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Adapting to Change: Enhancing Skills through collaboratively developing and integrated pest management strategy for lettuce

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NSW Agriculture

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Media Summary

A significant Lettuce Integrated Pest Management project has been completed. This project was a collaboration between researchers at NSW Agriculture's National Vegetable Industry Centre at Yanco and from Queensland Department of Primary Industries. Running between July 1998 and June 2001 the project was partially funded by Horticulture Australia.

Key outcomes include:

- significant variation from week to week and from paddock to paddock in pest and disease incidence.
- efficacy data that contributed in the registration of the soft insecticides Success® and Avatar®, the biological insecticide Gemstar®, and the minor-use permit for *Bacillus thuringiensis* for the control of Heliothis caterpillars. Other trial data generated will also be used to obtain registrations for two other insecticides for use in lettuce.
- trial data indicating some reduction in incidence of Sclerotinia with the use of a biological control agent, *Trichoderma* spp.
- comparisons of current spray techniques showed that equipment with air assistance and dropper attachments achieve better coverage and droplet densities over the whole plant than conventional hydraulic boom sprayers.
- BMO trials showed that regular crop monitoring and optimal timing of insecticide applications can reduce the number of sprays.
- grower discussion nights, field days, farm walks and pest ID workshops facilitated the flow of information between growers and researchers.
- the first Australian lettuce industry conference at Hay.
- LettuceLeaf newsletter, fact sheets, and a 160-page full-colour IPM manual.

Key recommendations for an IPM system in Lettuce are:

- weekly monitoring for insects and diseases.
- keeping records of monitoring and harvest assessments.
- using spray thresholds.
- timing spray applications for caterpillars at egg-hatch.
- using regularly calibrated spray equipment.
- modifying hydraulic spray booms with droppers to improve coverage or using air assist technology.
- being familiar with pest and disease organisms and their life or disease cycles.

Areas for further work include:

- trialing other new chemical or biological options for Heliothis caterpillars and other sap-sucking pests.
- conducting 'Best Management Options' trials to refine the lettuce IPM strategy in a range of conditions
- investigating the field biology of varnish spot.
- developing tools to help diagnose jelly butt.
- trials investigating the potential of sprayer shrouds to improve spray coverage and reduce drift.

Technical Summary

Lettuce is a crop in which all but a few outside wrapper leaves are harvested and sold for consumption. It therefore has very little tolerance for damage. Prior to this project lettuce growers in Australia were principally calender sprayers using overhead boom sprayers. Many growers were not confident in distinguishing between pest and beneficial insects of lettuce. This project defined a crop monitoring protocol, identified the key pests and diseases, developed management guidelines for all key pests, increased the number and improved the efficacy of control methods available to lettuce growers, and developed tools to aid growers in making pest management decisions.

Regular pest and disease surveys in Hay, NSW were conducted to monitor the range and incidence of pests in head lettuce throughout the growing season. Heliothis (*Helicoverpa armigera* and *H. punctigera)*, particularly *H. armigera* is the key insect pest in Hay in late summer and early autumn. Loopers (*Chrysodeixis* spp.) and Cluster caterpillars (*Spodoptera litura)* were also found in autumn and spring. Aphids (various species) were usually only present in late autumn and thrips (various species) were primarily a problem in spring. Rutherglen bug (*Nysius vinitor*) can be a spring pest, primarily as a contaminant of lettuce rather than from direct feeding damage. Very few insects were found in the crops in June or July. Sclerotinia (*Sclerotinia sclerotiorum* and *S. minor*) was the most frequent and widespread disease. Most winters Big Vein virus was present and prevented some lettuce from hearting. Varnish spot (*Pseudomonas* sp.) was observed in late winter and in some paddocks the crop was unharvestable. Necrotic Yellows virus was an occasional disease and reached levels above 1-2% in only one paddock.

In QLD *Helicoverpa armigera* is again the key insect pest, with loopers, Cluster caterpillar, thrips, aphids, Rutherglen bug, and Lucerne leafroller (*Merophyus divulsana*) being occasional or minor pests. In order of importance, Downy mildew (*Bremia lactucae*), Sclerotinia, bacterial diseases (leaf spots and soft rots), *Rhizoctonia* and virus diseases are the most commonly found disease disorders in lettuce.

Replicated small plot field trials were conducted in NSW and QLD to assess efficacy of various insecticides: Heliothis Nuclear Polyhedrosis virus (NPV), *Bacillus thuringiensis* (Bt), Petroleum Spray Oil (PSO), spinosad, indoxacarb, emamectin benzoate, chlorfenapyr and azidoractin. Feeding stimulants, Pheast® and milk powder, and a extender-sticker, NuFilm-17® were trialed as additives to improve the efficacy of Bt. spinosad, indoxacarb, Bt, emamectin benzoate and chlorfenapyr all performed well in controlling Heliothis. Bt efficacy was not improved by the additives. The NPV had some effect on Heliothis but was not as effective as a conventional program. Azidoractin performed poorly. The data from these efficacy trials have helped with the registration of Success® (spinosad), Avatar® (indoxacarb) and Gemstar® (NPV), and the permit for Bt. Data for emamectin benzoate (Proclaim®) and chlorfenapyr (Secure®) will aid with future registration.

Trichoderma spp., a biological fungicide was trialed in Hay against Sclerotinia with some success. A single application of procymidone immediately after thining (direct seeded crop) gave almost complete control of Sclerotinia.

Some 'best management option' trials were conducted to assess the potential of an IPM strategy using the best available options at the time of the trial as compared to the current grower practice. The results showed that the soft options Bt and spinosad performed as well as the conventional plots but tended to be more expensive.

A comprehensive trial was conducted comparing all the application methods currently used in lettuce. The results showed that a boom fitted with short droppers plus over the top spraying gave an significant increase in droplet densities in the bottom part of the plant canopy zone, compared to spraying with and without air assistance. The conventional boom had the lowest deposit within all zones, the bottom and top part of the canopy received below the recommended droplet densities for insecticide and fungicide application. Further testing is required with air-assisted sprayers to determine if there are significant differences in spray coverage for the different settings (air velocity and angle) of the equipment. Similarly work is needed on the use of shrouds on all applicator types trialed to investigate whether significant improvements in coverage and reduction in drift could be attained.

Pest identification workshops were held in Hay, Sydney, Werribee and central western NSW. Spray nights were held in Gatton and Hay. Discussion evenings were held in Hay, Sydney and Gatton. Some pest and disease information sheets and draft crop monitoring protocols were produced and combined into an IPM handbook for head lettuce.

Introduction

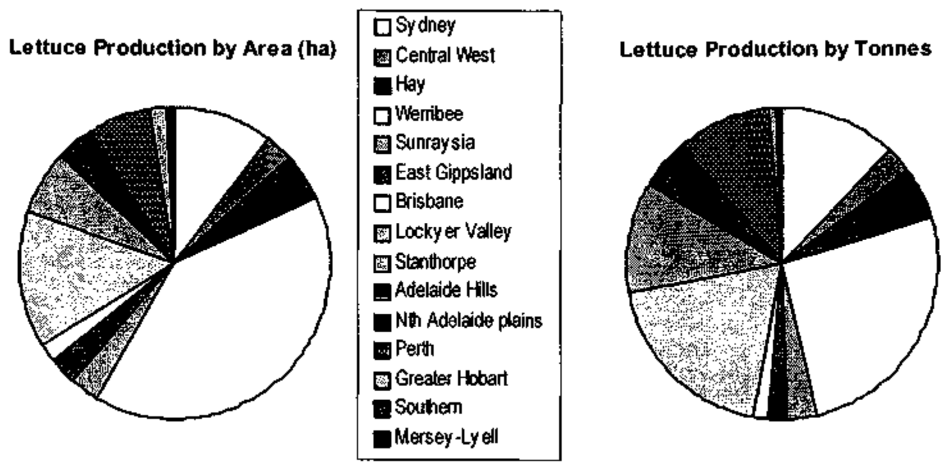
Australian Lettuce Industry

Approximately 125,924 tonnes of lettuce is grown on 5,917 ha in all states of Australia (Table 1, Figures 1a & 1b). Lettuce is conservatively worth $93 million in 1998, including $8 million from exported crops. Production is concentrated in 1 to 3 areas in each state and production windows overlap between areas, so lettuce is produced in at least 2 to 3 areas at any one time and is available all year round. Growing practices vary between region, but are fairly similar within each region.

Table 1. Major lettuce producing regions around Australia, 1999. Courtesy of Australian Bureau of Statistics.

Region (Statistic District)	State	Area (ha)	Production (t)	Spring	Summer	Autumn	Winter
Sydney	NSW	607	14986	Yes	Yes	Yes	Yes
Central West	NSW	171	3662	Yes	No	Yes	No
Murrumbidgee	NSW	305	6779	Yes	No	Yes	Yes
Melbourne	VIC	2398	33004	Yes	Yes	Yes	No
Mallee	VIC	188	3816	Yes	No	Yes	Yes
East Gippsland	VIC	163	2615	Yes	Yes	Yes	Yes
Brisbane	QLD	114	1796	Yes	Yes	Yes	Yes
Moreton	QLD	846	24135	Yes	No	Yes	Yes
Darling Downs	QLD	387	14587	Yes	Yes	Yes	No
Adelaide	SA	217	6069	Yes	Yes	Yes	Yes
Outer Adelaide	SA	26	498	Yes	Yes	Yes	Yes
Perth	WA	388	12168	Yes	Yes	Yes	Yes
Greater Hobart	TAS	55	1064	Yes	Yes	Yes	No
Southern	TAS	18	323	Yes	Yes	Yes	No
Mersey-Lyell	TAS	34	422	Yes	Yes	Yes	No

Figure 1a & 1b Australian Lettuce Production



Crisphead lettuce is the main lettuce grown and sold in Australia. It is primarily grown in ground and sold on the domestic market through the wholesale markets, directly to the supermarket chains or to the 'processors' for fast food preparation. A small proportion is exported. Increasing quantities of crisphead lettuce is shredded for fast food chains. Fancy lettuce is growing in popularity, is principally grown hydroponically but a small proportion is grown in-ground. Fancy lettuce may be sold whole or increasingly 'semi-processed' and sold in washed leaf mixtures. The fancy lettuce production is concentrated in peri-urban areas around the major cities.

Prices are variable and fluctuate depending on current levels of production and lettuce quality. Oversupply of the markets is a common complaint from growers as it drives the prices down and may result in marginal if not negative returns.

Lettuce varieties are chosen for their climatic suitability, for disease resistance and market acceptability. Growers have a wide choice of lettuce varieties from a number of seed companies.

Insect pests and diseases can cause major crop losses and create unacceptable contamination for the semi-processed lettuce and export markets. In Australia, annual losses to Heliothine moths, particularly *Helicoverpa armigera* Hubner, amount to $1.48 million, which represents about a 10% loss in profit margin. Diseases, such as sclerotinia, bigvein, downy mildew, botrytis and necrotic yellows, also cause production losses of about 10% in profit margin. Other insects, such as aphids, thrips and other caterpillars also pose serious problems to the lettuce industry. In addition, both pests and diseases can cause serious post-harvest quality problems.

Yields and growing practices vary between districts, however average yields are 55–60% of the maximum possible yield. Calculations by NSW Agriculture of gross margins for head lettuce in NSW indicate that if average yield is increased by 10% then net returns increase by 50%. Similarly, if average yield is decreased by 10% then net returns drop by 50%.

World Market Trends

The globalisation of the world market has and will continue to impact both export and domestic markets. With the dropping of trade tarrifs other non-tarrif barriers are being erected. One is MRLs or maximum residue limits for pesticides. Another that may be used is environmental impacts as assessed by PPMs or process and production methods. These are aiding a push for pesticide reduction and for greater accountability in production to consumers. One answer is the adoption of quality assurance or management (QA or QM) systems. Although MRLs and PPMs primarily impact on exporters, the domestic market for lettuce is increasingly being channelled through Supermarkets who are also starting to require QA certification. A fundamental for a QA system is to document the production or processing system protocol and be able to monitor its functioning. Critical control points, or points in the protocol which pose greatest risk to quality or safety of the product, are monitored closely. Pesticide residues are the major safety concern in vegetable production hence pesticide choice and application are critical control points. At the onset of this project most lettuce growers were calender sprayers and many were using chemicals not registered for lettuce, neither practice is acceptable for a QA system, nor within a social climate pushing for a reduction in pesticide use. An Integrated Pest Management (1PM) system is likely to be a minimum requirement for a QA system.

Integrated Pest Management

IPM systems are being developed all over the world for a range of crops. IPM systems are based on an understanding of the crop-pest-beneficial ecology and utilize a range of management strategies that may include the strategic use of pesticides for pest management. A fundamental component is to know what pests are in or affecting a crop on a regular basis and make management decisions to maximise the use of natural population control measures and to use more interventionist methods when pre-set economic thresholds are reached. The basic concept and approach is applicable anywhere but the specifics need to be worked out for a given region and cropping pattern.

Developing IPM strategies for Lettuce in Australia

At the onset of this project lettuce, like many vegetables, had relatively few pesticide registrations, particularly for some of the newer "softer" pesticides. The first steps to develop an effective IPM system for lettuce in Australia was to survey the fluctuation of pests in crops, to design a routine monitoring protocol and to increase the range of management options. Since IPM systems seek to utilize natural mortality factors where possible the evaluation of biological pesticides, such as: the Heliothis virus and Bt were given a priority. Monitoring of the range and density of beneficial insects was also undertaken to gauge their potential importance in the system. Given most growers use pesticide sprays as the preferred management strategy modifications in spray application methods have potential to greatly improve the targeting of sprays in time and space.

Because IPM requires a change in management culture and adaptation to the specifics of each cropping system it is important that growers are active in its development. IPM is a management tool that co-evolves as researchers and growers learn more about the important interactions within a cropping system. Successful IPM systems both here and overseas have had the active involvement of the growers early in its development. Traditional research development and extension practices have not been particularly successful in having IPM adopted, specifically because the pest management decision-maker needs to understand the system they are making decisions for, and outside prescriptions need to be modified for each situation.

The changing marketing environment requires a more systematic approach to pest management. Similarly societies values are demanding a reduction in the use of pesticides and greater accountability when they are used. IPM gives a systematic approach to pest management and offers the greatest potential for allowing growers to reduce their reliance on pesticides. The development of an IPM strategy needs the pooled talents of researchers and growers alike.

Project

This project grew initially out of an HRDC AusVeg meeting with Hay lettuce growers in December 1996. Subsequent meetings in May, July and August 1997 developed the project proposal that was submitted and approved for the 1998 round of projects. QDPI joined the project with expertise in Heliothis pest management and spray application technology before final approval. The basis of the project in Hay was to be the use of regular grower group meetings/workshops covering topics of interest to the growers, such as: pest and disease identification, pest and disease management, marketing, quality assurance.

We provided growers with the opportunity to bring in specimens for identification and to discuss pest and disease management issues. We monitored some lettuce crops through establishment to harvest over the three and a half growing seasons of the project. On-farm trials were conducted to test efficacy of a range of insecticides and disease control methods.

Through discussions with growers, researchers and other industry people it was evident that caterpillars are key pests of lettuce in all lettuce growing areas of Australia. At different times of the year and parts of Australia different caterpillar species are present, but the most problematic caterpillar is *Helicoverpa armigera* (Heliothis). The caterpillars of both Heliothis species (*H. armigera* and *H. punctigera*) feed on the lettuce leaf and usually burrow into the centre of the lettuce, protecting itself from some predators, spray applications and, if they move into the lettuce head early enough, they are difficult to detect at harvest. *H. armigera* is a particular problem in that it has developed resistance to the key insecticide groups used for its control. In southeastern Australia *H. punctigera* is most commonly a problem in spring, while *H. armigera* is most commonly a problem over the summer and autumn periods. With Heliothis, particularly *H.armigera* identified as the major insect pest our initial efforts were on establishing a monitoring protocol and increase the management options.

Monitoring crops on a regular basis is the most basic step in an IPM strategy and it then allows for informed decisions on what pests are present, and what stage and condition the crop is in. Another step in an IPM strategy is the use of agronomic or 'cultural' management techniques to minimise pest problems, such as choice of disease resistant varieties or timing of lettuce plantings to avoid the peak pest populations. Other steps include the use of biological pesticides, or pesticides that have minimal impact on beneficial organisms, timing any spray applications to coincide with the period of greatest vulnerability of the target pest, and the use of best available spray application techniques.

This research project has developed a monitoring procedure, and some guidelines for what numbers of a particular pest constitutes a problem that needs controlling (pest threshold), improved spray application techniques, and a wider range of choices for insecticidal control. Caterpillar management to date has relied very heavily on synthetic pyrethroid and carbamate insecticides for control. Most growers have routinely used these insecticides whether caterpillar pests were present or not. Since the key caterpillar pest, *H. armigera* is resistant to both these groups, control has not been as effective as growers or the market would like. Concerns about environmental and human safety have been raised with these chemicals and others like them. As part of this project small plot trials were conducted to evaluate the efficacy of a number of biological and new generation insecticides for control of *H. armigera*. Registration for a new insecticide in a new chemical group in lettuce was achieved in spring of 1999 with Success® (spinosad). A permit for the use of *Bacillus thuringiensis kurstaki* (Btk) was granted in 1998. And registration documentation has gone into the national registration authority on another new generation insecticide but has yet to be registered. All these insecticides are less harmful on most beneficial insects than the other broad-spectrum insecticides available for use. Btk is specific to caterpillars and does not adversely effect any beneficial insects. Whilst spinosad is known to be toxic to most caterpillars, some thrips and parasitic wasps.

Efficacy trials are usually conducted in small plots, using handheld spray devices, and to avoid confusion about what chemical is doing what, each treatment plot uses the same chemical and chemical rate repeatedly throughout the trial. Using the same chemical group repeatedly is the quickest way to encourage a resistant pest population and is therefore not considered good pest management practice. In the last year of this IPM research project we combined the tools we had developed into what we called the Best Management Option (BMO) and compared this to current grower management practice.

Grower Surveys

I. NSW Lettuce Grower Current Pest and Disease Management Practices

Growing Districts

Lettuce production in NSW is predominantly carried out in 3 main growing regions: Hay, Sydney Basin and more recently in the central western tablelands. In 1998 there were 14 Hay lettuce growing farms, in 2001 there are 9. Hay growers grow on average 15 hectares of lettuce per year, with the largest growers growing 100 ha per year. There has not been much change in the area grown over the last 4 years in Hay. As the smaller growers drop out the larger growers put more in. About 300ha of lettuce is grown each year in Hay. All Hay growers are supplying the fresh market and 2-3 growers supplying processors. About 600ha of lettuce is grown in the Sydney basin each year with it supplying primarily fresh market options with some going to processors.

Planting Times

Hay grows lettuce over the autumn, winter and spring periods, Sydney basin grows all year but with less production during the summer and in the central west lettuce is grown in the autumn and spring windows.

Hay growers direct seed their crops, some plant from early February with all growers sowing by mid March. The last sowing occurs from mid May to mid September depending on the grower. Growers sowing early and finishing late are generally taking some risks with respects to pest problems, in particular Heliothis. Some growers have daily sowing schedules, whilst the smaller growers tend to have a weekly schedule. Although climatic conditions are similar in the central west, growers there avoid the coolest time of the year and the risks of serious frost damage.

Central west and Sydney basin growers all use transplants. The more moderate climate and proximity to market allows from year-round lettuce production in the Sydney basin, although smaller plantings are grown over the summer and winter months. Quanitities grown vary depending on rainfall and humidity.

The central west spring transplanting starts the 2nd week in July and is finished by the end of September. Harvest starts in mid- September and runs through to December. The central west autumn transplanting starts in the 2nd week of January and is finished by mid March, with harvest running from mid March to late May.

Varieties Grown

Each region has it's preferred varieties:

Hay - Greenway, Wintergreen, Target, Magnum, El Toro and Patriot. Greenway is the only variety grown over the winter window.

Sydney – wide range

Central West – Greenway was the main variety in 1998 but very little is grown in 2001. Target and Magnum are the main varieties for the warmer periods and Assassin, Marksman and Musketeer are planted when its cooler.

Irrigation

In 1998 in Hay all growers used furrow irrigation. One grower has been experimenting with drip irrigation. During the winter months irrigation is rarely required. In the Sydney basin, and Central West all growers use overhead irrigation, except one Central West grower who uses drip irrigation for part of his lettuce operation.

Weed Control

Kerb® is the only pre-emergent herbicide used in Hay, but because of its cost it is only used by a few growers. Stomp® is never used in Hay as it is unsuitable for direct seeded crops. All Hay growers inter-row cultivate and hand weed.

Kerb® was the most popular pre-emergent herbicide 3 years ago in the central west and Sydney basin. Due to the low cost of Stomp®, it is now the most widely used per-emergent herbicide. Majority of growers would also scuffle once and go through and hand chip any remaining weeds generally once and sometimes twice.

Pest and Disease Management

Helicoverpa species are by far the most serious insect pest found attacking lettuce throughout NSW. They are most common during the autumn and spring periods with very little to no activity during the winter months. Where lettuce is grown during the summer months Heliothis can also be a major problem.

In 1998 the insecticides available for Heliothis control included the ovicide methomyl and various larvicides such as: endosulfan, diazinon, synthetic pyrethroid (alpha cypermethrin), methomyl, and carbaryl. Most growers used methomyl, the synthetic pyrethroid and endosulfan on a calender spray program. *Helicoverpa armigera*, corn earworm has resistance to these three insecticide groups. In 2002 Success®, Avatar® and Gemstar® have now been registered for Heliothis control and a permit for Bt has been in place for three seasons. Endosulfan is no longer available to lettuce growers.

The next most important pests are sucking insects such as thrips and aphids. Direct feeding from both thrips and aphids can sometimes be a problem with transplants or seedlings. The spreading of diseases by some species of thrips and aphids can occasionally be a major problem. Although Rutherglen bugs rarely do much damage to the lettuce itself they can be a problem from time to time with live or dead insects contaminating both processed and fresh lettuce. Sucking insect pests are generally controlled by dimethoate and endosulfan, and sometimes growers will use Pirimor for aphid control.

Sclerotinia and Downy Mildew were considered to be the main disease problems faced by all NSW growers. Hay growers also had problems with Big Vein virus, particularly during cold wet conditions. Sydney growers occasionally have trouble with Big Vein. Growers reported that in some years, in some paddocks Necrotic Yellows virus was a problem. Tomato Spotted wilt virus, Anthracnose, Grey mould and Bacterial rots were also reported as potential problems in Hay. Sydney basin growers reported potential problems with all lettuce diseases and the Central west growers reported viral diseases as being of major concern. Downy Mildew is primarily controlled using resistant varieties but in 1998 a new pathotype emerged which the previously resistant varieties were susceptible to and was a problem until the release of new varieties resistant to the new pathotype. In Hay iprodine (Rovral®) and procymidone (Sumisclex®) were used routinely for Sclerotinia. Metalaxyl (Ridomil®), mancozeb (various) and copper oxychloride were used on Downy Mildew.

Crop Monitoring

In 1998 none of the growers used routine systematic monitoring of lettuce crops in any of the NSW lettuce growing areas. All growers had a regular spray program with some modification depending on prevailing weather conditions or from casual observations in the crop when attending to other management matters. Growers looked for caterpillars, thrips and aphids; few other insects were recognized.

Pesticide Application

The majority of lettuce growers in NSW applied pesticides using a conventional boom sprayer. Two of the growers in Hay used droppers on their spray rigs. Water volumes used in spray application ranged from 150-800 L/ha .

In Hay most growers divided the growing season into early season, winter and late season and varied the frequency of insecticide applications accordingly. In the early season most growers sprayed for insects at 7-10 day intervals although some sprayed as frequently as every 4 days and another as long as 18 days depending on conditions. During winter some growers didn't spray others continued to spray at 7 day intervals. In the late season (spring) growers sprayed on 7-21 day intervals. Some growers only sprayed fungicides when weather conditions were wet and warm where as others sprayed on 7-14 day schedules. Some growers calibrated their equipment regularly, most didn't.

II. South East Queensland Lettuce Grower Current Pest and Disease Management Practices

Growing Districts

Lettuce production in South East Queensland is predominantly carried out in 4 main growing regions, Lockyer Valley, Redland Bay, Stanthorpe and Toowoomba. Stanthorpe and Toowoomba are generally restricted to the spring, summer and autumn periods while the Lockyer Valley and Redland Bay regions are restricted to the autumn, winter and early spring periods. The two districts tend to complement one another in their production cycles.

Planting Times

Growers in the Lockyer Valley would start planting their crops from the middle of February with the last planting occurring about the beginning of September, which is generally taking some risks with respects to pest problems, in particular Heliothis. Toowoomba and the Darling Downs will grow lettuce during the spring summer autumn periods while Stanthorpe can only grow during the summer autumn months as it is generally too cold for winter production.

Varieties Grown

Lockyer Valley – Those varieties most commonly grown in this region include:
Silverado, Greenway, Oxford, Titanic, Sea green, Crystal, Fame, Black Velvet and Raider.
Of the growers surveyed, their lettuce would be for both processing and fresh market with some export taking place especially when the local domestic market is depressed.

Darling Downs – Only one grower has been surveyed from this region and they were growing:
Classic during the warmer weather and Sea Green during the cooler months.
This grower sold both to fresh market 65% and processing 35%
Stanthorpe - similar to Darling Downs.

