenow for both species.

H. punctigera activity is higher in spring and early summer with peaks in November and late December/early January and then a fall to very low levels. *H armigera* tends to have a slight rise in activity in October, a second slightly larger rise in activity in mid December and a peak of activity with high counts occurring around mid-late February (Figs 1,2 & 3). These peaks represent an emergence of moths over an extended period. In the extreme year the peak of activity in mid December was comparatively high and rising to extreme levels in February. The average lines in the graphs indicate that this trend is consistent in the different districts but the average February/March peaks for *H. armigera* stretched out due to the variation in the time of peak pest pressure in different years.

Fig 1.

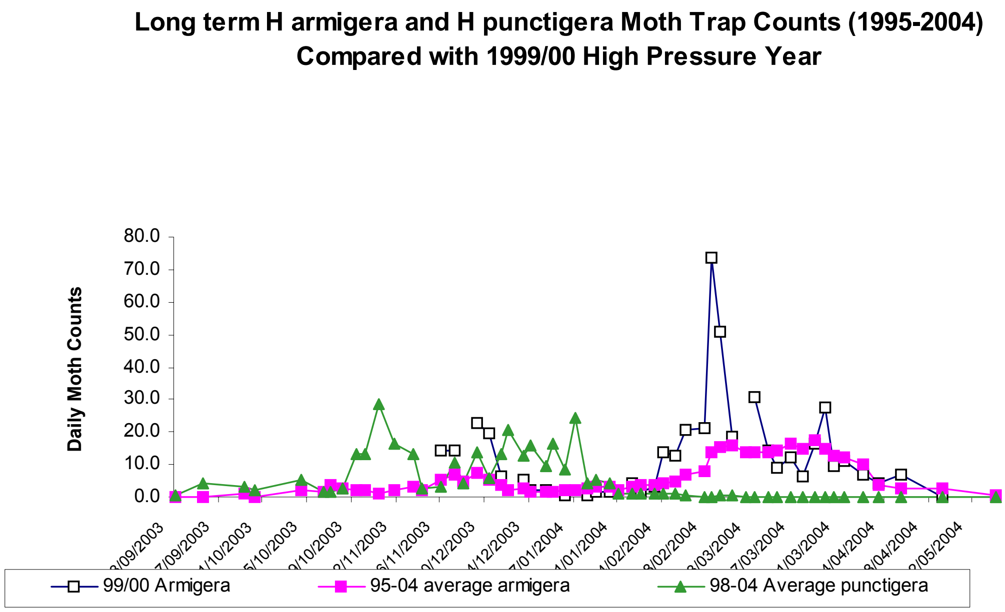


Fig 2.

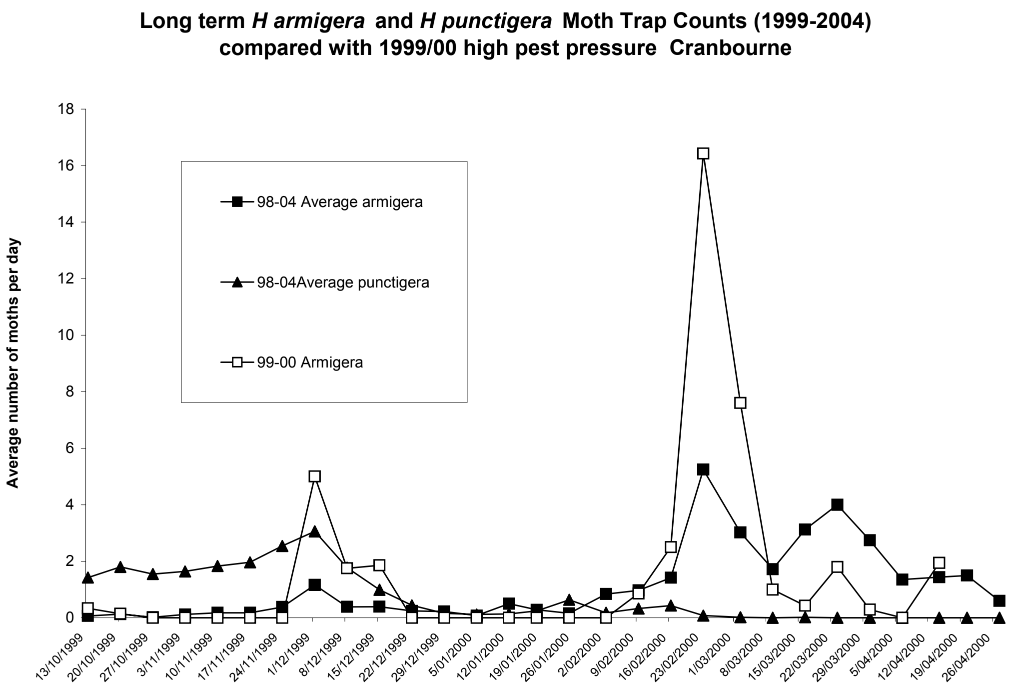
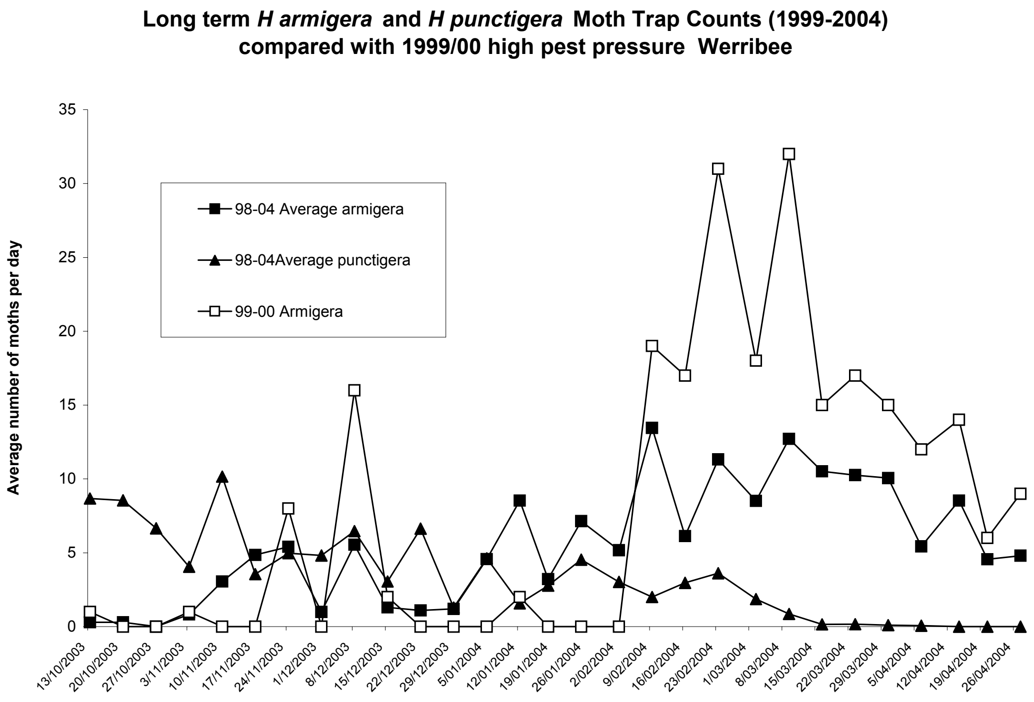


Fig 3.



Year 1 Season 2001/02

Moth activity was much lower in this first year of the project than in previous seasons at all sites monitored. The pattern of moth activity remains consistent with the average daily moth counts since 1995, although due to a very cool summer in 2001/2002 there was a slight delay in the late summer peak of activity. At Lindenow, moth activity peaked at around 23 moths per day in March/April while Werribee peaked at 15 and Cranbourne did not exceed 5 moths per day.

Table 1 compares the temperature conditions between January and April at Werribee from 1996 to 2002. The data for each year is also expressed as % of 1999/2000 season, when *Helicoverpa armigera* was a major problem. Important periods in terms of *H. armigera* activity are highlighted. It is clear that temperatures in February were much lower in 2002 than in 2000 (63.9%). It is also clear that temperatures in March 2000 were much higher than in the other years.

To measure the mildness of the summer, heat unit accumulation above an appropriate threshold temperature (in this case 10ºC) was used to compare temperature conditions between years and in particular the extreme pest pressure year between February and March 2000 for *H. armigera*. The mild temperatures may have had a significant impact on moth activity in this season.

Table 1 Heat unit accumulation (above 10ºC) for Werribee in last seven years.

Date	**2002**	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**
Jan	224.0	308.7	**227.0**	264.4	265.7	283.0	224.8
Feb	191.0	287.0	**299.0**	256.6	211.7	296.3	174.2
Mar	201.2	189.0	**240.0**	186.4	197.3	171.5	185.3
April	142.8	122.8	**140.4**	100.3	97.3	139.2	87.5
Jan-Mar	616.2	784.7	**766.0**	707.4	674.7	750.8	584.3
Feb-Mar	392.2	476.0	**539.0**	443.0	409.0	467.8	359.5
Feb-April	535.0	598.8	**679.4**	543.3	506.3	607.0	447
Jan	98.7%	136.0%	**100.0%**	116.5%	117.0%	124.7%	99.0%
Feb	63.9%	96.0%	**100.0%**	85.8%	70.8%	99.1%	58.3%
Mar	83.8%	78.8%	**100.0%**	77.7%	82.2%	71.5%	77.2%
April	101.7%	87.5%	**100.0%**	71.4%	69.3%	99.1%	62.3%
Jan-Mar	80.4%	102.4%	**100.0%**	92.3%	88.1%	98.0%	76.3%
Feb-Mar	72.8%	88.3%	100.0%	82.2%	75.9%	86.8%	66.7%
Feb-April	78.7%	88.1%	**100.0%**	80.0%	74.5%	89.3%	65.8%

Year 2. Season 2002/03

H. armigera counts were again very low this season, with moth numbers similar for the late summer peak for Lindenow and Werribee but much lower for the Cranbourne area (6/day, 7/day, and 2/day respectively). This season at Werribee the moths remained active for a much longer period of time with counts above 4/day by the end of April (due to the low moth numbers graphs are not shown for this year but data are included in the long term averages).

The numbers of *H. punctigera* were very high in spring. Although, the numbers were much lower in summer, a second generation of moths could be seen clearly in January and at Werribee. This would have led to mixed populations of larvae in lettuce in early February. While the trends were similar at all three locations numbers at Cranbourne were again lower and about half other areas (due to the low moth numbers graphs are not shown for this year but data is included in the long-term averages.

Year 3. Season 2003/04

The pattern was similar to the previous season for Werribee and Cranbourne with high *H. punctigera* activity in spring (although Cranbourne was lower). There was low *H. armigera* activity in summer at all sites. The activity of both species in Lindenow was low. Lindenow had the highest daily moth counts for the late summer peak of 7 moths/day respectively (due to the low moth numbers graphs are not shown for this year but data are included in the long term averages).

5.3 Discussion

The low moth counts for the period of the project indicated a low pest pressure. Nevertheless the pattern remained consistent with the long term pattern since 1995 for *H. armigera*. The spring peak reflects emergence of local overwintering moths, followed by the next generation peak in early summer and highest period of pest pressure in late summer/early autumn. The last peak in particular can be extended and varies in time due to the summer temperatures and possibly migration from more northerly regions. However, even though pest pressure was low, individual growers still experienced significant crop damage from time to time if egg lays were missed and spray timing was not accurate. Knowledge of moth counts and egg lay is critical in managing a spray program.

H. punctigera are more active in spring with moth counts increasing from October to November and counts dropping off to very low levels by early February.

Scentry® pheromone trap, for trapping male moths.

6. Chemical Evaluation Trials
Year 1. Season 2001/02

6.1 Materials and Methods
In the first year of the project field trials were carried out at three sites across southern Victoria to evaluate a range of insecticides on lettuce and their effectiveness in controlling *Helicoverpa armigera* (corn earworm). The sites were in Werribee, Cranbourne, and Lindenow. The trials were established in late February when pest pressure was expected to be highest.

Nine treatments were evaluated at each of the three sites:
1. Prodigy® - Methoxyfenozide (1.6 l/ha and 0.96ml/plot), an insect growth regulator insecticide, not registered on lettuce, but registered for control of *Helicoverpa* spp. on tomatoes.
2. Proclaim® - Emamectin benzoate (300g/ha and 0.18 g/plot), registered for control of *Helicoverpa* spp. on tomatoes but not registered for lettuce.
3. Avatar® - Indoxacarb (170g/ha and 0.1 g/plot), newly registered for control of *Helicoverpa* spp. on lettuce.
4. Success® - Spinosad (800g/ha and 0.48 g/plot), registered for control of *Helicoverpa* spp. on lettuce, tomatoes and sweet corn.
5. Dominex® - Alpha-cypermethrin (400ml/ha and 0.24 ml/plot), registered for lettuce and used as the standard chemical control.
6. Sumitomo 1812 - unregistered chemical (200 ml/ha and 0.12 ml/plot), which is undergoing extensive testing against *Helicoverpa* spp. in a range of crops.
7. Delfin® - *Bacillus thuringiensis* (100g/100l and 0.6 g/plot), not registered for lettuce.
8. Gemstar® - Nuclear Polyhedrosis Virus (NPV at 750 ml/ha and 0.45 ml/plot) newly registered for control of *Helicoverpa* spp. on lettuce.
9. Untreated Control

These treatments included two biological insecticides: Gemstar® and Delfin®. Apart from Dominex® which, is a broad-spectrum insecticide, the other insecticides are selective, and have less impact on beneficial arthropods.

The trial included four replicates and nine treatments, a total number of 36 plots. At Lindenow, a randomised complete block design was used, whereas at Werribee and Cranbourne, an incomplete block design was used and data were analysed with a generalised linear model using the Poisson distribution with a log function.

Four applications were made for each treatment, the first application at around 2 weeks after transplanting and the final application was made about 1 week before harvest. Plots were 5m long with around 40 plants per plot. There were no buffers between the treatments and trials were sampled from the middle 3 m of row. Application volumes were based on applying 800l/ha of water for the insecticide application, which equated to 480 ml of water applied per plot. A motorised back-pack sprayer was used. Spray pressure used for the Werribee and Cranbourne plots was 2.5 bar and at Lindenow the pressure used was 2.5-3 bar. Treatments were applied from around 8.30 am to 11.00 am to minimise the impact of the wind and afternoon sea breezes.

Crops at Lindenow were monitored weekly for pests and beneficials with a destructive sample after hearting and at harvest to assess crop damage. Crops at Werribee and Cranbourne were assessed with a destructive sample at harvest to assess insect numbers and crop damage.

Due to the low numbers of *H. armigera* in the field for the Werribee trials, a laboratory bioassay was conducted to give some information about the efficacy of the chemicals. First and second instar *H. armigera* larvae were placed onto leaf discs from treated lettuces in 30 mL plastic cups. Lettuces were collected from the trial site at Werribee 3 days after treatment. There were 20 larvae per treatment. The bioassay was set up on 19 April 2002, held at 25°C and assessed on 22 April 2002.

A resampling test was conducted by pooling all data for larvae (61 dead larvae from 180 larvae in total). The 61 dead larvae were assigned to numbers 1 to 61, while live larvae were represented by the series 62 to 180. From this pool of numbers, random samples of 20 were taken (with replacement). This was repeated 5,000 times. The number of dead larvae (i.e. the number of integers between 1 and 61) in each sample of numbers were counted. The results were then tabulated for all resamples to show the probabilities for obtaining each number of dead larvae in a sample of 20 larvae.

Parasitoid Monitoring – East Gippsland
Trichogramma pretiosum an American species is a parasitic wasp, which attacks the eggs of corn earworm and has been released on sweet corn crops in the Lindenow area over a number of years. Since eggs were scarce in the crops this season, egg cards of *Helicoverpa armigera* were placed in crops at Lindenow to check for the presence of egg parasitoids. The egg cards were produced at Bairnsdale from moths bred at IHD Knoxfield. The *Helicoverpa* culture was started from eggs kindly supplied from QDPI, Toowoomba.

On five separate occasions, egg cards were placed in the field to monitor the presence of egg parasitoids. Cards were placed in the field for around 24 hours and then brought back to the laboratory to determine the levels of parasitism by wasps.

A mass release of *Trichogramma pretiosum* had been carried out by Snowy River Seeds on their seed crops at Orbost. To check the success of the release, egg cards were placed in those crops in May 2002 to check on the presence of *Trichogramma pretiosum* in release areas. In seed corn crops at Orbost, there is usually no application of insecticides for *Helicoverpa* control. Egg cards had also been placed in the field in Orbost in February but were destroyed by ants in the laboratory.

Sumitomo Rate Trial
At Lindenow and Cranbourne, a rate trial was carried out for Sumitomo Chemicals for a new experimental chemical (S 1812). This product is part of a new insecticide group and is considered relatively harmless to beneficial arthropods. Three rates were evaluated (50, 100 and 200 ml per ha) with four replicates giving at total of 12 plots. These plots were also sampled according to the provided guidelines for residue assessment and samples sent for testing. The results of these trials are not discussed in this report due to low pest pressure and lack of significant differences between treatments but these and the residue data will contribute to the registration of this new soft pesticide.

6.2 Results

Numbers of *Helicoverpa* larvae were very low at each trial (Lindenow 4 larvae at harvest 1, 2 larvae at harvest 2; Cranbourne 11 larvae at harvest; Werribee 31 larvae at harvest). Consequently, there were no significant results between treatments for the field comparison of different insecticides for grub numbers. There was also no difference in crop damage either internally or externally to lettuce heads.

Only the trial at Werribee had sufficient pest pressure to allow a meaningful statistical analysis (Table 2). There was no difference between any of the treatments, including the control.

Table 2 Predicted number of larvae per 10 lettuces for each treatment at Werribee

Werribee	*Helicoverpa armigera* Predicted number of larvae per 10 lettuces	standard error
Delfin®	1.87	0.960
Control	1.80	0.839
Avatar®	0.96	0.817
Gemstar®	0.69	0.442
Sumitomo	0.68	0.444
Prodigy®	0.54	0.336
Success®	0.51	0.402
Proclaim®	0.48	0.370
Dominex®	0.31	0.329

Bioassay Results for Werribee

Assuming no difference between treatments, the probability of obtaining each result is shown in Table 3, together with the cumulative probability. The mortalities for Dominex®, Proclaim® and Prodigy® were all above the 95% level, while the mortalities for Gemstar®, Avatar® and the control were at or below the 5% level. The treatments were bioassayed 3 days after application, so the reduced mortality observed with Delfin® and Gemstar® would be consistent with UV degradation of Delfin® and Gemstar®. These results also confirm that synthetic pyrethroids (Dominex®) are still effective against early instar larvae.

The bioassay needed many more larvae per treatment to assist in statistical separation. However, the method would be very useful for establishing efficacy decay curves of test chemicals under field conditions.

Table 3 Numbers of live and dead *Helicoverpa armigera* larvae after 3 days' exposure to treated lettuce pieces taken from the experimental plots 3 days after the 4th application of the test insecticide had been applied

Treatment	Live larvae	Dead larvae	% mortality	probability	cumulative probability
Dominex®	8	12	60.0%	0.8	99.6
Proclaim®	9	11	55.0%	2.6	98.8
Prodigy®	10	10	50.0%	6.4	96.2
Success®	11	9	45.0%	10.4	89.9
Sumitomo 1812	11	9	45.0%	10.4	89.9
Delfin®	16	4	20.0%	8.6	13.8
Gemstar®	17	3	15.0%	3.9	5.2
Avatar®	18	2	10.0%	1.1	1.3
Control	19	1	5.0%	0.2	0.3

Aphids
In the trials at Cranbourne and Lindenow, very high levels of infestation were observed with the brown sowthistle aphid, *Uroleucon sonchi*. This is the first time that we have seen this aphid (a recent arrival to Australia) causing such problems in lettuce. It is more commonly now found colonising sowthistles, often in association with the green sowthistle aphid, *Hyperomyzus lactucae,* the vector of lettuce necrotic yellows.

In the trial at Cranbourne, aphid levels were very high in all treatments apart from the broad-spectrum Dominex® (Table 4). Results were more variable at Lindenow (Table 5) and differences were not significant.

Hoverfly (Syrphid) Larvae
At Cranbourne, the high numbers of aphids attracted many hoverflies which resulted in high numbers of syrphids (hoverfly larvae) on the lettuces, with 156 syrphid larvae being found in the 360 harvested lettuces. Hoverflies feed on pollen but their larvae are effective predators of aphids. Numbers of syrphid larvae found at Lindenow were much lower (8 syrphid larvae/360 lettuces at Harvest 1; 4 syrphid lettuces/360 lettuces at Harvest 2). No aphids or syrphid larvae were observed at Werribee when the trial was harvested.

Analysis of the syrphid larvae data from Cranbourne revealed that the numbers of syrphid larvae in the Success® treatment were significantly lower than for the other treatments (apart from Dominex®, table 4).

Table 4 The mean rating for the brown sowthistle aphid, *Uroleucon sonchi*, and the predicted number of syrphid larvae per 10 lettuces for each treatment in the insecticide evaluation trial conducted at Cranbourne (February - April 2002). Within a column, means followed by a different letter are significantly different (P<0.05).

Treatment	***Aphid rating***	**Syrphid larvae per10 lettuce**
Delfin®	2.95 a	13.36 a
Gemstar®	2.74 a	6.60 b
Control	2.88 a	5.62 b
Sumitomo 1812	2.96 a	4.87 b
Prodigy®	2.68 a	4.64 b
Avatar®	2.83 a	2.89 b
Proclaim®	2.68 a	2.88 b
Success®	2.75 a	0.59 c
Dominex®	0.02 b	0.00 d

Table 5 The mean rating for the brown sowthistle aphid, *Uroleucon sonchi*, and the predicted number of syrphid larvae per 10 lettuces for each treatment in the insecticide evaluation trial conducted at Lindenow (February - April 2002)

Treatment	**Harvest 1**		**Harvest 2**	
	Aphid rating	**Syrphid larvae per 10 lettuces**	**Aphid rating**	**Syrphid larvae per 10 lettuces**
Avatar	1.50	0.50	1.50	0.00
Delfin	1.50	0.00	1.00	0.00
Control	2.25	1.00	1.25	4.50
Dominex	2.00	0.00	1.00	0.00
Gemstar	2.50	0.00	1.25	1.00
Proclaim	1.75	0.50	1.75	0.00
Prodigy	1.25	0.00	1.25	0.00
Success	2.25	0.00	1.00	0.00
Sumitomo	1.00	0.00	2.00	0.50

Parasitoid Monitoring

There was significant mortality of eggs in the field due to other predators and climatic conditions. Typically 25–30% of eggs were lost in the field but losses as high as 50% were occasionally observed.

With egg cards in the field, there are usually some losses through wash off due to rain or irrigation and due to predation. However, the assessment of parasitism of eggs retrieved from the field is assumed similar to collection of naturally occurring pest pressure in the field.

No parasitism by *Trichogramma* was observed on the cards placed in Lindenow (Table 6). Low levels of *Trichogramma* parasitism were observed on cards in the Orbost crops, where releases of *T. pretiosum* had been made. Although releases had been made the low levels may be due to the very low pest pressure making it difficult to sustain the levels of the wasp within the crop.

Table 6 Details of parasitoid monitoring using *Helicoverpa armigera* egg cards at Lindenow and Orbost in 2001/2002 season

Release Date	Area	Crop	No. of Egg Cards	% Parasitised	*Telenomus* sp.	*Trichogramma* sp.
13 Feb 02	Lindenow	lettuce	50	23	Yes	Nil
13 Feb 02	Lindenow	corn	50	23	Yes	Nil
26 Feb 02	Lindenow	lettuce	25	23	Yes	Nil
26 Feb 02	Lindenow	lucerne	25	23	Yes	Nil
2 April 02	Lindenow	corn	50	nil	Nil	Nil
6 May 02	Orbost field 1	corn	50	5	Nil	Yes
6 May 02	Orbost field 2	corn	25	5	Nil	Yes

6.3 Discussion

In the field there were no significant differences observed between treatments due to low pest pressure. The bioassay allowed the treatments to be compared and provided results for the field treatments under conditions of very low field pest pressure. The lower response to Delfin® and Gemstar® could be due to the delay in exposing the larvae to these biological pesticides, which would be consistent with UV degradation. The lack of response to Avatar® is a surprise given the good field results reported in trials on sweet corn.

The impact of the pesticides on other pests is also worth assessing. The adverse impact of Success® was not unexpected because the compound is effective against other Diptera, such as leafminers, *Liriomyza* spp. The absence of syrphid larvae on the Dominex® treatment could not be definitely related to its known toxicity to syrphids; it may simply have reflected the absence of aphids on any of the Dominex® treated lettuces. At Lindenow, the numbers of hoverfly larvae were too low to conduct a meaningful statistical analysis.

Syrphid larvae are very effective predators of aphids, but were unable to provide adequate levels of control on the untreated plots. As part of an IPM strategy, it is important that such beneficials are conserved by avoiding broad-spectrum insecticides such as Dominex® and through the use of targeted insecticides. Further studies on impact of Success® on syrphid larvae are warranted.

These results highlight the need for careful monitoring of crops, particularly as the industry moves away from broad-spectrum insecticides towards more selective compounds.

Trichogramma pretiosum is not known to occur naturally in Victoria, despite having been released in the Lindenow area on sweet corn crops over a number of years. Unless *T. pretiosum* can successfully overwinter in Victoria, it will not play an important role in an integrated pest management program. In previous monitoring studies of egg parasitoids at Lindenow, the native parasitoid wasps, *Telenomus* sp. and *Trichogramma funiculatum*, have been found. *T. pretiosum* has only been positively recorded after its release.

From the parasitoid monitoring results there is still no evidence that *T. pretiosum* has successfully overwintered in Victoria. More detailed observations of activity of egg parasitoids is required. The low pest pressure experienced in this season would have meant that commercial releases would not likely prove to be beneficial as demonstrated by the low response to the release in Orbost. However we still need more assessments to determine whether of not *Trichogramma* spp. are active. Low pest pressure in comparison with other areas, combined with the cooler winter, may mean that it is unlikely, using current production systems, that endemic populations of parasitic wasps will provide significant control of *Helicoverpa* eggs in southern Victoria on lettuce.

7. Chemical Evaluation Trials
Evaluation of New Chemicals from Pre-Hearting to Harvest
Year 2. Season 2002/03

7.1 Materials and Methods
In the second year of the project, field trials were carried out in Werribee South and Lindenow to evaluate a range of new selective insecticides for their effectiveness in controlling *Helicoverpa armigera* on lettuce from pre-hearting to harvest. The trials were conducted in March when historically pest pressure is at its peak. For the trial at Werribee South, lettuce plants were manually infested with *H. armigera* to ensure trial results would be obtained, irrespective of local pest pressure.

Four treatments were evaluated at each site:
1. Proclaim® - Emamectin benzoate, registered for control of *Helicoverpa* spp. on tomatoes but not yet registered for lettuce 300 g /ha (0.18 g/plot at Werribee South and 0.5 g/plot at Lindenow).
2. Prodigy® - Methoxyfenozide, an insect growth regulator insecticide, registered for control of *Helicoverpa* spp. on tomatoes but not yet registered for lettuce, applied at 1.6 l/ha (0.96 ml/plot at Werribee South and 2.6 ml/plot at Lindenow).
3. Sumitomo 1812- an experimental insecticide not yet registered for use in Australia applied at 200 ml /ha (0.12 ml/plot at Werribee South and 0.33ml/plot at Lindenow).
4. Control – untreated.

The trial included four replicates and four treatments (Latin square) with a total number of 16 plots at Werribee South and a randomised block design at Lindenow also with four replicates and treatments. Four applications were made for each treatment, the first application at around 2 weeks after transplanting and the final application was made about 1 week before harvest. Treatments were applied from around 8.30 am to 11.00 am to minimise the impact of the wind and afternoon sea breezes.

At Werribee South plots were 5m long with around 40 plants per plot. There were no buffers between the treatments and trials were sampled from the middle 3 m of row. Application volumes were based on applying 800l/ha of water for the insecticide application, which equated to 480 ml of water applied per plot. A motorised back-pack sprayer was used with a spray pressure of 2.5-3 bar.

At Lindenow the plots were 12m long and the trials were sampled from the middle 10m of row. Application volumes were based on applying 800l/ha of water for the insecticide and 1300ml was applied per plot using a motorised back-pack sprayer with the application at 3.5 bar for the NPV application (a specific spray unit was used for NPV) and at 5 bar for the remaining treatments.

Pest pressure during the field trials was relatively low. In order to compensate at Werribee South, crops were seeded with *H. armigera* 3rd instar larvae onto 20 plants (1 larva/plant) per plot two days before spraying. Sprays were applied twice, one week apart. Six days after the first spray was applied, the 10 plants per plot were harvested and six days after the second spray was applied, the remaining 10 plants per plot were harvested. All harvested lettuce plants were assessed for *H. armigera* presence, feeding damage and presence of any other insects.

Bioassays of the field-sprayed plants at Werribee South were done in the laboratory to assess the residual efficacies of the treatments. Two bioassays were conducted after each spray, the first 24 hours (1 day) and the second 120 hours (5 days) after spraying. One randomly chosen leaf per plot was collected and placed into a 40 cm x 28 cm plastic bag and sealed. The wrapper leaf from lettuce plant (leaf between outer leaf and head leaf) was collected for bioassays.

The Werribee South trial was harvested twice (6 days after the first spray application was applied (ie, 8 days after larvae were placed on the lettuce plots) and 6 days after the second spray application was applied (ie, 15 days after larvae were seeded onto the lettuce). Data were analysed with Genstat® program using a Generalized Linear Model.

7.2 Results

Werribee Trials

At the first harvest, Proclaim® was the only insecticide with significantly lower numbers of surviving larvae compared to the control. Proclaim® and Sumitomo1812 showed significantly less feeding damage then the untreated control (Table 7).

At the second harvest, Proclaim® had significantly lower numbers of live larvae at harvest in comparison with other treatments (Table 8). Prodigy® and Sumitomo 1812 both had significantly lower numbers than the control. However, the best performing treatment (Proclaim®) still had only a 75% success rate. In two days pre-spraying, most of the larvae moved well inside lettuce and were sheltering deep inside. Applied insecticides were not able to make contact with larvae (directly or indirectly through leaves). Understandably, the efficacy of the spray is directly related to the protection of the larvae inside the head. In a production situation this means that if the insect presence was not detected on time, late sprays will not provide control.

Table 7 Lettuce assessment at harvest (1st harvest, 1 April 2003 Werribee)

Treatment	Larvae placed onto plants	Live larvae at harvest	Dead larvae at harvest	Plants with feeding damage
Proclaim®	40	#12 b	8	15 bc
Prodigy®	40	23 ab	6	21 ba
S-1812	40	19 ab	5	15 bc
Control	40	28 a	0	27 a

#Any two means with the same letter are not significantly different at the 95% probability level

Table 8 Lettuce assessment at harvest (2nd harvest 8th April 2003 Werribee)

Treatment	Larvae placed onto plants	Live larvae at the harvest	Dead larvae at the harvest	Plants with feeding damage
Proclaim®	40	#10 c	9	11 bc
Prodigy®	40	17 b	1	15 bc
S-1812	40	18 b	5	21 ba
Control	40	26 a	1	26 a

#Any two means with the same letter are not significantly different at the 95% probability level

Analysis of bioassays
All three insecticides were effective in controlling *Helicoverpa armigera*. Proclaim® was the fastest acting insecticide, providing more than 90% control in 24 hours. Although slower acting, Sumitomo 1812 and Prodigy® were equally effective as Proclaim® providing effective control after 4 days (Table 9, Figure 4). Tables 9-12 and Figs 4 -7 show the impact of time on mortality in the bioassay.

Placing *Helicoverpa armigera* larvae in the trial

Table 9 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 1/1 - l eaves were collected 24 hours (1 day) after first application of insecticides were applied

Treatment	Live larvae	live larvae after 24 hours	live larvae after 96 hours	live larvae after 120 hours
Proclaim®	40	[#]3 c	0 c	0
Prodigy®	40	37 a	2 b	0
S-1812	40	20 b	2 b	0
Control	40	40 a	37 a	37

[#] Any two means with the same letter are not significantly different at the 95% probability level

Figure 4 Bioassay 1/1 Survival of *Helicoverpa armigera* larvae exposed to treated leaves

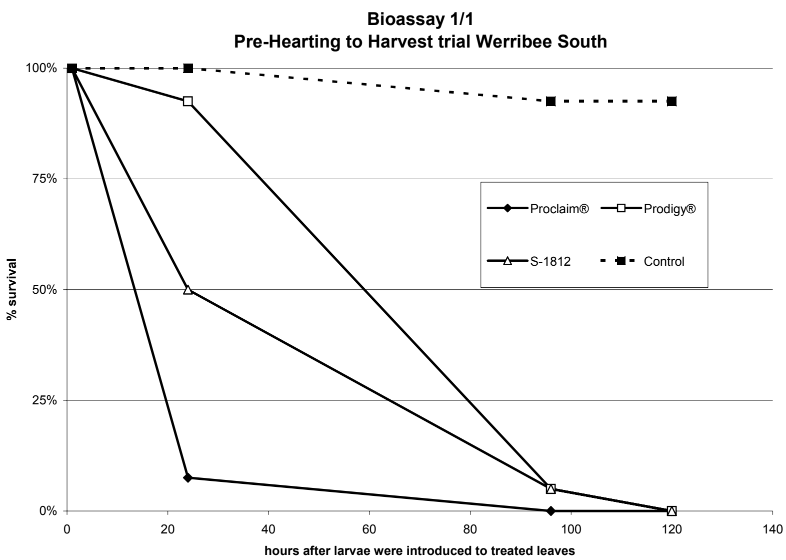


Table 10 Survival of *Helicoverpa armigera* larvae exposed to treated leaves Bioassay 1/2 Leaves were collected 120 hours (5 days) after first application of insecticides were applied

Treatment	Live larvae	live larvae after 24 hours	live larvae after 48 hours	live larvae after 72 hours	live larvae after 96 hours
Proclaim®	40	#15 a	7 b	2 b	0
Prodigy®	40	33 c	12 b	4 b	0
S-1812	40	25 ab	12 b	6 b	1
Control	40	39 bc	39 a	35 a	30

Any two means with the same letter are not significantly different at the 95% probability level

Figure 5 Bioassay 1/2 Survival of *Helicoverpa armigera* larvae exposed to treated leaves

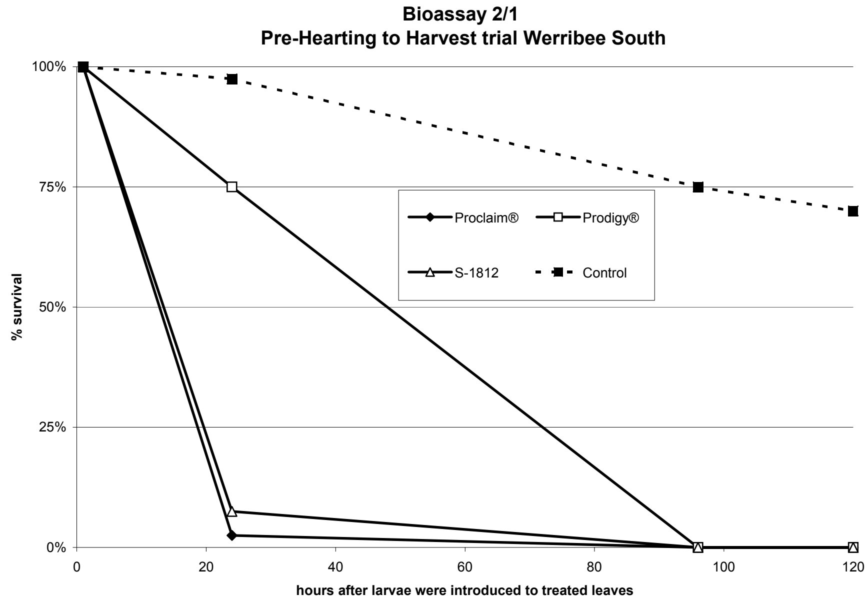


Table 11 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 2/1 Leaves were collected 24 hours (1 day) after second application of insecticides were applied

Treatment	Live larvae	live larvae after 24 hours	live larvae after 96 hours	live larvae after 120 hours
Proclaim®	40	#1 c	0	0
Prodigy®	40	30 b	0	0
S-1812	40	3 c	0	0
Control	40	39 a	30	28

Any two means with the same letter are not significantly different at the 95% probability level

Figure 6 Bioassay 2/1 Survival of *Helicoverpa armigera* larvae exposed to treated leaves

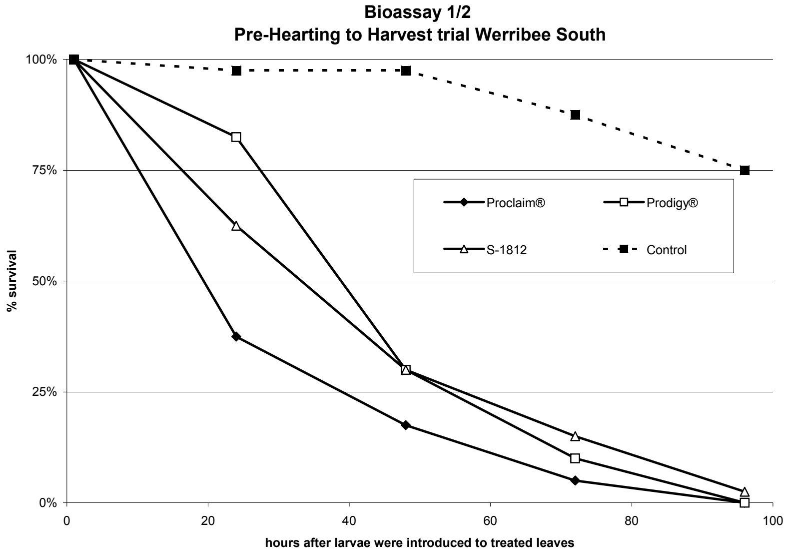
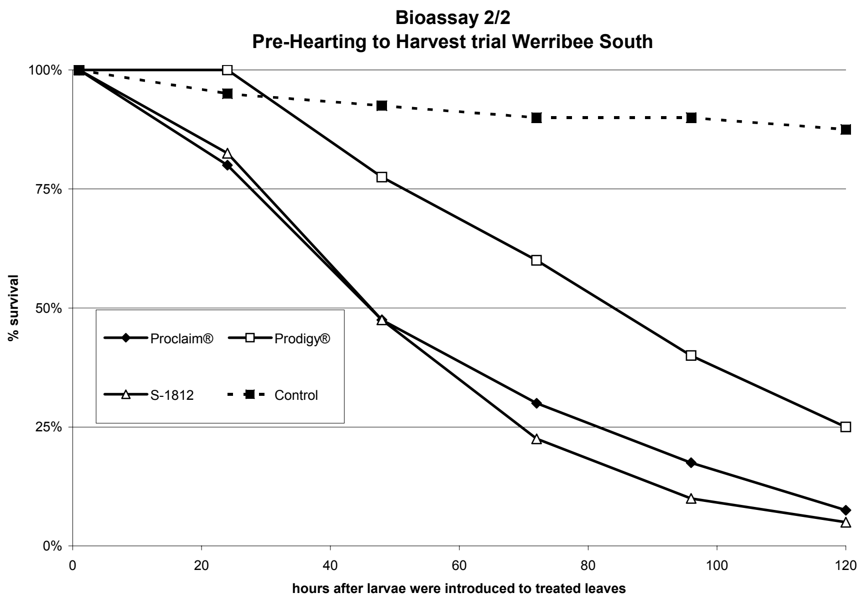


Table 12 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay2/2 Leaves were collected 120 hours (5 days) after second application of insecticides were applied

Treatment	Live larvae	live larvae after 24 hours	live larvae after 48 hours	live larvae after 72 hours	live larvae after 96 hours	live larvae after 120 hours
Proclaim®	40	#32	19 b	12 bc	7 b	3
Prodigy®	40	40	31 a	24 ab	16 b	10
S-1812	40	33	19 b	9 c	4 b	2
Control	40	38	37 a	36 a	36 a	35

Any two means with the same letter are not significantly different at the 95% probability level

Figure 7 Bioassay 2/2 Survival of *Helicoverpa armigera* larvae exposed to treated leaves



Secondary pests
At the harvest assessments almost all (317 out of 320 harvested lettuces) were infested with aphids (mainly the brown sowthistle aphid, *Uroleucon sonchi*) (Table 9). The numbers of aphids per lettuce head ranged from 10 to 150 aphids. None of three insecticides was effective in controlling aphids in lettuce. About half of the harvested lettuce heads were infested with thrips (Table 13). Most thrips were found inside the lettuces (sheltering deep inside on the mid-rib of heart leaves).

These results highlight the selective nature of the test insecticides and the need for growers to monitor crop closely for a range of pests when using selective insecticides.

Table 13 Lettuce assessment at harvest on presence of aphids and thrips

Treatment	1st harvest 40 plants		2nd harvest 40 plants	
	Plants infested with aphids	Plants infested with thrips	Plants infested with aphids	Plants infested with thrips
Proclaim®	40	18	40	18
Prodigy®	38	22	40	19
S-1812	39	14	40	22
Control	40	23	40	18

Results - Lindenow Trials
This trial commenced on 3 March 2003 when the plants were 4 weeks old. Proclaim® and Prodigy® resulted in heads with significantly fewer larvae and significantly less damage than either S-1812 or the untreated control (Table 14). This was a slightly unexpected result as S-1812 had been shown in other trials to be very effective. The untreated control treatment as expected showed the worst damage. The percentage of plants showing external damage indicated that only the untreated control was significantly worse than any other treatment.

The number of marketable heads in the untreated control was significantly lower than Proclaim® and Prodigy® treatments. This was due to the difference in the number of heads with internal damage. In many cases, there was no evidence of visible external damage. However, when the heads were cut open, there was significant damage right in the heart with no visible trail in from the external wrapper leaves. It would appear that larvae had entered the heart from the bottom of the plant with the early instars penetrating the heart. In the majority of cases the larvae were 3rd instar and had caused significant damage.

Table 14 Lettuce assessment at the harvest Lindenow trial

Treatment	% of Marketable Heads	% of Plants with External Damage	% of Plants with Internal Damage	*Helicoverpa* Larvae per 10 Heads	% of Plants with *Helicoverpa* Damage
Proclaim®	88.9 b	18.6 b	18.2 b	1.5 b	28.2 b
Prodigy®	91.9 b	10.6 b	17.9 b	1.3 b	20.4 b
S-1812	77.5 ab	25.0 b	65.0 a	5.0 a	65.0 a
Control	62.1 a	47.0 a	67.3 a	6.0 a	67.9 a

The amount of damage was also surprising given the relatively low pest pressure. Possibly the use of motorised backpack sprayers wasnot as effective as commercial spray application methods in getting good application into the plants. Notwithstanding that, there are significant differences between treatments.

The scouting of the crop indicated the presence of *Helicoverpa* spp. with a number of eggs present and some larvae observed in the non-destructive monitoring (Table 15). Aphids were present in all treatments, but the numbers of thrips and Rutherglen bug (*Nysius vinitor*) were much higher in the untreated control treatments compared to the insecticide treatments. The newly arrived coccinellid, *Hippodamia variegata,* (ladybird beetle) was the most common beneficial insect found and was associated with the aphids on the lettuce. However numbers of beneficials were too low to draw valid conclusions about the safety of the selective insecticides to non-target insects.