Irrigation

All growers used overhead irrigation especially with the establishment of their seedlings during the first two weeks. Only one grower then used drip irrigation after this time to continue watering, the other growers continued to use overhead irrigation.

Weed Control

Stomp® pre-emergent herbicide would be the most widely use amongst growers with Kerb® being used by only a small number of growers. Majority of growers would also scuffle once and go through and hand chip any remaining weeds generally once and sometimes twice.

Pest and Disease Management

Helicoverpa species are by far the most serious insect pest found attacking lettuce throughout Queensland. They are most common during the autumn and spring periods with very little to no activity during the winter months. Where lettuce is grown during the summer months Heliothis is also a major problem.

Those insecticides commonly used for Heliothis control include the ovicide methomyl and various larvicides such as endosulfan, diazinon, synthetic pyrethroids, carbaryl and Bt. The new insecticide Success® will be trialed by local growers during the next season for Heliothis control. This will hopefully relieve some of the resistance pressure on the other insecticides.

Sucking insects such as Thrips and Aphids would be the next most important insect pests in lettuce, although they are considered as minor in importance. Rutherglen bugs can also be a problem from time to time with dead insects ending up trapped with in the leaves which results in a consumer backlash about insects being found in their lettuce. This group of insect pests is generally taken care of by the synthetic pyrethroids and endosulfan, with Pirimor® or dimethoate for general aphid control.

In order of importance, Downy Mildew, *Sclerotinia*, bacterial diseases (leaf spots and soft rots), *Rhizoctonia* and virus diseases are the most commonly found disease disorders in lettuce growing regions of Queensland. DM is becoming more serious due to its ability to develop resistance to the commonly used fungicides. There are resistant or tolerant varieties available but they are not as appealing to the consumer as the older varieties. Depending on weather conditions growers may spray on a schedule basis, particularly during periods of overcast rainy weather when DM problems are exacerbated. *Sclerotinia* is generally a problem where weeds have been left, creating a moist environment for disease development. There is some anecdotal evidence that using a brassica crop in a rotation with lettuce help in reducing the incidence of soilborne diseases such as *Sclerotinia* and *Rhizoctonia.* This is due possibly to the biofumigation angle that brassicas perform when incorporated into the soil.

Crop Monitoring

Crops are checked twice a week when conditions are warm and pest pressure is high and once a week during the cooler times of the year. Monitoring seems to be carried out on a planting basis if the grower can afford the cost of a scout or on every second planting. One grower did monitor on an area basis, which may take up a number of plantings being monitored at any one time.

Monitoring for Heliothis is generally conducted on the presence of eggs. It is considered to be too late if grubs are found in the crop, as it is near impossible to control the larvae once they are covered by the lettuce leaves. Threshold levels range from 2 eggs per 10 plants to 2-3 eggs per 20 plants and on one property where they grower does his own monitoring the threshold levels are 1 egg in 50 plants before spraying is recommended. Larvae thresholds are generally 1 larva per 20 plants. Heliothis eggs are also checked by some growers for *Trichogramma* and this is used in their decision making process with regards to spraying.

Other insects generally monitored for include Loopers. These are treated in the same manner as Heliothis and are much easier to control as they feed on the outside of the leaves where they can be contacted by the insecticides. Lucerne leaf roller can be a problem due to their leaf rolling habit and the difficulty in controlling this pest due to its behaviour. Crop scouts in monitoring for this pest use a threshold of 2 larvae per 20 plants. There is a need to try and recognise the eggs so that they can be targeted before the larvae are a problem. Cluster caterpillars can also be a problem in lettuce with 2 egg masses per 20 plants or 1 larval mass per 20 plants being the recommended threshold for this pest before spraying is required. Aphids are the other insect pests of concern to growers due to their ability to spread diseases. They are generally found on the older leaves and if they are found on the majority of plants checked, they are then sprayed for. One crop scout also checks for the presence of parasitised aphids and uses this in his spray decisions. Aphids are usually kept in check with some of the larvicidal sprays.

The number of plants checked at each site varies between crop scouts and grower. Two to three plants are checked at each monitoring site when the plants are seedlings, to one plant per site as the plants get older, 2-3 weeks after planting, with monitoring finishing one week before harvest, which is due in part to the withholding periods of the insecticides and the Heliothis are not as attracted to the maturing heads.

Pesticide Application

Pesticides are applied using either a conventional boom sprayer without droppers or Control Droplet Applicators (CDA), micronair or air shear equipment. Both types of equipment have shown to give adequate control of both insects and diseases currently found in lettuce crops in Queensland. The CDA's put out between 120 to 170 Litres of water per hectare, whereas the conventional boom sprays will apply about 400 Litres of water per hectare. All growers are familiar with the need to calibrate their spray equipment and will tend to do this at least once a year and in some cases twice a year with the change of growing seasons. Growers will generally spray late in the after noon to try and avoid any wind problems or as one grower does, very early in the morning, between 1am and 2am. Lights are essential on the tractor if this is to take place.

Disease Survey

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Introduction

Common diseases of lettuce in Australia include members of the three groups of microorganisms, viruses, bacteria and fungi. The main diseases are listed in Table 1.

Table 1. Common diseases found on lettuce in Australia.

Viruses	**Bacteria**	**Fungi.**
Tomato Spotted Wilt virus.	Dry Leaf spot (*Xanthomonas campestris pv vitians.*)	Anthracnose (*Microdochium panattonianum*)
Necrotic Yellows.	Bacterial rots (*Erwinia* sp)	Black root rot (*Thielaviopsis basicola*)
Mosaic Virus	Varnish spot (*Pseudomonas* sp)	Downy mildew (*Bremia lactucae*)
Big Vein virus	Corky root. *Rhizomonas suberifaciens*	Sclerotinia rot (drop). (*Sclerotinia sclerotiorum* and *S. minor*)
		Septoria spot (*Septoria lactucae*)
		Grey Mould (*Botrytis sp*).
		Bottom rot (*Rhizoctonia sp*)

Table 2. Some cultural differences between the growing districts.

Region.	**Irrigation Type**	**Transplants or direct seed.**
Sydney Basin	Overhead	Transplants.
Hay	Flood	Direct seed.
Canowindra	Overhead	Transplants.

Materials and Methods

In 1998 surveys were undertaken to assess the amount of damage caused by all diseases of lettuce in Hay. This was carried out through field surveys on growers' properties weekly.

Throughout the course of the project when visits were made to other New South Wales growing regions, disease incidence was recorded.

Results

Survey results throughout the 1998 season showed the main diseases were *Sclerotinia minor* and to a lesser degree *Sclerotinia sclerotiorum*, grey mould caused by *Botrytis cinerea* and Downy mildew. Three viral diseases were found, Big Vein, Necrotic Yellows and Tomato Spotted Wilt.

Lettuce with Big Vein was the most common disease with 10-30% showing symptoms. However, even though symptoms were present, marketable hearts were achievable. Other viral diseases such as Necrotic Yellows and Tomato Spotted Wilt virus were in low levels ranging from 0-2%. *Sclerotinia minor* was the next major disease with 0-20% of lettuces infected. *Sclerotinia sclerotiorum* was not seen in this season at high levels. Botrytis was found commonly on Cos type lettuce.

Downy mildew was seen due to a breakdown of varietal resistance. Frost damage was a common problem during the June-July growing periods.

Other growing areas were visited during the course of the project. Diseases found during these visits are listed in Table 3.

Table 3. Diseases found in each growing district.

Disease	Hay	Sydney Basin	Central West
Tomato Spotted Wilt virus.	✓	✓	✓
Necrotic Yellows.	✓	✓	✓
Mosaic Virus		✓	?
Big Vein virus.	✓	✓	✓
Anthracnose	✓ (very occasional)	✓	✓
Black root rot	?	?	?
Downy mildew	✓ (only when new race develops or a variety is grown that is not resistant)	✓ (only when new race develops or a variety is grown that is not resistant)	✓(only when new race develops or a variety is grown that is not resistant)
Sclerotinia rot	✓	✓	✓
Septoria spot	✓(very occasional)	✓	✓
Bottom rot	?	✓	?
Grey mould	✓	✓	✓
Dry Leaf spot		✓	✓
Bacterial rots	✓	✓	✓
Varnish spot	✓	✓	✓
Corky root.		?	?

Varnish spot

During this project there was a number of reports from the Hay area and the Sydney Basin of serious problems in lettuce caused by what has been identified as Varnish spot. These reports also came from the Sydney Basin. Lettuces became infected in the field and often went slimy during transit or in some cases during cold storage. The disease was most severe in 1999 but other years had some outbreaks.

Viruses in the Central West

Viruses were found to be an issue in the Central West. Some of these viruses were found to be cause for concern. Their identification proved to be difficult. More work will be necessary in this region on viruses.

Discussion

The important issue that was found during this project was the variability in knowledge of growers of the various diseases. A considerable part of the disease section of this project was one to one discussions with growers in the field, concerning any diseases present on their farms. Growers were always keen to find out information about the diseases. Disease diagnosis was always stressed as an important part of disease management but there appeared to be reluctance from growers to submit plant material for diagnosis. This was either because they were too busy or because they didn't see the problem as being too severe. Introduced charging by diagnostic laboratories may also contribute to the reluctance in having samples diagnosed.

Growers in Hay had minimal problems with disease. The severest case of Sclerotinia was 20% of lettuces infected in one planting. In this case the grower had restricted amounts of land for rotations. Generally the level was about 5% of lettuce infected in each block in each season. The most common species in Hay was *Sclerotinia minor* as was the case in the other growing areas. *Sclerotinia sclerotiorum* was seen spasmodically with infection either at the top of the heart via wind blown spores or at the base of the plant through direct sclerotial germination.

Big Vein was an issue in some seasons with flood irrigation coupled with rain causing increased levels of this disease. This disease is caused by a virus but transmitted by the swimming spores of a fungus that relies on free moisture to be able to move through the soil. The disease caused the usual range of symptoms with some plants not hearting, whereas others although infected could still be harvested.

Irrigation management is an important issue in controlling Big Vein. With flood irrigation correctly lasered land is critical so that water can be run on and off quickly, without any low spots. The correct timing so that irrigation is not applied at the time rain is expected is important.

In the Central West the main issues were Botrytis, Dry Leaf spot, Septoria and Downy mildew. These diseases were accentuated by overhead irrigation and variety selection. In the Sydney basin the main issue was Sclerotinia, which was mainly due to the land availability for rotations.

Varnish spot caused losses in all the growing areas. The reason for the appearance of this disease is not known. The bacteria implicated in the disease (*Pseudomonas sp.*) is known to be soil borne but could be also water borne. This raises implications in the quality of water used for irrigation and spraying as the bacteria may build up in water reserves. Whole plantings of lettuce were lost due to this disease.

The crop may look healthy until they are being picked. The spots may not be visible from the outside of the lettuce but when the outer leaves are removed the brown spots are found, often along the midrib of inner leaves. The smaller lesions can expand rapidly from discrete spots to rotting of the whole heart. Other bacteria may then infect through the damaged tissue. Unfortunately whole blocks of lettuce can be affected. Symptomless, but infected heads can develop the disease rapidly in storage. Where rotting can also be caused by secondary bacterial infections. Varnish spot can be found all year but seems to be most serious in the late winter and spring months.

The bacteria survives in crop debris, other hosts and in the soil. They are spread by rain and wind. The infection process is not that clear. Maybe insects are involved or frost. Insects can cause injuries through which the bacteria may enter the plant. It is most likely that rain or overhead irrigation contributes to the disease. Water reservoirs are probably a source of the bacteria. The bacteria may be introduced through water used for regular sprays or by soil splashed by the rain.

There are some gaps in the knowledge of this disease and hence control recommendations are difficult. Ideas for future research on this disease would include the effect of nutrition on disease, and the disease carrying status of seeds, seedlings, water and soil. The cropping history is an important factor that may contribute to the occurrence of this disease. However, it has been found on areas where lettuce had not been grown for three years.

Corky root appeared to be another disease that requires some work. The diagnosis of the disease is difficult in that ammonium toxicity can give similar symptoms. One sample submitted could not be positively identified. Unfortunately there is no work going on with this disease at present in Australia.

Summary of weekly crop monitoring for insects in lettuce grown at Hay, NSW (July 1998-Sept 2001)

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Introduction

The basis of any IPM strategy is a thorough knowledge of the range of potential pests that may attack the crop, some indication of their relative importance and seasonal fluctuations. Initially a pest management strategy can be developed for the key pest and gradually expanding to include more minor pests. Since initial discussions with growers did indicate that this information was known by the growers in Hay this project set out to survey the insect pests through the seasons.

Materials and Methods

Approximately once per week 1 to 3 lettuce plantings were monitored for insects. Where possible the same crop was followed through the season. As much as possible a planting from the east side of Hay and one from the Maude Road was monitored each week. At the seedling to pre-hearting stage 40 plants were visually inspected for all insects. From pre-hearting to pre-harvest 20 plants were visually inspected. Some specimens were collected for further identification but generally broad insect categories were used, e.g. thrips. Pheromone trap data for *Helicoverpa armigera* and *H. punctigera* was collected for most of the 1999-2001 seasons.

Results and Discussion

Insects observed in regular monitoring of lettuce in Hay varied from week to week. Some species were regulars, such as *Helicoverpa armigera* from February to April or May, whilst others such as Cluster caterpillars were only observed in autumn 2000. Table 1 lists species or groups of insects observed at least on 5 monitoring days.

Table 1 Insects observed on Lettuce

Category	Common Name	Scientific name	Frequency found in Lettuce
Caterpillar	Heliothis	*Helicoverpa armigera*	Common (autumn)
Caterpillar	Heliothis	*Helicoverpa punctigera*	Common (spring)
Caterpillar	Loopers	*Chrysodeixis spp.*	Common (spring)
Caterpillar	Cluster caterpillar	*Spodoptera litura*	Occasional
Caterpillar	Cutworm	*Agrotis spp.*	Occasional
Sap Sucker	Aphids*	Aphidae	Common (early/late winter)
Sap Sucker	Green Peach Aphid	Myzus persicae	
Sap Sucker	Aphid sp.	*Sitobion sp.*	
Sap Sucker	Cotton Aphid	*Aphis glossypii*	
Sap Sucker	Rose Aphid	*Macrosiphum roseae*	
Sap Sucker	Turnip aphid	*Lipaphis erysimi*	
Sap Sucker	Red aphid	*Uroleucon sonchi*	
Sap Sucker	Thrips*	Thysantera	Common (spring-autumn)
Sap Sucker	Onion Thrips	*Thrips tobacci*	
Sap Sucker	Thrips sp.	*Haplothrips robustus*	
Sap Sucker	Tubular black thrips	*Haplothrips victoriensis*	
Sap Sucker	Broadwinged thrips	*Desmothrips tenuicornis*	
Sap Sucker	Psyllids	*Acizzia spp.*	Occasional
Sap Sucker	Whitefly	*Bemesia tobaci*	Occasional
Sap Sucker	Leafhoppers*	Cicadellidae	Occasional
Sap Sucker	Vegetable Leafhopper	*Austroasca viridigriesea*	
Sap Sucker	Brown Leafhopper	*Orosius argentatus*	

Sap Sucker	Green Mirrid	*Creontiades dilutus*	Occasional
Sap Sucker	Brown Mirrid	*Creontiades pacificus*	Occasional
Sap Sucker	Rutherglen Bug	*Nysius vinitor*	Common (spring)
Sap Sucker	Flea beetles	Halticinae	Occasional
Beneficial	Apple Dimpling Bug	*Campylomma liebknechti*	Occasional
Beneficial	Red & Blue Beetle	*Dicranolaius bellulus*	Moderately-common
Beneficial	Nabid	*Nabis kingergii*	Occasional
Beneficial	Brown Lacewing	*Micromus tasmaniae*	Occasional
Beneficial	Green Lacewing	*Mallada sp.*	Occasional
Beneficial	Wasps*	Various Braconids, Ichneumonids, & Chalcids	Occasional
Beneficial	Aphid parasitoids	*Aphidius and Aphelinus spp.*	Common (early/late winter)
Beneficial	Transverse Lady beetles	*Coccinella transversalis*	Occasional
Beneficial	Striped lady beetles	*Micraspis frenata*	Occasional
Beneficial	2-spot lady beetles	*Diamus notescens*	Occasional
Beneficial	Rove Beetles*	*Staphilinid spp.*	Occasional
Beneficial	Hover flies*	Syrphidae	Occasional
Beneficial	Spiders*	Araneida	Common
Beneficial	Garden wolf spiders	*Lycosa godeffroyi*	
Beneficial	Jumping spiders	Salticidae	
Beneficial	Orbweaver spiders	Araneide	
Beneficial	Crab spiders	Thomisidae	
	Fungus beetles*	Lathridae	Common
	Flower beetles*	*Carpophilus* spp., Melyridae	Occasional

* specimens not identified to species

Common	Seen most sampling days
Mod-common	Seen every 2-3 sampling days
Occasional	Seen irregularly

For the 1999-2001 season insect numbers were generally less than two per plant when averaged across all plants monitored (Figure 1.). Sap suckers were the most numerous of the categories with some seasons seeing hundreds of aphids or thrips on some plants. All insects had patchy distribution with some plants with many individuals of a single species, whilst other nearby plants having no individuals. Numbers of insects monitored in August and September 1998 were 8 times higher than the subsequent years at the same time and is attributable to particularly large numbers of aphids on some plants. Aphid parasitoids also contributed to a slightly higher number of predators found during this period. Generally spiders were the most consistently numerous of the predators. Brown lacewings were prevelant throughout the 1998 season.

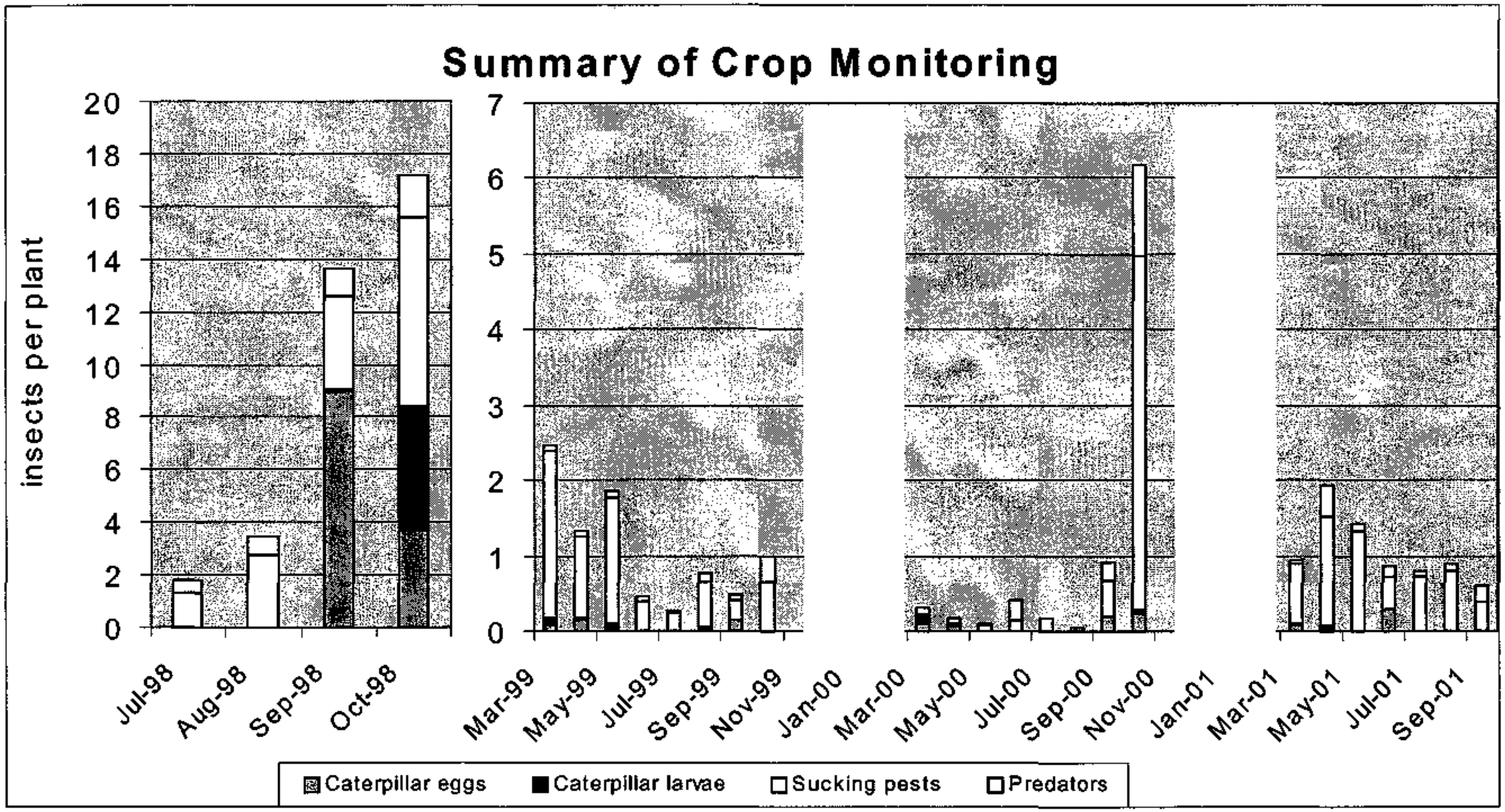

Figure 1. Summary graph of weekly monitoring of lettuce in Hay over 3.5 cropping seasons. Averaged per plant for each month crops were grown.

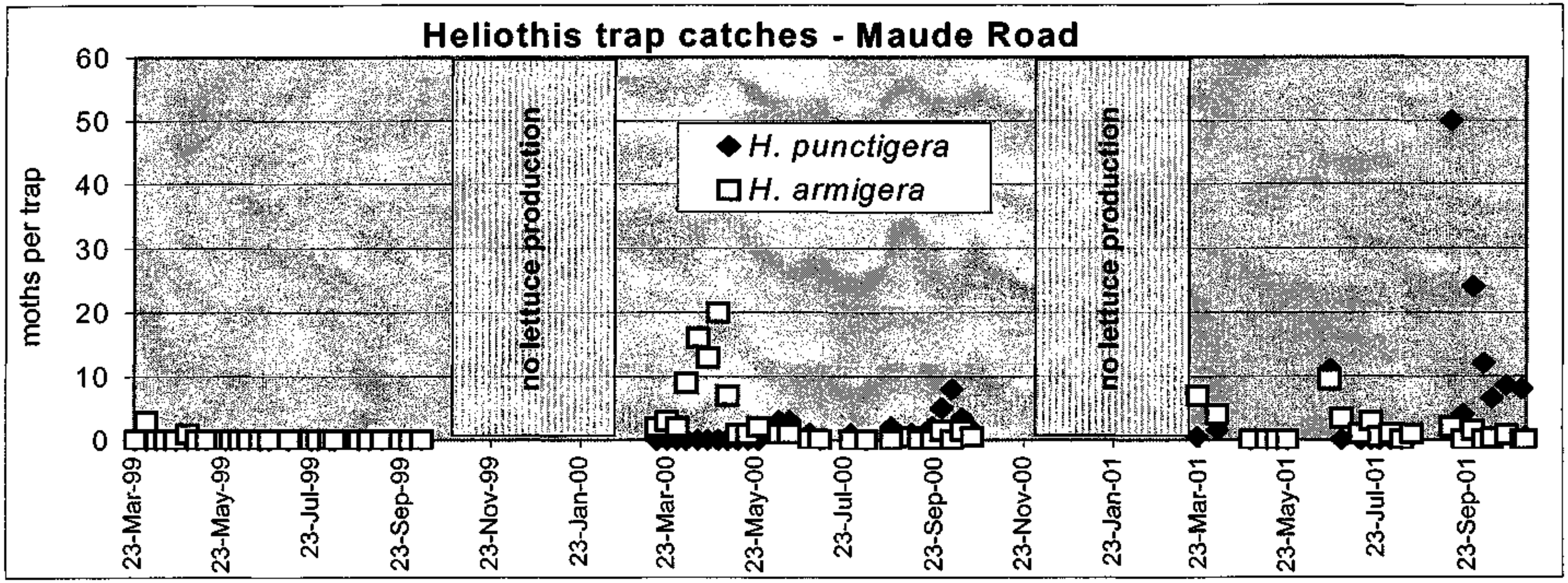

Figure 2a. Weekly pheromone pot trap catches for Heliothis moths on Maude Road, west Hay NSW.

Pheromone traps were placed near lettuce crops in the two areas of lettuce production in Hay over the 1999, 2000 and 2001 seasons. Very low numbers of moths were trapped in 1999 in Hay (Figures 2 a&b). Moth traps did not necessarily reflect what was found in the paddock, for example Heliothis eggs and caterpillars were observed in the crops in March to May and in August and September 1999. Moth trap catches were more evident in 2000, showing a *Helicoverpa armigera* peak in April and a smaller peak (8 moths) for *H. punctigera* in early October on Maude Road and a much larger peak (35 moths) on University Road. Traps were not placed on University Road until August 2000. In 2001 *H. armigera* registered small numbers in February and again in June on Maude road and a single flight in May on University Road. *H. punctigera* moths registered a flight in traps on both Maude and University Roads in September.

The first plantings of lettuce (Feb-Mar) saw moth egg lays in the three years monitored [1999-2001](see Figures 4-6a). In 1999 egg lays were higher and monitored for longer than either in 2000 or 2001. As the lettuce matured eggs were laid in preference on the more mature lettuce than on more recently planted lettuce. In 1998-2000 no eggs were monitored from May to August or September. In 2001 there was unusual egg laying activity late June and early July and no activity later in the spring as was observed in previous years. Moth larvae or caterpillars were observed at lower numbers than eggs on the first plantings and were present for 1 to 5 weeks after the last eggs

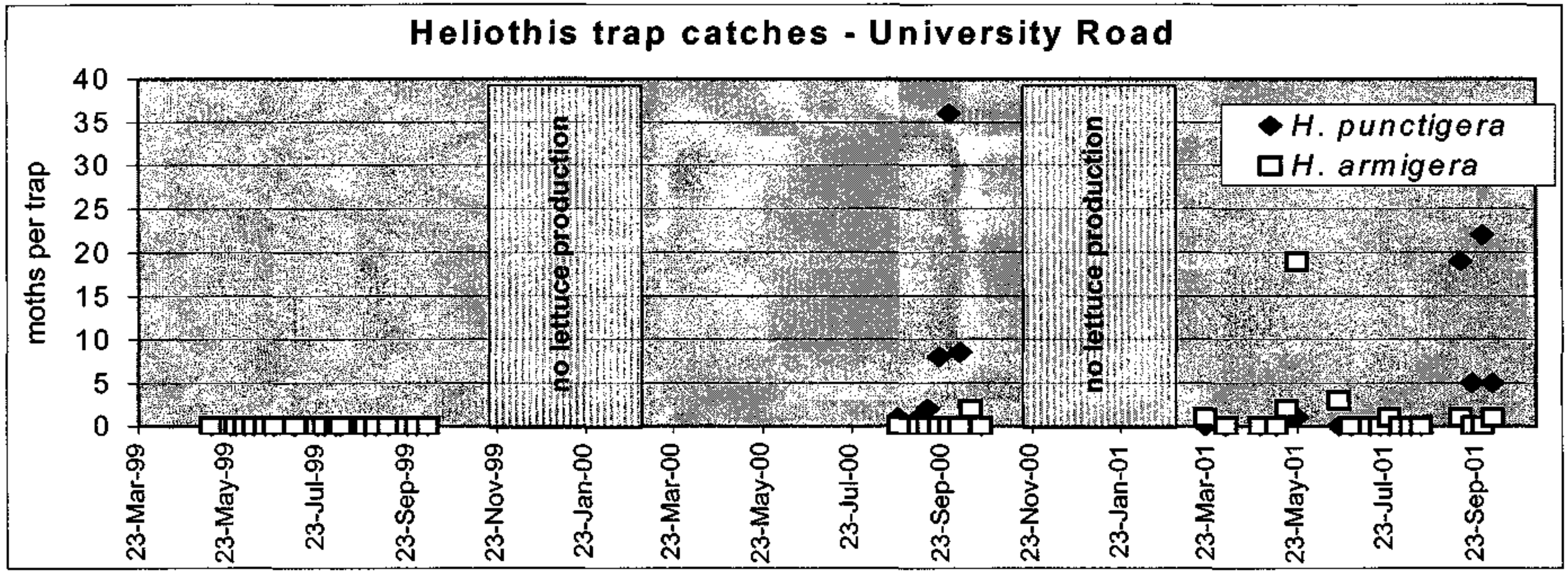

Figure 2b. Weekly pheromone pot trap catches for Heliothis moths on University Road, east Hay NSW.

were monitored (see Figures 4-6b). Larvae in 1999 were monitored for longer than in later years due to the cooler temperatures experienced at hatch after the later egg lay. In 2000 and 2001 the relative numbers of larvae on each the three age categories reflected the previous egg lays, in 1999 the pattern was not so clearly followed and that larvae were found on seedlings when eggs hadn't been found on seedlings for a number of weeks suggest that some eggs were not picked up in previous monitoring. In spring 1998 very few of the large egg lays [up to 25 per plant] resulted in many larvae hatching (Figures 3 a&b). The *Helicoverpa punctigera* moths were observed to come in with a storm front and many of the eggs that were collected did not hatch, so it is possible that many of the moths had not mated and their eggs were in fact infertile. Similarly in the spring of 1999 only very small numbers of larvae were observed on a single monitoring day, suggesting that many of the eggs were not fertile or predators were very effective and Figure 4d does show 0.5 beneficial on average per plant. Relative larval numbers on each lettuce age-category in spring 2000 was reflective of the egg lays, yet beneficial insect numbers were higher than in 1999 (Figure 5d). Sap suckers were by far the most numerous on all cropping stages, but particularly on the pre-hearted and hearted lettuce in 1998 (Figure 3c). In 1999 sap suckers were most numerous in autumn with very few observed in winter or early spring (Figure 4c). Sap sucker numbers were very low in 2000 until October (Figure 5c). And 2001 illustrated a different sap sucker pattern again, with no more than 2 sap suckers per plant throughout the observation period (Figure 6c). Beneficial insect numbers were highest in 1998 (Figure 3d), with approximately 2 beneficial insects per plant from July to October when the crops were monitored. A peak of 9 beneficial insects per plant was observed in late August. Most beneficials, as with the sap suckers were found on pre-hearted and hearted lettuce in 1998. In 2001 the beneficial insect numbers were very low [0.1 per plant], but the pattern of beneficials appears to reflect the pattern of sap suckers (Figure 6d).

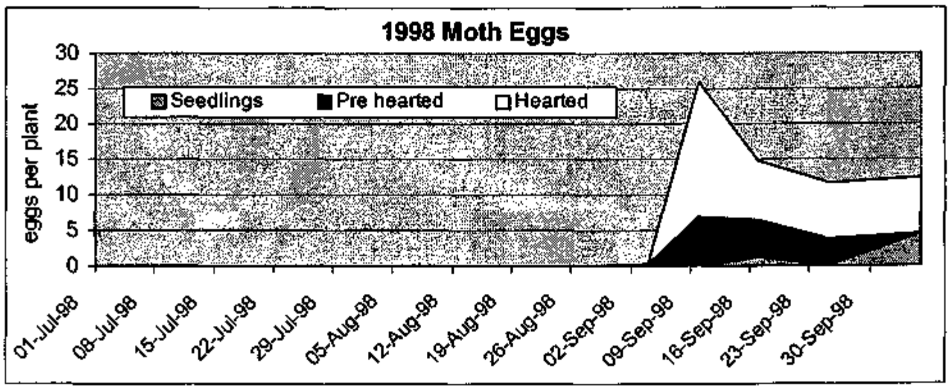

Figure 3a. 1998 weekly moth egg sampling on three stages of lettuce in Hay.

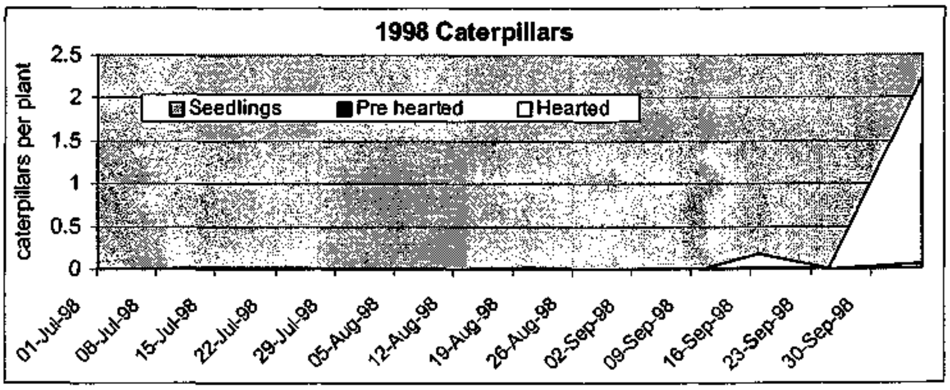

Figure 3b. 1998 weekly caterpillar sampling on three stages of lettuce in Hay.

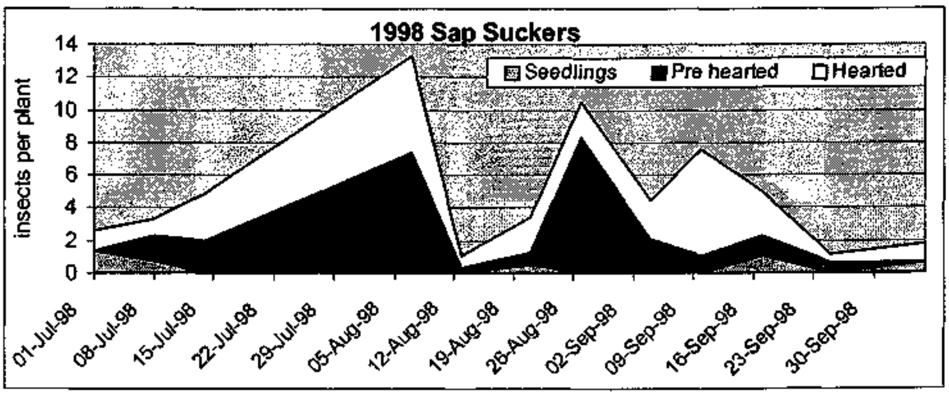

Figure 3c. 1998 weekly sap sucker sampling on three stages of lettuce in Hay.

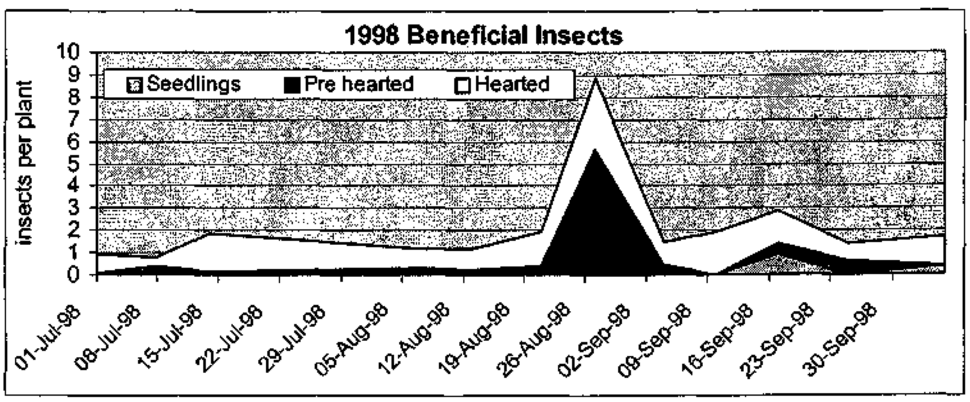

Figure 3d. 1998 weekly beneficial insect sampling on three stages of lettuce.

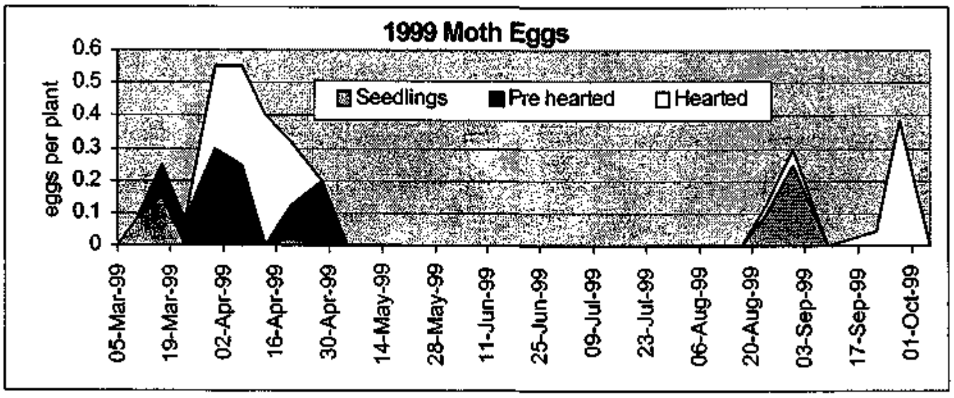

Figure 4a. 1999 weekly moth egg sampling on three stages of lettuce in Hay.

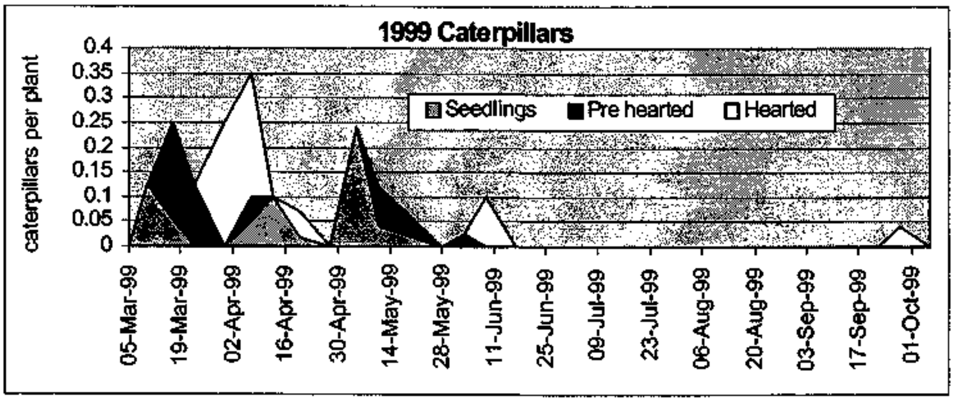

Figure 4b. 1999 weekly caterpillar sampling on three stages of lettuce in Hay.

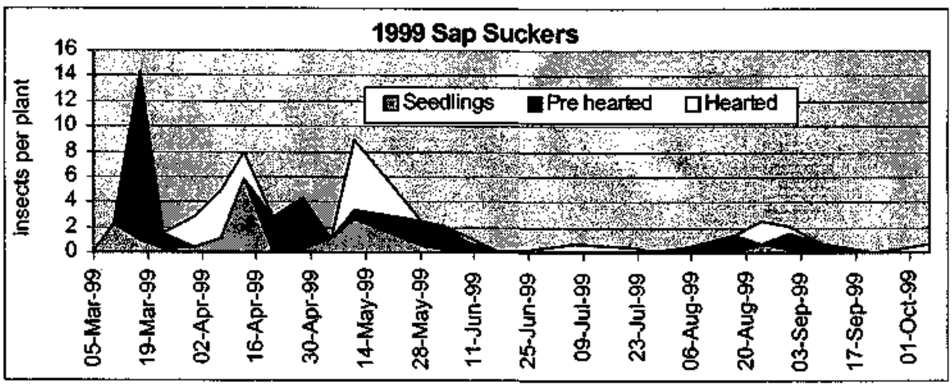

Figure 4c. 1999 weekly sap sucker sampling on three stages of lettuce in Hay.

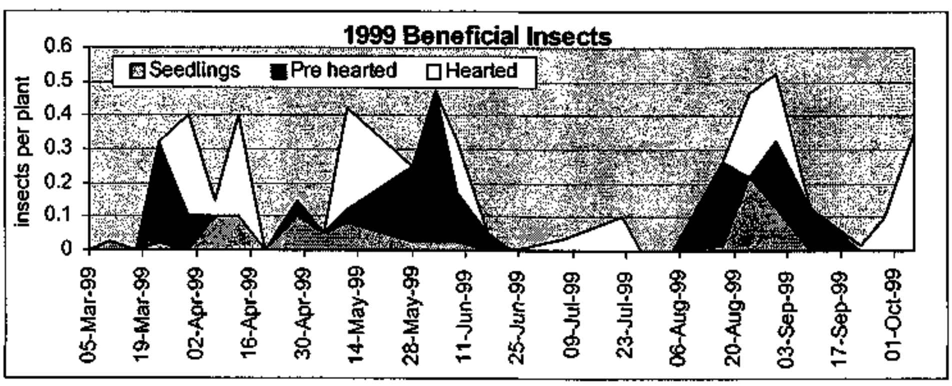

Figure 4d. 1999 weekly beneficial insect sampling on three stages of lettuce in Hay.

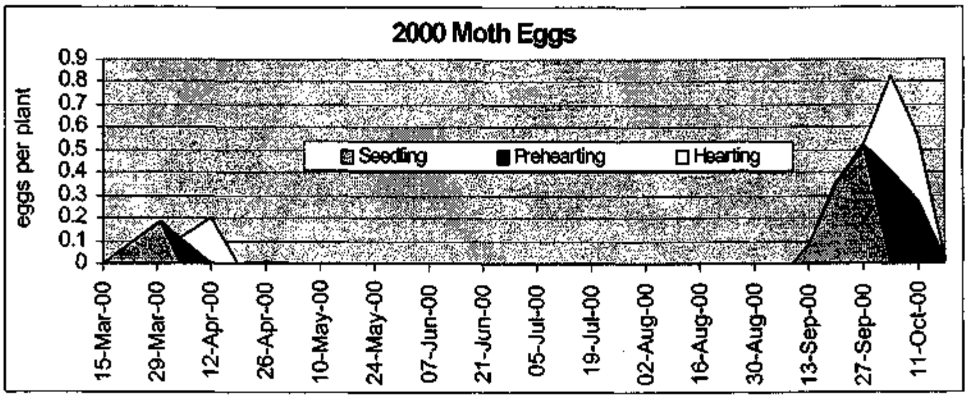

Figure 5a. 2000 weekly moth egg sampling on three stages of lettuce in Hay.

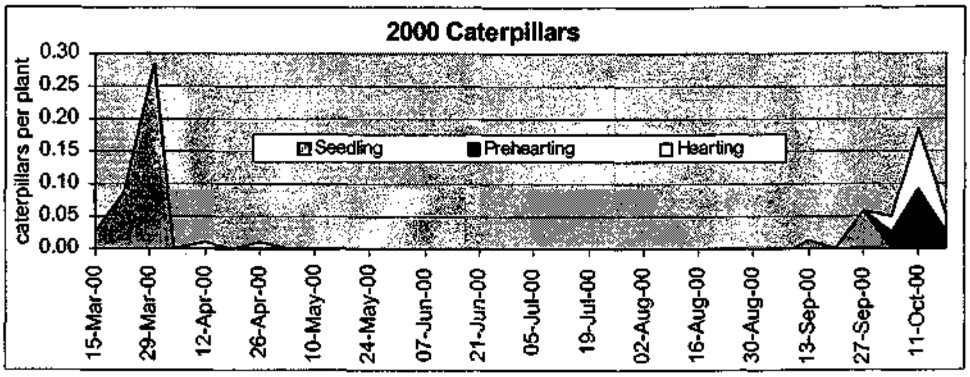

Figure 5b. 2000 weekly caterpillar sampling on three stages of lettuce in Hay

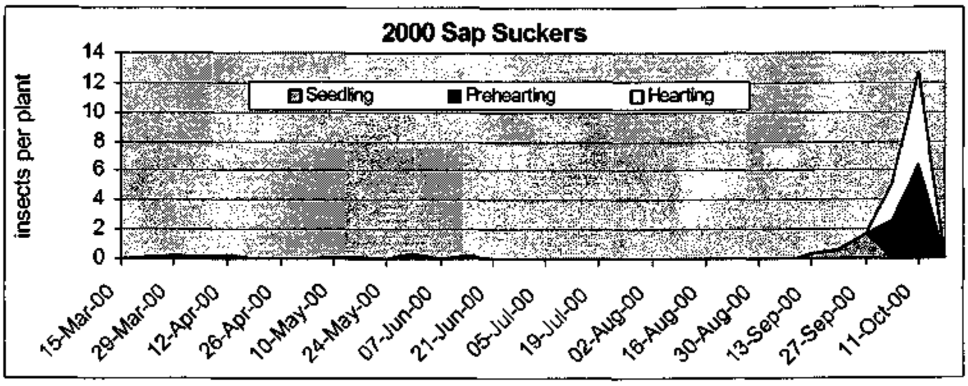

Figure 5c. 2000 weekly sap suckers sampling on three stages of lettuce in Hay

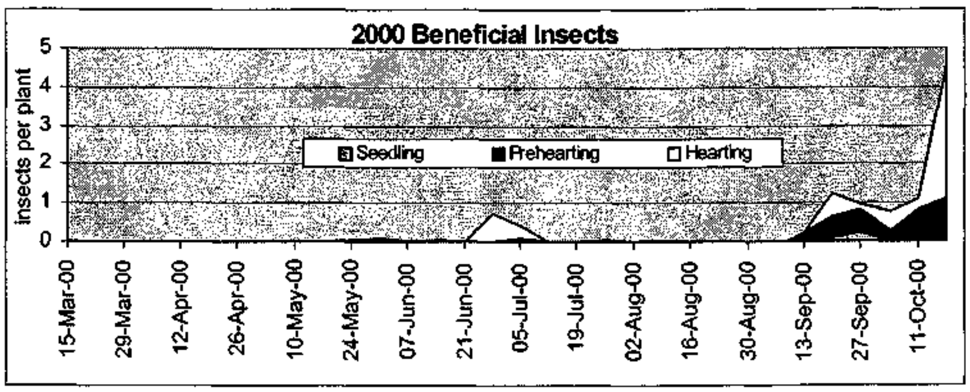

Figure 5d. 2000 weekly beneficial insect sampling on three stages of lettuce in Hay

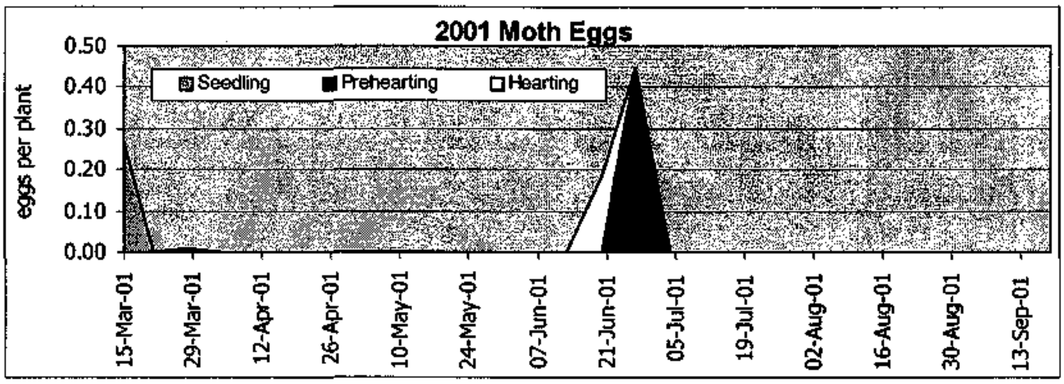

Figure 6a. 2001 weekly moth egg sampling on three stages of lettuce in Hay.

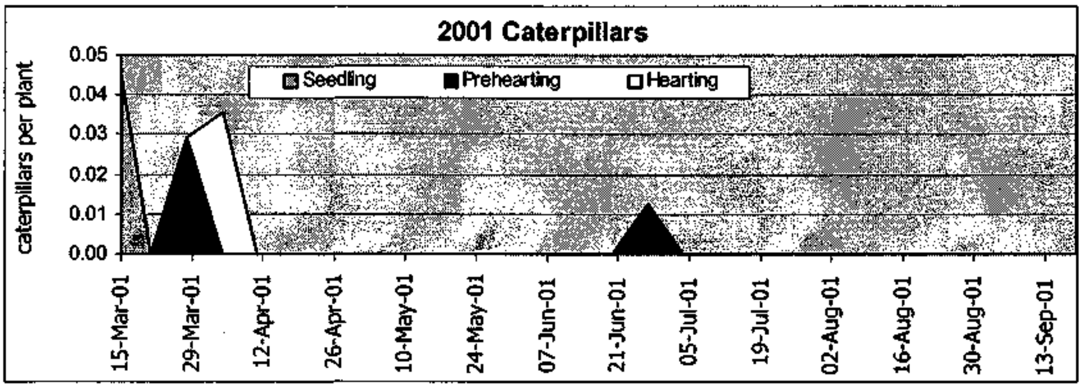

Figure 6b. 2001 weekly caterpillar sampling on three stages of lettuce in Hay.

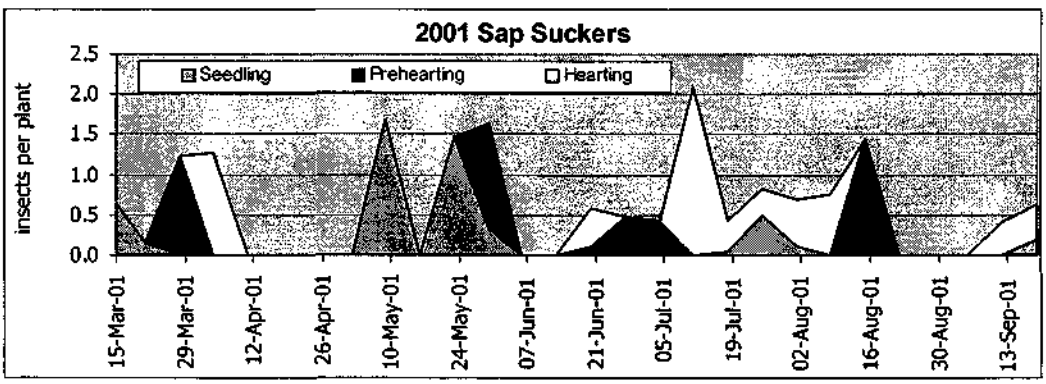

Figure 6c. 2001 weekly sap suckers sampling on three stages of lettuce in Hay.