7.3 Discussion

The timing for this trial (pre-hearting to harvest) is the logical place in the control program for the utilisation of these targeted insecticides with the place for the biological insecticides from transplanting to pre-harvest. *Helicoverpa* control is achieved relatively quickly, there is less opportunity for the larvae to move into the head and, as the leaves close over the head, these insecticides will remain more active in comparison with the biological insecticides.

Low pest pressure in the field did have some impact upon results but seeding of the crop with larvae and the bioassays helped provide meaningful results for the project. All three insecticides were effective in controlling *Helicoverpa*, with Proclaim® being consistently effective. There were some differences in efficacy between bioassays and field assessment within the same treatment. This may be explained by a lack of contact between insecticides and larvae in the field due to the ability of the larvae to take cover within the head, given the 2-day lead time between applying larvae to the crop and spray application.

The field results at Lindenow also highlighted the importance of crop monitoring for eggs and destructive monitoring of crops, because in many cases there was no external indication of damage. While pest pressure was not high, significant crop damage can still occur.

The way to increase efficiency of insecticides is by regular crop monitoring which allows pest detection at early stages (eggs, small larvae), when they are easier to control. However, from hearting (stage when lettuces start to form a heart) until harvest, larvae moving into the lettuce heart will be almost impossible to control. It is also vital to be monitoring for other pests and the beneficials that will control them for the targeted chemicals for *Helicoverpa* control will not provide any direct control.

Table 15. Crop Monitoring data Lindenow – 12 plants per treatment

Treatment	Data	date 25/02/03	3/03/03	11/03/03	17/03/03	Grand Total
Proclaim®	*Helicoverpa* white egg			3	1	4
	Helicoverpa brown egg				1	1
	Helicoverpa larva					
	aphid		13	3	6	22
	rutherglen bug		1			1
	ladybird beetle		1			1
	thrips		2		1	3
	spider			1		1
	wasp				1	1
	soldier beetle			1	2	3
	mite		1			1
Prodigy®	*Helicoverpa* white egg		1	1		2
	Helicoverpa brown egg		2			2
	Helicoverpa larva			1	1	2
	aphid		14	5	1	20
	rutherglen bug		2		1	3
	ladybird beetle				2	2
	thrips			2	2	4
	leafhopper			2		2
	spider			1	1	2
	soldier beetle				1	1
S-1218	*Helicoverpa* white egg		5	8	3	16
	Helicoverpa brown egg					
	Helicoverpa larva				1	1
	aphid		23	3	3	29
	rutherglen bug			2	1	3
	ladybird beetle		2	3	1	6
	thrips		4		3	7
	leafhopper				3	3
	spider		1	2	1	4
	wasp		1			1
Control	*Helicoverpa* white egg	3	2	3	2	10
	Helicoverpa brown egg	1		2		3
	Helicoverpa larva				1	1
	aphid	19	24	11	3	57
	rutherglen bug	9	4	5		18
	ladybird beetle	2		2		4
	thrips	14	7	1	3	25
	spider	1				1
	wasp		1	2	1	4

8. Biological Insecticide Trials
Years 2 & 3. Seasons 2002-04

Two field trials were carried out at Werribee South and Lindenow in southern Victoria. The aims of the trials were to assess the effectiveness of several biological insecticides for controlling *Helicoverpa armigera* on lettuce crops from seedling stage to pre-hearting. The trial work was carried out in February and March when historically pest pressure is at its peak.

8.1 Materials and Methods
Year 2. Season 2002/03
Treatments were applied from 2 weeks after transplanting to just after hearting with, 3 to 4 applications depending on the growth rate of the crop. The plots were scouted weekly prior to application of the treatments and assessed for damage and the presence of pests and beneficial insects. At harvest 10 heads per plot were destructively sampled and assessed for damage, pest presence and marketability. Plots were also destructively sampled after hearting.

Five treatments were evaluated at each of two sites:
1. Gemstar® - Nuclear Polyhedrosis Virus (NPV), registered for control of *Helicoverpa* spp. on lettuce applied at 750 ml/ha (0.45 ml/plot at Werribee South and 1.2 ml/plot at Lindenow).
2. DiPel® DF – *Bacillus thuringiensis,* registered for use in vegetables for control of lepidopteran larvae applied at 100g/100l (0.6 g/plot at Werribee South and 1.6 g/plot at Lindenow).
3. Vivus® - Nuclear Polyhedrosis Virus (NPV) registered for control for of *Helicoverpa* spp. on lettuce at 750 ml/ha (0.45 ml/plot at Werribee South and 1.2 ml/plot at Lindenow).
4. New NPVa - Nuclear Polyhedrosis Virus (NPV) 750 ml/ha (0.45 ml/plot at Werribee South and 1.2 ml/plot at Lindenow).
5. Untreated Control

Gemstar® is a formulation of *Helicoverpa zea* NPV and is produced in USA. Vivus® and New NPV are formulations of *Helicoverpa armigera* NPV and are produced in Australia.

At Werribee South the trial used a Latin Square design (5 treatments, 5 replicates) and each plot was 5 m x 1.2 m and at Lindenow a random block design was used with plots 12 metres long and of 5 treatments with 4 replicates. Treatments were applied from around 8.30 am to 11.00 am to minimise the impact of the wind and afternoon sea breezes.

At Werribee South there were no buffers between the treatments and trials were sampled from the middle 3m of row. Application volumes were based on applying 800l/ha of water for the insecticide application, which equated to 480 ml of water applied per plot. A motorised back-pack sprayer was used with a spray pressure of 2.5-3 bar.

At Lindenow the plots were 12m long and the trials were sampled from the middle 10m of row. Application volumes were based on applying 800l/ha of water for the insecticide and 1300ml was applied per plot using a motorised back-pack sprayer with the application at 3.5 bar for the NPV applications and at 5 bar for the DiPel® (a specific spray unit was used for Bt).

Crops were monitored weekly to determine pest pressure before and after sprays were applied with a destructive sample after hearting and at harvest to assess crop damage. Each week, four plants per plot (one plant randomly chosen from each row) were assessed for presence of eggs, larvae and evidence of damage as well as the presence of beneficial arthropods. Monitoring commenced two weeks after transplanting and one day before the first spray was applied. When the crop was ready for harvest, 10 lettuces were taken at random from each plot and taken back to the laboratory for assessment of damage and presence of insects.

Werribee Bioassay Sampling
Helicoverpa pressure during the Werribee field trial was relatively low and the limited data collected from weekly monitoring were insufficient for statistical differentiation between treatments. To compensate for this, bioassays using laboratory populations of *Helicoverpa armigera* were conducted after the second and third spray applications to assess residual efficacy of the treatments.

Lettuce leaves for bioassay were collected 2 days after the 2nd insecticide application and 1 & 5 days after the 3rd insecticide application. One randomly chosen leaf per plot was collected and placed into 40 cm x 28 cm plastic bag and sealed. The leaves were then transported back to the laboratory in a portable ice-box. In the first two bioassays, the youngest fully expanded leaf was collected while a wrapper leaf was used for the third bioassay.

In the bioassay, one 2nd instar *Helicoverpa armigera* larva was placed in a 30 mL Solo plastic cup with two 2.5 cm leaf discs cut from leaves sampled from the plots. Treatments were randomised by plots and replicates. There were 30 larvae per treatment (6 larvae per replicate). The trays of cups were held at 25°C. Each day, the larvae were checked. When a larva had eaten all of the lettuce in its cup, it was fed with a diet cube (based on beans supplemented with 10% wheat germ).

Survival data were analysed using probit analysis to calculate time for 50% of larvae to die. Differences between treatments were considered to be statistically significant if there was no overlap of 95% confidence limits. Mortality of larvae in treatments was adjusted using Abbott's formula to allow for mortality in the untreated control. Data were analysed with the Genstat® program using a Generalised Linear Model using binomial distribution link. Crop monitoring results were not analysed because of low numbers recorded.

Year 3. Season 2003/04
Two field trials were carried out at Cranbourne and Lindenow in southern Victoria. Werribee was not considered as a site due to the drought, lack of water and lack of suitable lettuce crops later in the season. Pest pressure in Cranbourne is normally lower than that experienced at Werribee. The aims of the trials were to assess the

effectiveness of several biological insecticides for controlling *Helicoverpa armigera* on lettuce crops from seedling stage to pre-hearting. The trial work was carried out in February and March when historically pest pressure is at its peak.

The trial methodology was the same as the previous year for Werribee South and Lindenow.
The treatments were evaluated at each of two sites (rates as above):

- Gemstar® - Nuclear Polyhedrosis Virus (NPV), registered for control *Helicoverpa* spp. on lettuce
- DiPel® DF – *Bacillus thuringiensis,* registered for use in vegetables for control of lepidopteran larvae
- Vivus Gold® - Nuclear Polyhedrosis Virus (NPV)
- Untreated Control
- In addition Vivus® - Nuclear Polyhedrosis Virus (NPV) was applied in the Lindenow trials only.

At harvest at Lindenow, apart from assessing the number of heads with damage and marketable percentage, the severity of the damage to heads was also assessed and given a rating of 0 (no damage), 1 (minor), (moderate) or 3 (severe). The trial was scouted weekly prior to each application and the results reported and there were 5 applictions for this crop. Due to the high number of aphids a rating was used to indicate aphid numbers. Rating: **0** – no aphids present, **1** – 5-10 aphids, **2** – 10-20 aphids, **3** – 20+ aphids.

For the biological crop monitoring data a generalised linear model with over-dispersed poisson error distribution was used. The poisson distribution is suitable for count data, although its limitations are to properly account for the repeated measures structure. Therefore in addition an ANOVA with a log(x+1) transformation was used to help normalise the data. For the harvest data for the field trials a statistical analysis package called StatXact was used on both these sets of data, to do "exact" versions of the non-parametric Kruskal-Wallis tests, to test for equal distribution of data for the five treatments. Analysis of Variance was also carried out using Genstat for a random block design to compare results.

For the Cranbourne trial crop monitoring results were not analysed because of low numbers recorded so bioassays were was again carried out.

8.2 Results
Year 2. Season 2003/04

Werribee
Beneficial levels were low (Table 16) and although *Helicoverpa* levels were relatively low, the field trials did have some pest pressure as indicated by the scouting data (table 17). *Agrotis* (cutworm) was a major pest with similar numbers of *Agrotis* larvae to *Helicoverpa*. The harvest assessment results (Table 18) showed that Vivus® and Dipel DF® were not significantly different from the control. However Gemstar® and New NPV were significantly better than the untreated control treatment in reducing crop damage and the New NPV formulation was significantly better than the Dipel DF® (reduced feeding damage and numbers of live larvae). Dipel Df® and Vivus® were not significantly different in the field in comparison with the control but did show a trend to providing some damage reduction on the lettuce heads.

The bioassay results confirmed that all biological insecticides were effective in controlling *Helicoverpa armigera* larvae and all were equally effective. Significant control of larvae was achieved 4 to 8 days after treatment (Tables 19 - 24). The different timing of the bioassay also indicated that the quickest response with caterpillar mortality was achieved in 4 to 6 days when the caterpillars were exposed to the treated leaves within 24 hours of application. The time for mortality to occur increased when the larvae were exposed after 48 hours but did not increase much further if the exposure was after 5 days.
Note that corrected mortality is the mortality due to the application of the treatment less the mortality of the control treatment ie, the larvae that would have died naturally.

Table 16 Crop Monitoring: Beneficial Insects, Werribee (20 plants per treatment)

		date				
Treatment	Species	18/02/03	26/02/03	4/03/03	13/03/03	Grand Total
DiPel® DF	brown lacewing		1			1
	damsel bug		1			1
	ladybird beetle					
Control	brown lacewing				2	2
	damsel bug			1		1
	ladybird beetle		2			2
Gemstar®	brown lacewing					
	damsel bug		1		1	2
	ladybird beetle		2			2
Vivus®	brown lacewing				1	1
	damsel bug				1	1
	ladybird beetle		1			1
New NPV	brown lacewing				2	2
	damsel bug		1			1
	ladybird beetle					
Total brown lacewing			1		5	6
Total damsel bug			3	1	2	6
Total ladybird beetle			5			5

Table 17 Crop Monitoring (scouting) data Lepidoptera, Werribee
(20 plants per treatment)

Treatment	Data	18/02/03 -1DAT1	26/02/03 +7DAT1	4/03/03 +6DAT2	13/03/03 +7DAT3	Grand Total
	white egg	1				1
	brown egg					
DiPel®DF	*Helicoverpa* larva			1	3	4
	dead *Helicoverpa* larva					
	cutworm larva		1	3	4	8
	dead cutworm larva					
	white egg	2				2
	brown egg					
Control	*Helicoverpa* larva		3	4	5	12
	dead *Helicoverpa* larva	1	1			2
	cutworm larva		1	1	4	6
	dead cutworm larva					
	white egg	1				1
	brown egg					
Gemstar®	*Helicoverpa* larva	1	2		2	5
	dead *Helicoverpa* larva		2			2
	cutworm larva				4	4
	dead cutworm larva					
	white egg	2				2
	brown egg	2				5
Vivus®	*Helicoverpa* larva	2		2	2	6
	dead *Helicoverpa* larva	1	2			3
	white egg cutworm	8				8
	cutworm larva	3		1	6	10
	dead cutworm larva				2	2
	white egg	2				2
	brown egg	1				1
New NPV	*Helicoverpa* larva	1	1	1	2	5
	dead *Helicoverpa* larva		6			6
	cutworm larva	2		3	1	6
	dead cutworm larva					
Total white eggs		8				8
Total brown eggs		6				6
Total *Helicoverpa* larvae		4	6	8	14	32
Total dead *Helicoverpa* larvae		2	11			13
Total white egg cutworm		8				8
Total cutworm larvae		5	2	8	19	34
Total dead cutworm larvae					2	2

(+7DAT1 = 7 days after treatment.)

Table 18 Lettuce assessment at the harvest, Werribee

Treatment	Number of plants assessed	Live *Helicoverpa* larvae	Live *Agrotis* larve	Dead *Helicoverpa* larvae	Feeding damage at the harvest
Control	50	#24 a	2	0	18 a
Vivus®	50	18 ab	1	1	10 abc
DiPel DF®	50	16 ab	1	3	15 ab
Gemstar®	50	9 bc	0	1	8 bc
New NPV	50	5 c	0	1	5 c

Any two means with the same letter are not significantly different at the 95% probability level

Table 19 Bioassay 1. Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Leaves were collected 48 hours (2 days) after second application of insecticides were applied

Treatment	Live larvae	Live larvae after 96 hours	Live larvae after 120 hours	Live larvae after 144 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 216 hours
DiPel DF®	30	24	22	17	#11 ab	6 b	5 b
New NPV	30	30	25	18	10 ab	3 b	2 b
Vivus®	30	25	21	14	10 ab	7 b	5 b
Gemstar®	30	23	22	14	6 b	4 b	2 b
Control	30	27	26	23	19 a	19 a	19 a

Any two means with the same letter are not significantly different at the 95% probability level

Table 20 Bioassay 1. Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves

Bioassay 1	LD50(hours)	95% confidence limits(hours)	
DiPel DF®	172.10	157.25	193.15
New NPV	166.93	160.72	173.29
Vivus®	168.12	160.99	176.27
Gemstar®	149.96	135.06	165.71

Figure 6 Bioassay 1 Survival of *Helicoverpa armigera* larvae exposed to treated leaves

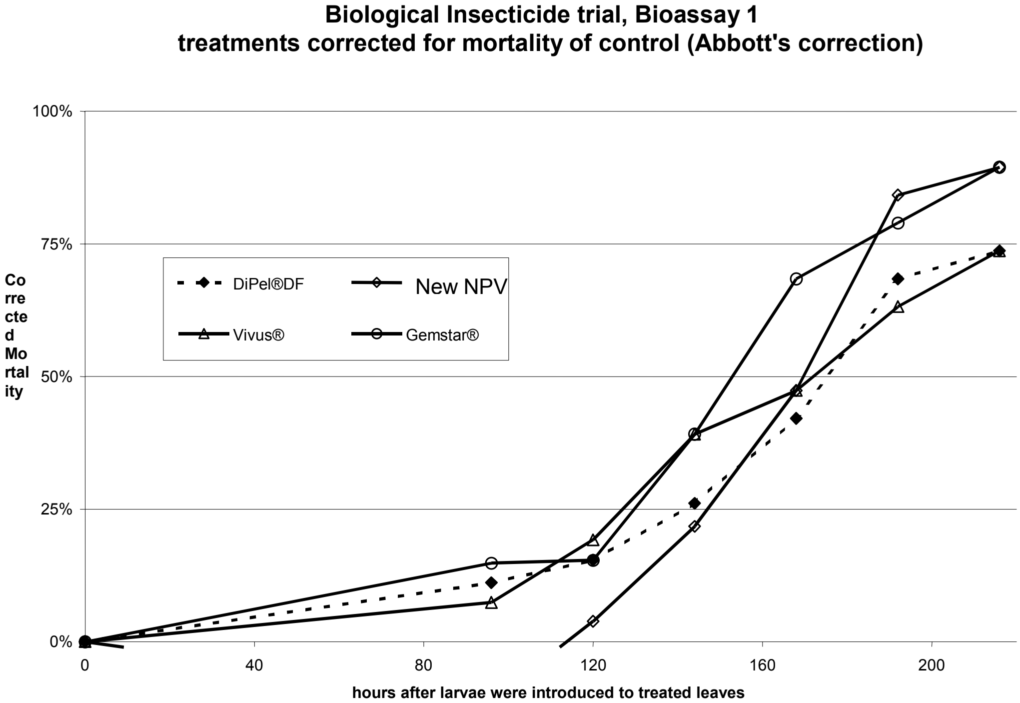


Table 21 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 2 - leaves were collected 24 hours (1 day) after third application of insecticides were applied

Treatment	Live larvae	Live larvae after 120 hours	Live larvae after 144 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 216 hours
DiPel DF®	30	#8 b	3 b	2	2	1
New NPV	30	10 b	3 b	1	0	0
Vivus®	30	12 b	3 b	1	1	0
Gemstar®	30	12 b	2 b	1	1	0
Control	30	27 a	24 a	23	22	22

Any two means with the same letter are not significantly different at the 95% probability level

Table 22 Bioassay 2. Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves

Treatment	LD50 (hours)	95% confidence limits (hours)	
DiPel DF®	84.18	23.55	109.85
New NPV	112.23	103.57	118.25
Vivus®	112.73	67.61	128.76
Gemstar®	111.51	*	

* could not be calculated at 95% probability level

Fig 7 Bioassay 2 Survival of *Helicoverpa armigera* larvae exposed to treated leaves

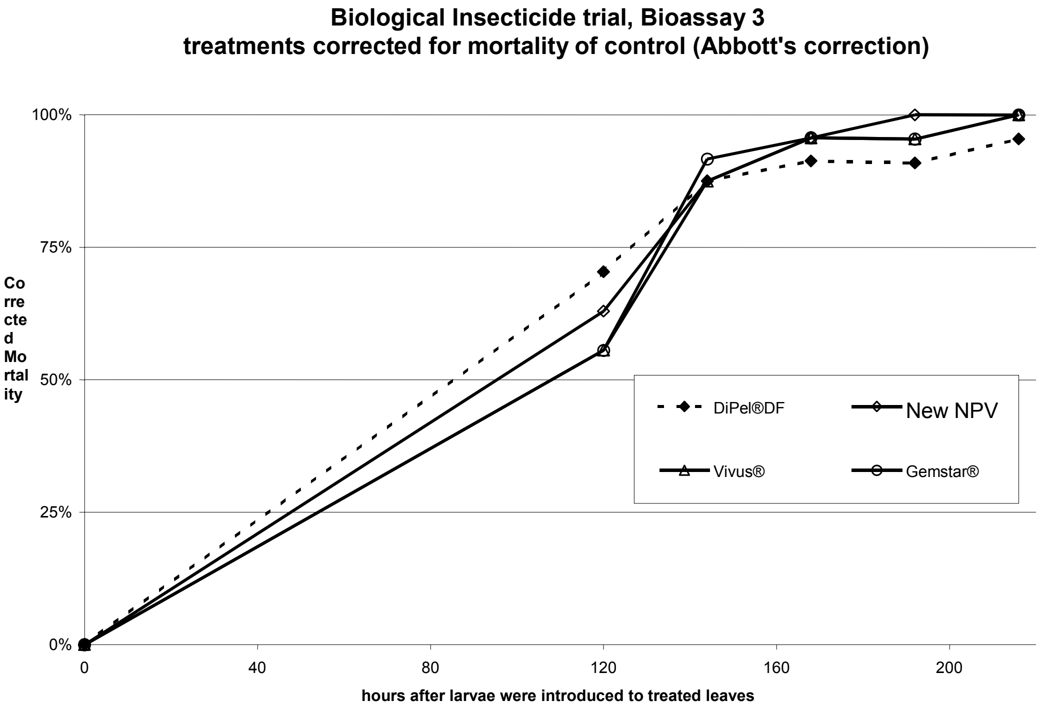


Table 23 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 3 - leaves were collected 120 hours (5 days) after third application of insecticides were applied

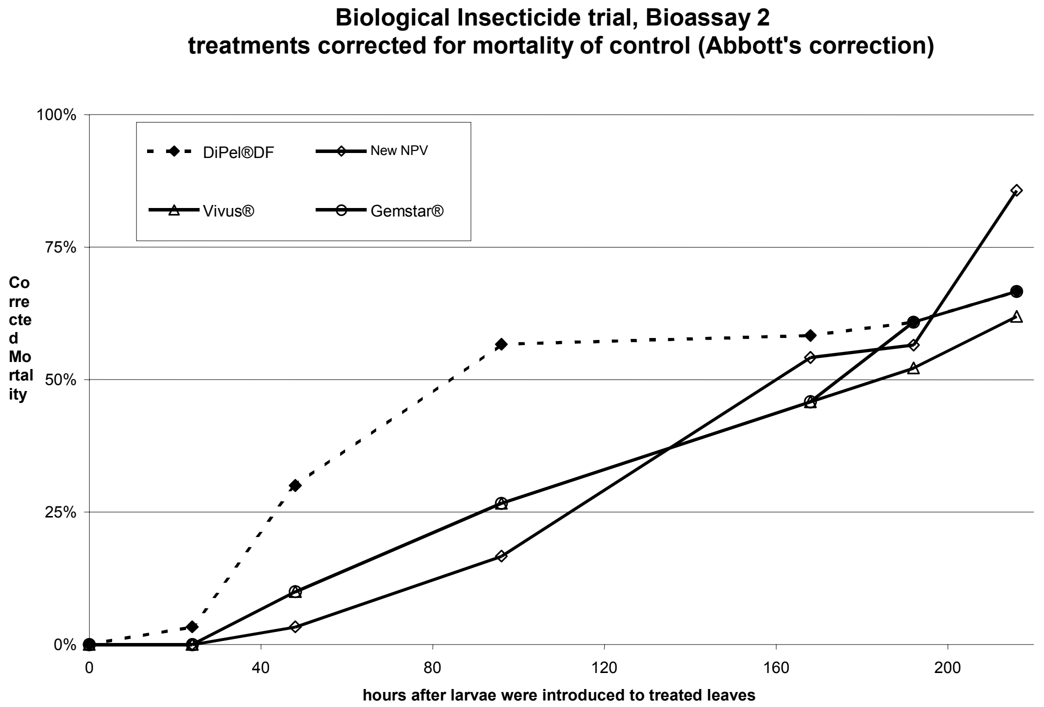
Treatment	Live larvae	Live larvae after 24 hours	Live larvae after 48 hours	Live larvae after 96 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 216 hours
DiPel® DF	30	#29 a	21 b	13 b	10 b	9 b	7 b
New NPV	30	30 b	29 ab	25 b	11 b	10 b	3 b
Vivus®	30	30 b	27 ab	22 b	13 b	11 b	8 b
Gemstar®	30	30 b	27 ab	22 b	13 b	9 b	7 b
Control	30	30 b	30 a	30 a	24 a	23 a	21 a

Any two means with the same letter are not significantly different at the 95% probability level

Table 24 Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves

Bioassay 3	**LD50 (hours)**	**95% confidence limits (hours)**	
DiPel® DF	115.99	75.05	187.78
New NPV	153.05	124.85	186.55
Vivus®	173.85	156.02	197.30
Gemstar®	159.40	138.05	188.41

Fig 8. Bioassay 3 Survival of *Helicoverpa armigera* larvae exposed to treated leaves



Lindenow

There were no significant differences between treatments in this trial due to the low pest pressure (Table 25) although there were some differences between treatments with external damage. There was a wide variation between plots in the level of pest damage. While there was a trend for the control to have more damage across all treatments, there were plots with some damage and plots with no damage

The trial results were affected by low pest pressure. Treatment application commenced on the 12th of March on 2 week old transplants but pest pressure had dropped off and was lower in comparison to the chemical evaluation trial.

Scouting (Tables 26 & 27) indicate the low level of *Helicoverpa* activity and generally low levels of aphid activity, although in the middle of the trial there was a peak of aphid activity. There was continuing thrips and soldier beetle (a general predator) presence with leafhoppers also being active.

Table 25 Lettuce assessment at the harvest, Lindenow

Treatment	% Marketable Heads	% Plants with External Damage	% Plants with Internal Damage	Larvae per 10 Heads	% of Plants with Larval Damage
Control	90	20 a	17.5	2	30
Dipel® DF	100	2.5 b	7.5	0.75	12.5
Vivus®	100	2.5 b	5.0	0.50	10.3
New NPV	100	5.0 b	5.0	0.25	7.5
Gemstar®	97.5	10.0 a	0	0.25	10

8.3 Discussion

Low pest pressure was a problem but despite this the use of bioassays for the Werribee trials provided some results and enabled an assessment of treatments. All the biological pesticides were effective in providing control in the bioassay and were still effective 5 days after the treatment application despite the exposure to UV light, sun and irrigation although the mortality was not as high from two days after treatment.

Both NPV in all formulations and Bt were effective in controlling *H armigera* but, given the time for mortality to occur, application of these sprays would be preferable prior to hearting so that larvae do not move into the heart. Application of these biological sprays has traditionally been of an evening to reduce exposure to UV light. However recent results reported in Heliothis Hotline (Heliothis Hotline, August 2002, Issue number 41, DPI's Agency for Food and Fibre Farming Systems, Qld) indicate that better control is achieved in the morning when larvae are feeding actively. Also in coastal areas an evening application is not practical due to the sea breezes that develop early afternoon.

There were no obvious differences between the treatments for levels of other pests such as aphid, thrips or leafhoppers. Similarly there were no obvious differences between treatments with the numbers or types of beneficial insects.

Table 26 Crop Monitoring data, Lindenow (16 plants per treatment)

		date					
Treatment	Data	11/03/03	17/03/03	24/03/03	31/03/03	7/04/03	Grand Total
Control	white egg		1				1
	brown egg						
	Helicoverpa larva						
	aphid	2	1	18	1		22
	rutherglen bug						
	thrips	1	6	12	2	4	25
	mite		1				1
	leafhopper				3	1	4
Dipel®DF	white egg						
	brown egg			1			1
	black egg			1			1
	Helicoverpa larva						
	aphid		7	18	1		26
	rutherglen bug					1	1
	thrips		6	16	1	3	26
	mite						
	leafhopper				3	4	7
Gemstar®	white egg			1			1
	brown egg			1			1
	Helicoverpa larva						
	aphid		4	15	2		21
	rutherglen bug						
	thrips		8	9	3	5	25
	mite			1	1		2
	leafhopper					3	3
Vivus®	white egg			2			2
	brown egg				1		1
	Helicoverpa larva						
	aphid		3	48	2		53
	rutherglen bug					1	1
	thrips		8	20	2	2	32
	mite				1		1
	leafhopper				1	1	2
New NPV	white egg			3			3
	brown egg			2			2
	Helicoverpa larva						
	aphid		13	13	1		27
	rutherglen bug					1	1
	thrips		7	19	7	6	39
	mite		1				1
	leafhopper		1	2	5	5	13
Total white egg			1	6			7
Total brown egg				4	1		5
Total black egg				1			1
Total *Helicoverpa* larva							
Total aphid		2	28	112	7		149
Total rutherglen bug						3	3
Total thrips		1	35	76	15	20	147
Total mite			2	1	2		5
Total leafhopper			1	2	12	14	29

Table 27 Crop Monitoring data: beneficial insects, Lindenow (16 plants per treatment)

Treatment	Data	date 11/03/03	17/03/03	24/03/03	31/03/03	7/04/03	Grand Total
Control	ladybird beetle		1	1	2		4
	spider		2				2
	wasp				1	1	2
	soldier beetle			1		3	4
Dipel®DF	ladybird beetle				1		1
	spider		1	1			2
	wasp			1		2	3
	soldier beetle			1	1		2
Gemstar®	ladybird beetle						
	ladybird beetle egg				18		18
	spider			2	2	1	5
	wasp						
	soldier beetle				1	2	3
Vivus®	ladybird beetle		1	1			2
	spider			1			1
	wasp			2		1	3
	soldier beetle					4	4
New NPV	ladybird beetle				2		2
	spider			2	2		4
	wasp			1			1
	soldier beetle					1	1
Total ladybird beetle			2	2	5		9
Total ladybird beetle egg					18		18
Total spider			3	6	4	1	14
Total wasp				4	1	4	9
Total soldier beetle				2	2	10	14

8.4 Results

Year 3. Season 2003/04

Cranbourne

The harvest assessment results were inconclusive due to the low pest pressure as indicated in tables 28 & 29 with virtually no larvae or damage at harvest. Aphids and thrips were active as can be seen from the scouting data (Table 29) and this resulted in the subsequent higher numbers of *Hippodamia* (ladybird beetle - Table 30). Again no differences were observed between the treatments.

Table 28 Lettuce assessment at the harvest, Cranbourne

Treatment	Number of plants assessed	Live *Helicoverpa* larvae	Feeding damage at the harvest	Aphids	Thrips
Control	40	0	1	17	21
DiPel DF®	40	0	1	15	19
Gemstar®	40	0	1	12	20
Vivus Gold®	40	1	0	11	19

Table 29 Crop Monitoring (scouting) data Lepidoptera, Cranbourne (20 plants per treatment)

		date					
Treatment	Data	3-Mar	10-Mar	17-Mar	24-Mar	31-Mar	Grand Total
Control	white egg				2		2
	brown egg			1			1
	Helicoverpa larva			1	1		2
	feeding damage		1		1		2
DiPel® DF	white egg			1			1
	brown egg						
	Helicoverpa larva					1	1
	feeding damage						
Gemstar®	white egg		1		1		2
	brown egg				1		1
	Helicoverpa larva				1		1
	feeding damage	1					1
Vivus Gold®	white egg		1				1
	brown egg						
	Helicoverpa larva					1	1
	feeding damage						
Total white egg			2	1	3		6
Total brown egg				1	1		2
Total *Helicoverpa* larva				1	2	2	5
Total feeding damage		1	1		1		3

Table 30 Crop Monitoring: Beneficial Insects, Cranbourne (20 plants per treatment)

		date					
Treatment	Data	3-Mar	10-Mar	17-Mar	24-Mar	31-Mar	Grand Total
Control	damsel bug		1	2		2	5
	ladybird beetle	1	2		1	2	6
DiPel® DF	damsel bug		2				2
	ladybird beetle	3	3		1	2	9
Gemstar®	damsel bug		1		1	1	3
	ladybird beetle	1	1		4	2	8
Vivus Gold®	damsel bug		2	1	1		4
	ladybird beetle	1	1		3	1	6
Total *Nabis*			6	3	2	3	14
Total *Hippodamia*		6	7		9	7	29

The mean results of the bioassays are presented in tables 31 & 32 and show the time taken for 50% of larval mortality.The bioassay trial results indicated that all biological insecticides were effective in controlling *Helicoverpa armigera* larvae. All three insecticides were significantly better than the untreated control.

There was no significant difference between the three biological insecticides or between the times when the spray was applied. The impacts of spray one and three were not different, and there did not appear to be any cumulative affect.

The results showed that insecticides lost effectiveness with time, probably due to degradation in the presence of ultra violet light and environment effects (irrigation). Significant results were still achieved 4 to 7 days from treatment. On average over 4 days was required for 50% mortality on samples taken 24 hours after spray was applied (Table 33).

Table 31 Means on the time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves (means for the 3 bioassays) - Data transformed (log(time) scale),

Treatment Leaves collection time after spray	DiPel DF®	Control	Vivus Gold®	Gemstar®
1 day	4.503	5.911	4.569	4.595
5 days	4.941	5.916	4.788	4.755
7 days	5.015	5.83	4.899	4.876

LSD (5%) 0.2775 except when comparing means with the same collection time LSD is 0.2237

Table 32 Analysed means converted back to the original scale, averaged after three sprays were applied, time (hours) taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves (means for the 3 bioassays)

Treatment / Leaves collection time after spray	DiPel® DF	Control	Vivus Gold®	Gemstar®
1 day	90.3	369.1	96.4	99.0
5 days	139.9	370.9	120.1	116.2
7 days	150.7	340.4	134.2	131.1

The results of the first bioassay are presented in the tables 33-35 and the graphs (Figs 11 -13) which show the differences in mortality after sampling 1 day, 5 days and 7 days after treatment. The results of the other 2 bioassays carried out are not presented because the results for all 3 bioassays were very similar. The results show that larvae are still dying after 192 hours (8 days) on leaves collected 24 hours after treatment. Leaves collected 7 days after treatment still resulted in significant larval mortality but the percentage of larvae dying was lower.

Table 33 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 1 - leaves were collected 24 hours (1 day) after first application of insecticide were applied

Treatment	Live larvae after 24 hours	Live larvae after 120 hours	Live larvae after 144 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 240 hours
DiPel® DF	40	12	10	9	8	6
Vivus Gold®	39	17	14	11	6	2
Gemstar®	40	18	17	12	7	3
Control	40	36	35	35	32	28

Fig 11

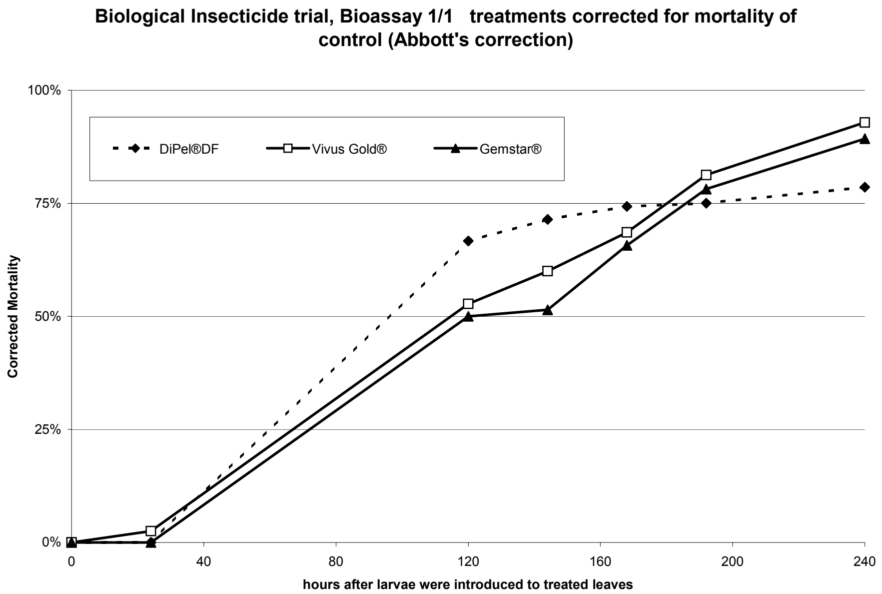


Table 34 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 2 - leaves were collected 120 hours (5 days) after first application of insecticide were applied

Treatment	Live larvae after 24 hours	Live larvae after 48 hours	Live larvae after 72 hours	Live larvae after 96 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 216 hours
DiPel® DF	40	31	29	23	18	15	11
Vivus Gold®	39	37	33	21	14	9	7
Gemstar®	40	38	30	21	16	10	8
Control	40	39	38	36	34	30	28

Fig 12.

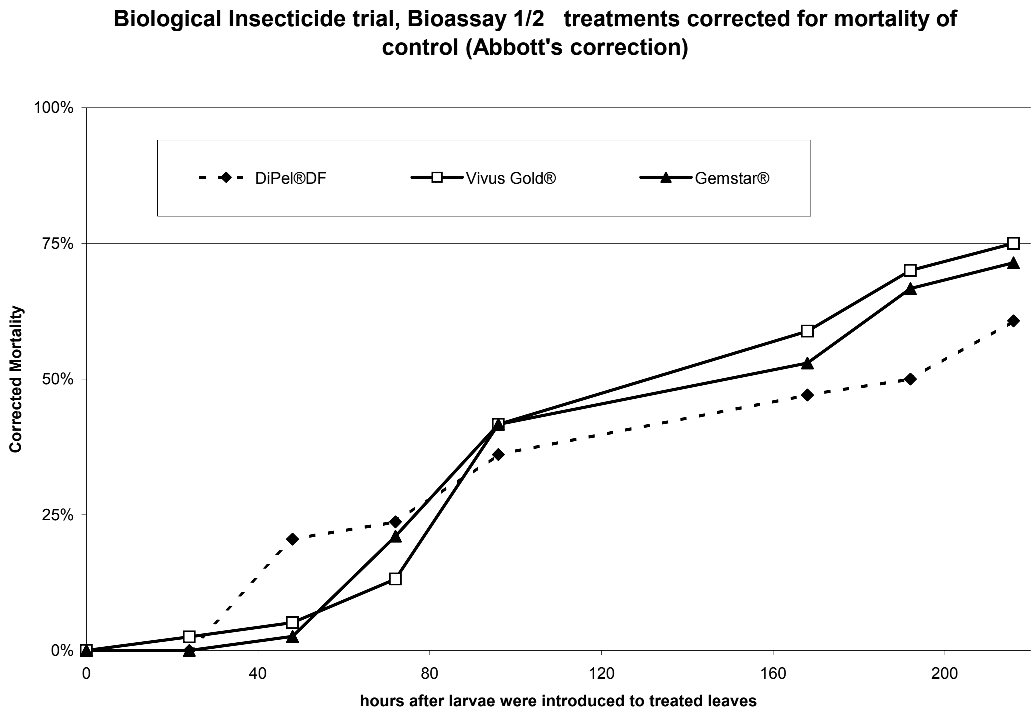
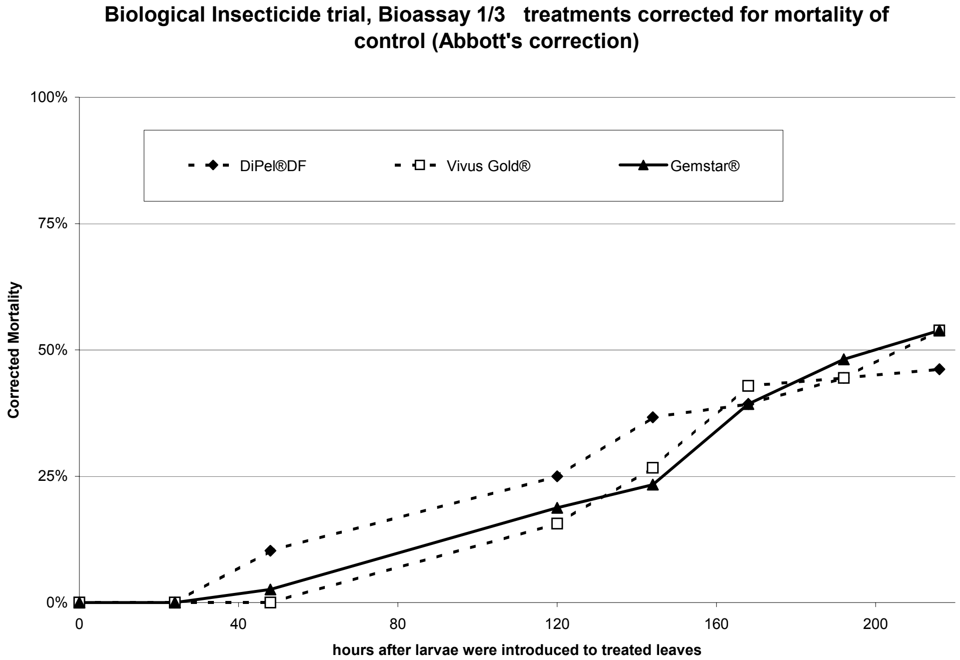


Table 35 Survival of *Helicoverpa armigera* larvae exposed to treated leaves. Bioassay 3 - leaves were collected 168 hours (7 days) after first application of insecticide were applied

Treatment	Live larvae after 24 hours	Live larvae after 48 hours	Live larvae after 120 hours	Live larvae after 144 hours	Live larvae after 168 hours	Live larvae after 192 hours	Live larvae after 216 hours
DiPel® DF	40	35	24	19	17	15	15
Vivus Gold®	40	39	27	22	16	15	12
Gemstar®	40	38	26	23	17	14	12
Control	40	39	32	30	28	27	26

Fig 13.



Lindenow

Despite low pest pressure, some significant differences did occur in the field trials for Lindenow. At harvest all treatments were significantly better than the control for the percentage of marketable heads (Table 36). For external head damage Vivus®, Vivus Gold® and Gemstar® all had significantly less external head damage than the control.

There were no differences in the severity of the head damage externally, the percentage of heads showing internal damage nor in the number of larvae found in the head at harvest. Although there were no significant differences between treatments concerning the percentage of internal damage, both Vivus® and Vivus Gold® had no damage internally while the control had 12.5% of heads damaged.

There were significant differences in the internal intensity of damage (ie, the amount of damage in the heads) between treatments. All treatments were significantly better than the control and Vivus® and Vivus Gold® had no internal damage. There were differences between treatments for the larval instars found at harvest. All treatments had significantly lower instar levels than the control. This is consistent with the amount of damage in the head, with the larger instars causing significantly more damage and also spending more time within the head.

Table 36 Results at harvest assessment.

Treatment	Marketable (%)	Percentage of heads with external damage	External damage severity	Percentage of heads with internal damage	Internal damage severity	Larvae Number per head	Instar stage
Control	77.5 [b]	15 [b]	1.38	12.5	2.12 [b]	1.75	2.9[b]
Dipel DF®	97.5 [a]	7.5 [a]	1.25	5	0.25 [a]	1.5	1.08 [a]
Vivus®	97.5 [a]	2.5 [a]	0.75	0	0 [a]	0.25	0.5 [a]
Vivus Gold®	100 [a]	0 [a]	0	0	0 [a]	0	0 [a]
Gemstar®	97.5 [a]	0[a]	0	2.5	0.25 [a]	1	0.75 [a]
			NS	NS		NS	
LSD .05	13.6	9.6			1.0		1.8

The crop monitoring data for the trials are shown in Tables 37 & 38. Statistical analysis of the levels of beneficials and other pests such as aphids and thrips showed that there were no significant differences between the treatments. There were high numbers of aphids and thrips as well as wasps and ladybird beetles observed during this trial.