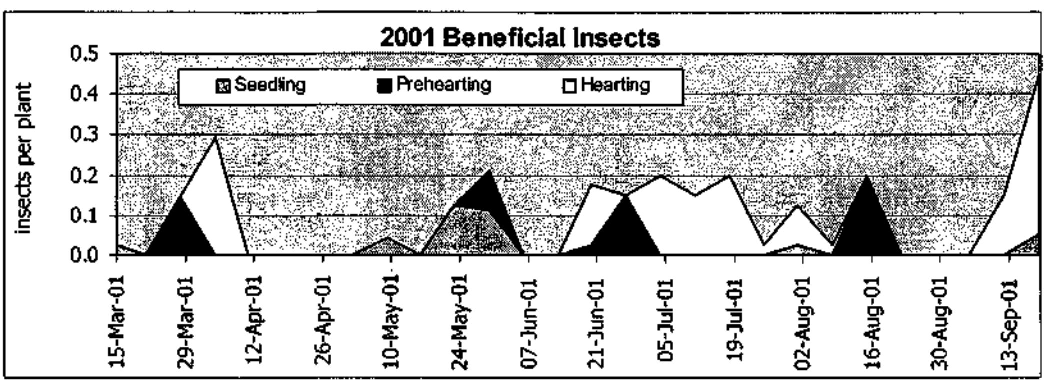

Figure 6d. 2001 weekly beneficial insects sampling on three stages of lettuce in Hay.

Conclusion

The data collected from crop monitoring 3.5 seasons of lettuce in Hay, NSW shows considerable variation between seasons, weeks, and crop stage highlighting the need for routine crop monitoring. Generally we can expect to see moth egg and larval pressure in late summer – early autumn, particularly from *Helicoverpa armigera*, and again in spring from *Helicoverpa puctigera* and loopers. Sap suckers are observed each year but vary considerably when the pressure is highest. Thrips are the most consistently prevalent sap sucker but aphid numbers and Rutherglen bugs can build up high numbers in the crop. Beneficial insect numbers were never very high but were greatest when aphid numbers were high. Spiders were a consistently present beneficial insect. Pheromone traps gave some indication of Heliothis pressure and were indicative of the relative mix of the two moth species but crop monitoring was more important for making management decisions.

Acknowledgments

Thanks to all the Hay lettuce growers who allowed us to regularly walk through their paddocks. Thanks to the other staff and casual assistants who were involved over the years helping monitor lettuce.

Insecticide evaluation trials for *Helicoverpa* spp. in lettuce

Introduction

Heliothis, *Helicoverpa armigera* and *Helicoverpa punctigera*, are the most important pests to attack lettuce crops throughout Australia. Of the two pests *H. armigera* is the most serious due to its ability to develop resistance to a wide range of synthetic insecticides and the limited number of insecticides currently registered for Heliothis control in lettuce. *H. punctigera* has not been shown to be resistant to insecticides and is readily controlled with currently registered insecticides.

Those insecticides traditionally used for control of Heliothis, namely endosulfan, methomyl and alpha-cypermethrin are facing increased pressures from environmentalists and government agencies due to concerns over environmental impact and consumerdemand for clean produce. With these concerns in mind lettuce growers are behind a national Lettuce Integrated Pest and Disease Management (IPDM) project funded by the Horticultural Research and Development Corporation (HRDC). As part of this project, insecticide trials were conducted to help with the registration of new insecticides for the control of Heliothis. These insecticides are considered to be more environmentally friendly, to both the consumer and the beneficial insects attacking Heliothis and other insect pests.

Scholz (1998) looked at the efficacy of new insecticide products against Heliothis. These trials builds on his work and each of the previous trials to gather additional data to help in the registration of new insecticide products that are showing promise in the management of Heliothis in lettuce producing regions across Australia. These are products soft on the environment and reportedly safe to a wide range of beneficial insects, which makes them ideal candidates for an IPM system in lettuce.

For IPM to be successful in lettuce a few more beneficial friendly options are needed. For the successful introduction of an insecticide resistance management strategy new chemical groups need to be registered for control of *Helicoverpa armigera*. Scholz (1998) looked at the efficacy of new insecticide products against Heliothis. These trials builds on his work and each of the previous trials to gather additional data to help in the registration of new insecticide products that are showing promise in the management of Heliothis in lettuce producing regions across Australia. These are products soft on the environment and reportedly safe to a wide range of beneficial insects, which makes them ideal candidates for an IPM system in lettuce.

Dipel Forte® is a formulation of *Bacillus thuringiensis* kurstaki strain (Btk) that was trialed in the 1999 trial but found to be less effective than the industry standard. Anecdotal evidence suggests that efficacy of Btk can be improved with feeding enhancers and possibly with UV inhibitors.

In 1999 Gemstar®, Dipel Forte®, Success®, DC Tron® and Avartar® were tested in Hay. In 2000, three insecticide evaluation trials were conducted. The first conducted in Hay, evaluated Avatar® at different rates and assessed the impact of including Nufilm-17®, milk powder, and Feast® on efficacy of Dipel Forte®. The second and third were conducted in Gatton and evaluated Avatar®, Success®, Secure®, Proclaim®, Xentari® and Gemstar®. In 2001 an efficacy trial was conducted in Hay and evaluated NeemAzel® and Proclaim®.

The following information on the various trial insecticides was largely provided by the companies distributing the products in Australia:

1. Gemstar®, a Nuclear Polyhedrosis Virus (NPV), attacks Heliothis caterpillars (Rhône-Poulenc 1998). Caterpillars need to consume only one virus particle to become infected. Small larvae, particularly newly hatch larvae, are killed by the virus quickly where as larger larvae take longer to kill. Once the virus has been ingested feeding stops within 2-5 days. Infected larvae have a tendency to climb to the top of the plant where they die and eventually rupture releasing virus particles. These particles may be eaten by other larvae, which will in turn die potentially infecting more larvae. Gemstar can be applied using conventional spray equipment and does not affect beneficial invertebrates or vertebrates (including humans) therefore leaving no toxic residues (Scholz, 1997). NPV is sensitive to UV exposure and breaks down rapidly in sunlight, therefore, it should be applied in the evening where possible. Gemstar is persistent in the field for up to 2 days.

2. Dipel Forte®[Bayer], *Bacillus thuringiensis* kurstaki strain, is toxic to a broad range of caterpillars. Unlike NPV, where only one virus particle needs to be consumed to result in death of the larvae, caterpillars need to eat a deadly dose of Bt. Smaller larvae require a smaller amount of Bt to kill them than larger larvae. Affected larvae cease feeding but may survive up to four days. Like NPV it is UV degraded, temperatures above 30 °C

will reduce its effectiveness so it is also best applied close to evening. Bt has a low toxicity to beneficials and humans and leaves no toxic residues.

3. Success® (Spinosad) [Dow Agro Sciences] is a mixture of two compounds, spinosyn A and spinosyn D. The two compounds are representatives of a new class of compounds isolated from the fermentation of a newly discovered bacterium (actinomycete), *Saccharopolyspora spinosa*. *Spinosyns* act on the insect nervous system by a unique mechanism but has a low toxicity to predatory beetles and some other beneficial insects as well as to humans. It is rapidly broken down in soil and water leaving no toxic residues (Saville and Hughes,1997).

4. Avatar® (Indoxacarb) [Dupont] is a new generation synthetic insecticide in the oxadiazine group, a neurotoxin which inhibits sodium ion entry into nerve cells resulting in paralysis and death Indoxacarb shows activity in lepidopteran larvae and some sucking insects. It shows residual activity of 10-14 days. Indoxacarb is 'soft' on aquatic species, relatively low mamalian toxicity and has little impact on beneficial insects or on mites (Dupont Technical Bulletin 1997). The new mode of action makes it a good tool for resistance management of *Helicoverpa armigera* and its low toxicity to beneficial insects makes it a good candidate for IPM.

5. DC Tron plus is a petroleum spray oil that has been shown to repel ovipositioning by the native budworm (*Helicoverpa punctigera*) and of other lepidoptera. Work conducted by Dr Andrew Beattie (HRDC HG611) has indicated that high volume 0.5% oil sprays have reduced damage to a range of ornamental, fruit and vegetable crops for a range of lepidopterous and soft bodied insect pests.

6. Caterpillars need to eat a deadly dose of Bt, efficacy is reduced above 30 °C and it is photodegraded. Nufilm-17® (Miller) is a sticker extender derived from pine resin. It is reported to resist wash-off by rain and provide UV protection. Milk powder and Pheast® (Miller) are feeding stimulants which when combined with an insecticide should encourage increased ingestion of the insecticide, hence increased efficacy if the insecticide has dose dependant toxicity.

7. Chlorfenapyr is a pyrrole compound with broad spectrum contact and stomach poison (Avcare). It is formulated as Secure® (BASF) and has activity on Heliothis, thrips and 2-spotted mites.

8. Emamectin benzoate is a semi-synthetic member of the avermectin class (6A) of macrocyclic lactone compounds, formulated by Novatis as Proclaim®. It is an insect neurotoxin that adversely affects the chloride ion channels. Emamectin is derived from a modification of the terminal disaccharide on abamectin which is produced by fermentation of the soil microorganism *Streptomyces avermitilis*. Emamectin is active against a broad range of pests, particularly lepidopteran larvae. It is primarily toxic through ingestion but has some contact activity. The active ingredient shows translaminar movement in plants providing some residual activity for leaf chewers, but degrades rapidly on the leaf surfaces reducing impact on beneficial insects (technical information from Novartis).

9. Xentari® is another Bt but of a different strain (*Bacillus thuringiensis* aizawai strain) that is primarily used against Diamond Back moth (Bayer). Like *Bacillus thuringiensis* kurstaki strain,it is toxic to a broad range of caterpillars .

10. Azadirachtin is a tetranortriterpenoid and is the principal active ingredient in the oil derived from neem tree kernels (extoxnet 2000). NeemAzal-T/S® is an emulsifiable concentrate of this oil and one of many different formulations. It acts as an insect growth regulator and feeding inhibitor. Once ingested, it blocks ecdysone hormone release and prevents the insect from moulting, thus breaking its lifecycle. Azadirachtin has some activity on a broad range of insects including: caterpillars, beetles, whiteflies, leafhoppers, aphids, mites and thrips. There may be residual activity for 7 to 10 days. Because the product must be ingested it is considered relatively friendly to beneficial insects (Parrys 1999).

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Insecticide evaluation trial for *Helicoverpa* spp. in lettuce – autumn 1999 (Hay, NSW)

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Introduction

The primary aim of this investigation was to screen some new biological insecticides and a new synthetic insecticide for possible inclusion in a lettuce IPM strategy. Specifically we were assessing efficacy against Heliothis.

Materials and Methods

A replicated small plot trial was established at a site in Hay. Table 1 presents the field layout of the trial. There were 5 blocks with 10 treatments, laid out in a 10 x 5 rectangular array. The 10 treatments were allocated so that each treatment occurred in each column. Each treatment plot comprised of 4 Beds (6 m) x 18m = 0.0108ha/ plot.

Table 1: Field layout of lettuce trial

Block1	1	2	3	4	5
	6	7	8	9	10
Block2	4	6	1	5	8
	9	10	7	3	2
Block3	3	9	2	6	1
	10	4	5	8	7
Block4	7	5	6	10	3
	2	8	9	1	4
Block5	5	1	4	2	9
	8	3	10	7	6

The treatments were as follows:

1. "Grower" methomyl –450gai (2L/ha),
   endosulfan – 735gai/ha (2.1L/ha), or
   alpha-cypermethrin (Fastac®) – 40gai/ha (0.4L/ha)

which was used depended on the chemical and the rate the grower was using at that spraying time in the remaining paddock.

2. Low Avatar® 37.5 gai/ha (125g/ha)
3. High Avatar®51 gai/ha (170g/ha)
4. Low Success® 48 gai/ha (400ml/ha)
5. High Success® 96 gai/ha (800ml/ha).
6. Dipel® 1kg/ha
7. DC Tron® 0.5%bv
8. Low Gemstar® 2.4gai/ha (375ml/ha) + 0.025% X77 wetter
9. High Gemstar® 3.2 gai/ha (500ml/ha) + 0.025% X77 wetter
10. Unsprayed control.

Sprays were applied with a 14lt Silvan battery powered backpack sprayer. The sprayer ran at 200Kpa. Sprays were applied using a boom and droppers. The first two sprays used four T-jet cone (TXVK 6) nozzels per bed, putting out a volume equivalent to 410L/ha. Subsequent sprays were applied using 6 nozzels per bed at an equivalent water rate of 456L/ha.

Every week from the four-leaf stage unto harvest each plot was sampled. Spray decisions were based upon an action threshold of (1 egg per 20 plants). If the threshold was equalled or exceeded then sprays were applied to treatment plots. Sprays were applied according to egg colour as all the biologicals were larvicides and if, for example, the majority of eggs were orange then sprays were applied 3-4 days later depending on daily temperatures. The action threshold for grubs was 1 grub per 20 plants (grubs over 3rd instar not included) and if exceeded sprays were applied as soon as possible.

At harvest damage was assessed. Two assessments were made, the first was a visual sample of 100 lettuce from the centre two beds and the second was a destructive sample of 30 lettuce selected at random from the centre two beds. The destructive sample was done to compare the accuracy of assessing heliothis damage visually rather than cutting open the lettuce plant to assess damage.
The visual sample also assessed for common diseases: sclerotinia, big vein, necrotic yellows and small heads.

The heliothis damage data was analysed using a generalised linear mixed model with blocks as random effects and treatments as fixed effects (Schall , 1991). The relationship between visual and cut damage was assessed using logistic regression (McCullagh and Nelder, 1987), with the empirical logit of the proportion of damage using the cutting method as the independent variable.

Results

The pheromone traps indicated that *Helicoverpa armigera* was the species present. Egg pressure was low in the first two weeks peaking on the 4th and decreasing again in 5th. Larvae were also present on the 4th week and continued to be present for the rest of the trial in the Unsprayed, DC Tron, Dipel and Gemstar plots whereas they declined in the Grower, Avatar and Success plots after 6th week. Three sprays were applied to the Grower, Avatar and Success plots and five sprays were applied to the DC Tron, Dipel and Gemstar plots.

The harvest assessment was conducted on the 24th May 1999. There was agreement between the visual and the destructive assessments. Heliothis damage was highest in the unsprayed plots (37.9%) and lowest in the 800ml rate of Success (1.9%) [see Table 2]. There was no statistically significant difference between the Grower, Avatar and Success treatments at the 1% significance level but at the 5% significance level the low Avatar treatment was less effective than the high Success treatment. There was no statistical difference between the Dipel and Gemstar treatments at either significance level. DC Tron was statistically different from the Dipel and Gemstar treatments at the 5% level, and was not significantly different from the unsprayed treatment at either level. The F test for treatment effects was 22.83 ($p<.01$). There was no statistical difference between treatments for any of the diseases assessed.

Table 2. Visual Damage Assessment of 100plants/plot

TREATMENT	%Heliothis Damage (adjusted)	5% significance	1% significance	% Sclerotinia	% Necrotic Yellows	% Big Vein
Grower	3.9	cd	c	0.2	0	0.2
High Avatar	2.9	cd	c	0	0	0.2
Low Avatar	5.0	c	c	0.2	0	0
High Success	1.9	d	c	0.2	0.2	0
Low Success	3.0	cd	c	0.4	0	0.2
DC Tron	28.3	a	ab	0	0	0.6
Dipel	17.7	b	b	0.2	0	0.6
Low Gemstar	18.3	b	b	0.2	0	0.4
High Gemstar	19.6	b	b	0.4	0	0.2
Nil	37.9	a	a	0	0	0.2

Column means for a given treatment followed by the same letter are not significantly different.

Conclusion

The Avatar and Success products gave excellent control of Heliothis. Dipel and Gemstar reduced damage by almost 50% compared to the unsprayed control. DC Tron did not perform well at the water rates used. Other research in tomatoes and orchard crops has shown good control with water rates close to 1000L/ha. The visual sample was not 100% correct with some cases of over estimating damage and some cases of underestimating damage. In plots with low damage our estimates were more acurate than plots with high damage. The Grower plots in the trial averaged higher damage than either of the comparable neighbouring lettuce plots which in part can be explained by a single plot with 13% damage skewing the average of the remaining four treatment plots. The Gemstar and Dipel may both perform better with the addition of 1kg/ha of milk powder.

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Acknowledgements

Thanks to Gravina Farms for providing the trial site and accommodating us so well. Thanks to Meryl Snudden, Sharon Dunne and Herman Kuipers for help monitoring and harvesting. Thanks to Rhône-Poulenc, Dow Agro Sciences, Bayer, Ampol and DuPont for providing Gemstar, Success, Dipel, DC Tron and Avatar respectively. This project was partially funded by the AUSVEG levy, HRDC and a voluntary contribution from GSF.

Insecticide evaluation trial for *Helicoverpa* spp. in lettuce – autumn 2000 (Hay, NSW)

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Introduction

The primary aim of this investigation was obtain some more efficacy data on Avatar® and to assess the impact of including Nufilm-17®, milk powder, and Feast® on efficacy of Dipel Forte®.

Materials and Methods

A replicated small plot trial was established at a site in Hay. Target variety lettuce was planted on Ist March and harvested 3rd May 2000. Nine treatments were chosen each replicated five times. The treatments were as follows:

1. "Grower"- methomyl –450gai (2L/ha), or alpha-cypermethrin (Fastac®) – 40gai/ha (0.4L/ha) which was used depended on the chemical and the rate the grower was using at that spraying time in the remaining paddock.
2. Low Avatar® - (85g/ha) + 0.05% Agral wetter
3. Med. Avatar® - (125g/ha) + 0.05% Agral wetter
4. High Avatar®- (170g/ha) + 0.05% Agral wetter
5. Dipel Forte®-(1kg/ha)
6. Dipel Forte® (1kg/ha) + NuFilm-17® (600ml/ha)
7. Dipel Forte® (1kg/ha) + milk powder (1kg/ha)
8. Dipel Forte® (1kg/ha) + Pheast® (3kg/ha)
9. Unsprayed control.

The nine treatments were arranged randomly into 5 blocks and each treatment plot comprised of 4 Beds (6 m) x 18m = 0.0108ha/ plot (Figure 1).

Figure 1 Diagram of Trial plots

T8	T6	T5	T7	T2	T3	T4	T1	T9
T7	T3	T2	T9	T8	T1	T6	T5	T4
T9	T5	T4	T6	T7	T8	T1	T3	T2
T4	T2	T3	T1	T5	T6	T9	T8	T7
T1	T9	T8	T4	T3	T7	T2	T6	T5

Sprays were applied with a 14lt Silvan battery powered backpack sprayer, running at 200Kpa and using a handheld boom with droppers. The first two sprays used four T-jet cone (TXVK 6) nozzels per bed, putting out a volume equivalent to 410L/ha. Subsequent sprays were applied using 6 nozzels per bed at an equivalent water rate of 467L/ha.

Every week from the four-leaf stage unto harvest each plot was sampled. In each plot whole plants were monitored for a total of 8 minutes. The eggs were categorised into: white (fresh), orange, brown (near hatching), and black (parasitised). Larvae were categorized into 1-6 larval instars. Spray decisions were based upon an action threshold of (1 egg per 20 plants). If the threshold was equalled or exceeded then sprays were applied to treatment/s.

Sprays were applied according to egg colour as all the biologicals were larvicides and if, for example, the majority of eggs were orange then sprays were applied 3-4 days later depending on daily temperatures. The action threshold for grubs was 1 grub per 20 plants (grubs over 3rd instar not included) and if exceeded sprays were applied as soon as possible.

Helicoverpa armigera and *H. punctigera* moths were monitored with pheromone baited pot traps weekly.

At harvest a visual assessment of 100 lettuce from the centre two beds was made for caterpillar damage and for incidence of sclerotinia, big vein, and necrotic yellows. Lettuce that were too small for sale were also noted. The

Heliothis damage data was analysed using a generalised linear mixed model with blocks as random effects and treatments as fixed effects (Schall , 1991).

Results

The pheromone traps indicated that *Helicoverpa armigera* was the species present although the numbers of moths caught in the pheromone pot trap per week was small (Figure 2).

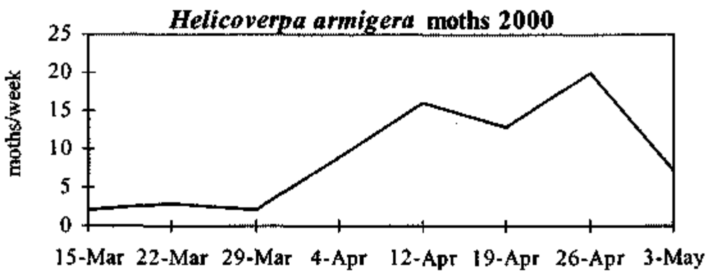


Figure 2. Weekly *Helicoverpa armigera* moth trap catches

Weekly monitoring was conducted for 8 minutes per plot which was equivalent to an average of 94 plants at seedling stage and 15 plants at full heart. Cluster caterpillar (*Spodoptera litura*), Heliothis (*Helicoverpa armigera*) and Loopers (*Chrysodeixis spp.*) were all found in the crop. Combined numbers of eggs peaked in the second and third weeks of monitoring and very few were seen subsequently (Figure 3). Larvae numbers peaked in the third week and gradually declined (Figure 3). Cluster caterpillars deposit clusters of eggs ranging in size from 4-40 eggs, and averaging 21 eggs per cluster. In Figure 4. cluster caterpillar clusters were counted as 1 egg to compare to the other two species.

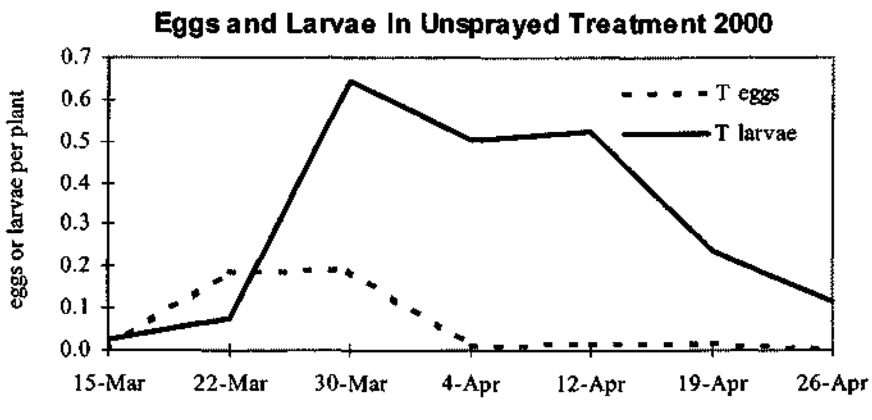
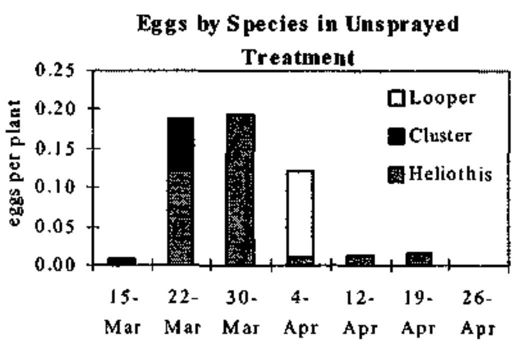


Figure 3. Weekly observations of moth eggs and larvae per plant in the Unsprayed treatment plots



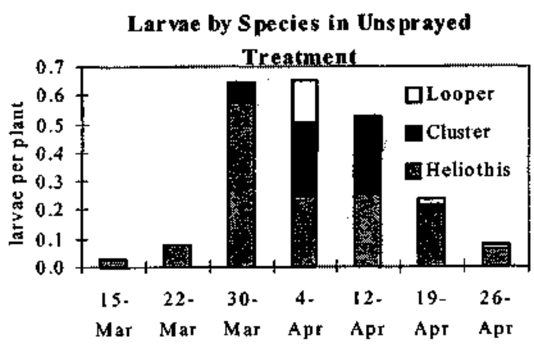


Figure 4. Weekly observations of moth eggs and larvae by species. Heliothis = *Helicoverpa armigera*; Looper =*Chrysodeixis* sp.; Cluster = *Spodoptera litura.*

The threshold of 1egg or small larvae per 20 plants was exceeded in weeks 1-4 for all treatments and in week 5 the low rate of Avatar, the Dipel treatments except Dipel + Pheast were sprayed (Table 1).

Table 1.	Treatments applied and conditions at application						
Treatment	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7
Avatar 85g/ha	y	y	y	y	y	n	n
Avatar 135g/ha	y	y	y	y	n	n	n
Avatar 170g/ha	y	y	y	y	n	n	n
Dipel 1kg/ha	y	y	y	y	y	n	n
D+Nufilm 0.6L/ha	y	y	y	y	y	n	n
D+Pheast 3kg/ha	y	y	y	y	y	n	n
D+milk 1kg/ha	y	y	y	y	y	n	n
Grower	y	y	y	y	n	n	n
Grower sprays		Fastac	Endo+Lannate	Fastac	Lannate		
Water rate L/ha	410	410	467	467	467		
Nozzel no. /bed	4	4	6	6	6		
Temperature °C	27.1	27.9	26.9	33.4	23.7		
% RH	32.9	32.7	33.3	19.4	53.8		
Wind m/s	2.1	1.95	1.49	2.29	2.65		
Wind direction	sw	s	s	nw	nw		

The harvest assessment was conducted on the 3rd May 2000. The Grower treatment performed the best with 0.8% of lettuce heads with heliothis present or with heliothis damage (Table 2). The damage level for Grower was not significantly different to the Avatar treatments. There was no difference between the different rates of Avatar (2.8, 2.0, and 2.6% damage). Dipel mixed with 1kg of milk powder slightly improved performance at 7.4% than Dipel by itself (10.2%) and this treatment was not significantly different from Avatar nor from the other Dipel mixes. The Dipel mixes were not significantly different than Dipel by itself. The Unsprayed treatment had the highest damage at 36.2%. The F test for treatment effects was 24.49 ($p<.01$). There was no statistical difference between treatments for any of the diseases assessed. Means were separated using the least significant difference test.

Table 2. Damage to lettuce at harvest for each treatment

TREATMENT	%Heliothis Damage	*5% significance*	*1% significance*
Grower	0.8	e	e
Avatar 85g/ha	2.8	de	cde
Avatar 125g/ha	2	de	cde
Avatar 170g/ha	2.6	de	cde
Dipel 1kg/ha	10.2	bc	bc
D+Nufilm 0.6L/ha	13.8	b	b
D+milk 1kg/ha	7.4	cd	bcd
D+Pheast 3kg/ha	10.6	bc	b
Unsprayed	36.2	a	a

Means followed by the same letter are not significantly different $p<0.05$.

There were insignificant levels of sclerotinia, necrotic yellows or bigvein (<1%) and there was no statistical difference between numbers of small lettuce and treatment.

Conclusion

Avatar® has shown to give good control of caterpillar larvae and that the 85g/ha rate performed as well as the 170g/ha rate. Dipel Forte® did not perform quite as well as the synthesized chemistries and the addition of a sticker-extender or feeding stimulants did not significantly improve its efficacy. Milk powder appeared to give some advantage.

Acknowledgements

Thanks to Gravina Farms for the trial site, Meryl Snudden, Karen Ryan, John Conallin and Rebecca Helson for help monitoring and harvesting, and Bayer, LeFroy Valley Seeds and DuPont for providing treatment materials.

Insecticide evaluation trial for *Helicoverpa* spp. in lettuce – autumn 2000 (Gatton, QLD)

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Introduction

The specific aim of this trial was to compare the efficacy of Avatar®, Success®, Secure®, XenTari®, Gemstar® and Proclaim® against grower standard and unsprayed controls for control of Heliothis in lettuce.

Materials and Methods

A replicated small plot trial was set up at the Gatton Research Station to evaluate the effectiveness of a range of insecticides, both new and old, for the Heliothis control in lettuce.

The treatments were as follows:

1. Standard grower application spray schedule – methomyl (2 L/ha)
   alpha-cypermethrin (0.4 L/ha)
   endosulfan (2.1 L/ha)
2. Avatar ® - indoxacarb at 125 g/ha
3. Avatar - indoxacarb at 170 g/ha
4. Success® - spinosad at 400-800 ml/ha
5. Secure® - chlorfenapyr at 550 ml/ha
6. XenTari® - *Bacillus thuringiensis* at 1 Kg/ha
7. Gemstar® at 375-500 ml/ha
8. Proclaim® - emamectin benzoate at 440-880 ml/ha
9. Unsprayed control

Each product will be applied using Bond® wetting agent.

The trial was planted on the 22 February 2000. Each treatment was replicated 4 times using a randomised complete block design. Plot size was 4.5m (6 rows of lettuce) x 18m long beds. Total area of lettuce planted was approximately 3240m^2. Treatment design is shown in Figure 1.

Figure 2: Field layout of lettuce trial

Block1	1	2	3	4	5
	6	7	8	9	
Block2	4	6	1	5	8
	9		7	3	2
Block3	3	9	2	6	1
		4	5	8	7
Block4	7	5	6		3
	2	8	9	1	4

Treatments were applied using a SOLO motorised backpack sprayer with a 1.2m boom attachment delivering approximately 450 to 500L water per ha.

Monitoring of the crop commenced one week after planting and then twice a week until harvest. Spray decisions were based upon action thresholds of 2-3 Heliothis eggs per 20 plants and 1 Heliothis larva per 20 plants sampled. Other insect pests such as aphids, thrips, Lucerne leafroller and Rutherglen bugs were likewise monitored. Disease levels were also monitored with fungicide sprays being applied when needed as preventative treatments.

At harvest, 11 April 2000, 25 plants were selected at random from the middle two rows of lettuce in each plot, a total of 100 plants from each treatment. Plants were checked for the presence of Heliothis, Loopers, Cluster caterpillars and Lucerne leafroller larvae both in the wrapper leaves and in the heads. Damage assessment was also carried out on the wrapper leaves and the heads. This was a rating scale of 1 to 5, indicating no damage, minimum damage, slight damage, moderate damage and severe damage, respectively. Ratings of 1 and 2 could be considered as marketable while 4 and 5 would most likely be rejected. A rating of 3 could also be considered as marketable after some trimming but this would depend on where the damage was on the plant. Heads were also cut open to inspect for the presence of Heliothis larvae. Assessment of disease incidence was also carried out on these plants at harvest.

Results and Discussion

During the life of the crop, four applications of the treatments were applied, with 8-11 day intervals between applications. There were four main lepidopteran pests, *Helicoverpa* species, *Thysanoplausia orichalcea* (Soybean looper), *Spodoptera litura* (Cluster caterpillar) and *Merophyus divulsana* (Lucerne leafroller). Of these the Lucerne leafroller was the most common. Pressure from the other three pests was variable and very low, making it difficult to determine the effects of the various treatments. As a result, data for these pests were not analysed and included in this report. However, a high egg lay of loopers, 83.5 eggs per 20 plants in the unsprayed plots, was observed on the 28 March. This did not however result in a high number of larvae in the unsprayed control plots as might have been expected. At harvest on the 11 April, there were only, on average, 2.6 larvae per 20 plants in the unsprayed plots. Parasitism from *Trichogramma* was up to 80% and numerous other beneficial insects were observed during the life of the crop. These combined might have accounted for such high mortality of this pest.

Lucerne leafroller was the most important pest throughout this trial and as seen in Figure 2 and it was still of concern at harvest. Harvest assessment was made separately for wrapper leaves, and the the head/heart. As seen in Figure 1 the lucerne leafroller was a problem in both parts of the plant, with no one insecticide giving 100% control of this pest (Table 1). Its habit of folding over leaves and living beneath silk threads, as seen in Figure 3, makes it extremely difficult to control with insecticides.

Figure 2. Lucerne leafroller pulls the leaf together and holds them with fine silk threads.

Table 1. Treatment means per 20 plants for Lucerne leafroller (LLR) and quality assessment ratings of the plants at harvest.

Treatments	LLR Means		Quality assessment	
	LLR in wrapper leaves	LLR in the head/heart	Damage to wrapper leaves	Damage to head/heart
Standard	14.25 a	4.00 a	1.75 a	1.25 a
Proclaim	14.75 ab	12.00 ab	1.74 a	1.59 ab
Success	22.50 ab	20.25 abcd	1.94 ab	1.76 bc
Avatar 170g	27.00 abc	9.50 ab	2.33 bc	1.68 abc
Secure	32.00 bc	23.75 bcd	2.44 c	1.92 bcd
Avatar 125g	44.25 cd	14.25 abc	2.7 cd	1.77 bc
XenTari	55.75 d	31.00 cd	2.72 cd	2.15 cde
Gemstar	52.75 d	31.75 cd	3.05 de	2.39 de
Unsprayed control	76.25 e	36.50 d	3.21 e	2.44 e

NB: Means with the same subscript are not significantly different at the 5% level

There were no significant differences between the Grower Standard, Proclaim, Avatar and Success treatments at controlling LLR, both in the wrapper leaves and in the head of the plants. Although there was not any significant difference between Success and the newer products Proclaim and Avatar, the trend did show that these newer products gave better control of LLR particularly on the head of the lettuce. All products were better at controlling LLR than if doing nothing, with XenTari and Gemstar being the least effective at controlling this pest. This was also reflected in the damage assessments of the plants as seen in Table 1.

It would appear that Avatar and Proclaim have a place in pest management in lettuce. Although the data was not generated against the usual pests Heliothis, Loopers and Cluster Caterpillars, these 2 products did have an impact against LLR, which seems to be a Queensland insect pest problem. This data will go along way to help in the registration of these products against this pest.

Further work needs to be carried out to try and improve on the performance of the various products either through better timing of the sprays or with better application methods. Also a trial later in the season on a grower property when the pest pressures might be higher may give us better insights of the relative effectiveness of these treatments.

Acknowledgments

Thanks to the farm staff at Gatton Research Station for maintenance and assistance with the trial site. Thanks also to Tamara and Michael Bolland for their assistance with harvesting of the trial and with monitoring and also to Shane Gishford and Simon White for monitoring the crop. Thanks to Dow Agro Sciences, Aventis, and Norvartis for providing Avatar, Gemstar and Proclaim respectively. This project was funded as part of the HRDC project "Lettuce Integrated Pest and Disease Management (IPDM)".

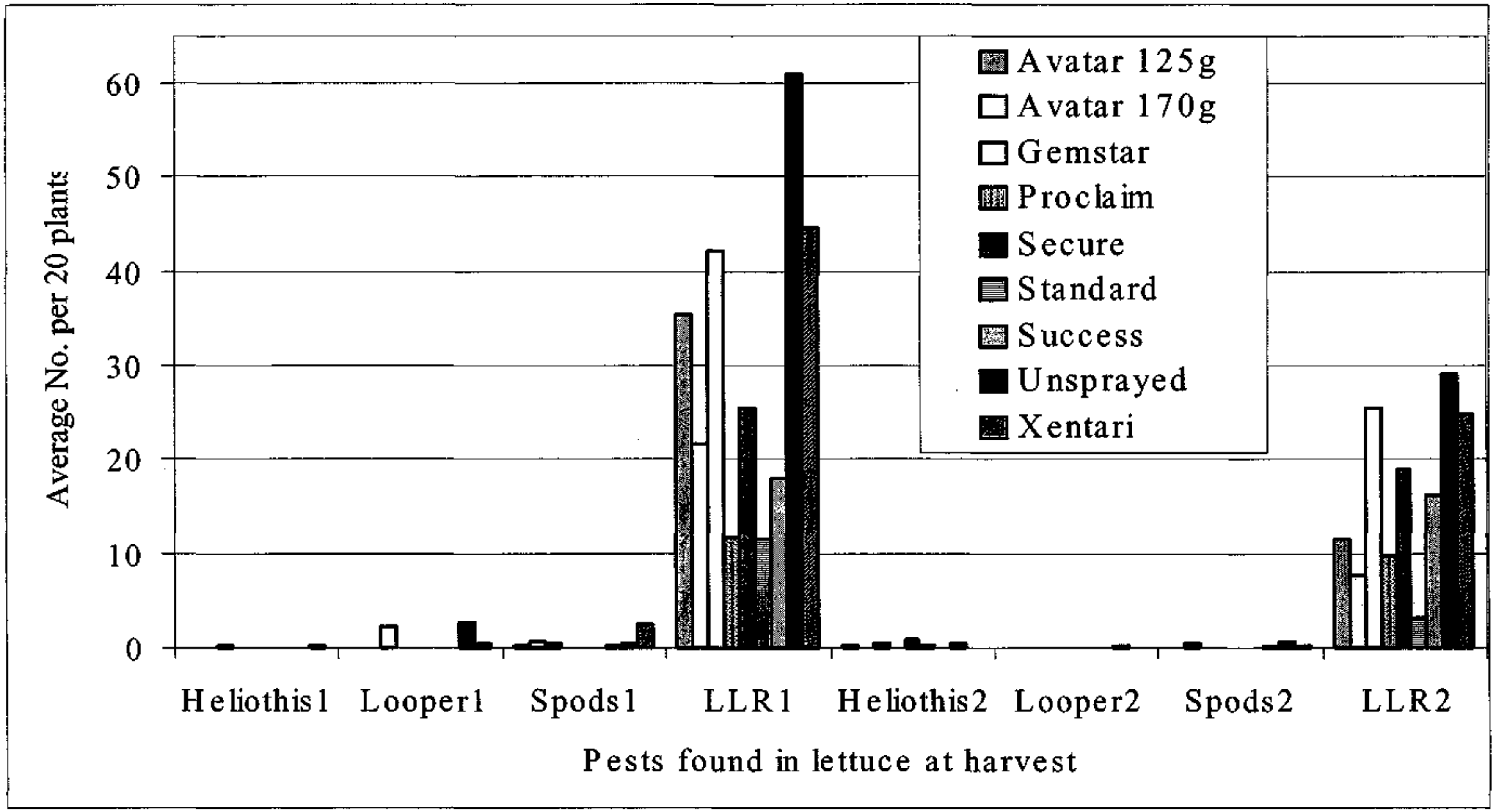

Figure 3. Average pest counts per 20 plants at harvest. Those with labelled with 1 indicate the pests were found in the wrapper leaves and those labelled 2 indicate the pests were found in the head or heart of the plant.

Insecticide evaluation trial for *Helicoverpa* spp. in lettuce – spring 2000 (Gatton, QLD)

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Introduction

This insecticide efficacy trial compared Avatar®, Proclaim®, Secure® to the standard grower control, a best management option (BMO) and an unsprayed control on *Helicoverpa* spp. and other insects on lettuce.

Materials and Methods

A replicated small plot trial was set up on a grower property just outside of Gatton in the Lockyer Valley to evaluate the effectiveness of a range of insecticides, both new and old and two products yet to be registered for the control of *Helicoverpa* species in lettuce.

The treatments were as follows:
1. Standard grower application spray schedule *– methomyl (2 L/ha), endosulfan (2.1 L/ha)
2. Best Management Option (BMO) – Success®* (spinosad at 400-800 ml/ha)
   - XenTari®* (*Bacillus thuringiensis* at 1 Kg/ha)
3. Avatar®* - indoxacarb at 170 g/ha
4. Proclaim® - emamectin benzoate at 150 g/ha
5. Proclaim - emamectin benzoate at 200 g/ha
6. Proclaim - emamectin benzoate at 250 g/ha
7. Secure® - chlorfenapyr at 550 ml/ha
8. Unsprayed control

Each product was applied using Bond® wetting agent.
*Current registrations or permits available for use.

Each treatment was replicated 4 times using a randomised complete block design. Plot sizes were approximately 5.25m (9 rows of lettuce) x 15m long beds. Total area of lettuce planted was 2520m^2. Treatment design is in Figure 1.

Rep1		Avatar	BMO	Proclaim 150	Proclaim 200	Proclaim 250	Secure	Control
Rep2	Control		Proclaim 250	Proclaim 200	Proclaim 150	Avatar	BMO	Secure
Rep3	Proclaim 250	Proclaim 200	Proclaim 150	Control		Secure	Avatar	BMO
Rep4	Proclaim 200	Secure	Control	BMO	Avatar	Proclaim 150		Proclaim 250

N
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Figure 1: Field layout of lettuce trial

Treatment sprays were applied using a SOLO motorised backpack sprayer with a 1.2m boom attachment delivering approximately 450L water per ha. Sprays were applied to the middle two beds or six rows of lettuce with one bed or three rows of lettuce on either side acting as a buffer between the next treatment. Sprays were applied either late afternoon as for the BMO or early morning when conditions were calm and favourable for spray application.

Monitoring of the crop commenced one week after planting and then weekly until harvest. The crop was planted on the 30 August 2000. Ten plants per plot were monitored and spray decisions were based upon action thresholds of 2-3 Heliothis eggs per 20 plants and 1 Heliothis larva per 20 plants sampled. Other insect pests such as Loopers *(Thysanoplusia orichalcea)*, Aphids (*Macrosiphum rosae*), Thrips (*Frankliniella occidentalis*), Lucerne leaf roller (*Merophyus divulsana*) and Rutherglen bugs (*Nysius vinitor*) were monitored for at the same time, but no separate sprays were applied for their control. Disease levels were also monitored for but no sprays were necessary.

At harvest, 20 October 2000, 10 plants were selected at random from the middle of each plot, a total of 40 plants from each treatment. Plants were checked for the presence of Heliothis, Loopers, Cluster caterpillars and Lucerne leafroller larvae both in the wrapper leaves and then in the heads. Damage assessment was also carried out on the wrapper leaves and the heads. A rating scale of 1 to 5 was used, 1 having no damage, 2 was minimum damage, 3 had slight damage, 4 was moderate damage and 5 was severe damage. Ratings 1 and 2 could be considered as marketable while 4 and 5 would most likely be rejected. A 3 rating with some trimming could also be considered as marketable but this would depend on where the damage was on the parts of the plant being assessed. Heads were also cut open to inspect for the presence of Heliothis larvae. Assessment of disease incidence was also carried out on these plants at harvest.

Results and Discussion

During the life of the crop, up to five sprays were applied with the first spray being applied on the 22 September, 3.5 weeks after planting (Table 1). Heliothis *Helicoverpa* species was the main Lepidopteran pest with only minor occurrences of *Thysanoplusia orichalcea* (Soybean looper), *Spodoptera litura* (Cluster caterpillar) and *Merophyus divulsana* (Lucerne leafroller). A high Heliothis egg lay was detected on the 21 September just prior to the first spray application. This coincided with strong westerly winds and high pheromone trap counts observed by local consultants and QDPI officers. Subsequent monitoring revealed only slight egg lays.

Table 1. Number of sprays applied to lettuce treatments.

	Standard	**Avatar**	**BMO**	**Secure**	**Proclaim 150**	**Proclaim 200**	**Proclaim 250**	**Unsprayed**
22/9/00	✓	✓	✓	✓	✓	✓	✓	✗
2/10/00	✓	✓	✗	✗	✗	✓	✓	✗
6/10/00	✓	✓	✓	✓	✓	✗	✗	✗
13/10/00	✓	✓	✗	✓	✓	✓	✓	✗
19/10/00	✓	✓	✓	✓	✓	✓	✓	✗
Total	**5**	**5**	**3**	**4**	**4**	**4**	**4**	**0**

Thrips and Rutherglen bugs would be the other pests most commonly found when monitoring. However no sprays were applied to keep these in check, instead it was decided to see if the above treatments had any effect on their presence compared to the unsprayed control and the fact that this trial was looking at the control of Heliothis using the above insecticides.

The data collected at harvest showed that the majority of treatments were better than the unsprayed control (Table 2 and Figure 2) both with keeping the wrapper leaves and the heads free form Heliothis larvae.

Table 2. Average number of larvae found on 10 plants (replicate) on either the wrapper leaves or the head of the lettuce plant.

Treatments	**Wrapper leaves**	**Wrapper leaves***	**Head**	**Total Heliothis**
Avatar	0.25a	0.25a	0.25a	0.50a
Proclaim 150	0.25a	0.25a	1.00a	1.25a
Proclaim 200	0.75a	0.6036ab	1.00a	1.75ab
Proclaim 250	0.75a	0.6036ab	1.25a	2.00ab
Standard	0.75a	0.6036ab	1.50a	2.25ab
Secure	2.00a	1.1626abc	1.00a	3.00ab
BMO	2.50ab	1.5731bc	2.25a	4.75b
Unsprayed	5.75b	1.9603c	4.75b	10.5c
l.s.d.	3.541	1.099	2.342	3.124

* This column has been transformed using the Square Root transformation to improve residual plot fit.
Means with the same subscript are not significantly different at the 5% level.

The presence of Heliothis on the wrapper leaves was considered only slightly significant between treatments as a result of large residual values in some of the replicates. When transformed, this significance was more pronounced as indicated in the above table. The only treatments that showed a clear significant difference from the control treatment were Avatar and the three rates of Proclaim as well as the Standard treatment. The BMO treatment was not significantly different from the unsprayed treatment as was the case with the Secure treatment.
The presence of Heliothis in the heads showed that all treatments were significantly better than the unsprayed treatment including the BMO treatment.

When considering the total number of Heliothis present on the whole plant, all treatments gave significantly better control of Heliothis than the unsprayed control. Avatar and Proclaim 150 were also significantly better at controlling Heliothis than the BMO treatment. This could be attributed to the timing of the sprays and the fact that a slightly longer period was allowed to elapse between BMO sprays as seen in Table 1. As the BMO is still in its trial phase it was felt that a greater interval between sprays might have been possible, but this may not be the case and may depend on the Heliothis pressure at the time. The BMO treatment was however not significantly different when compared to the two higher rates of Proclaim, the Standard or the Secure treatments, although the trend did indicate an increased number of Heliothis with the BMO treatment. Better timing with this treatment might help to improve its performance in the field and needs to be further tested in future trials.

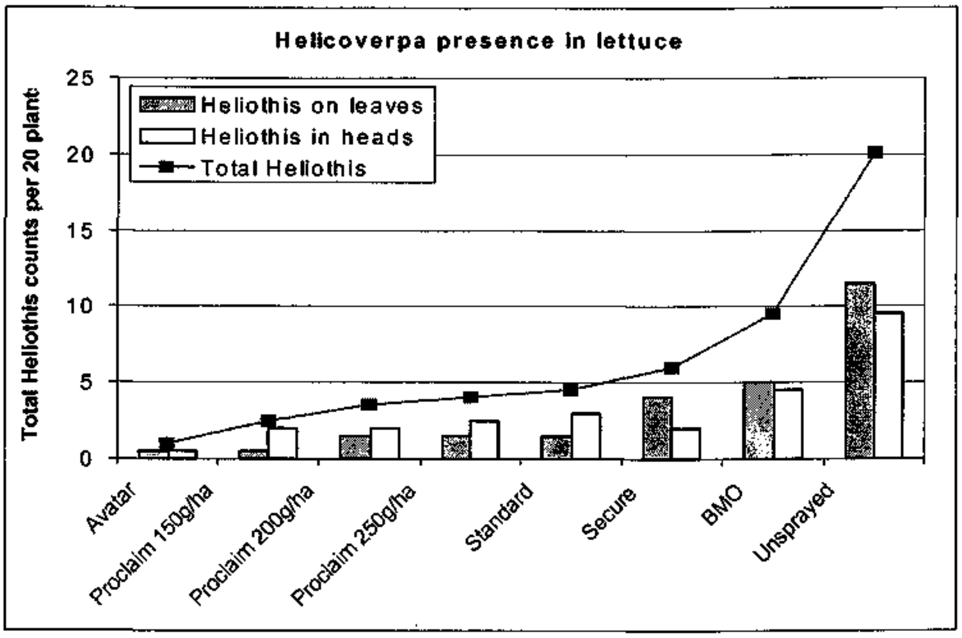

Figure 2. Heliothis larval numbers per 20 plants per treatment at harvest.

As a percentage of crop loss or number of plants with Heliothis, Table 3 and Figure 3 again show that Avatar and Proclaim to be the best performers, although they are not significantly different from the grower standard. All insecticide treatments were however significantly better at Heliothis control than the unsprayed control with regards the number of clean heads or clean whole plants. The BMO treatment consistently performed poorly against the other treatments and was generally not significantly different from the unsprayed control.

Table 3. Average number of plants per replicate (10 plants) that have Heliothis present on either the wrapper leaves, the head or the whole plant.

Treatments	**Wrapper leaves**	**Head**	**Whole plant**
Avatar	0.25a	0.25a	0.5a
Proclaim 150	0.25a	1.00a	1.25ab
Proclaim 200	0.75a	0.75a	1.50ab
Proclaim 250	0.75a	1.25a	1.75ab
Standard	0.75a	1.25a	2.00ab
Secure	2.00ab	1.00a	3.00b
BMO	2.25ab	2.00ab	3.25b
Unsprayed	4.00b	3.75b	6.50c
l.s.d.	2.229	1.936	2.077

Means with the same subscript are not significantly different at the 5% level.

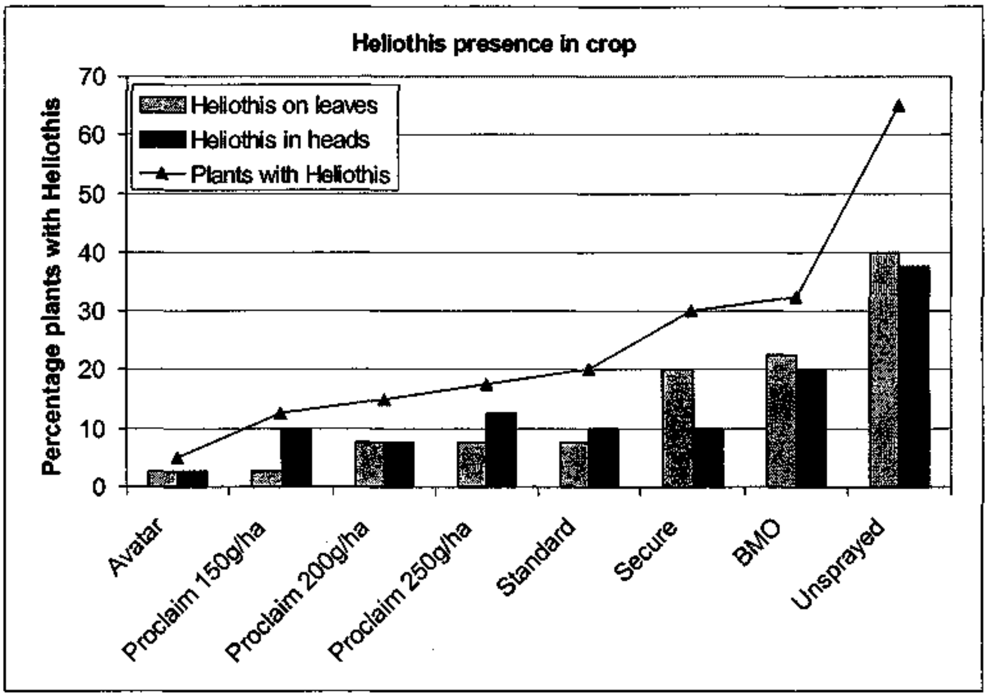

Figure 3. Percentage of the treatment (crop) infested by Heliothis larvae.