Table 37 Crop monitoring data, Lepidopteran and other pest species, Lindenow (16

Treatment	16 Plants per treatment						
	Data	**4/03/2004**	**10/03/2004**	**17/03/2004**	**22/03/2004**	**2/04/2004**	**TOTAL**
Control	**white egg**			1			**1**
	orange egg						
	brown egg	1					**1**
	***Helicoverpa* larvae**	1	1				**2**
	lucerne leaf roller	1	1			1	**3**
	aphids	120	24	77	160	310	**691**
	thrips		3	5	2	1	**11**
	leafhopper	1		2		1	**4**
	mites	2	1	1			**4**
Dipel DF	**white egg**						
	orange egg	1					**1**
	brown egg						
	***Helicoverpa* larvae**		1	2			**3**
	lucerne leaf roller						
	aphids	145	39	95	137	310	**726**
	thrips		6	2		1	**9**
	leafhopper	3		1			**4**
	mites	1				1	**2**
Vivus	**white egg**						
	orange egg	3		1			**4**
	brown egg						
	***Helicoverpa* larvae**			1		1	**2**
	lucerne leaf roller	1					**1**
	aphids	125	48	105	169	280	**727**
	thrips		8	6			**14**
	leafhopper			2			**2**
	mites						
Vivus Gold	**white egg**		1				**1**
	orange egg				1		**1**
	brown egg						
	***Helicoverpa* larvae**						
	lucerne leaf roller	3		1		2	**6**
	aphids	140	65	100	189	340	**834**
	thrips	2		3	1	2	**8**
	leafhopper			2			**2**
	mites			1			**1**
Gemstar	**white egg**		3				**3**
	orange egg	1					**1**
	brown egg	2					**2**
	***Helicoverpa* larvae**			2			**2**
	lucerne leaf roller	2		2			**4**
	aphids	115	39	130	183	320	**787**
	thrips	1	1	8		1	**11**
	leafhopper	2					**2**
	mites						

Table 38 Crop monitoring: Beneficials, Lindenow.
(16 plants per treatment)

Treatment							
	Species	4/03/2004	10/03/2004	17/03/2004	22/03/2004	2/04/2004	TOTAL
Control	ladybird beetle	6			21	3	**30**
	ladybird beetle eggs					30	**30**
	brown lacewing	1		2	1	2	**6**
	Predatory thrips	2		3	1		**6**
	wasps	1		2	1	5	**9**
	spider	1	2	1	2		**6**
	hoverfly larvae						
	tachinid fly						
Dipel DF	ladybird beetle	5		1	2	2	**10**
	ladybird beetle eggs			10	10	80	**100**
	brown lacewing	4			1	2	**8**
	Predatory thrips	2		1		2	**5**
	wasps	1	2	2	1	5	**11**
	spider			2	1		**3**
	hoverfly larvae						
	tachinid fly					1	**1**
Vivus	ladybird beetle	5		1	2	6	**14**
	ladybird beetle eggs	20			20	40	**80**
	brown lacewing	3		1	2	3	**9**
	Predatory thrips			1			**1**
	wasps	2	1	3		1	**7**
	spider		2			1	**3**
	hoverfly larvae						
	tachinid fly					2	
Vivus Gold	ladybird beetle	7		1	2	5	**15**
	ladybird beetle eggs			22	20	12	**54**
	brown lacewing	2	1	3	2	2	**10**
	Predatory thrips			2			**2**
	wasps	4		2	2	11	**19**
	spider		1		1		**2**
	hoverfly larvae	2					**2**
	tachinid fly					1	**1**
Gemstar	ladybird beetle	3		1	2	5	**11**
	ladybird beetle eggs	18		12	13	12	**55**
	minute 2 spotted ladybird beetle			2			**2**
	brown lacewing			1	3	3	**7**
	Predatory thrips			1			**1**
	wasps	2	2		5	7	**16**
	spider	1			1	1	**3**
	hoverfly larvae						
	tachinid fly					1	**1**

Statistical analysis showed significant differences between scouting dates for aphids and thrips and also some beneficials (Table 39). The trends in aphid and thrips levels correlated with numbers of some beneficials when looking at all treatments following the date sequence (Figs 14 &15). As the numbers of aphids and thrips increased the number of predators and parasitoids also increased as indicated in the graphs.

Fig 14

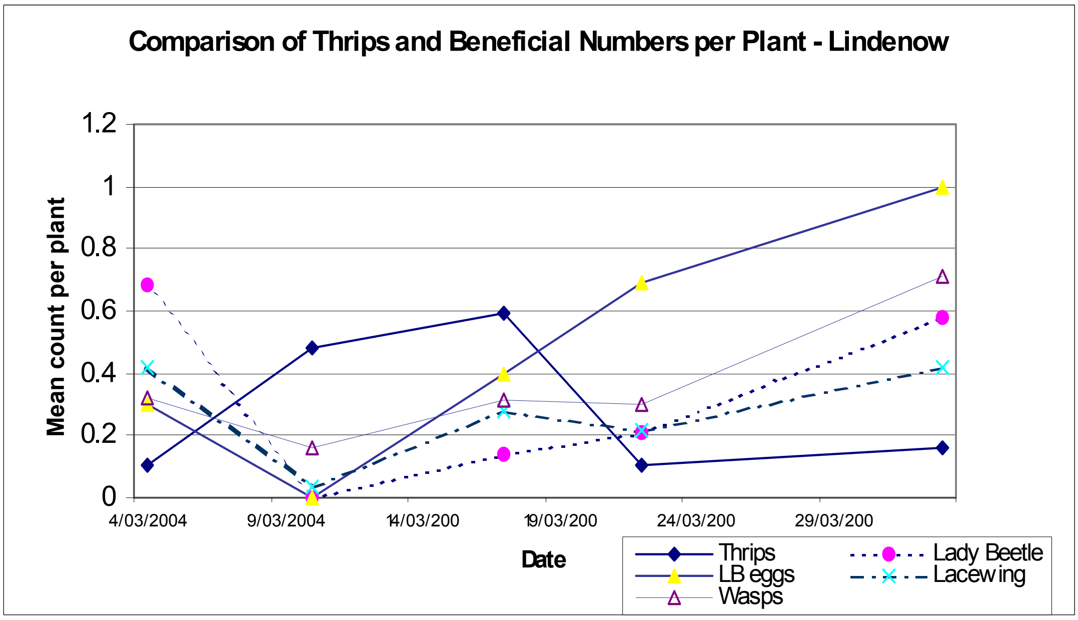
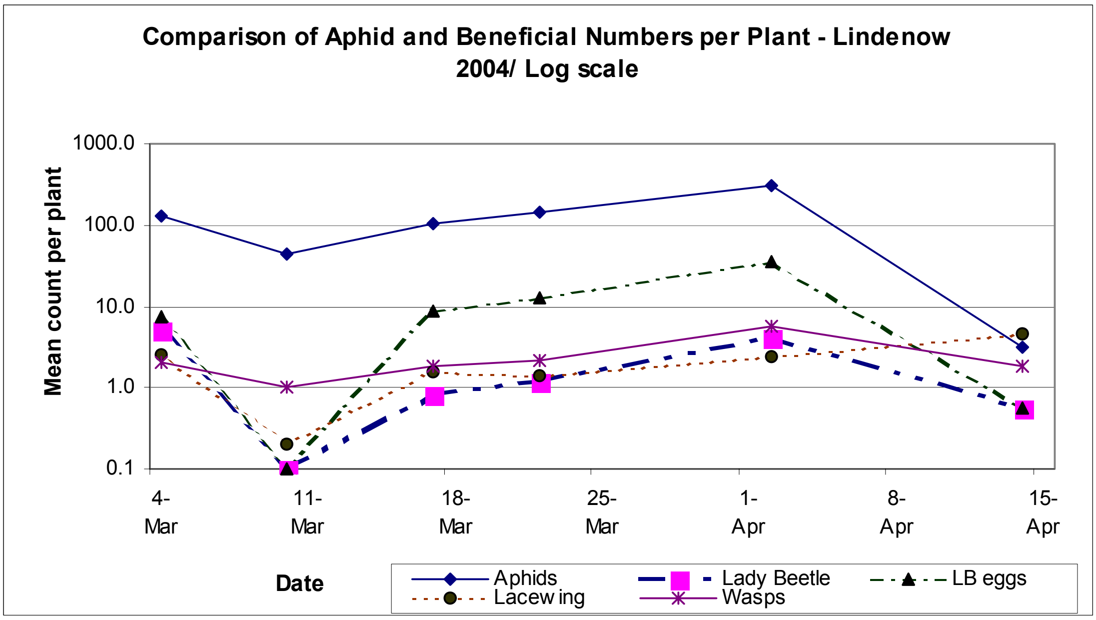


Fig 15



Aphid numbers were significantly higher on the 2nd of April than all other dates (Table 39) and lowest on the 10th of March. The ladybird beetles, wasps and lacewings followed a similar pattern throughout the crop-monitoring period. Thrips also increased from the 4th of March to the 17th of March and by the 22nd of March had significantly decreased.

Table 39 Crop monitoring, 14/04/2004 levels to harvest – using ANOVA and a transformation of Log ((aphid +1)) for each date.

Date	4/03/2004	10/03/2004	17/03/2004	22/03/2004	2/04/2004	14/04/2004	L.S.D
Aphids	3.4	2.2	3.1	3.4	4.3	0.3	0.44
Thrips	0.1	0.5	0.6	0.1	0.3	2.2	0.33
Ladybird Beetle	0.7	0	0.1	0.2	0.6	0.6	0.34
LB eggs	0.3	0	0.4	0.7	1	0.5	0.83
Lacewing	0.4	0.04	0.3	0.2	0.4	4.7	0.26
Wasps	0.3	0.2	0.3	0.3	0.7	1.9	0.34

By harvest, both thrips and aphid levels were low but counts of beneficials were comparatively high. These results indicate the response of beneficials to rises and falls of pest levels within the crop.

8.5 Discussion

Both bioassays and field trials showed that the four biological pesticides evaluated all provided some control of *Helicoverpa* spp. There were no clear differences between the treatments but the formulation of Vivus Gold® appeared to be consistently more effective. Results from the bioassays confirmed a slower response after more than 24 hours from application of the treatment, however there was still an effective response up to 7 days after application of the pesticide. Larvae were still dying up to 8 days after exposure to the treatment.

The trials showed no impact on other pests such as aphids or thrips as expected with the targeted biological pesticides used. The scouting results demonstrated the relationship between pest levels and the levels of beneficials, including predators and parasitoids, when high pest pressure for aphids and thrips was experienced.

9. Evaluation of Application of Nuclear Polyhedrosis Virus Through Overhead Sprinklers

The aim of this trial was to assess the feasibility of controlling *Helicoverpa* spp. in lettuce by applying Gemstar® through the overhead sprinkler irrigation system. Applying NPV through the sprinkler irrigation system is potentially a cheaper and faster way of controlling *Helicoverpa* spp. in lettuce than using a conventional boom spray system. It also can be used in conjunction with irrigation where Gemstar® is applied at the end of irrigation to prevent it being washed off. The most important thing with applying Gemstar® through the sprinklers is correct calibration. Typical calibrations involve injection of an industrial dye into the irrigation system to calculate the travel time from entry point and the time that is needed for a given amount of Gemstar® to be applied to particular area.

The first trial was carried out in season 2002/03 the second year of the project and the trial was repeated again in the following season 2003/04.

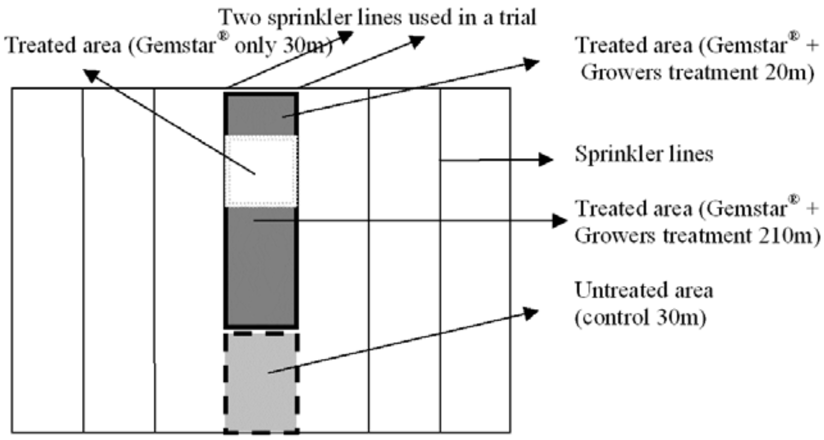
9.1 Materials and Methods

Season 2002/03
Gemstar® was applied three times at 750 mL/ha. Applications were made 20 (20 February), 27 (27 February) and 35 (6 March) days after transplanting. We were unable to conduct a replicated trial because of the large area that would have been needed. Gemstar® was injected through the irrigation system, using only two sprinkler lines. The area between those two sprinkler lines was the Gemstar® trial site. At the other end of these two sprinkler lines, four sprinklers in each line were switched off (i.e. Gemstar® was not applied at that area) to act as an untreated control plot.

Gemstar® application (injection through irrigation system).
Gemstar® was applied through two sprinkler lines (covering area of 0.52 hectare in total, 390 mL of Gemstar® was used - Fig 15). The insecticide was mixed with 150 L of water in a plastic barrel. The irrigation system was turned on for a few minutes to allow water to reach the end point of the sprinkler lines. Then the hose connected to the irrigation system was put into the plastic barrel. The suction generated by the irrigation system drew the liquid from the plastic barrel into the irrigation system. After the barrel was emptied, the irrigation system continued to work for one minute to allow time for the insecticide to be completely flushed from the system.

Grower applying Gemstar® through sprinklers.

Fig 15.



Trial diagram

After each application, leaf samples were taken for bioassay. Leaf samples were taken 24 hours (1 day), 96 hours (4 days) and 144 hours (6 days) after Gemstar® was applied. Two randomly chosen leaves per raised bed (6 beds) and three from the untreated areas were collected and placed into 40 cm x 28 cm plastic bag and sealed. The youngest fully expanded leaf was collected. In the first two bioassays, the youngest fully expanded leaf was collected while a wrapper leaf was used for the third bioassay.

In the bioassay 1-1, one 2nd instar *Helicoverpa armigera* larva was placed on a two 2.5 cm leaf disc, from leaves sampled from the plots, in a 30 mL Solo® plastic cup. Due to unavailability of 2nd instar larvae in the culture, 3rd and 1st instar larvae were used for bioassays 1-2 and 1-3 respectively. There were 75 larvae per bioassay, (5 larvae per plant; 15 plants (12 from treated and 3 from untreated area)) and the trays of cups were held in a 25°C cabinet. Each day, the larvae were checked. When a larva had eaten all of the lettuce in its cup, it was fed with a diet cube (based on beans supplemented with 10% wheat germ).

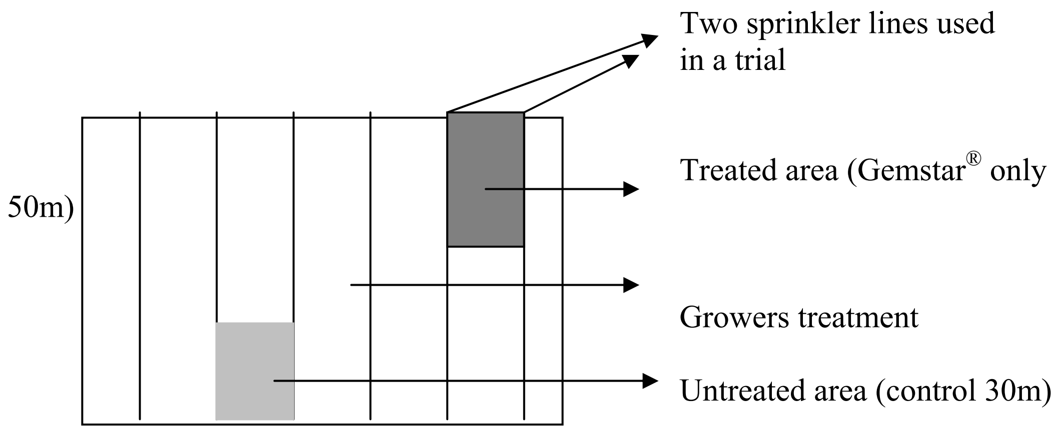
Season 2003/04

Gemstar® was applied three times at 750 mL/ha. Applications were made 10 days (4 March), 17 days (11 March) and 24 days (18 March) after transplanting. Gemstar® was injected through the irrigation system, using only two sprinkler lines. The other end of the paddock area on two other sprinkler lines was used as an untreated control plot, (i.e. Gemstar® was not applied at that area – Fig 16).

Gemstar® application (injection through irrigation system).

Gemstar® was applied through two sprinkler lines (covering area of 0.45 hectare in total, 340 mL of Gemstar® was used). The insecticide was mixed with 50 L of water in a plastic barrel. The application then followed the procedure in the previous season.

Fig 16



Bioassay sampling and analysis was carried out as per the method for the previous season. In the bioassay for this season, a 3rd instar *Helicoverpa armigera* larva was used.

Data analysis
Due to trial size (area that was covered), it was not possible to replicate the trial and therefore to statistically analyse the trial in conventional manner. Results from harvest assessment and bioassays were presented in tabular form.

9.2 Results

Year 2. Season 2002/03
The field results were inconclusive, with the treated area having more live and dead larvae than the untreated area when crop monitoring was carried out (Tables 40 & 41). There was also no difference found in a comparison of the two areas with respect to the number of beneficials present (Table 42).
At harvest less larvae per plant were observed for the Gemstar® treated block than for the untreated area. The bioassay allowed some statistical analysis of the impact of application through the overhead sprinklers.

Table 40 Harvested lettuce heads assessed on pest presence. Gemstar® Chemigation Trial

Treatment	Number of assessed plants	Number of *Helicoverpa* larvae	Number of *Agrotis* larvae	Feeding damage	Plants infested with aphids	Plants infested with thrips
Gemstar®	42	4	2	3	39	6
Control	20	5	3	5	18	5

Table 41 Crop Monitoring at Gemstar® Chemigation Trial: Lepidoptera, Werribee South

Treatment	**Data**	**18/02/03**	**25/02/03**	**4/03/03**	**13/03/03**	**Grand Total**
Gemstar® (42 plants)	white egg	2				**2**
	brown egg					
	Helicoverpa larva		3	2	7	**12**
	dead *Helicoverpa* larva			2	2	**4**
	cutworm larva	4	6	6	6	**22**
	dead cutworm larva		1			**1**
Control (20 plants)	white egg					
	brown egg		1			**1**
	Helicoverpa larva	1	2	2	3	**8**
	dead *Helicoverpa* larva					
	cutworm larva	2	5	3	4	**14**
	dead cutworm larva					
Total white eggs		2				2
Total brown eggs			1			1
Total *Helicoverpa* larvae		1	5	4	10	20
Total dead *Helicoverpa* larvae				2	2	4
Total cutworm larvae		6	11	9	10	36
Total dead cutworm larvae			1			1

After the second Gemstar® spray was applied, all bioassays had the same number of control larvae alive (10 larvae) after 168 hours (7 days). The difference was recorded in level of live larvae between three bioassays. The first bioassay taken 1 day after spray had 5% live larvae (3 larvae), the second bioassay (4 days after) had 25% (15 larvae), the third bioassay (6 days after) had 31.5% (19 larvae) (Fig 17). The graphs of the other two bioassays are similar and are not shown.

These results showed that Gemstar® lost effectiveness with time probably due to degradation in the presence of ultra violet light. Tables 43 – 45 show the similarities in time taken to kill 50% of larvae 1, 4 & 6 days after sampling of treated leaves, for the 3 bioassays

Table 42 Crop Monitoring at Gemstar® Chemigation Trial: Beneficial Insects, Werribee South

Treatment	Species	18/02/03	25/02/03	4/03/03	13/03/03	Grand Total
Gemstar®	Micromus		1			1
	Nabis		1			1
	Hippodamia		2	1	6	9
Control	*Micromus*				1	1
	Nabis		1			1
	Hippodamia	1	2	2	6	11
Total *Micromus*			1		1	2
Total *Nabis*			2			2
Total *Hippodamia*		1	4	3	12	20

Table 43 Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers (Bioassay 1)

Bioassay 1		**LT_{50} (hours)**	**95% fiducial limits**	
24 h	Gemstar®	111.8	104.8	118.7
(II instar)	Control	no estimate*		
96 h	Gemstar®	109.6	93.8	131.4
(III instar)	Control	no estimate		
144 h	Gemstar®	64.0	42.5	87.2
(I instar)	Control	172.0	135.8	272.6

* 50% mortality not observed

Figure 17 Bioassays 1/1, 2 & 3 Corrected mortality of *Helicoverpa armigera* larvae exposed to treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers. All bioassays were corrected for the effect of mortality in the untreated control treatment using Abbott's formula.

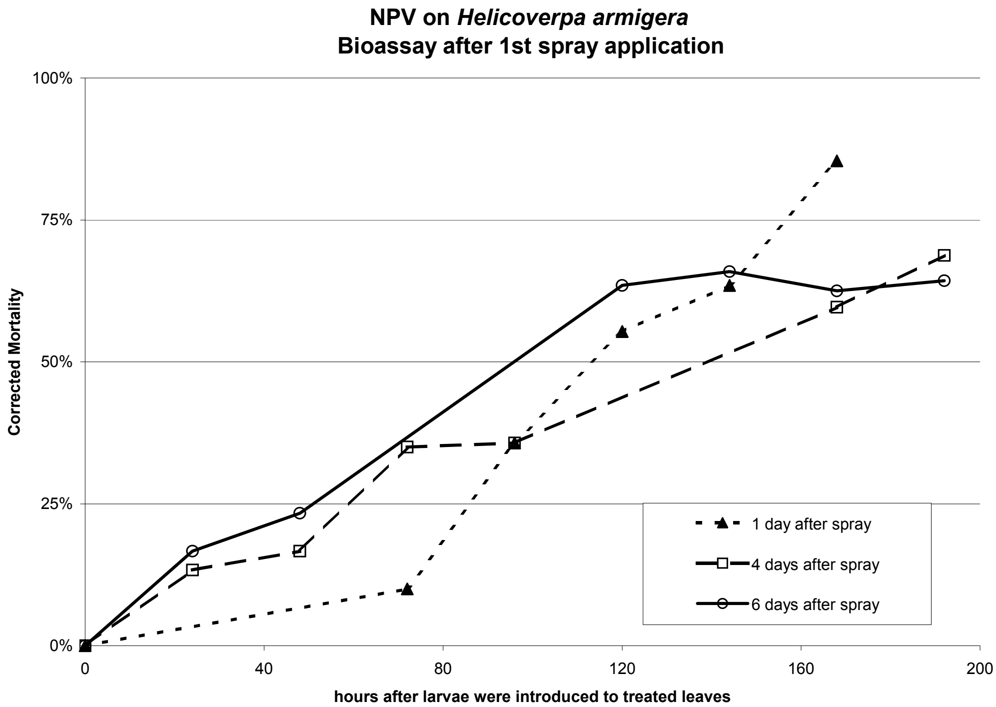


Table 44 Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers (Bioassay 2)

Bioassay 2		**LT_{50} (hours)**	**95% fiducial limits**	
24 h	Gemstar®	114.7	109.8	119.7
(II instar)	Control	185.5	157.1	393.5
96 h	Gemstar®	91.2	66.6	123.3
(II instar)	Control	247.0	166.9	962.0
144 h	Gemstar®	127.0	108.56	146.4
(II instar)	Control	no estimate		

Table 45 Time taken for 50% survival of *Helicoverpa armigera* larvae after feeding on treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers (Bioassay 3)

Bioassay 3		**LT_{50} (hours)**	**95% fiducial limits**	
24 h	Gemstar®	78.8	73.1	83.4
(II instar)	Control	no estimate		
96 h	Gemstar®	96.1	87.0	105.2
(II instar)	Control	193.9	156.6	331.0
144 h	Gemstar®	106.9	73.6	181.3
(II instar)	Control	no estimate		

Year 3. Season 2003/04

Very low pest pressure was observed in this year's trial and the crop monitoring data showed very low levels of *Helicoverpa* in both the treated and untreated areas. There were also no differences in the number of beneficials in each area (table 47). At harvest only one larvae was found in total for the samples taken from treated and untreated areas (table 46).

Table 46 Crop Monitoring at Gemstar® Chemigation Trial: Lepidoptera, Werribee South 2004

Treatment	**Data**	**24-Feb**	**3-Mar**	**9-Mar**	**16-Mar**	**23-Mar**	**29-Mar**	**6-Apr**	**14-Apr**	**Grand Total**
	white egg			1	1	3				**5**
	brown egg									
Control	*Helicoverpa* larva					1				**1**
(42 plants)	dead *Helicoverpa* larv									
	feeding damage				1		1			**2**
	white egg			1						**1**
	brown egg		1							**1**
Gemstar®	*Helicoverpa* larva					1				**1**
(42 plants)	dead *Helicoverpa* larv					1	1			**2**
	feeding damage									
Total white egg				2	1	3				6
Total brown egg			1							1
Total *Helicoverpa* larvae						2				2
Total dead *Helicoverpa* larvae						1	1			2
Total feeding damage					1		1			2

Table 47 Crop Monitoring at Gemstar® Chemigation Trial: Beneficial Insects, Werribee 2004

Treatment	**Species**	**24-Feb**	**3-Mar**	**9-Mar**	**16-Mar**	**23-Mar**	**29-Mar**	**6-Apr**	**14-Apr**	**Grand Total**
	brown lacewing							3	2	**5**
Control	damsel bug	1	1	4	1					**7**
(42 plants)	ladybird beetle		3	4	2	1				**10**
	brown lacewing							2	1	**3**
Gemstar®	damsel bug	2	2	5						**9**
(42 plants)	ladybird beetle		2	2	1	1				**6**
Total brown lacewing								5	3	8
Total damsel bug		3	3	9	1					16
Total ladybird beetle			5	6	3	2				16

With such low pest pressure the bioassays again provided some meaningful results. The best results were achieved with bioassays conducted immediately after spray application (1 day after spray). Mortality for leaf samples taken 24 hours after spray application ranged from 60% to 75% 168 hours after spraying for the each of three consecutive spray application (Figs 19-21). However, for leaf samples taken 144 hours after insecticide were applied mortality was significantly lover 30%, 48% and 45% for the each of three consecutive spray application. These results indicate that Gemstar® with time loses effectiveness. This is most likely due to degradation in the presence of ultra violet light.

Fig 19 Bioassays 1/1, 1/2 & 1/3 Corrected mortality of *Helicoverpa armigera* larvae exposed to treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers. All bioassays were corrected for the effect of mortality in the untreated control treatment using Abbott's formula.

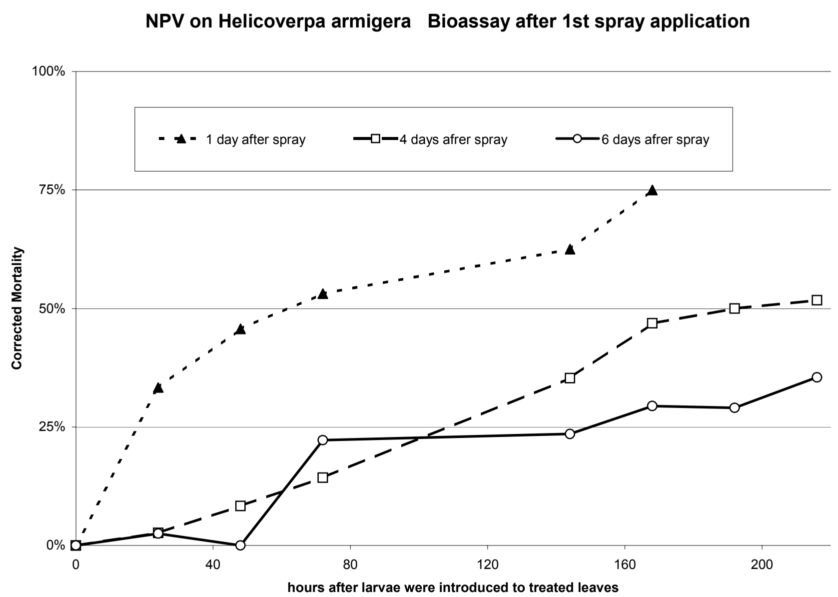


Fig 20 Bioassays 2/1, 2/2 & 2/3. Corrected mortality of *Helicoverpa armigera* larvae exposed to treated leaves 1, 4 and 6 days after application of Gemstar® through overhead irrigation sprinklers. All bioassays were corrected for the effect of mortality in the untreated control treatment using Abbott's formula.

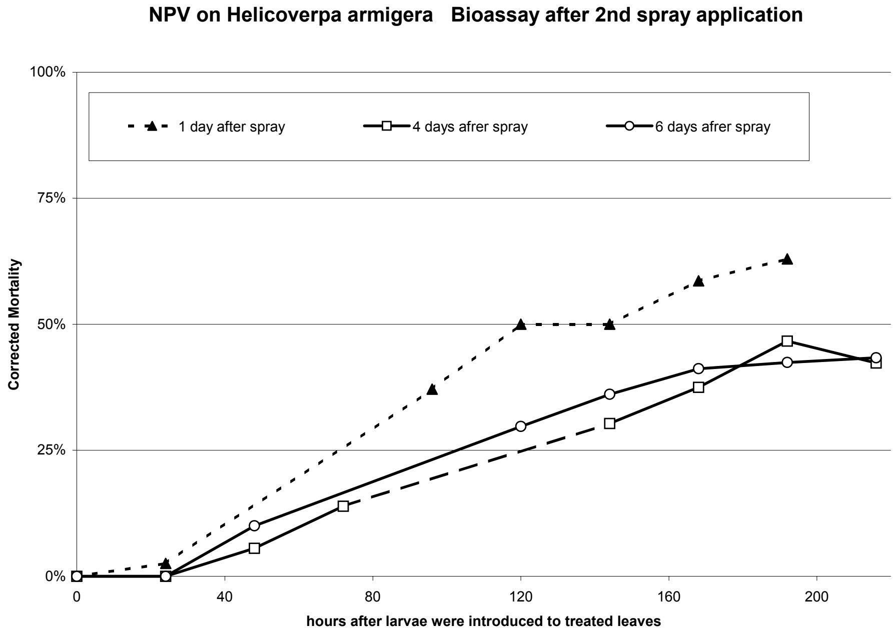
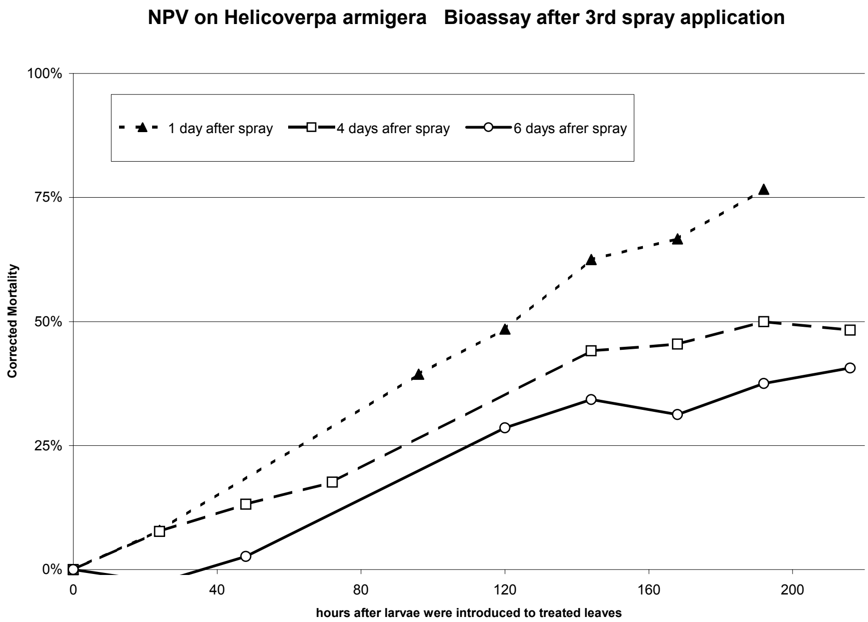


Fig 21 Bioassays 3/1, 3/2 & 3/3. Corrected mortality of *Helicoverpa armigera* larvae exposed to treated leaves 1, 4 and 6 days after 3rd spray application of Gemstar®. All bioassays were corrected for the effect of mortality in the untreated control treatment using Abbott's formula.



9.3 Discussion

Results showed that Gemstar® was successful in controlling *H. armigera* larvae when applied through overhead irrigation sprinklers. The best results were achieved 24 hours after spray application. In the first year of the trial mortality after 4 days of exposure to the treated leaves was 28% of larvae, after 7 days it was 86% (in the second year of this trial it was 80%). This is an effective method of application of NPV and despite the impact of UV light and irrigation on the crop samples taken 6 days after spraying, 68% of larvae had died after 168 hours exposure in the bioassay.

The field assessments were inconclusive, because of relatively low *Helicoverpa* pressure and high *Agrotis* (cutworm) pressure and NPV will not control *Agrotis*. In the first year of application through the overhead sprinklers there appeared to be some differences in the field but field results for both seasons were not conclusive.

The bioassays were able to provide an assessment of the effectiveness of application of NPV through overhead sprinklers. It is important to note that the bioassays (laboratory testing) were conducted in controlled environment cabinets with a constant temperature 25°C. In the field situation, results will be slower and more variable, depending on environmental conditions.

10. Comparison of Management Options

10.1 Materials and Methods

A comparison of grower management options was carried out in the second year of the project for Werribee and Cranbourne and in the final year for Werribee, Cranbourne and Lindenow.

Werribee/Cranbourne
In season 2002/03 and 2003/04 two lettuce crops were monitored in both Werribee South and Cranbourne from transplanting through to harvest to compare different pest management methods.

In each area:
- Grower No A: Used a Best Management Options (BMO) IPM system. This may include a Bt or other biological to pre-hearting and pre-hearting to harvest a soft insecticide such as Avatar®, Success®, ie. A combination of biological and soft pesiticides , crop monitoring and scouting.
- Grower No B: Used a preventative spray strategy, minimal crop monitoring and more broad-spectrum insecticides.

Crops were scouted weekly and 40 randomly chosen plants were inspected for the presence of eggs, larvae, feeding damage and presence of any beneficial insects. At harvest, 40 randomly chosen plants were harvested and assessed leaf by leaf for presence of eggs and larvae, feeding damage and presence of any other insects.

Weekly activity of male *Helicoverpa armigera* and *Helicoverpa punctigera* moths in the monitored lettuce crops were recorded using Scentry® pheromone traps. Spray records from each individual grower were compared for overall assessment.

Lindenow
Crops were monitored in season 2003/04. Two lettuce crops around 1.5-2km apart were monitored in Lindenow from 2 weeks after transplant to harvest. Due to changes in the growers who were growing iceberg lettuce, Grower A could not be considered to be following a strict IPM program but was using a more targeted and softer spray program. Neither grower used crop scouts.

Grower A: used targeted sprays for *Helicoverpa*.
Grower B: used a traditional spray program.

Crops were monitored weekly and 30 randomly chosen plants were inspected for the presence of eggs and larvae, other pest species and beneficial insects.
Both crops were at 2-week stage after transplant on the 4th of March and harvested for our trials on the 14th of April. Thirty random plants were harvested at 6 weeks for assessment and at harvest after 7 weeks for analysis. They were assessed for internal and external damage, marketability, and presence of other pests and beneficials.

10.2 Results Year 2 - 2002/03

Werribee
At Werribee crops were monitored on two properties, which were approximately 1.5 km apart. For the whole season, Property A had lower moth numbers, compared with property B, and the other properties we monitored in 2003.

Crop A
Both *Helicoverpa* species were trapped throughout the life of the crop but *H. armigera* numbers were highest at the end of February while *H. punctigera* were most commonly trapped at the start of the crop at the end of January(Table 49).

Relatively high numbers of *H. punctigera* and *Agrotis* (cutworm) larvae were detected between Weeks 2 and 4, as would be expected by the earlier egg counts (Table 48). Only two eggs and one larva were detected at Week 5, yet 8 larvae were found 2 weeks later when the plants were harvested. This highlights the difficulty of detecting eggs and young larvae by crop monitoring as plants begin to heart.

Aphids had built up but the application of an aphicide at Week 5 reduced the population and very few aphids were observed at harvest. On the other hand, low numbers of thrips were observed throughout the life of the crop and the number of thrips found at harvest was much higher than seen in the crop monitoring. Rutherglen bugs (*Nysius vinitor*) were found only at week 5 (end of February).

Very few natural enemies were observed during the scouting, despite the use of selective insecticides (Success® and Bt).

Crop B

Numbers of *Helicoverpa* moths trapped at this crop were consistently higher than at crop A. Generally, numbers of *H. armigera* were higher than *H. punctigera* numbers (Table 52). *Helicoverpa* eggs were found readily in the first 4 weeks and larvae were observed in Weeks 2 and 5, as would be expected (Table 52). Similarly, the high numbers of cutworm eggs (laid in clusters) observed in Weeks 1-3, was followed by larvae observed in Week 5. While no larvae were found on the lettuces at harvest, four heads of the 40 harvested had *Helicoverpa* feeding damage.

The number of thrips present was much lower than in Crop A, which presumably reflects the use of broad-spectrum insecticides on Crop B. The numbers of aphids observed at harvest was lower in Crop A than Crop B, despite being more common during the life of the crop in Crop A.

As in Crop A, very few natural enemies were observed. No brown lacewings were seen and *Hippodamia* ladybirds were only seen in Week 5.

Table 48 Scouting summary Werribee Crop A (per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg	3	11			1			**15**
brown egg					1			**1**
cluster white egg*		10						**10**
cluster brown egg*								
cutworm larva				5			2	**7**
dead cutworm larva								
Helicoverpa larva		3	2	6	1		8	**20**
dead *Helicoverpa* larva				2	1			**3**
feeding damage							7	**7**
aphid	1	7	1		8		3	**20**
rutherglen bug					5			**5**
thrips	2	4	2	1	8		35	**52**
leafhopper				4	4	1		**9**
brown lacewing				1				**1**
ladybird beetle					3			**3**

* Cutworm egg clusters new and ready to hatch as opposed to the other eggs which are *Helicoverpa*

Table 49 Moth counts Werribee Crop A

Time		***Helicoverpa punctigera***	***Helicoverpa armigera***
Week 0	20 January (planting)	20	0
Week 1	28 January	23	9
Week 2	4 February	5	8
Week 3	11 February	2	6
Week 4	18 February	n/a	n/a
Week 5	25 February	26	38
Week 6	4 March	4	15
Week 7	13 March (harvesting)	0	4

Table 50 Spray Record Werribee Crop A (from Growers spray records)

Date	**Spray used**	**Rate**
20 January (planting)	Kerb®	1 L/acre
1 February	Xentari® Sumisclex®	800 mL/800 L 1 L/800 L
6 February	Success®	800 mL/800 L
12 February	Delfin®	800 mL/800 L
19 February	Success®	800 mL/800 L
25 February	Xentari® Pirimor® Ridomil®	800 mL/800 L 600 mL/800 L 1 kg/800 L
6 March	Delfin®	800 mL/800 L

Table 51 Scouting summary Werribee Crop B
(per 40 plants)

Data	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (H)	Grand Total
white egg	5	5	5	5				**20**
brown egg				5			1	**6**
cluster white egg	7	100	10					**117**
cluster brown egg				10				**10**
cutworm larva		3			2			**5**
dead cutworm larva								
Helicoverpa larva		5		1	4	1		**11**
dead *Helicoverpa* larva					1			**1**
feeding damage				1			4	**5**
aphid		4	1		2		3	**10**
rutherglen bug	2			3				**5**
thrips		1			1		1	**3**
leafhopper	2	1						**3**
brown lacewing								
ladybird beetle					5			**5**

* Cutworm egg clusters new and ready to hatch as opposed to the other eggs which are *Helicoverpa*

Table 52 Moth counts Werribee Crop B

Time		*Helicoverpa punctigera*	*Helicoverpa armigera*
Week 0	20 January (planting)	38	35
Week 1	28 January	23	43
Week 2	4 February	20	17
Week 3	11 February	16	48
Week 4	18 February	14	25
Week 5	25 February	25	58
Week 6	4 March	23	38
Week 7	13 March (harvesting)	3	24

Table 53 Spray Record Werribee Crop B
(from Growers spray records)

Date	Spray used	Rate
5 February	Lannate®	2 L/ha
	Rumble®	1 L /ha
	Dithane®	2 kg/ ha
	Agral®	500 mL/100L
16 February	Lannate®	2 L/ha
	Success®	500 mL/800 L
	Agral®	200 mL/100L
24 February	Gemstar®	500 mL/ha
	Dominex®	500 mL/ha
1 March	Gemstar®	500 mL/ha
	Dominex®	500 mL/ha

Cranbourne
In the Cranbourne area, crops were monitored on two properties that were approximately 15 km apart. Generally, pest pressure was much lower than in Werribee South, especially in the first few weeks of monitoring. At harvest, both properties had similar pest pressure. There was not a contrast in pesticide application strategies for these two crops, for both growers used soft pesticides. Only one spray for *Helicoverpa* was used on Crop B in comparison with 4 sprays for Crop A.

Crop A
The spray strategy was to alternate spinosad (Success®) with Bt (*Bacillus thuringiensis)* every eight days. At the last spray, Pirimor®, a selective aphicide, was applied to control aphids (Table 56).

Helicoverpa and *Agrotis* (cutworm) larvae were observed in week 5 (March). However, no eggs were observed before that, indicating the difficulties of detecting *Helicoverpa* eggs when the lettuce plant goes beyond the seedling stage (Table 54). In the pheromone traps, the numbers of *H. punctigera* were highest at the start of the crop while the numbers of *H. armigera* were highest in March, just before harvest (Table 55).

Thrips and aphids were observed in low numbers during most weeks. However, the numbers of aphids and thrips observed after the destructive harvest were substantially higher than observed in the non-destructive crop monitoring. Rutherglen bugs (*Nysius vinitor*) were observed in most weeks, with peak numbers found at the end of February. The most common natural enemy observed was the newly-arrived ladybird, *Hippodamia variegata*. At harvest, feeding damage by *Helicoverpa* larvae was observed in 8 of the 40 plants assessed.

Table 54 Scouting summary Cranbourne Crop A (per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg								
brown egg								
cutworm larva					3	1	1	**5**
dead cutworm larva								
Helicoverpa larva				1	8	3	8	**20**
dead *Helicoverpa* larva				1				**1**
feeding damage							8	**8**
aphid		2	1	7	4	3	17	**34**
rutherglen bug	4		2	8	26	8		**48**
thrips	6	5		8	3	3	31	**56**
leafhopper	2	2	1	3		2		**10**
brown lacewing					2			**2**
ladybird beetle					4	9		**13**

Crop B had lower numbers of *Nysius* and slightly fewer aphids while *Helicoverpa* numbers were similar to A (Table 57) but feeding damage was higher.