With regards the damage to the wrapper leaves and the head, all treatments were significantly better than the unsprayed control (Table 4). The BMO treatment did have significantly more damage to the wrapper leaves than the Avatar and Proclaim leaves. This was not the case with the heads however. All treatments resulted in relatively clean heads, with the exception of the unsprayed control, which would be useful from the point of view of processing. There was still the trend for Avatar to out perform the other treatments. Average ratings of between 1 and 2 would allow the majority of plants to be sold provided they did not have Heliothis larvae present on or within the plant.

Table 4. Damage by Heliothis to the wrapper leaves and the head of the lettuce.

Treatment	**Wrapper leaves**	**Head**
Avatar	1.225a	1.075a
Proclaim 150	1.225a	1.200a
Proclaim 200	1.250a	1.20a
Proclaim 250	1.300a	1.25a
Standard	1.400ab	1.325a
Secure	1.525ab	1.35a
BMO	1.700b	1.60a
Unsprayed	2.875c	2.40b
l.s.d.	0.3659	0.685

Means with the same subscript are not significantly different at the 5% level.

From this trial, it would appear that both Avatar and Proclaim have a place in pest management in lettuce. This follows on from an earlier report at the beginning of the season, which showed these 2 products do have an impact against Lucerne Leafroller, which seems to be a Queensland insect pest problem. It is hoped that this data will help in the registration of these products against these pests.

There was no differences between treatments when it came to Thrips control, all performed poorly. There were significantly higher numbers of Rutherglen bugs found in the standard treatment compared to the other treatments including the unsprayed control. It is unclear why this would be the case. Whether beneficial insects had a role to play or the standard treatment created a situation whereby competition with other insects and/or beneficial insects was reduced allowing the Rutherglen bugs to feed unchecked may need further investigation.

From the data generated above, further work needs to be carried out to try and improve on the performance of the Best Management Strategy, either through better timing of the sprays or with the application of the sprays.

Acknowledgments

Thanks to Max Durham from Durham Farms for allowing this trial to be conducted on his crop. Thanks Paul Kleinmeulman for his assistance with harvesting of the trial. Thanks to DuPont and Norvartis for providing Avatar and Proclaim respectively. This project was funded as part of the HRDC project "Lettuce Integrated Pest and Disease Management (IPDM)"

Insecticide evaluation trial for *Helicoverpa* spp. in lettuce – autumn 2001 (Hay, NSW)

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Introduction

This insecticide efficacy trial compared a new chemistry insecticide, emamectin benzoate and a Neem oil product, azadirachtin on *Helicoverpa* spp. and other insects on lettuce.

Materials and Methods

The field trial was conducted between 15 March - 19 April 2001 on a lettuce farm in Hay, southern NSW. The treatments included in the trial were:

1. NeemAzal® @ 1000 ml/ha
2. NeemAzal® @ 1000 ml/ha + Synertrol (wetter/sticker) at 2000 mlL/ha
3. NeemAzal® @ 2000 ml/ha
4. Proclaim® (44gai/kg) @ 150 g/ha
5. Proclaim® (44gai/kg) @ 200 g/ha
6. Proclaim® (44gai/kg) @ 250 g/ha
7. Grower spray options
8. Unsprayed control

The trial was designed as randomised complete blocks with 5 blocks (replicates) per treatment. One plot consists of a 23-m section of 4 consecutive beds (ca. 0.014 ha) (Figure 1).

Figure 1. Diagram of insecticide efficacy trial plots

T1	T2	T3	T4	T5	T6	T7	T8
T4	T6	T8	T5	T7	T2	T3	T1
T3	T1	T2	T4	T8	T5	T6	T7
T7	T5	T6	T3	T2	T1	T8	T4
T1	T8	T4	T7	T6	T5	T2	T3

Sprays were applied with a 14lt Silvan battery powered backpack sprayer, running at 200Kpa and using a handheld boom with droppers. While the lettuce were small (pre-hearted) the boom was set up with 4 T-jet cone nozzels (TXVK 6) to spray over the two rows of lettuce in effect covering only 50% of the soil area. As the crop grew and covered more of the beds sprays were applied using 6 nozzels per bed essentially covering the whole area. In both cases the equivalent water rate was 350 L/ha.

Each plot was sampled weekly from the four-leaf stage until harvest. In each plot whole plants were monitored for a total of 8 minutes. The eggs were categorised into: white (fresh), orange, brown (near hatching), and black (parasitised). Larvae were categorized into 1-6 larval instars. Spray decisions were based upon an action threshold of (1 egg per 20 plants). If the threshold was equalled or exceeded then treatment/s were applied.

When the action threshold was exceeded in the Grower spray option treatment the grower was consulted and the same insecticide as his most recent spray was used. Four insecticides were normally sprayed by the grower to control Heliothis: spinosad (120gai/L @ 400-800 ml/ha), methomyl (450gai/L @ 2L/ha), endosulfan (350 gai/L @ 2.1L/ha), and alpha-cypermethrin (100 gai/L @ 400ml/ha).

Given different numbers of lettuces were inspected during the 8-minute searches, the numbers of insects (eggs or larvae) found during the searches were standardised to numbers per 100 lettuces. Percentages of insect damaged lettuces observed at harvest were subjected to arcsine transformation. The standardised or transformed data were then analysed with ANOVA for the complete random block design. Where significant differences were detected the treatment means were separated with Duncan's Multiple Range Test.

Results

Heliothis pressure immediately before the trial was low to moderate. The number of Heliothis eggs per 100 plants as determined from visual inspection among the 40 plots ranged from 4 to 65 and that of heliothis larvae from 0 to 22. The pre-treatment data showed no significant differences among the treatments in either the egg numbers or the larval numbers (P >0.05). Recruitment of Heliothis to the trial site after the trial had started was negligible, ranging from 0 to 3 eggs per 100 plants.

All 8 treatments were applied on March 15th. Plots for the Grower spray options were sprayed with a mixture of alpha-cypermethrin and endosulfan. On March 28th, treatments 1-3 and 6-7 were sprayed. Plots for the Grower spray options were sprayed with methomyl. On April 4th, treatments 1-4 and 6 were sprayed.

Numbers of Heliothis larvae decreased dramatically in all plots after the first treatment application (Figure 2).

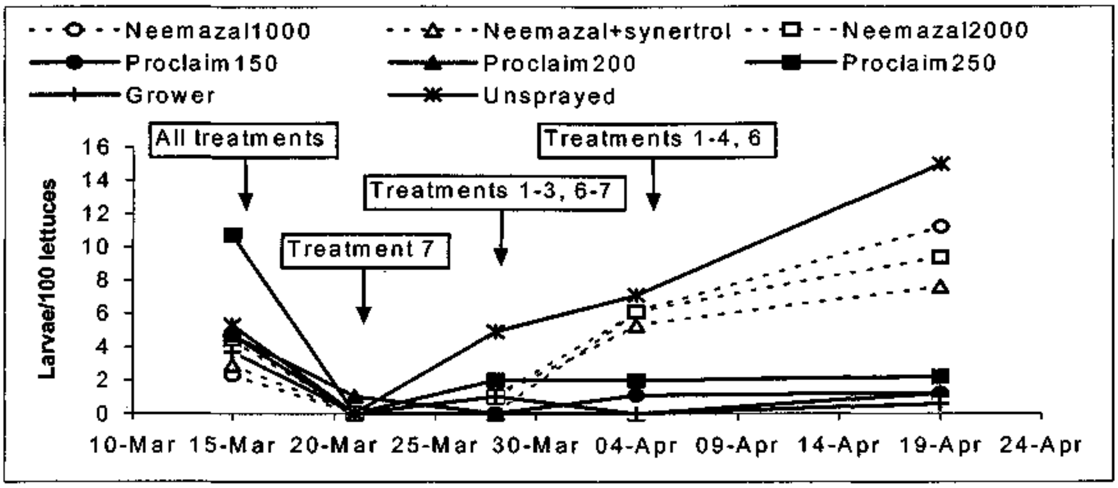

Figure 2. Heliothis larval density during the trial. (Arrows show the timing of treatment applications.)

Two weeks after the first application, the larval numbers gradually recovered in Unsprayed plots and in plots subjected to the 3 NeemAzal treatments. However, the larval numbers remained relatively low for the rest of the trial period in plots subjected to the 3 Proclaim treatments and Grower spray options. By the time of harvesting, 3 distinct groups of the treatments can be seen. The 3 groups were, in decreasing order of larval numbers, Unsprayed control, 3 NeemAzal treatments, and 3 Proclaim treatments plus the treatment for Grower spray options. The differences in larval numbers among the 8 treatments were slightly significant 2 weeks after the first spray (P < 0.1) and highly significant at the time of harvesting (P < 0.000). The multiple range tests put Unsprayed control in one group and the rest of the treatments in another group 2 weeks after the first spray. Statistical grouping of the treatments in larval numbers at the harvest time agreed with the visual grouping shown in figure 2. Data collected from the destructive sampling (cut-open inspection) at harvest time again showed highly significant differences in larval numbers among the treatments (P <0.000). However, only 2 statistical groups were detected: Unsprayed control and the 3 NeemAzal treatments in one group and Grower spray options and the 3 Proclaim treatments in another group, the former group having significantly higher numbers of larvae than the second group.

Percentages of lettuces damaged by Heliothis at harvesting time ranged from 5% in plots for Growers spray options to 29% in Unsprayed plots. The percentages in plots for Grower spray options and those for the 3 Proclaim treatments were significantly lower than that in the Unsprayed plots (P <0.05), whereas those for the 3 NeemAzal treatments were not significantly different from that in the Unsprayed plots (P >0.05) (Figure 3). No significant differences were detected among the treatments in the percentages of small lettuces at harvest time.

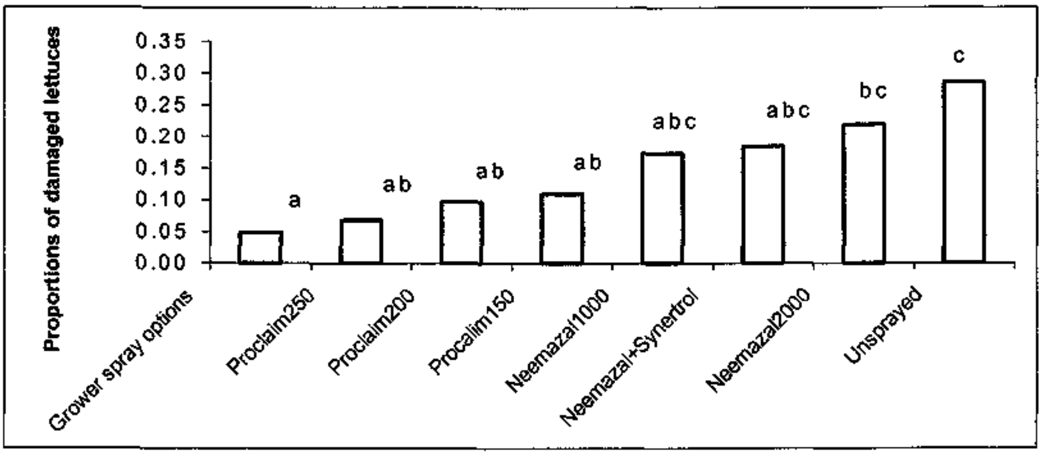

Figure 3. Proportions of lettuces damaged by Heliothis.
Column labels not sharing common letters indicate significant differences of the corresponding columns at 95% confidence level.

Apart from Heliothis, the following insects or insect groups were commonly found at the trial site at some stages during the trial period: aphids, leafhoppers, Rutherglen bug, beetles (including lady beetles), spiders, small wasps, thrips, and whiteflies. The treatments showed no significant effects on the abundance of aphids, beetles, spiders, small wasps, thrips and whiteflies. However, significant effects of the treatments were detected in the abundance of leafhoppers and Rutherglen bug ($P < 0.05$). On March 28th, plots for NeemAzal plus Synertrol and those for Proclaim250 had significantly higher numbers of leafhoppers than plots for Grower spray options. On April 4th, NeemAzal plus Synertrol, Proclaim250, Neemazal2000, and Unsprayed control had significant higher numbers of leafhoppers than Grower spray options. Rutherglen bug was absent at the trial site until April 4th, when large numbers of them suddenly appeared. Significantly higher numbers of the Rutherglen bug were found in plots of NeemAzal2000 than in other plots.

Conclusions

Three Neemazal treatments and 3 Proclaim treatments were compared with grower spray options in controlling Heliothis in lettuces. The study found that the 3 Proclaim treatments were as effective as Grower spray options. The lowest rate Proclaim treatment (150 g/ha) was as effective as the highest rate Proclaim treatment (250 g/ha). On the other hand, Proclaim did not seem to have significant effect on other pests such as leafhoppers, Rutherglen bug, thrips and whiteflies or beneficial insects such as spiders, wasps, and ladybeetles. The NeemAzal treatments were not effective against Heliothis or other insects observed in this trial.

Acknowledgements

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Evaluating a Best Management Option for the control of *Helicoverpa* spp. in lettuce

Introduction

Pest management is a fundamental part of cropping. It involves the management of one or more pests capable of damaging a crop to such an extent that it is not fit to harvest. Such pest(s) may be a recurring or occasional problem. Whatever the case growers need to manage the pest(s) in a way that results in the maximum amount of crop harvested and at a quality that is acceptable to the end user, the consumer. The traditional means of control has been the bombardment of the pest(s) with whatever insecticides registered for use in that particular crop against that particular pest. This has in the past worked, but with increasing insecticide resistance problem alternative control methods have to be developed. Consumers are also driving this through demand for cleaner produce.

Over the past 10-15 years increasing number of growers have adopted the practice of Integrated Pest Management (IPM). IPM encourages the use of non-chemical ways to control pests including cultural control and the utilisation of beneficial insects. Findings from IPM researches can be used to develop Best Management Options (BMO) for pest control. BMO looks at those practices that growers can readily use to help manage their pest(s) with the minimum of input of harsh chemicals.

Crops that are in the ground longer and have canopy structures conducive to the build-up of beneficial insect are better suited to IPM approaches. Sweet corn is a good example of such a crop and has reaped the rewards of IPM. Lettuce on the other hand is a short-lived crop low to the ground and is most attractive to pests, Heliothis in particular, rather than beneficial insects. Therefore a BMO in lettuce may only involve the use of monitoring to inform growers when to spray, and the strategic use of softer option insecticides which are safe to the environment, the grower, consumer and if there are any, beneficial insects.

This research project has developed a monitoring procedure, and some guidelines for what numbers of a particular pest constitutes a problem that needs controlling (pest threshold), improved spray application techniques, and a wider range of choices for insecticidal control. As part of this project small plot trials were conducted to evaluate the efficacy of a number of biological and new generation insecticides for control of *H. armigera*. Registration for a new insecticide in a new chemical group in lettuce was achieved in spring of 1999 with Success® (spinosad). A permit for the use of *Bacillus thuringiensis kurstaki* (Btk) was granted in 1998, in 2001 Avatar® (indoxacarb) and in 2002 Gemstar® (Heliothis nuclear polyhedrosis virus) were registered for use in lettuce. Other insecticides trialed in this project are expected to be registered for use in lettuce in the future.

Efficacy trials are usually conducted in small plots, using handheld spray devices, and to avoid confusion about what chemical is doing what, each treatment plot uses the same chemical and chemical rate repeatedly throughout the trial. Using the same chemical group repeatedly is the quickest way to encourage a resistant pest population and is therefore not considered good pest management practice. After the registration of Success® and having a permit for use of Bt we decided it was valuable to combine the tools we had developed into what we called the Best Management Option (BMO) and compare to current management practice.

Evaluating a Best Management Option for the control of *Helicoverpa* spp. in lettuce – spring 2000 (Hay, NSW)

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Introduction

This trial aimed to compare the combined tools we had developed and were available to growers in what we called the 'Best Management Option' (BMO) to an existing grower practice.

Materials and Methods

The lettuce Best Management Option trial was direct seeded in a 4th August 2000 planting of Magnum on the Maud road in Hay, NSW. The two treatments were a 'grower' treatment and a 'best management option' (BMO). This was an unreplicated trial. The BMO plot was 5 beds wide extending the full length of the lettuce planting (193m), totaling 0.144 ha. From emergence until the lettuce began to heart 40 lettuce were monitored from the centre three beds of lettuce in the BMO plot. The application of the threshold of 1 egg or larvae in 20 plants was used to indicate whether the crop required treatment. Sprays in the BMO were applied with an overhead boom modified with droppers, with three T-Jet twin fan nozzels (TJ60-11004VS) directed per lettuce row and 400L/ha. The remaining beds were managed by the collaborating grower, and although, the crop was monitored for insects on a weekly basis, the information was not used to inform what treatments were to be used. The grower used an overhead boom for spray applications.

The choice of insecticides for Heliothis control in the BMO was as follows:

1. Btk be used in early crop stages and if caterpillar pressure is light.
2. Spinosad be used if caterpillar pressure was high or a failure with Btk was observed

After the crop was monitored a decision to spray was based on a threshold of 0.05 eggs per plant. Timing of sprays was to be timed to egg hatch if possible. So if larvae were present then sprays were applied immediately otherwise they were delayed. Given the cooler temperatures white eggs would not hatch until after the following scheduled monitor. Once the lettuce had hearted sprays were not considered to provide much benefit.

Btk sprays were to be applied as late in the day as practical to reduce the exposure to UV radiation and give the caterpillars as best a chance to ingest a toxic dose before the Btk was photodegraded.

At harvest 1000 plants were visually assessed in each plot for Heliothis or other caterpillar damage and for incidence of disease.

Results

This trial was conducted in spring and as was expected *Helicoverpa punctigera* predominated in pheromone trap catches (Figure 1).

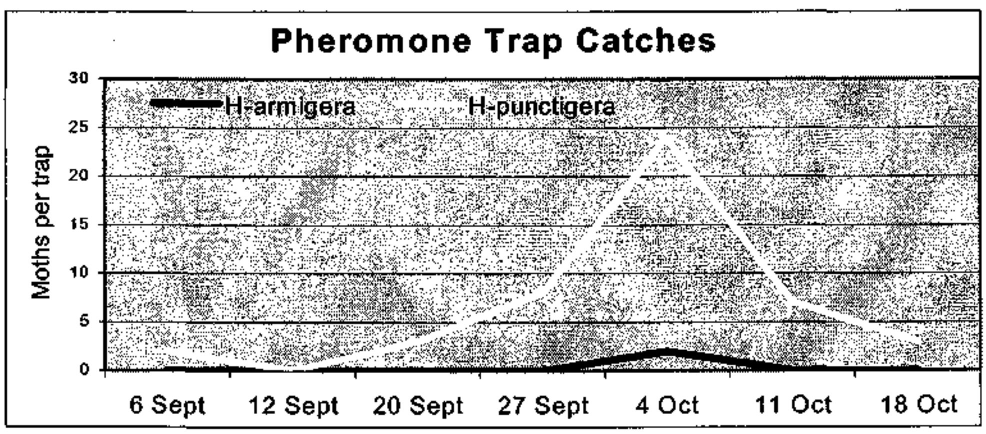

Figure 1. Weekly catches of Heliothis moths in pheromone pot traps

Caterpillar eggs were consistently above the conservative threshold of 0.05 eggs per plant (Figure 2). Heliothis egg numbers tended to be higher in the Grower plot and were 5-6x higher in the first two weeks of October. Looper eggs were also found in the plots, with peak numbers in late September.

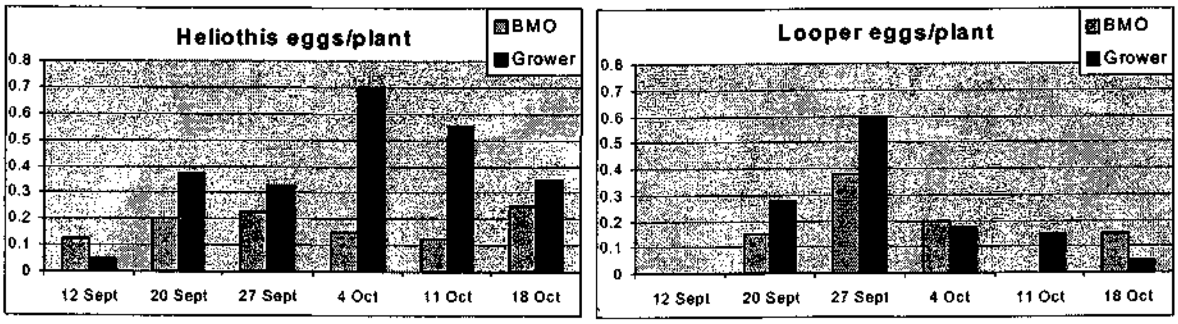

Figure 2. Weekly moth egg numbers per plant in the BMO and Grower plots

Most of the eggs monitored, Heliothis or Looper, were freshly lain (white) with only small numbers of eggs close to hatching (brown) (Figure 3).

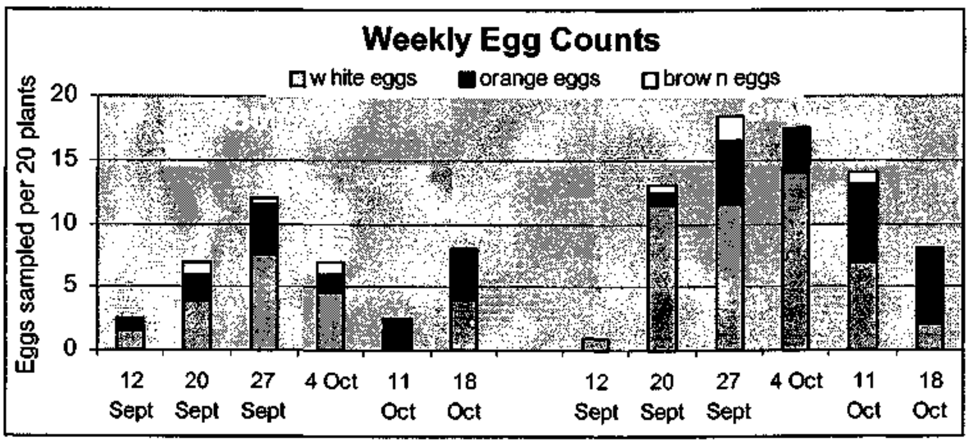

Figure 3. Weekly observations of moth eggs (by age) sampled per 20 plants monitored for each treatment.

Smaller numbers of larvae were monitored each week, with more seen in the BMO plot early on and larger numbers observed in the Grower plot close to harvest (Figure 4). All of the larvae found in the BMO plot were small larvae (1st or 2nd instars) and in the Grower plot some were medium larvae (3rd or 4th instars) (Figure 5).

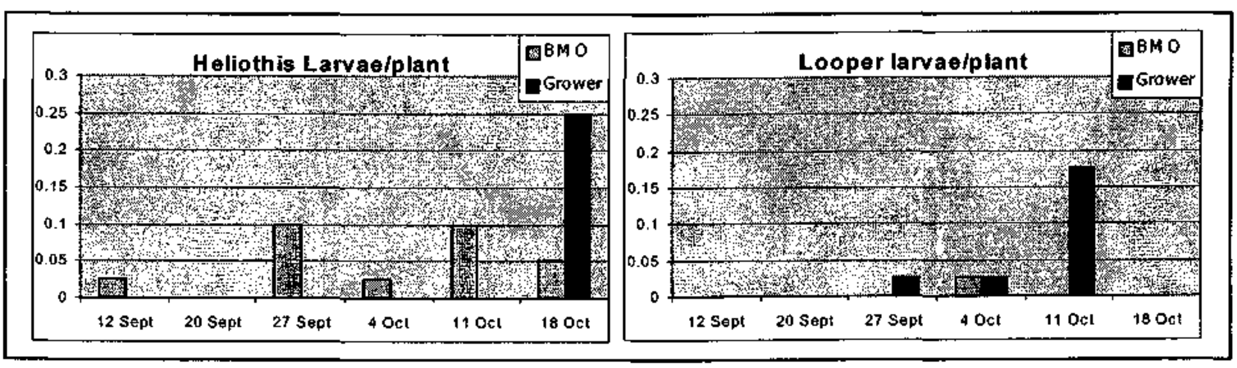

Figure 4. Weekly moth larval numbers per plant in the BMO and Grower plots

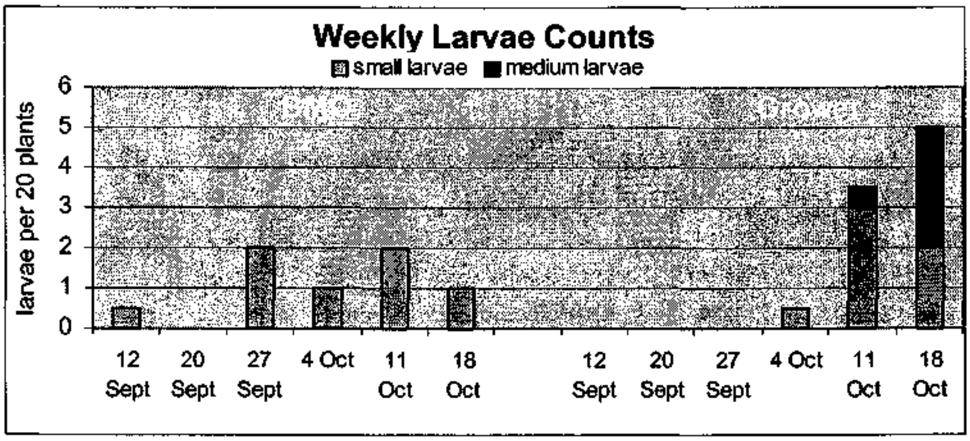

Figure 5. Weekly moth larval counts by size and treatment per 20 plants monitored

Sap sucker numbers per plant increased steadily over the crop development (Figure 6a). Almost half of the sap suckers monitored were thrips, and the remaining were made up of aphids, leafhoppers and Rutherglen bugs. Predator numbers were low through most of the crop development and increased just prior to harvest (Figure 6b). More than 75% of the predators were spiders, with small number of aphid parasitoids being observed towards the latter half of the crop development and a few individual big-eyed bugs (*Geocoris* spp.), brown lacewings and Pollen beetles also observed.