Table 55 Moth counts Cranbourne Crop A

Time		***Helicoverpa punctigera***	***Helicoverpa armigera***
Week 0	28 January (planting)	2	2
Week 1	4 February	7	5
Week 2	11 February	3	1
Week 3	18 February	0	2
Week 4	25 February	0	4
Week 5	4 March	1	16
Week 6	11 March	0	10
Week 7	17 March (harvesting)	1	3

Table 56 Spray record Cranbourne Crop A (from Growers spray records)

Date	**Spray used**	**Rate**
12 February	Success®	800 mL/ha
	Potassium/Nitrate	25 kg/1000L
	Agral®	750 mL/100L
20 February	Penncozeb®	2 kg/ha
	Wuxal®	10 L/1000L
	Xentari®	0.5 kg/ha
	Agral®	750 mL/100L
28 February	Kocide®	1.5 kg/1000L
	Dipel®DF	0.5 kg/ha
	Hortiwett	10 mL/100 L
6 March	Rovral®	1 L/1000 L
	Success®	600 mL/ha
	Wuxal®	10 L/1000L
	Agral®	750 mL/100L
14 March	Rovral®	1 L/1000 L
	Pirimor®	1.5 kg/1000 L
	Agral®	800 mL/100L

Table 57 Scouting summary Cranbourne Crop B (per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg								
brown egg								
cutworm larva							2	**2**
dead cutworm larva								
Helicoverpa larva				1	6	3	11	**21**
dead *Helicoverpa* larva								
feeding damage							14	**14**
aphid	2		2	5	4	3	9	**25**
rutherglen bug	1				3	3		**7**
thrips	2	2		5	3	2	36	**50**
leafhopper				2	1			**3**
brown lacewing								
ladybird beetle					2			**2**

Table 58 Moth counts Cranbourne Crop B

Time		*Helicoverpa punctigera*	*Helicoverpa armigera*
Week 0	28 January (planting)	4	0
Week 1	4 February	1	2
Week 2	11 February	2	1
Week 3	18 February	0	0
Week 4	25 February	2	0
Week 5	4 March	0	1
Week 6	11 March	0	3
Week 7	20 March (harvesting)	0	3

Table 59 Spray Record Cranbourne Crop B (from Growers spray records)

Date	Spray used	Rate
17 February	Mag-nitrate Mantrac®	10 kg/ha 800 mL/ha
25 February	Success® Pirimor® Mankocide®	500 mL/ha 500 mL/ha 3 kg/ha

10.3 Discussion

There was little difference between the Cranbourne treatments due to low pest pressure and growers in the area are using similar management systems. Both the monitored growers used very few sprays for *Helicoverpa* control although other pests were active and there was some beneficial activity. Crop B at Cranbourne had more damage at harvest but had used only 1 spray.

While the Werribee grower B had slightly less damage and range of pests, significantly more insecticides were used. Grower B also combined hard and soft chemicals in the one spray application. This was not a good strategy because it would be detrimental to resistance management, is more expensive and did not achieve significantly better control.

Scouting, moth monitoring and harvest assessments are tools that will help us to assess pest pressure and assess IPM options for lettuce.

10.4 Results Year 3 – 2003/04

Werribee

At Werribee South, we monitored crops on two properties, which were approximately 3 km apart. For the whole season, Property A had lower moth count numbers, compared with property B, and some other properties that we monitored that season.

Crop A

Only one *H. punctigera* moth was trapped for the life of the crop (Table 61). Presence of *H. armigera* moths were in the range from low to moderate; this crop had the lowest recording of moths compared with other traps in the area. Scouting detected only three eggs and two *H. armigera* larvae for the life of the crop (Table 60).

Aphids were present from week 2 until harvest in relatively moderate numbers, they did not cause a problem for the grower and insecticides were not used. Rutherglen bugs (*Nysius vinitor*) were found only in the first few weeks but not at harvest. On the other hand, thrips were found towards the end of crop life and the number of thrips found at harvest was much higher than seen in the crop monitoring (Table 60).

Very few natural enemies were observed during the scouting, despite the use of relatively selective insecticides (Success®, Gemstar® and Bt).

Crop B

Numbers of *Helicoverpa* moths trapped in this crop were slightly higher than at crop A, except in the last week (week 7) which was high (54 moths) (Table 64). *H. punctigera* moths were trapped only once, a total of 4 moths. The scouting report was similar to crop A. There were a few *Helicoverpa* eggs at week 3 and 4 and three larvae close to harvest (Table 63).

Similarly to crop A, aphids were present from planting until harvest in moderate numbers and Rutherglen bugs were present from planting until week 5 (Table 63). Thrips were observed just prior to harvest at week 5. At the harvest assessment half of lettuce plants were infested with thrips.

Grower B was not aware of the thrips problem, otherwise he would have applied sprays for control. Very few natural enemies were observed during the scouting; only some brown lacewings and damsel bugs (*Nabis*).

Table 60 Scouting summary Werribee Crop A (per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg	2		1					**3**
brown egg								
Helicoverpa larva					2			**2**
feeding damage								
aphid		6	7	2	6	5	13	**39**
rutherglen bug	9	9	2		4			**24**
thrips					1	3	10	**14**
leafhopper	3	2						**5**
brown lacewing					2	2		**4**
damsel bug	1	1	2					**4**
ladybird beetle	1	3	2	1	2			**9**
mites				1			2	**3**
spiders		1						**1**

Table 61 Moth counts Werribee Crop A

Time		***Helicoverpa punctigera***	***Helicoverpa armigera***
Week 0	23 February (planting)	0	0
Week 1	2 March	0	0
Week 2	10 March	1	4
Week 3	16 March	0	4
Week 4	23 March	0	6
Week 5	30 March	0	3
Week 6	6 April	0	0
Week 7	15 April (harvesting)	0	10

Table 62 Spray Record Werribee Crop A
(from Growers spray records)

Date	**Spray used**	**Rate**
23 February (planting)	Kerb®	1 L/acre
5 March	Success® Sumisclex®	800 mL/800 L 1 L/800 L
15 March	Success®	800 mL/800 L
19 March	Gemstar®	500 mL/800 L
26 March	Gemstar®	500 mL/800 L
2 April	Xentari®	0.6kg/800L
7 April	Gemstar®	500 mL/800 L

Table 63 Scouting summary Werribee Crop B
(per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg				2				**2**
brown egg			2					**2**
Helicoverpa larva			2	1		2	1	**6**
feeding damage					1			**1**
aphid	1	12	6	3	4	7	6	**39**
rutherglen bug	12	5	5	2	5			**27**
thrips					3	14	19	**36**
leafhopper		1	2					**3**
brown lacewing			2		1	2		**5**
damsel bug		1		2	2			**5**
ladybird beetle	1		2					**3**
mites		1						**1**
spiders						2		**2**

Table 64 Moth counts Werribee South Crop B

Time		*Helicoverpa punctigera*	*Helicoverpa armigera*
Week 0	23 February (planting)	0	9
Week 1	2 March	4	1
Week 2	10 March	0	4
Week 3	16 March	0	1
Week 4	23 March	0	1
Week 5	30 March	0	9
Week 6	6 April	0	11
Week 7	13 April (harvesting)	0	54

Table 65 Spray record Werribee South Crop B
(from Growers spray records)

Date	Spray used	Rate
23 February (planting)	Stomp®	1.5L/600 L
1 March	Folidol®	1L/600 L
9 March	Barrack®	1.5L/600 L
15 March	Avatar®	0.25 kg/600 L
25 April	Folidol ®	1.5L/600L
2 April	Avatar®	0.25 kg/600 L

Cranbourne
Pest pressure was low and very similar to Werribee, although Grower B had higher moth counts in the traps for *H armigera* (Tables 67 & 70). However, scouting and harvest levels of larvae were very low and there was little difference between the two (Tables 66 & 69). Again, both growers were following similar control strategies, so different control options could not be compared. In the Cranbourne area, most growers are using a soft pesticide program, which includes some scouting and monitoring (Tables 68 & 71).

Table 66 Scouting summary Cranbourne Crop A
(per 40 plants)

Data	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (H)	Grand Total
white egg		2		2	1	1		**6**
brown egg								
Helicoverpa larva					1	1		**2**
feeding damage								
aphid					4	7	14	**25**
rutherglen bug	3	11	7	8	8	9		**46**
thrips				2	4	5	10	**21**
leafhopper	8	2						**10**
brown lacewing		1	1					**2**
damsel bug	1	3	2	1		1		**8**
ladybird beetle	6	3		1	1	2	1	**14**
mites		2		1			1	**4**
spiders					1			**1**

Table 67 Moth counts Cranbourne Crop A

Time		***Helicoverpa punctigera***	***Helicoverpa armigera***
Week 0	13 February (planting)	0	1
Week 1	17 February	0	2
Week 2	24 February	0	0
Week 3	2 March	0	0
Week 4	10 March	0	0
Week 5	16 March	0	2
Week 6	23 March	0	0
Week 7	29 March (harvesting)	0	0

Table 68 Spray record Cranbourne Crop A
(from Growers spray records)

Date	**Spray used**	**Rate**
13 February	Ramrod® Kerb®	5 L/acre 2.5L/acre
21 February	Fortress®	0.6L/ha
27 February	Success® Chess®	0.5L/ha 0.2kg/ha
28 February	Fortres®	0.6L/ha
5 March	Success® Chess®	0.5L/ha 0.2kg/ha
12 March	Avatar® Pirimor®	0.17kg/ha 0.2kg/ha
19 March	Fruvit® Pirimor®	2.5kg/ha 0.2kg/ha
26 March	Avatar® Pirimor®	0.17kg/ha 0.2kg/ha

Table 69 Scouting summary Cranbourne Crop B
(per 40 plants)

Data	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7 (H)**	**Grand Total**
white egg	1	1		3				**5**
brown egg				1				**1**
Helicoverpa larva						1	2	**3**
feeding damage			1					**1**
aphid	1	9	12	4	13	5	14	**58**
rutherglen bug	3	3	4				2	**12**
thrips						8	16	**24**
leafhopper		4	3					**7**
brown lacewing								
damsel bug	1	1						**2**
ladybird beetle	3			4		4		**11**
mites		1			3		1	**5**
spiders				1	2			**3**

Table 70 Moth counts Cranbourne Crop B

Time		*Helicoverpa punctigera*	*Helicoverpa armigera*
Week 0	10 February (planting)	0	n/a
Week 1	17 February	0	1
Week 2	24 February	0	0
Week 3	2 March	0	13
Week 4	10 March	0	10
Week 5	16 March	0	14
Week 6	23 March	0	6
Week 7	30 March (harvesting)	0	n/a

Table 71 Spray Record Cranbourne Crop B
(from Growers spray records)

Date	Spray used	Rate
9 February	Kerb®	2.5L/ha
20 February	Success® Ridomil®	3L/3000L 2.5kg/ha
1 March	Success® Sumisclex®	3L/3000L 3.5L/3000L
10 March	Avatar® Pirimor®	2L/3000L 5kg/3000L
18 March	Avatar® Pirimor®	2L/3000L 5kg/3000L

Lindenow
The results for both growers' crops were similar. The pest pressure was similar due to the close proximity of the crops. Pressure was relatively low in the area (Tables 72 & 75).

Beneficials were scarce, but surprisingly Grower B, who had used the more traditional harder chemistry, had a slightly higher population of beneficial insects, namely ladybird beetles, parasitic wasps, parasitised aphids and lacewings. However, Grower B did not achieve greater control of pests than Grower A (Table 75). Grower B overall only achieved a slight reduction in aphid numbers of aphids at harvest compared with grower A, who did not use any chemistry for control of sap-sucking insects such as aphids and thrips.

Grower B achieved 100% marketable yield, whereas Grower A at 96% was not significantly different (Table 77). However Grower B applied a series of four sprays to the crop and tank mixed targeted lepidopteran chemistry with broad-spectrum chemistry for lepidopteran and sap sucking insects and always used the highest rate of chemical registered. In comparison, Grower A applied a series of three sprays during the crop and used the lowest registered rate of the selective lepidopteran chemistry and no broad-spectrum insecticides (Table 76 & 74).

Table 72 Grower B: crop monitoring (scouting) results during trial period, Lindenow. (per 30 plants)

Data	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (H)	Grand Total
white egg		2	3		2	1	**8**
brown egg						3	**3**
Helicoverpa larva			1	2		3	**2**
feeding damage							
aphid	1	5	2	21	4	1	**34**
rutherglen bug		1					**1**
thrips	2	1	2	2	1	1	**9**
leafhopper							
brown lacewing				5			**5**
damsel bug				4			**4**
ladybird beetle				20			**20**
Parasitised aphids				6			**6**
spiders				4		4	**8**

Table 73 Grower B: Scentry® trap results during trial period, Lindenow.

Date	Armigera	Punctigera
March 3	53	0
March 10	52	0
March 18	27	0
March 25	56	0
March 30	31	0
April 6	130	0

Table 74 Grower B: Spray record for trial crop, Lindenow.
(from Growers spray records)

Date	Spray used	Rate
3rd of March 04	Fortress	1 Ltr / Ha
	Saboteur	750 ml /Ha
	Agral	200 ml/Ha
	Bortrac	1 Ltr / Ha
15th of March 04	Tri base blue	3 Ltr/ Ha
	Fortress	1 Ltr / Ha
	Dimethoate	750 ml /Ha
	Agral	200 ml/Ha
	Marrnsal	500 ml/Ha
24th of March 04	Success	800 ml/Ha
	Fortress	1 Ltr / Ha
	Lanate	1 Ltr / Ha
	Agral	200 ml/Ha
	Bortrac	1 Ltr / Ha
3rd of April 04	Tri base blue	3l/Ha
	Fortress	1 ltr/Ha
	Success	800 ml/ Ha
	Dimethoate	750 ml/ Ha
	Agral	200 ml /Ha

Table 75 Grower A: Scouting results for trial crop period, Lindenow. (per 30 plants)

Data	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7 (H)	Grand Total
white egg		4	1		1	1	**7**
brown egg		1				1	**2**
Helicoverpa larva			1				**1**
feeding damage							
aphid		7	2	4	9		**22**
rutherglen bug					1	1	**2**
thrips	4	2	3		3	1	**13**
orange egg			1		2	4	**7**
brown lacewing				1			**1**
damsel bug				1			**1**
ladybird beetle		3	1		2	2	**8**
Parasitised aphids					1		**1**
Wasps parasitic					2	4	**6**
spiders		4	1	3		3	**11**

Table 76 Grower A: Spray records for trial crop, Lindenow. (from Growers spray records)

Date	Spray used	Rate
2nd of March 04	Avatar	170gms/ha
	Polyram	200gms/100ltrs
12th of March 04	Success	400mls/Ha
	Sumisclex	100 mls/100 ltrs
22nd of March 04	Success	400mls/Ha
	Sumisclex	100 mls/100 ltrs

Table 77 Harvest results for Grower A & B, Lindenow.

grower	marketable	head damage (%)	head damage Intensity	larvae	instar	aphids	aphid intensity	thrips	spider	wasp
A	96.4	3.6	3	0.036	3	0.32	1	0.25	0	0.107
B	100	0	0	0	0	0.03	1	0.178	0.03	0.285

10.5 Discussion

Low pest pressure at all sites has resulted in difficulties in carrying out effective comparisons but nevertheless, some issues have been identified.

At Cranbourne since most growers are using some sort of an IPM program there was not an effective comparison and both grower types applied the same number of sprays with relatively low pest pressure. At both sites beneficial insects and pests other than *Helicoverpa* were active.

For the comparison at Werribee, results were similar, although Grower B (not carrying out any scouting) was unaware of the thrips pressure. Beneficial and pest levels were similar between the two crops even though the control practices used were different, although beneficial numbers for Crop A, would be low due to the lower pest pressure. The use of soft chemistry does not appear to have resulted in higher numbers of beneficials but crop monitoring carried out at Lindenow for the biological comparison trials demonstrated that the level of beneficials is dependant on the level of pests.

Grower B at Werribee also employed some questionable practices, such as using a broad-spectrum insecticide as his first spray, then alternating with a softer targeted insecticide. This would have killed any beneficials, which would have otherwise been unaffected if the targeted insecticide had been used as the first spray. In this comparison, Grower A, using the selective chemistry, had less larvae present at harvest although no other benefits of using the softer chemistry were evident.

Differences between the two growers in Lindenow also did not result in much difference between pest and beneficial levels. However, again some questionable practices were identified. Grower B tank mixed soft and hard chemistry and also used high rates of spinosad even though pest pressure was low. This is not a good strategy for resistance management and runs counter to the recommendations for the use of spinosad. The cost of application for Grower B would have been higher, with no additional benefit.

There were production differences between the growers, which may account for the fact that pest and beneficial numbers were similar despite different practices. Grower A had a very small area of crop in comparison to Grower B and with a range of sequential plantings (some of which may not have been sprayed), there is a potential harbour for pests and beneficials which can then move into the rest of the crop.

11. Evaluation of Spinosad insecticide as a Drench

The aim was to assess the effectiveness of spinosad as a soil drench for controlling *Helicoverpa armigera* on lettuce crops. This experimental trial was based on reported work done with spinosad in cabbage against insects from the *Lepidoptera* family - *Plutella xylostella* (diamondback moth), *Trichoplusia ni* (cabbage looper) and *Artogeia rapae* (cabbage white butterfly) - which had indicated some control as a soil drench (Ester A. de Putter H, van Bilsen JPGM, TI Film coating the seed of cabbage (Brassica oleracea L. var Botrytis L. with imidacloprid and spinosad to control insect pests. SO Crop Protection 22(5):761-768, 2003 Jun).

Small trials were set up to test whether there was any control achieved using a soil drench for *Helicoverpa* spp. in lettuce. The experimental trial work was carried out in the glasshouse at DPI Knoxfield Centre and at Werribee on a grower's property.

Materials and Method

Lettuce seedlings were transplanted into 15 cm black polypropylene pots and grown in potting media of 6 mm pine bark, 10mm pine bark, Seymour grit and deep mined sand (8:6:1:1 v/v). The potting medium contained fertiliser consisting of 3-5 kg/m^3 lime, 1 kg/m^3 GU-49™ (source of iron), 500g/m^3 Micromax and 600g/m^3 I.B.D.U. (isobutylidene diurea). For the second glasshouse trial, which was carried out due to inconclusive results from the first trial, a mixture of 60% clay soli and 40% potting media was used. When potted, plants were top-dressed with calcium nitrate. Plants were also fed weekly with the liquid fertiliser Vital® at the prescribed rate of 5ml/L . The temperature in the glasshouse was maintained between 21°C and 25°C with good air movement. The plants were on open mesh benches and were watered with an automatic sprinkler irrigation system for one minute three times a day.

Ten days after plants were transplanted, Success® (spinosad, active ingredient 0.02 g/plant-pot) was applied to the base of the lettuce plants. Insecticide was applied 10 days after plants were transplanted to allow time for root systems to establish in the pots. A shallow bowl was dug at the base of each plant and water added to moisten the soil before applying the treatment. Each treatment was applied with 50 ml of water. The bowl was refilled with soil once the treatment was fully absorbed into the soil.

The trial included ten replicates and two treatments (split system) with a total number of 40 pots in a randomised block design. Plant samples were taken (one leaf per pot) on the 8th and 15th day after drench was applied.

In the bioassay, one 3rd instar *Helicoverpa armigera* larva was placed in a 30 mL Solo plastic cup with 2.5 cm leaf discs cut from leaves sampled from the pots. The same trial design was used as carried out for bioassays in the insecticide trials. The trays of cups were held at 25°C. Each day, the larvae were checked. When a larva had eaten all of the lettuce in its cup, it was fed with a diet cube (based on beans supplemented with 10% wheat germ).

Results

There was no significant difference between treatment and control. Results from the first trial were inconclusive and it was thought that the absorption of the potting media used was too low to allow effective uptake of the spinosad by the roots. The potting mix was modified using a different more absorbent mix, to attempt to improve the absorption but as tables 78 & 79 indicate the results did not show any difference between treatments.

Table 78 Survival of *Helicoverpa armigera* larvae exposed to lettuce leaves Bioassay 1 leaves were collected 8 days after lettuce plants were treated with Spinosad® as a soil drench.

Treatment	Live larvae	live larvae after 24 hours	live larvae after 48 hours	live larvae after 120 hours	live larvae after 144 hours	live larvae after 168 hours	live larvae after 192 hours
Spinosad	20	20	20	19	19	19	19
Control	20	20	20	19	18	18	18

Table 79 Survival of ***Helicoverpa armigera*** larvae exposed to lettuce leaves Bioassay 2 leaves were collected 15 days after lettuce plants were treated with Spinosad® as a soil drench.

Treatment	Live larvae	live larvae after 24 hours	live larvae after 48 hours	live larvae after 120 hours	live larvae after 144 hours	live larvae after 168 hours	live larvae after 192 hours
Spinosad	20	20	18	16	16	15	14
Control	20	20	19	18	17	16	15

12. Technology Transfer

Results from the Lettuce Project

A range of methods of technology transfer have been used including newsletters, field days, website, meetings, information sheets, faxed information and text messaging.

Among the most effective have been specific industry presentations to grower groups particularly targeted to suppliers of various companies and specific growers groups. The use of newsletters and information sheets has been backed up with more detailed information available in annual trial reports and presented on a web site where specific details could be downloaded. Specific information sheets have also been circulated to all stakeholders including control strategies for *Helicoverpa* and another on thrips control in lettuce.

In response to industry interest faxed information was particularly used to keep industry informed of pest pressure. Moth monitoring figures and scouting results were faxed weekly to industry and also via phone messaging. This information collected for the project was provided to inform the industry about abundance of both *Helicoverpa* spp. in these areas. This information was also used by chemical resellers and growers of other crops susceptible to attacks from these pests.

Information from the project has also been extended to industry via the Department of Primary Industry extension project Vegcheque, to groups and in the newsletter arising from that project “Vegetable Matter of Facts”.

Several activities have already been undertaken to extend information from the previous project. This includes the presentation of a paper at the National Lettuce Conference in Gatton and press releases.

The project has also been very active in addressing the issue of Lettuce Aphid, setting up a Steering Committee in conjunction with the VegCheque project when the aphid became an issue in New Zealand. Following the incursion of the aphid into Tasmania the project has also responded by helping to facilitate a number of industry meetings and providing industry information.

Several key methods were used to provide information to industry and these included:

- A brochure produced detailing results in point form of the previous project and providing direction for more detailed information and circulated to all stakeholders. Also more detailed Agnotes were produced to support the brochure and these are available on the web and the Prime Notes CD.

- Newsletters have been produced in conjunction with the complementary project in VG01028 and are produced jointly with NSW and Qld. These will continue to be produced and once existing templates are finished a new template common to both projects will be developed.

- Information sheets for control of key pests.

- All the newsletters and information sheets produced are available on the website and can downloaded.

- In conjunction with the NSW/Qld project workshops on pest and beneficial identification have been held.

In addition after the withdrawal of some scouting services in East Gippsland and in response to grower and industry interest the project provided training for some Growers, their staff and chemical resellers (8 participants) in insect pest and beneficial scouting.

An evaluation survey has been carried out as part of the project and this is included as part of the evaluation report.

13. Project Evaluation

An evaluation was carried out on the Lettuce Best Practice project to assess whether the project was effective and resulted in outcomes to industry and practice change. The evaluation is based on Bennets Hierarchy and can provide useful feedback on whether or not extension and communication methods can be improved. A random telephone survey was carried out with Lettuce growers in the Werribee, Somerville and East Gippsland region. This evaluation identifies whether the project communication medium was an effective way of delivering information; and whether the information provided influenced change – as demonstrated by on farm practice change or in growers decision making process. Two objectives of the project were to improve crop management practices and improve pest management practices. The key questions the evaluation was designed to answer were:

- Are lettuce growers aware of the ‘Lettuce IPM project?
- Are the growers using the information on farm?
- What on farm or decision making processes have changed as a result of information obtained from the project?

The feedback was collated in a Bennett’s Hierarchy and shows what resources and inputs were used and what the results of these resources and inputs were. This is shown in Table 81.

The results indicate that the project has had an important contribution to growers increased awareness and understanding of the issues.

	Bennett's Hierarchy Level	*Comments*
Inputs	Inputs and Resources	DPI staff time, fax machine, computer, industry support, budget etc.
Inputs	Extension Activities	Lettuce Leaflet SIM text messaging/ Faxes for moth counts Information sheets Weekly moth count reports including beneficial activity have been distributed by Fax, email and SMS, to stakeholders Web pages Field days/Workshops Trial work at various locations Scout Training
Results of Inputs	People Involved Participation	Database of 130 stakeholders including a range of industry, processors and government. 27 growers from Victoria surveyed at random. 93% had heard of the Lettuce Insect Pest Management Project 92% received moth count information 100% received information on lettuce projects 100% received tip-burn information
Results of Inputs	Reaction of people involved	Only 15% used the web page 74% indicated that they liked getting information in the Lettuce Leaflet. 70% of growers surveyed liked getting specific information sheets. 67% would like more information on insect pests and 44% would like more information on crop management. 89% felt that tipburn was less of a problem. 85% found the Lettuce Leaflet Newsletter useful. 52% used the Helicoverpa strategy. 44% found the tipburn information useful. 100% had received information on Lettuce Aphid.
Results of Inputs	Change in Knowledge, Attitudes, Skills, Aspirations	81% found the moth count information useful. 63% found the nutrition management information useful in the tipburn brochure and 30% used the irrigation information. 63% were able to use the tipburn management information. 67% used the pest monitoring information 52% thought that the use of crop scouts increased quality, 55% thought that crop scouts saved money and 41% considered that there were environmental benefits. 100% of growers were aware that Lettuce Aphid had been found in Tasmania.
Results of Inputs	Practice Change	30% are using less fertiliser but most that use calcium side dressings or foliar applications are still continuing to use them. 37% of growers are now scheduling their irrigation and 52% have changed the time of day that they irrigate. 5 years ago 78% of growers did not use crop scouts with currently 55% of growers doing crop scouting. 63% of growers indicate that they use some form of an integrated pest management program and 5 years ago 63% of growers used a calender spray program which has dropped to 33% with 48% of growers using a spray program based on IPM 92% of growers indicated that the chemicals they use have changed in the last 5 years. The sale of NPV from E.E. Muir & Sons this year has increased by 500%, which indicates acceptance of the work by growers.

Table 81. Evaluation of Lettuce Project results according to Bennett's Hierarchy

Improving Lettuce Insect Pest Management - Victoria

Objective 1
Improved crop management practices

Key Question	Indicator	Result
Industry information produced	Results of previous project circulated to industry	Brochure on tipburn. Lettuce Leaflet. Articles in Good Fruit and Vegetables. Information on website. Information delivered at National Lettuce Conference.
Have growers management practices changed?	Changes to production methods	63% were able to use the tipburn management information.
	Changes to nutrition practices	63% found the nutrition management information useful in the tipburn brochure and 30% are using less fertiliser but most that use calcium side dressings or foliar applications are still continuing to use them. Comment that Calcium nitrate is an easy to use side dressing others still believe it may help with tipburn. 30% of growers have reduced fertiliser use in the last 5 years
	Changes to irrigation practices	30% used the irrigation information. 37% of growers are now scheduling their irrigation and 52% have changed the time of day that they irrigate.
	Changes to varieties grown	Growers using a greater range of varieties with some more resistant to tipburn to spread risk.
Tipburn management has it improved?	Tipburn less of an issue	89% felt that tipburn was less of a problem.

Objective 2
Improved pest management practices

Key Question	Indicator	Result
Have growers pest management practices changed?	Has scouting and monitoring increased	52% thought that the use of crop scouts increased quality. 5 years ago 78% of growers did not use crop scouts with currently 55% of growers doing crop scouting.
	Increased use of soft and biological pesticides	the sale of NPV from E.E. Muir & Sons this year has increased by 500%, which indicates acceptance of the work by growers.
	Reduced and more efficient use of broad spectrum insecticides	67% used the pest monitoring information 100% had received information on Lettuce Aphid.
Was an IPM strategy produced?	Documentation and information	52% used the *Helicoverpa* strategy. 63% of growers indicate that they use some form of an integrated pest management program and 5 years ago 63% of growers used a calender spray program which has dropped to 33% with 48% of growers using a spray program based on IPM
Have new insecticides been evaluated?	Larger range of soft insecticides available	92% of growers indicated that the chemicals they use have changed in the last 5 years. Registered soft pesticides Avatar, Success, Proclaim and biological pesticides Gemstar and Vivus
	More IPM friendly insecticides used	85% indicated that softer chemicals were now used and 92% considered that more targeted pesticides were now used. Used to manage resistance

		Most growers have changed chemicals due to better manage rotation and resistance issues and they are more user and environmentally friendly.
Increased use of IPM?	Growers implementing relevant components of IPM on farm	55% thought that crop scouts saved money and 41% considered that there were environmental benefits.
	Greater understanding of beneficial insects and their role	Recognition that new insecticides are softer on beneficial insects.

Additional comments in relation to survey.

Number of growers are asking when moth counts will start again

Water use "drought (lack of water was main driver for change in irrigation practice), it had to manage water more carefully, make sense to irrigate evening or early morning in summer when you have limited amount of water, no water no income, apply fertiliser or gemstar though sprinkler irrigation"
"Use less water for disease and better root development'

Helicoverpa strategy "heliothis control strategy needs to be revised every year, more local info, spraying strategy is very useful, monitoring tip makes sense I like those, info about new chemicals should be included"

Crop Scouts "Business decision, part of QA, quality of life, to grow best lettuce with minimum use of pesticides, I got time to concentrate more on running the farm, happy to pay someone who know what to look for"

Spray Programs "IPM saves you money and time if you do not spray (clean field), insecticides are more targeted are effective, changed chemicals because of resistance problems, rotation and resistance issues, changed because of registration problems, availability of new chemicals, some new chemicals are user friendly better for the environment and more safer for humans."

Lettuce aphid "All survey growers are aware that lettuce aphid has been found in Tasmania, and all growers received information or have been to a meeting on lettuce aphid
Number of grower's sound worried over the lettuce aphid and what implication aphids may have on lettuce production in Victoria"

Feedback comments on scouting services.
(further comments are list in Appendix 2)

- ❖ The costs associated with scouting are negligible compared to chemical outputs of previous seasons.
- ❖ We used to spray on a calendar basis, once or twice weekly, now we have had crops of lettuce that have not had to be sprayed or maybe only once.

- We are concerned and would like to do the right thing by the pesticide resistance strategies. If people keep using Spinosid all year and plutella and Helicoverpa develop resistance, there may not be enough time to develop new specific and softer options and we will find ourselves in the same situation as 1999 and 2000.
- We now rely on Crop monitoring and it is a crucial part of our business, we can't imagine not having this service.
- We see crop-monitoring valuable not only for applying fewer sprays, but for getting a better product at the end, that can be sold into any market.
- We do not have time to walk our crops, we need to rely on someone who has the skills and training to do this for us, and we need to be able to trust them.
- We had a bad season for TSWV, but as there is no IPM friendly option for thrips, we decided not to throw our program out the window and bear the brunt of the virus. As it turned out the money we saved in sprays outweighed the small percentage of crop we did not harvest.
- Need to change processing factories opinions on IPM, they are not convinced of the success we have had. There are too many beneficals in produce for them now.

Learning to scout lettuce crops

14. Conclusions

- Results in the first seasons trials showed that synthetic pyrethroids are still effective against early instar *Helicoverpa armigera* larvae.

- Beneficial insects can provide effective control of pests such as aphids. At a number of times during the field trials when aphid pressure was high a large number of hoverfly larvae (syrphids) and lady beetles were present and these are very efficient aphid predators.

- The scouting results in the trials using biological pesticides demonstrated the relationship between high pest levels of aphids and thrips and the high levels of beneficials, which occur in response. By harvest, the beneficials had reduced the aphid and thrips pest to low levels.

- Nuclear polyhedrosis virus can be successfully applied through overhead sprinklers for control of *Helicoverpa* spp. and demonstrated effective control when evaluated under bioassay conditions.

- Several groups of new selective insecticides were effective against *Helicoverpa* larvae and these were emamectin, methoxyfenozide and Sumitomo 1812. Near total control was provided under bioassay conditions after 4 days.

- None of the new evaluated insecticides, biological or soft chemicals, were effective in controlling aphids or thrips.

- Field and bioassay results indicated that all the biological insecticides were effective in controlling *Helicoverpa armigera* larvae but that it took 4-8 days after application for larvae to die.

- The bioassays showed that the best results using nuclear polyhedrosis virus were achieved when larvae come into contact within 24 hours after application.

- Results indicated the nuclear polyhedrosis virus loses effectiveness over time probably due to degradation however some effective control is still achieved with up 68% of larvae dead on samples taken 6 days after application.

- Monitoring moth counts in all areas showed that *H. punctigera* activity is higher in spring and early summer with peaks in November, and late December early January and then dropping to very low levels. *H. armigera* tends to have a slight rise in activity in October, a second slightly larger rise in activity in mid December and a peak of activity with high counts occurring around mid February.

- It is unlikely using current production systems that endemic populations of parasitic wasps will provide significant control of *Helicoverpa* eggs in southern Victoria.

15. Key Issues

- For the first time in lettuce crops, in the trials at Narre Warren and Lindenow, very high levels of the Brown Sowthistle aphid (a recent arrival to Australia) were observed.

- Some growers have preferred to maintain an IPM program rather than use broad spectrum insecticides to control the thrips and tolerated some crop loss to Tomato Spotted Wilt Virus as part of their pest and disease management.

- There needs to be better understanding of resistance management and the use of IPM programs. Some growers are tank mixing soft and broad-spectrum chemicals. This is not good resistance management practice, is more expensive and will reduce the value added effect of using soft chemicals because the beneficials will also be killed.

- If broad-spectrum chemicals are to be used and alternated with targeted soft chemicals the first spray application should be with the targeted soft chemicals to retain the impact of beneficials.

- Some growers are continuing to use the high rates of spinosad when pest pressure is low. This will not aid resistance management or improve the kill and will be more expensive.

- The results from the project highlight the need for careful monitoring of crops, particularly as the industry moves away from broad-spectrum insecticides towards more selective compounds. Crops need to be monitored carefully for eggs of *Helicoverpa* and destructive sampling needs to begin once hearting has commenced for early instar larvae can enter the plant from underneath leaving little or no visible sign and cause significant internal damage.

- There is still no evidence that *T. pretiosum* has overwintered in Victoria. It is unlikely that endemic populations of parasitic wasps will provide significant control of eggs in southern Victoria. Under low pest pressure it is unlikely that the release of the wasp would be useful but more detailed observations of activity of egg parasitoids are required.

- In the first seasons trials, analysis of the syrphid larvae data revealed that the numbers of syrphid larvae in the Success® treatment were significantly lower than for the other treatments (apart from Dominex®).

- There needs to be monitoring for other pests and subsequent response in beneficial numbers needs to be assessed before using broad-spectrum insecticides. Effective predators of pests such as aphids exist and control sprays may not be needed. Once aphids are found, virus transmission would already have occurred, the issue will be the protection of subsequent crops.

- During the course of the project even though pest pressure, was low individual growers still experienced significant crop damage from time to time if egg lays were missed and spray timing was not accurate.

16. Recommendations

- Don't mix broad spectrum and targeted or biological pesticides. Do not use high rates of pesticides when pest pressure is low if there are high and low pest pressure rates on the label.

- Careful monitoring of crops for the range of pests and beneficials is essential, as the industry moves away from broad-spectrum insecticides towards more selective compounds.

- There needs to be better understanding of resistance management and the use of soft targeted and biological pesticides in an IPM program.

- The appropriate timing for the use of biological insecticides such as NPV or Bt is from transplant to pre-hearting and the targeted soft insecticides should be used from pre- hearting to harvest unless pest pressure is high.

- Once lettuce have hearted it will be beneficial to destructively sample some of the crop to check scouting observations because in some cases there may be no external indication of damage.

- As part of an IPM strategy it is important that beneficials are conserved by avoidance of broad-spectrum insecticides such as Dominex®.

- Knowledge of moth counts and egg lay is critical in managing a spray program.

17. Recommendations for Future Work

Further studies on impact of spinosad on syrphid and lacewing larvae are warranted.

More detailed observations of activity of egg parasitoids are required for *Helicoverpa* spp.

There is a need to develop IPM strategies for the control of thrips in an IPM system

Lettuce aphid is the major threat to the Victorian industry and its impact on IPM systems and the use of various control methods need to be assessed.

The development of user friendly software for forecasting emergence of local moth and egg hatch times of *Helicoverpa* spp based on near real time temperature to allow better targeted pesticide application.

18. Appendix 1 – Technology Transfer

Scout Training/ Courses

For industry in East Gippsland a scout training course was delivered to up to 8 industry participants comprising growers and staff from chemical resellers. Each participant was provided with a pack that included magnifying glass, vials paint brush,ute guide, thrip ID information, scouting record sheets and an instar card for *Helicoverpa*.

Around 8 full days scout training was supplied to this group in addition there was one on one direct support. The days included 3 on lettuce, in brassicas, 1 on sweet corn and 3 days covering a range of crops.
Five of this group also took part in a Thrips Identification course delivered at the Institute for Horticultural Development, Knoxfield.

Media Articles

Lettuce storage improved by choosing the right cultivar. Good Fruit and Vegetable Grower January 2002.

Improving Lettuce Crops. Bairnsdale Advertiser June.

Nitrogen could be affecting lettuce crops. Good Fruit and Vegetable Grower and Bairnsdale Advertiser July 2002.

Project addresses lettuce pests. Good Fruit and Vegetable Grower September 2002.

Best practice in lettuce. *SHORTs* Edition 7, September 2002.

"Focus on biological insecticides". Good Fruit and vegetables September, 2003

Vegetable Matters of Facts, Number 11 December 2003, article on "Managing Tipburn"

Are we wasting nitrate on lettuce in summer? Vegetable Matters, Issue 6, October 2002.

Information Sheets / Brochure

"Improving Insect Pest Management in Lettuce" – recommendations for corn earworm control in lettuce circulated to all stakeholders for the current season.

Lettuce – Best production management practices February 2003.
A 4 page brochure distributed to all stakeholders with notes on nutrition, irrigation and pest management practices and a section on improved Tipburn management.

Agnote on Lettuce Production to support brochure – available on web and CD rom

Agnote on Tipburn in Lettuce to support brochure – available on web and CD rom

Managing Thrips in Lettuce

Lettuce Aphid meeting Notes, DPI – Knoxfield April 2004.

"Improving Insect Pest Management in Lettuce" – recommendations for corn earworm control in lettuce circulated to all stakeholders at end of the project.

"Scouting Protocol for Lettuce Crops" – recommendations for corn earworm control in lettuce circulated to all stakeholders at end of the project.

All these brochures and information sheets have been circulated to all stakeholders and are also available on the web at the following site:-
www.nre.vic.gov.au/agvic/ihd/projects/lettuce.htm

Newsletters and Articles

Lettuce Leaflet, Issue 8, February 2003
Lettuce Leaflet, Issue 9, April 2003
Lettuce Leaflet, Issue 10, June 2003
Lettuce Leaflet Issue 11, August 2003
Lettuce Leaflet Issue 12, December 2003
Lettuce Leaflet Issue 13, December 2003
Lettuce Leaflet Issue 14, February 2004
Lettuce Leaflet Issue 15, April 2004
Lettuce Leaflet Issue 16, June 2004
These have been produced in conjunction with NSW Agriculture and are a joint effort circulated to all stakeholders.

Web Site
A web site has also been set up to service the project with reports from the previous project and the current project as well as copies of the newsletters, links and more detailed information.

www.nre.vic.gov.au/agvic/ihd/projects/lettuce.htm

Meetings
Scouting field days held in conjunction with NSW Ag at Werribee 24/3/04 and Cranbourne 25/3/04
Lettuce Aphid Conference Knoxfield 6/4/04.
Lettuce Aphid Meeting Riverside 16/6/04
Lettuce Aphid Meeting Cranbourne 25/6/04
Lettuce Aphid Video Conference Werribee and Lindenow 30/6/04
Lettuce Aphid Meeting Lindenow 30/6/04.

Fax/E-mail Moth Counts
Weekly moth counts were e-mailed, faxed or sent via SMS to lettuce growers in Cranbourne and Werribee areas during the period of the project from October until the end of April.

Weekly moth counts were e-mailed or faxed to lettuce growers industry scouts and spray contractors in the East Gippsland area from September until May.

This information collected for the project was provided to industry to keep it up to date on pest pressure of both *Helicoverpa* spp. in these areas. The information was also used by other industries, which have crops susceptible to attacks from these pests.

These weekly moth count reports including beneficial activity have been distributed by Fax, email and SMS to over 100 stakeholders during the life of the project.

Lettuce Aphid Steering Committee

Through the auspices of this project and Vegcheque a Lettuce Aphid Advisory Group has been formed and a second meeting was held on the 28th of November 2003, and attended by lettuce growers and representatives from AusVeg, chemical industry, IPM providers, agronomists, seed suppliers, nurseries, wholesale distributors and DPI-Vic staff. Minutes from the meeting are circulated and a report on the steering committee has been in the newsletter.

The industry has also become much more aware of the potential of beneficial insects, so much so that an unusual number of ladybird beetle present in crops in the last spring, resulted in a reduced need to apply chemical control for aphid but caused comments from supermarkets regarding contamination of lettuce due to the presence of the beetles.

19. Appendix 2

Feedback comments on scouting services.

- Have saved much more money this season than last, not just in chemicals, but in wages for spray contractor.
- We don't like using chemicals, especially methomyl's and OP'S, carbonates. Bad for health and beneficials.
- We hated using phosdrin® and lanate®/marlin®.
- IPM is really interesting, I wish I had time to learn more about it.
- You really need the right person you can trust with monitoring, last few seasons's lost us money for not only scouting but a bad crop at the end.
- IPM is definitely the way of the future, those that don't want to except it will fall by the wayside, it's what we want and what the consumer demands.
- IPM is a whole systems approach, where the crop monitor can pass on information not only about invertebrate pests, but about diseases, viruses, nutritional disorders and fungal problems.
- We would like to learn more about day degree modelling.
- We do use scentry trap data as an indicator for potential rises in populations.
- We are surprised by the numbers of beneficals since we have been using more selective chemistry and applying chemical's less frequently.
- We would like to implement IPM over our whole farm, maybe plant some cover crops for beneficials to build up and sustain populations, so they are in higher numbers when they are needed the most.

20. Appendix 3

List of Pests Commonly Observed

Common name	
Corn earworm	*Helicoverpa armigera*
Native budworm	*Helicoverpa punctigera*
Lucerne leaf roller	*Merophyus divulsana*
Leaf hoppers	*Cicadellidae*
Green peach aphid	*Myzus persicae*
Brown sowthistle aphid	*Uroleon sonchi*
Sowthistle aphid	*Hyperomyzus lactucae*
Onion thrips	*Thrips tabaci*
Plague thrips	*Thrips imaginis*
Tomato thrips	*Frankiniella schultzei*
Rutherglen bug	*Nysius*
Cutworm	*Agrotis* spp.
Cluster caterpillar	*Spodotera litura*
Whitefly	*Trialeurodes vaporariorum*
Mites - various	

List of Beneficials Commonly Observed

Common name	
Transverse ladybird beetle	*Hippodamia variagata*
Striped ladybird beetle	*Micraspis frenata*
Minute two spotted ladybird beetle	*Diomus notescens*
Brown lacewing	*Micromus*
Hoverfly larvae	*Syrphidae*
Soldier beetle	*Chauliognathus lugubris*
Damsel bug	*Nabus kinbergii*
Pirate bug	*Orius spp*
Assassin bug	*Pristhesancus* spp.
Tachinid flies	*Tachinidae* spp.
Wasps - various	
Spiders - various	