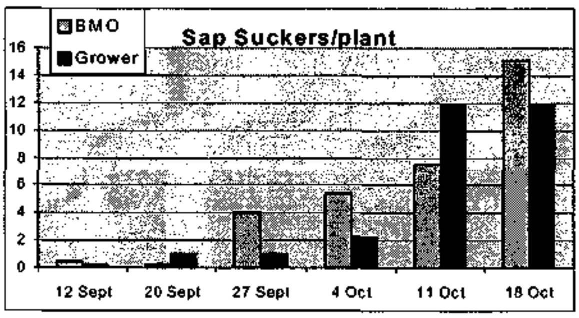

Figure 6a. Weekly counts of sap suckers monitored per plant per treatment

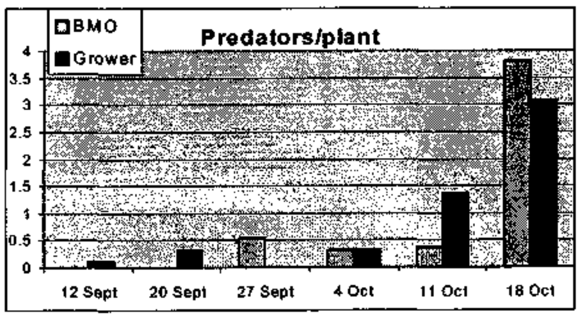

Figure 6b. Weekly counts of predators monitored per plant per treatment

At harvest of the 1000 plants sampled in each plot, 2 lettuce in the Grower plot had grub inside the head and 14 had feeding damage on the outer leaves indicating total caterpillar damage of only 1.6%. In the BMO plot none of the lettuce had caterpillars inside the head and 10 had feeding damage on the outer leaves indicating total caterpillar damage of 1%. Of the 1000 plants sampled in the Grower plot one lettuce had bigvein, 2 had necrotic yellows and 2 had tomato spotted wilt virus. In the BMO plot only 1 tomato spotted wilt virus and 2 necrotic yellows virus lettuce were sampled.

The fungicides and insecticides used on the Grower plot were:

2x Sumislex® (procymidone) – 1000gai/ha (2L/ha) – [fungicide]
Mancozeb® (mancozeb) – 1275gai/ha (2L/ha) – [fungicide]
Lannate® (methomyl) – 450gai/ha (2L/ha) [broad-spectrum insecticide with some ovacidal activity, used here against caterpillars]
2x Rogor® (dimethoate) – 150gai/ha (L/ha) [broad-spectrum insecticide used against sucking insects]
Success® (spinosad) – 96gai/ha (800ml/ha) [new-generation insecticide used against caterpillars]

The fungicides and insecticides used on the BMO plot were:

1x Sumislex® (procymidone) – 1000gai/ha (2L/ha) – [fungicide]
3x Dipel Fortè (*Bacillus thuringiensis kurstaki*) – 1L/ha [biological insecticide used against caterpillars]
Success® (spinosad) – 96gai/ha (800ml/ha) [new-generation insecticide used against caterpillars]

The biological and new generation insecticides are more expensive than the older broad spectrum insecticides, which translates into the BMO costing 25% more per hectare than the Grower treatment.

Table 1. Comparison of treatment costs

	BMO			Grower		
Spray Date	Chemical	Chemical rate /ha	Chem$/ha	Chemical	Chemical rate /ha	Chem$/ha
8/09/00	Sumislex	2	$ 158.00			
15/09/00				Sumislex	2	$ 158.00
20/09/00	Dipel	1	$ 61.60			
27/09/00	Success	0.8	$ 110.40	Mancozeb	2.2	$ 15.29
				Lannate	2	$ 24.00
				Rogor	0.8	$ 7.00
				Sumislex	2	$ 158.00
4/10/00	Dipel	1	$ 61.60			
11/10/00	Dipel	1	$ 61.60			
13/10/00				Success	0.8	$ 110.40
				Rogor	0.8	$ 7.00
TOTAL			$ 453.20			$ 362.29

Discussion

This trial indicated that using the softer options of biological sprays gave as good if not slightly better results than treatments with the broader spectrum insecticides in spring. The damage levels were very low despite reaching the thresholds most sample periods. This suggests that in the spring when the more insecticide susceptible caterpillars predominate the threshold could be higher. The costs of the newer chemistries are significantly higher than the older chemistry. Conducting this trial again when pressure is higher or when the caterpillar population is primarily of the synthetic pyrethroid and carbamate resistant *Helicoverpa armigera* may show greater differences between the treatments and perhaps justify the higher costs of the BMO.

Acknowledgments

Thanks to the Gargaro family for providing the trial site and accommodating us so well. Thanks to Meryl Snudden, Karen Ryan, Andrew Watson for helping with the harvest assessment. Thanks to Bayer for supply of Dipel Forté® and Dow AgroScience for supply of Success®. This project was partially funded by HRDC and from AUSVEG levy funds.

Evaluating a Best Management Option for the control of *Helicoverpa* spp. in lettuce - autumn 2001 (Gatton, QLD)

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Introduction

This trial was set up to investigate a BMO strategy on a local lettuce grower's property to determine the potential of such a system and any benefits which might stem from it.

Materials and Methods

The trial was initiated at the beginning of the growing season to coincide with expected high Heliothis pressure. Only those products currently registered for use in lettuce were considered for use in a BMO. Intensive monitoring of the crop to determine the most appropriate time to apply insecticides also played a major part in this system.

The treatments were:
Grower treatment (What ever the grower wanted to use to control Heliothis. This was determined from crop monitoring records provided by a local crop consultant.)
Best Management Option (Using predominantly softer option insecticides such as Bt and Success®, but not eliminating the use of harder synthetic insecticides.)
Standard Practice (What a grower might be expected to use, eg. methomyl, synthetic pyrethroids and possible endosulfan.)
Unsprayed control
Insecticide applications were carried out by the grower and applied according to the monitoring results and when it was deemed most appropriate.

Due to a last minute change in size of spray booms to be used by the grower, plot sizes had to be readjusted and as a result plots were larger than initially planned for. This led to 2 replications in the control treatment having to be missed as we were restricted by the amount of land being supplied by the grower for this trial. Plot sizes were 24m wide (spray boom width) by 25m long. Plots were monitored twice weekly with 2 plants at 5 locations, 10 in total from each plot being checked for insect pests. All pests were monitored for, not just Heliothis. The crop was planted on the 6th March and harvested on the 27th April 2001. All other management decision such as fungicide applications, nutrition and irrigation were carried out by the grower as part of the crops management program.

Harvest coincided with when the grower started harvesting the adjacent crop. Plants were assessed on damage and the presence of Heliothis larvae or any other Lepidoptera larvae such as Lucerne leaf roller (*Merophyus divulsana*). Ten plants from each plot or replication were destructively harvested with percentage infestations and marketable crop being determined.

Results

Heliothis pressure during the trial was considered by the grower as moderate. However the numbers of both eggs and larvae found with in the crop were consistently above the pre-determined action threshold (2 eggs or larvae /20 plants) (Figure 1).

Figure 1 is a result of the intensive monitoring carried out twice weekly during the life of the trial with eggs being well above the threshold recommended to growers for most of the trial period. Larvae were only a problem latter in the life of the crop. For reasons yet unkown, decreases in the number of white eggs were often associated with increased in number of brown eggs.

Harvest results of this and the adjacent grower's crop indicated the potential of a best management option (Figure 2 & 3). There was no significant difference among the BMO, Grower treatment and the Standard practice. The unsprayed control had the greatest number of Heliothis larvae found in both the wrapper leaves and the head. There was an indication from the results that the Grower practice gave a better quality crop than other treatments

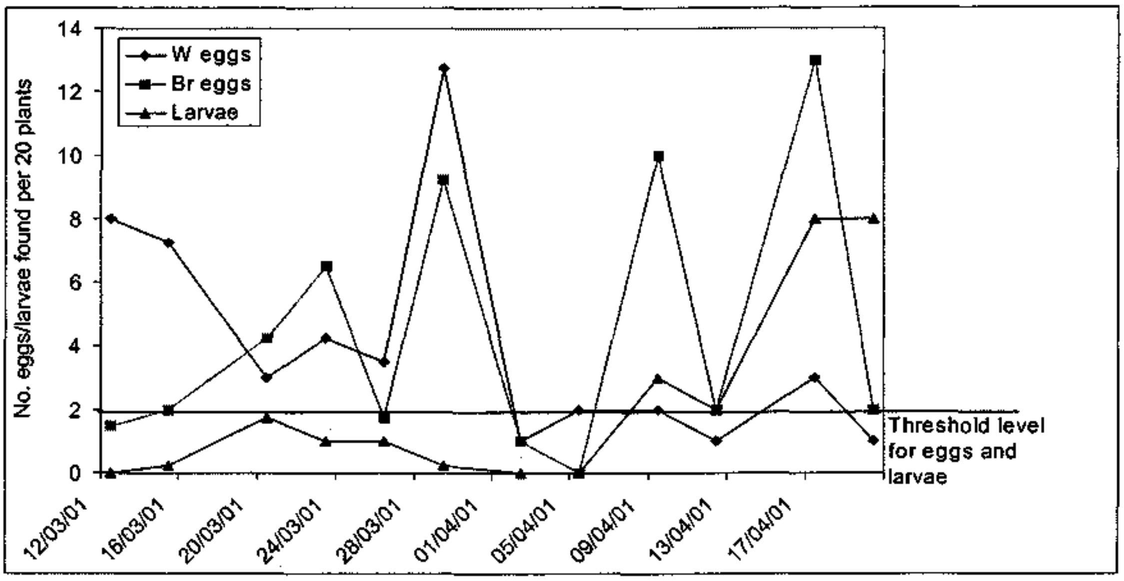

Figure 1. Heliothis pressure during the trial period from the 12 March until the 20 April 2001. A threshold level of 2 eggs or larvae per 20 plants clearly shows pressure to be fairly high throughout most of the period.

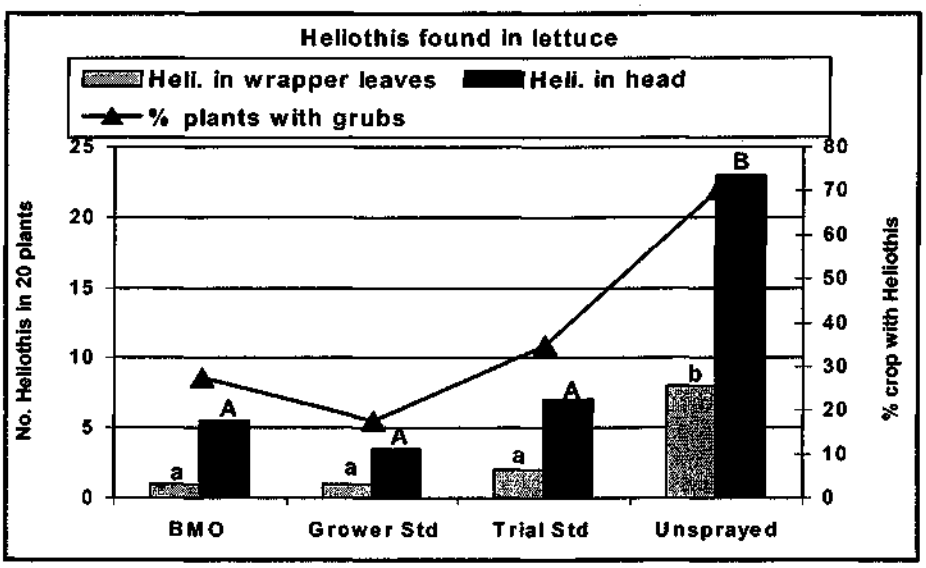

Figure 2. Incidence of Heliothis in the lettuce crop at harvest.
BMO = Best Management Option; Grower Std = Grower crop grown next to the trial site; Trial Std = What a grower might use.

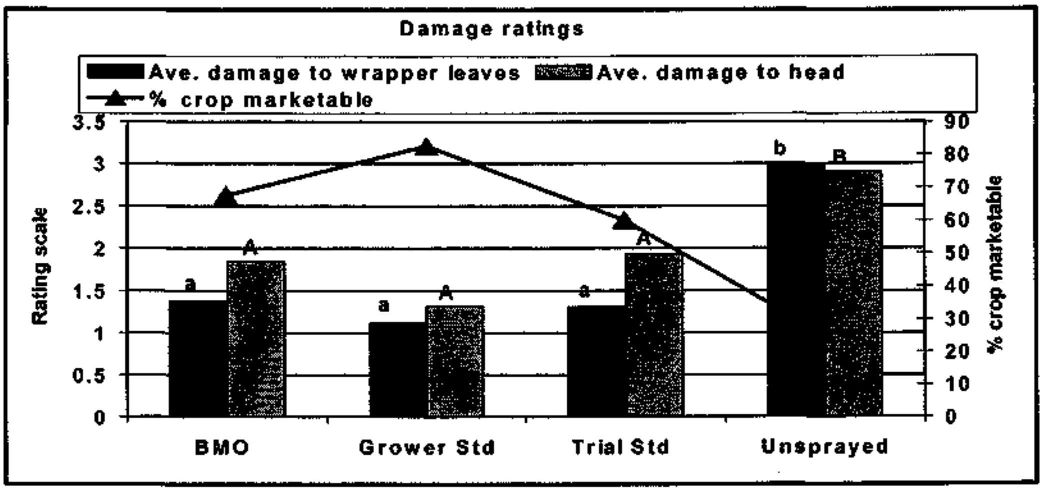

Figure 3. Damage ratings for the different treatments and percentage of the crop that was marketable.

but the differences were not significant. At harvest the Grower treatment also had fewer number of plants with detectable larvae on them but again this was not significant. Doing nothing could result in over 70 of the crop with Heliothis present on or in it.

Crop damage also showed no significant difference between the BMO and the Grower treatment or the Standard practice. It would appear however, that the Grower treatment was slightly better at delivering a cleaner crop. The unsprayed control was by far the worst with only 25% of the crop being of a fit state to be marketed compared to almost 82.5% for the Grower treatment, 67.5% for the BMO and 60% for the Standard practice. A marketable plant is a plant which has no or acceptable damage and no larvae present on or within the plant.

Discussion

The implementation of a Best Management Option for use in lettuce is a clear possibility. The results show that there are no significant differences between the number of larvae, damage or percentage of crop marketable when trying to implement a BMO compared to a grower or standard practice. The grower practice did however show a slight improvement in Heliothis control, marketable crop and less damage. This indicates that there is still room for improvement when trying to develop a BMO for lettuce. This will be pursued in future BMO work. What was clear from this trial was that the number of insecticides used in the grower treatment, in order to control Heliothis, were not justified. Figure 4 below clearly shows that a grower practice may still be using combinations of insecticides costing by far the greatest of the three treatments. When targeting predominantly eggs and newly hatched larvae, those products that have been traditionally used should still be effective on their own.

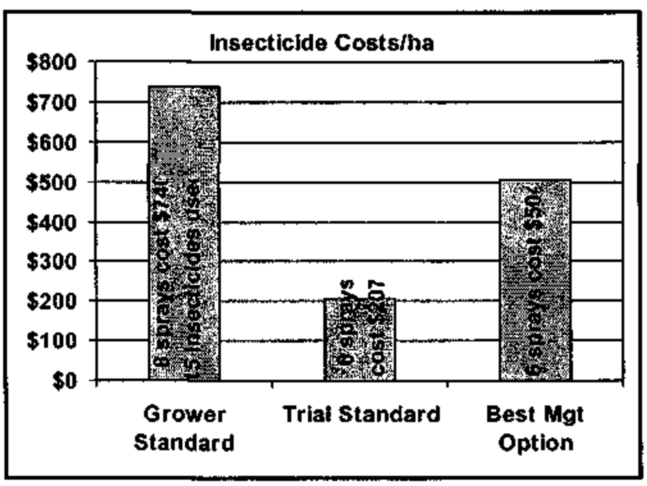

Figure 4. Cost analysis of each treatment and the number of spray applications and insecticides used.

Only when larvae escape an insecticide spray and starts to put on some size does it become more difficult to control due to resistance factors. This should be a minimum occurrence due to the intensive monitoring that does occur in lettuce within southeast Queensland and the need to target the brown egg stage of Heliothis. With more refinement of the BMO system, growers could expect to save on the number of insecticides being applied to their crops and on the costs associated with insecticidal treatments. Timing of sprays will be an important issue with lettuce and this could have been part of the reason why there was slightly more damage in the BMO treatment and a reduced marketable yield when compared to the intensive spray program of the grower. There was a tendency to leave spraying if threshold levels were at or slightly above what is currently recommended and also leaving spraying one or two days more than what the grower would do. This would need to be looked at more closely and with greater consultation with the grower whose property the trial is on.

Subsequent BMO treatments will still look at utilising softer option insecticides such as Bt, Success® and now Avatar® which can give a greater residual than methomyl and are much softer on the beneficial populations and the environment. Future BMO trials may also need to look at the control of other pests such as thrips which could become more of an issue as softer option, narrow spectrum insecticides are used in lettuce.

Sclerotinia field trials

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Introduction

One of the more common diseases found in lettuce is lettuce drop caused by *Sclerotinia minor* and *Sclerotinia sclerotiorum*, which cause wilting and death of the plants. Control of the disease can be achieved through cultural and chemical methods but as yet not through varietal resistance. Cultural controls include rotation to non-host crops. Sclerotia, the survival structures of Sclerotinia, are very hardy and can last for many years in the soil. This survival however is reduced by ploughing the sclerotia deep into the soil, flooding soil and by improving conditions for antagonistic microorganisms. The sclerotia can be broken down with soil borne microorganisms that invade the sclerotia. Chemicals currently registered for Sclerotinia control are iprodione and procymidone. Sclerotinia was identified as a disease that needed greater grower understanding, therefore part of this project was directed at developing improved control measures for this disease.

Growers expressed interest during the initial stages of the project the need for improved Sclerotinia control. As a result current recommended treatments with some new treatments were tested.

The recommended application of procymidone for *Sclerotinia sclerotiorum* is to apply it to the point of run-off shortly after transplanting or thinning out, then at 10-14 day intervals to harvest. And for *Sclerotinia minor* to apply to seedlings immediately before transplanting and to apply a soil surface spray immediately after transplanting (or thinning) and repeat applications at 1 and 2 weeks. The sprays must be applied before it is covered by crop growth. Trials were therefore established to look at the timing of application of chemicals for controlling Sclerotinia.

Biological control of Sclerotinia using various *Trichoderma* treatments is being promoted by many companies selling those products. Whereas the future value of these treatments was not an issue, their success under varying growing conditions did not appear to be evaluated by the sellers of these products. Trials were included to assess the success of these products. The lack of success of one product was later suggested to be due to the soil temperature being too cold. Those selling the product would have known this but growers were not made aware of it.

Materials and Methods

The sites for disease trials were selected on paddock history that should have provided conditions conducive to Sclerotinia infection however on some trials no disease occurred. Trials were part of the growers planting ie they were sown by the grower and treated by the grower as part of their crop. However, the grower did not spray them with any fungicide. The replicated trials consisted of five replicates with each plot measuring 10 metres by one bed and with two rows of lettuce on each bed.

Applications of fungicides in all trials were made using a backpack at the recommended label rates. The fungicides and *Trichoderma* were applied to reach underneath the lettuce plants, concentrating around the stem and soil around the lettuce. They were applied as per the information supplied on the labels.

Lettuces were counted at the start of the trial. Lettuce plants that were infected with Sclerotinia were counted each week till harvest.

1999

The trial was part of the growers commercial planting sown on the 4th April and harvested on the 13th July. The variety, Wintergreen, an iceberg type lettuce, was sown directly with seed and thinned. The soil is a grey self-mulching clay. Alternative methods of control were also examined. The treatments were a commercial form of *Trichoderma* (Trichopel®), compost, compost plus the *Trichoderma*, Benomyl® and Sumisclex®. Benomyl was included for *Botrytis* control if it occurred. The fungicides were applied either once or twice. The first spray was applied just after thinning, the second at mid-hearting. Thinning is necessary to reduce plant numbers.

Soil samples were collected from each plot. Sclerotial numbers were counted using a wet sieving technique

2000

In 2000, two trials were carried out except only the iprodione was used as well as the *Trichoderma* treatment. However the *Trichoderma* treatment was another product called Tri-D 25®. The trials were set out in a similar pattern to the trial in the previous year.

2001

In 2001, three trials were conducted with similar treatments as in 2000. The trials were set out again in a similar fashion to those described for in 1999. The variety in two of the trials was Greenway, in the other Wintergreen. The crops used were grown in the period from April to August.

Results

Sclerotinia field trials-1999

One spray of sumisclex after thinning gave excellent control of *S. minor* as seen in Figure 1. *S. sclerotiorum* was not found during the course of this trial.

The *Trichoderma* control did not have any effect. Sclerotial numbers found were very low, from 0-5 sclerotia per 100 grams of air-dried soil.

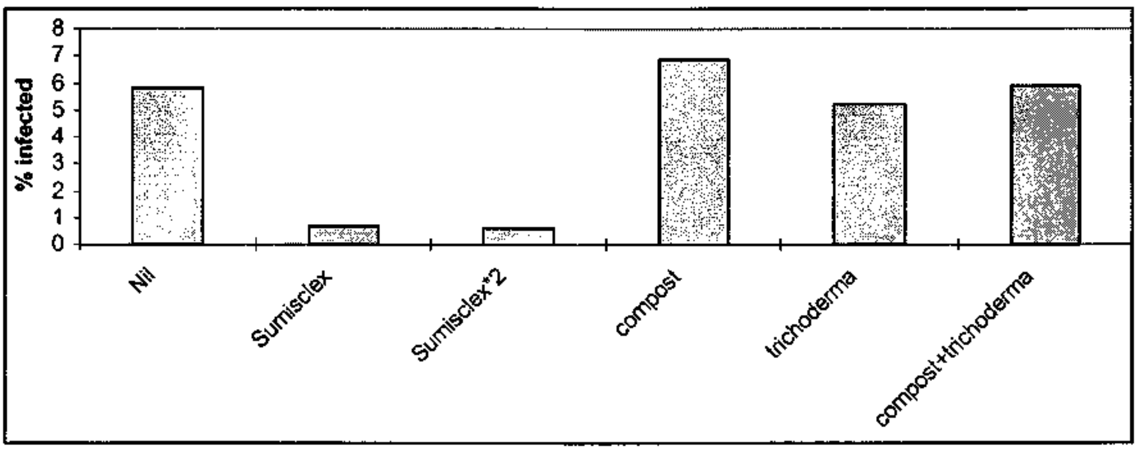

Figure 1. Control of Sclerotinia in Lettuce in 1999 trial. Percent infected by Sclerotinia versus treatment.

Sclerotinia field trials-2000

Two trials were completed in this season however there was no Sclerotinia recorded.

Sclerotinia field trials-2001

Three trials were undertaken in this season. Two trials did not have any Sclerotinia problems.
The results of the other trial is represented in Figures 2.

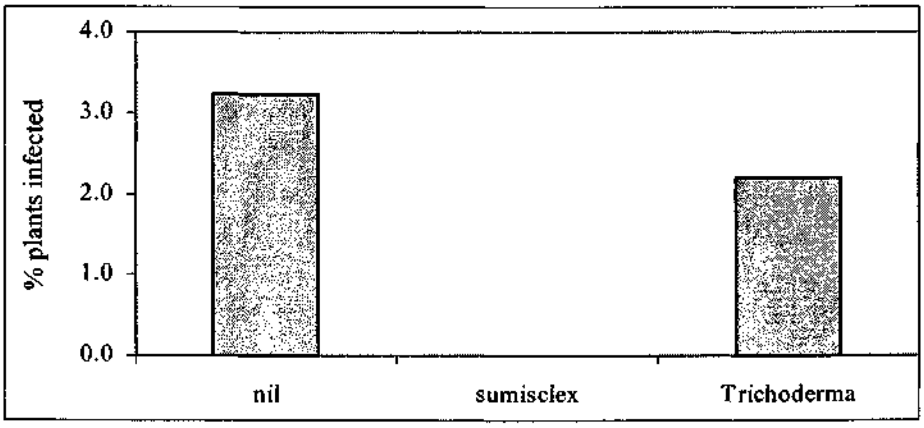

Figure 2. Trial results of the Sclerotinia trial in 2000, indicating the level of disease and the treatment.

Discussion

Sclerotinia is a disease that will not be controlled with plant resistance. The sclerotia that are formed by the fungi can survive long periods in the soil. However, they do breakdown, being overtaken by fungi and bacteria. High soil moisture coupled with increased soil biological activity aids the breakdown of the sclerotia. Growers need to practice crop rotation, green manures, removal of infected plants, and sprays to reduce this disease. The availability of sprays is an issue in controlling Sclerotinia with only three being available at this stage and two of these are in the same group. This issue should be addressed with more chemicals being available for Sclerotinia control such as azoxystrobin and ronilan.

Biological control is an excellent option to assist in the control of this disease. However it must be considered that many of the microorganisms suggested for biological control would already be present in soils. It is important to improve the microbiological status of these soils, to improve the balance with the addition of packaged biological control is a worthy issue. Green manures would also benefit the breakdown of sclerotia but not enough growers undertake this management option.

The spray trials undertaken showed some good results but the degree of infection was low. Application of fungicide just once after thinning gave excellent control of Sclerotinia when *S. minor* was the main type causing infection at the low levels of disease found in these trials. Hay, where the trials were conducted is an intense lettuce growing area and it was encouraging to see that generally, Sclerotinia was not building up to any degree. It is difficult when carrying out field trials dealing with soil borne diseases to be assured of getting any disease as was the case in 2000.

Pesticide application in lettuce

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Introduction

Insect pests and diseases can cause major crop losses and create unacceptable contamination for the semi-processed lettuce and the export markets. Heliothis moths and other insects such as: aphids, thrips and some other caterpillars pose serious problems to the lettuce industry causing about 10% loss per annum. The range of diseases cause losses of production close to 10%. Both pest and diseases can cause serious post-harvest quality problems.

All major lettuce production regions in Australia have some requirement to apply insecticides to manage *Helicoverpa armigera* (Heliothis) and other insect pests in fresh market or processed lettuce production. Heliothis larvae have the potential to cause damage at all stages of lettuce growth however the cupping stage is critical, as once larvae enter the heart of the lettuce they can not be controlled. Best management options are being evaluated in a number of regions and compared with conventional practices to help reduce Heliothis damage. Best management options consider a range of strategies that can be employed in combination such as improved targeting of insecticides, improved timing of application through monitoring and using more selective insecticides that preserve beneficial insects. This report presents some of the work undertaken to test commonly used application techniques for lettuce production in Australia.

A range of ground based spraying equipment is used throughout most production areas in Australia. Some of the equipment evaluated to date include, ground sprayers with over the top booms and droppers, ground based air assisted sprayers and CDA ground based sprayers. Equipment performance was assessed using a UV fluorescent dye. Data was collected by visually counting the fluorescent dye droplets from various parts of the lettuce canopy. Spray deposits were expressed either as number of droplets per cm^2 or percent coverage per unit target area.

Even though equipment plays a significant role in the effectiveness of coverage, particularly on the underside of leaves, the interaction between the plant canopy and application equipment is also important. The crop canopy has a large influence on the spray penetration and spray distribution on the plant. The distribution on the plant is very difficult to manipulate when spraying over the top with a boom. When spraying from over the top, the deposit is highest in the top part of the canopy and reduces rapidly as you move down the side of the canopy. Some lettuce varieties have large crinkly leaves, others have long elongated leaves and some have short leaves with long stems. There can also be variations in canopy height amongst lettuce varieties. All these factors will have an impact on the spray efficiency especially when there is additional foliage sheltering the target or the target is crinkled making good coverage difficult.

Many lettuce growers and contract spray operators use conventional boom sprayers or air assisted boom sprayers to ensure good coverage over the whole plant. All areas of lettuce production used ground based sprayers, these vary in size, shape and form.
The sprayers used to apply pesticides to lettuce by ground rigs are:

- over the top booms with hydraulic nozzles or air-shear outlets,
- over the top booms with hydraulic nozzles and air-assistance,
- over the top booms with hydraulic nozzles plus droppers,
- over the top booms with CDA nozzles and air assistance, or
- spray directed from the side across multiple rows using an air-shear cannon.

The three main principles used for droplet formation on these booms are hydraulic pressure, air-shear, and spinning disc/cages (CDA). Hydraulic pressure is used to produce droplets from nozzles such as flat fans and hollow cones. Sprayers using the air-shear principle produce droplets by using high velocity air (> 200 km/hr) to shatter the spray liquid into droplets. Sprayers using CDA (spinning disc) principle used the kinetic energy velocity of the spinning disc to produce droplets of a narrow droplet spectrum.

Trials were conducted comparing all the application methods currently used in lettuce. This included conventional booms, air-assisted boom, controlled droplet applicators (CDA) and a boom with nozzles extensions/ droppers.

One trial was been conducted comparing the effectiveness of similar spray volumes with over the top spraying and directed spraying with droppers. This trial compared the amount of spray collected on leaves using a boom fitted with droppers containing 2 nozzles directed at each plant plus a nozzles over the top of the bed applying 400 L/ha and another sprayer applying a similar volume (400L/ha) but from above only. A Hardie linkage sprayer was modified with short droppers and the standard sprayer was a Hardie Twin (used with and without air).

Air-assisted sprayers are used for spraying lettuce as they have considerable benefits including spray drift management and spray penetration. Further testing is required with air-assisted sprayers using leaves as targets to determine if there are significant differences in the spray deposit for the different settings (air velocity and angle) that can be used on this equipment.

The Basics of Spray Application

Target

The target can vary depending on the growth stage of the plant and the pest attacking the plant. This may change from lower leaves being the target to the lettuce heart or an insect pest being the target. Ultimately the aim of growing fresh market lettuce is to produce a heart with minimal pest damage and free from larvae or other insect contamination. Once insects are in the heart of the lettuce they are impossible to control. Therefore it is important to control them when they are exposed on the leaves. Other growth stages such as seedling emergence, transplanting and the vegetative growth stage (pre-heart) may be equally important in some production regions.

Spray deposit uniformity will influence the ability of insecticides and fungicides to effectively control pests and diseases. There are several issues that influence spray uniformity:

- The influence of application equipment on spray distribution.
- The influence of crop canopy on spray distribution.
- The influence of environmental factors on spray distribution.

If the application equipment used to spray the crop is not delivering a uniform dose across the paddock then some sections may be receiving more spray than needed and other sections being under-dosed. Blocked nozzles, worn nozzles or even subtle changes in travel speed are factors that will contribute to variable application across the paddock.

The crop canopy has a large influence on the spray penetration and spray distribution on the plant. The distribution on the plant is very difficult to manipulate when spraying over the top with a boom. When spraying from over the top, the deposit is highest in the top part of the canopy and reduces rapidly as you move down the side of the canopy

Some lettuce varieties have large crinkly leaves, others have long elongated leaves and some have short leaves with long stems. There can also be variations in canopy height amongst lettuce varieties. All these factors will have an impact on the spray efficiency especially when there is additional foliage sheltering the target or the target is crinkled making good coverage difficult.

The spray distribution and droplet counts have been measured on both sides of lettuce leaves for the entire plant. Also visual inspection of fluorescent tracer deposits at the 1st Australian lettuce industry conference has shown that the undersides of leaves receive limited spray deposits. Depending on where the egg lays occur on the plant, emerging larvae may easily escape contact with pesticide deposits.

Know Your Equipment

The most expensive sprayer will perform poorly if used inappropriately. Regular calibration of equipment is important (measuring individual nozzle outputs, replacing worn nozzles and calculating the sprayer output), so the correct quantity of pesticide can be added to the tank. A range of nozzle types are available and each have specific operating requirements such as pressure, spacing and height to perform optimally. Controlled droplet application (CDA) equipment and sprayers using the air-shear principle for generating droplets have specific operating parameters to work efficiently.

Techniques for Assessing the Performance of Spray Equipment

There are numerous tools available for checking the performance and setup of spray application equipment used in lettuce. Some of the techniques are used by researchers can also be used by growers for assessing the efficiency of application equipment in lettuce.

i) Fluorescent dyes for visual observation

Fluorescent dyes that show up under black lights are ideal for visually inspecting the spray deposit over the entire lettuce canopy. A pink or red coloured dye is best for observing the droplet deposits on lettuce. Yellow coloured dyes do not show up as well on lettuce due to the amount of yellow pigment in the leaves.

The spray deposit is best viewed on the crop in the field at night. This requires a 'black' light and generator or power supply nearby. Viewing deposits in the paddock makes it possible to observe the interaction between adjacent plants on the spray deposit. If plants are removed and taken back to a dark room an appreciation of the influence of neighbouring plants is difficult and may lead to misleading evaluation of the equipment's performance.

ii) Water Sensitive paper

Although water sensitive paper (WSP) is useful, it has many limitations and the interpretation of spray deposit results can be misleading. WSP is produced on small cards of varying sizes depending on the situation where they are to be used. WSP has a yellow surface and when water based droplets hit the surface the droplet leaves a blue stain. Although WSP is relatively cheap and can be placed almost anywhere in the lettuce canopy, they should be cut to size to match the target.

Some key points to remember when using water sensitive paper:

- The card surface is sensitive to moisture and high humidity. Care must be taken when handling cards (wear gloves) and the cards must be stored in sealed plastic bags if you wish to keep them for extended periods.
- Spray droplets impacting the surface of the card leave a stain that is larger than the actual droplet size. This is called the spread factor. A spread factor of 2 means that the stains size is twice the true droplet size. For water sensitive paper the spread factor varies and depends on droplet size. Water sensitive paper should not be used to determine droplet size.
- Droplets smaller than 50µm will evaporate before leaving a stain on water sensitive paper. The card is therefore biased towards collecting larger droplets and will not give a true indication of the fine end of the droplet spectrum.
- To give a true indication of spray deposit and penetration, cards need to be the same size and orientation as the target.

Trial

Leafy vegetables are inheritably difficult to spray, due to their structure, shape and also their growth habits. A problems with insect and disease control on lettuce can be a result of spray failure due to insufficient coverage and a lack of penetration into the leafy canopy. The purpose of these trials was to assess the efficiency of different application methods on achieving uniform coverage on lettuce.

Materials and Methods

Two methods were used in two different field trials

Method 1:

Used a uniformity layout design, the plot area was 3 beds wide by 30m long. There was a buffer of 10m around the plot. The beds were 3 rows wide, with the middle row being sampled within each treatment. This design was used as a preliminary experiment, to assess the viability of doing droplet counts on lettuce using a UV fluorescent tracer in a dark room to obtain droplet densities and coverage.

Method 2:

A randomised complete block design with 4 replications was used in field trial. Plots were 13.5m wide by 15 m long. A 5-m buffer was established along the rows and a 2m buffer of forage sorghum between plots to prevent contamination from spray drift.

The assessment of spray coverage was conducted by spraying an UV fluorescent pink dye and estimating the percent coverage and also by counting the number of droplets per cm^2. The leaves were numbered from the outer most to the inner most exposed leaf (wrapper leaf). After each application, the spray was allowed to dry for 1-2 h, eight plants were selected randomly in the centre two rows of each plot. Whole plants were picked up and taken to the laboratory. Droplet density per cm^2 and coverage of five locations on the top and underside of each leaf were determined under an ultra violet light in a dark room.

The spray application experiments focused on the different application methods, and consisted of the following treatments, which are outlined below:
Standard Boom @ 400L/ha at 3km/h (Hollow cones [ATR Red])
Air assisted Boom @ 400L/ha at 3km/h (Hollow cones [ATR Red])
Boom with droppers @ 400L/ha, 3km/h (Hollow cones [ATR Red])
CDA unit apply 46L/ha, 3km/h. (grey nozzle)

Results

Spray coverage

Spray coverage and densities in the crop canopy are shown by treatment (application method) in Figure 1 and 2. Coverage and droplet densities were effected by the type of equipment being used.

Figure 1 shows that air assisted and droppers can achieve better coverage than the standard boom with no air or the CDA. The minimum numbers of droplets required for insecticide and fungicide applications is 40 - 60 droplets per cm^2. From the graph air-assistance and short droppers achieve greater than this while CDA and no air achieve poor to marginal results. It should be noted that the CDA sprayer did not have air assistance probably contributed to its poor performance in this trial.

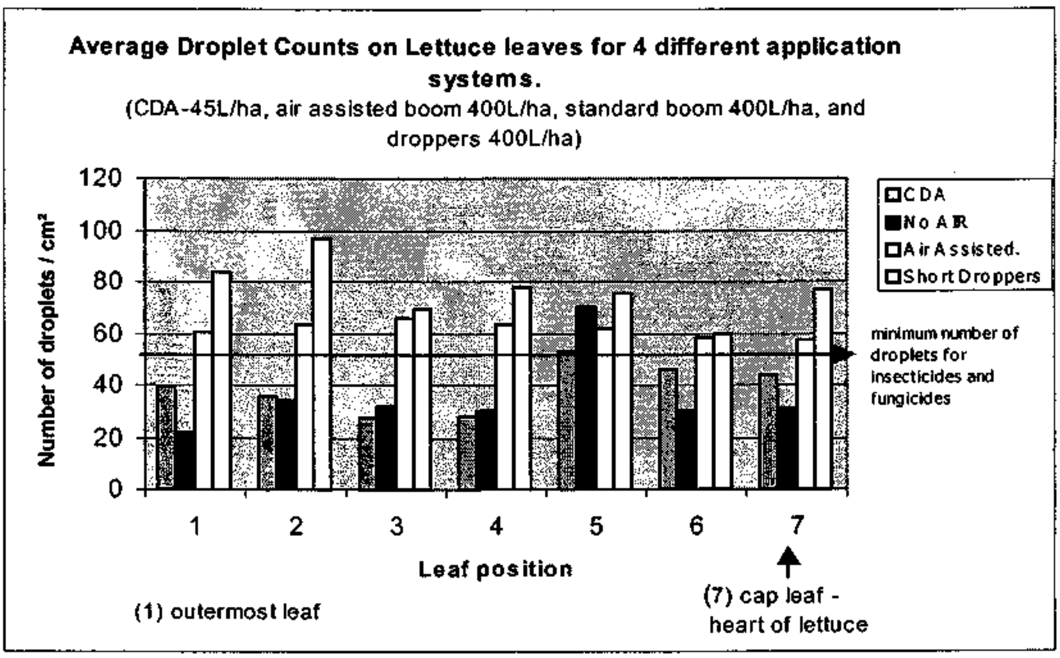

Figure 1. The graph below shows the number of droplets per cm^2

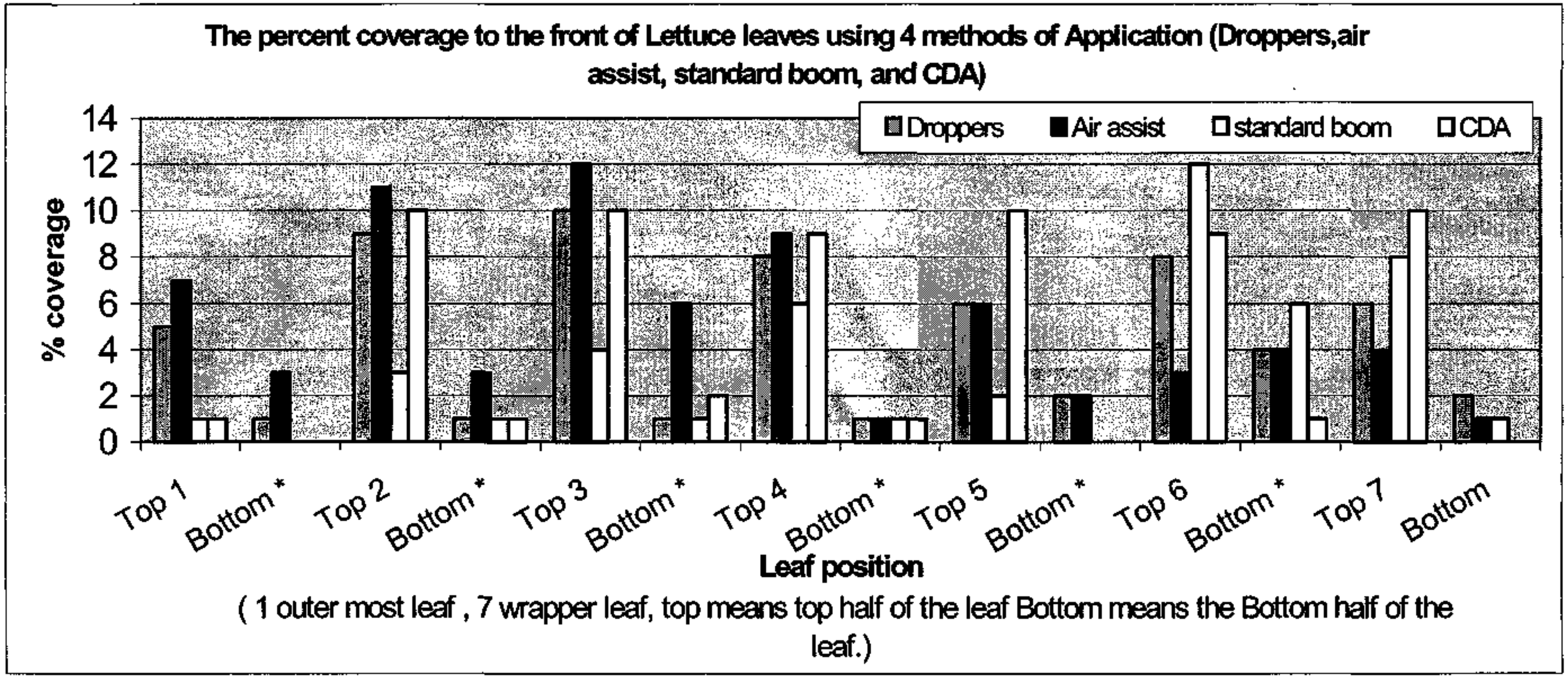

Figure 2. The graph below shows the estimated percent coverage of UV droplets on top surface of lettuce leaves.

In Figure 2 the 'top of the leaf' refers to the surface facing the upward. It shows there is considerable variation within all methods of application..

Spray distribution

Often the expectation is that most of an applied spray hits the intended targets. Unfortunately if the targets are the underside of leaves, then leaves above filter out or block most of the spray applied. Only a small proportion finds it way to the lower leaves or the back of leaves. Table 1 shows the droplet densities of UV tracer was deposited on different zones of the lettuce canopy.

Table 1. UV Fluorescent Tracer deposited on different zones of the lettuce plant canopy.

	Bottom leaves	Middle leaves	Top leaves (cap leaf)
unit	Droplets per cm^2	Droplets per cm^2	Droplets per cm^2
Average deposit per leaf	35	55	50
Average deposit on top leaf surface	45	60	56
Average deposit underside of leaf.	10	30	25
Range both sides of leaf	0 ~ 55	0 ~ 70	0 ~ 80

Underside of leaf spray coverage

Emerging leaves and the cap leaf are important target sites for insecticide coverage. Equipment that directs spray to this region more precisely will give higher levels of spray deposits to this site. Trials have been conducted using spray booms fitted with droppers. One trial was been conducted comparing the effectiveness of similar spray volumes with over the top spraying and directed spraying with droppers. This trial compared the amount of spray collected on leaves using a boom fitted with droppers containing 2 nozzles directed at each plant plus a nozzles over the top of the bed applying 400 L/ha and another sprayer applying a similar volume (400L/ha) but from above only. A Hardie linkage sprayer was modified with short droppers and the standard sprayer was a Hardie Twin (used with and without air). The mean spray volume collected from leaves is presented in figure 3.

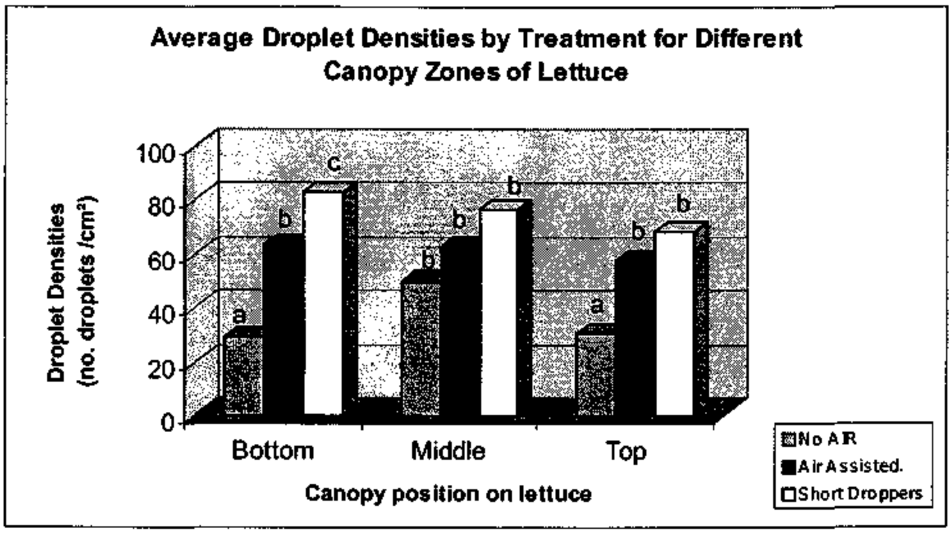

Figure 3. Average droplet densities for each spray applicator at three canopy zones.

Figure 3 shows that a boom fitted with short droppers plus over the top spraying gave an significant increase in droplet densities in the bottom part of the plant canopy zone, compared to spraying with and with air assistance. The conventional boom had the lowest deposit within all zones, the bottom and top part of the canopy received below the recommended droplet densities for insecticide and fungicide application. This low deposit is a result of the droplets not having the momentum to penetrate the canopy or hit vertical targets.

Air-assisted sprayers

Air-assisted sprayers offer many advantages compared to conventional spray booms. An axial flow fan, usually hydraulically powered, is used to create air and this is then ducted through a bag attached along the boom. Along the bottom of the air bag this air is released as an air curtain. The air curtain produced by these sprayers assists in the reduction of drift and improves spray penetration into the canopy of crops. The air curtain also produces turbulence within the crop which can result in improved coverage on the undersides of leaves and hard to get at targets such as the underside of leaves and in the petiole of the leaf. Some sprayers have the capability to alter the direction of the air curtain. Rather than straight down it may be orientated forward or backward to the direction of travel. This enables spraying to be undertaken in less than optimum conditions when strong wind may otherwise cause large spray losses. Even under ideal spraying conditions, spray penetration and coverage may also be improved in parts of some crops by having the air curtain directed forwards or backwards. Figure 3 shows that air assistance gives significantly higher deposit in the bottom of the canopy compared to convention boom, but also in the top of the canopy. The better coverage is due to the droplets being forced into the canopy and onto leaf surfaces by the force of the air curtain.

Discussion

Ground based sprayer are the most common means of spraying lettuce in Australia. The work conducted in this project shows that there is room for improvement in all types of sprayers and that some of the most basic models can find it difficult to get good coverage over the whole plant. Performance of these sprayers can be improved with the aid of air assistance or boom attachments such as droppers.

The performance of agricultural sprayers generally depends on their ability to precisely deposit chemical on the target (Cayley et al., 1987). In the present study, high volume sprayers gave significantly better deposit than the CDA sprayer. High volume sprayers also provided significantly better coverage and higher density of coverage on the top and bottom surfaces of bottom canopy leaves and better coverage in the top of the canopy, where most Heliothis larvae live. The CDA may lack enough downward force for good penetration and uniform coverage (Hislop, 1987). Maber et al. (1984) reported that the small axial fan used on CDA sprayers appears to give satisfactory crop penetration, and pest control resulting from CDA spraying is comparable to that achieved by conventional sprayers.

The spray deposition on leaves or artificial substrates was assessed visually under an ultra violet light in a darkened room. Guo et al. (1998) reported that chlorophyll could reduce the actual dye concentration display when using a fluorometric technique to determine spray deposit on brassica crops. Spray coverage evaluated with water sensitive cards could not adequately substitute for aphid evaluation (Welty et al., 1995). The visual assessment method using pink fluorescent dye, however, is very simple, and should have solved these problems.

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Variety trials and disease incidence

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Introduction

Two trials were sown at Hay in the 2000 season to evaluate some new lettuce varieties suitable for a mid-autumn sowing.

The variety a grower may use is based both upon physiological considerations and personal preferences for a particular variety. All varieties are bred for early vigour, size, earliness and uniformity of maturity, shape, texture, and pest resistance. The primary physiological considerations for selecting a variety are seed germination temperature, length of growing season, and day length sensitivity.

Growers select varieties for reasons such as yield, quality, appearance and disease incidence. Disease resistance is also an important consideration when selecting varieties. Some varieties are more susceptible to certain diseases than others, eg Salinas type varieties tend to be more susceptible to dry leaf spot, a bacterial disease prevalent in wet weather. Varietal resistance to downy mildew, corky root, black root and big vein are also available.

Varietal selection for Hay can be difficult with large temperature fluctuations throughout the whole growing season. Temperatures reach into the high thirties early in the season, dropping at times to below freezing during winter and than rising into the thirties again by the end of the season.

Growers in Hay use warm weather varieties early in the season looking for cultivars less likely to bolt and less likely to get too large and unmanageable. As the days shorten and get colder, growers switch to cold weather varieties looking for more vigorous cultivars to get good heart size. Growers than change back to warm weather varieties for their later planting's maturing in late spring. Greenway, a cool weather variety, has been the major cold weather cultivar sown at Hay with Target and Magnum the most popular warm weather cultivars.

Varieties were assessed for their yield and disease levels.

Materials and Methods

The Yates varieties of Greenway and Marksman were used as the standard comparison. The trials were sown using a randomised block design with 18 treatments x 4 reps, into a commercial crop of Wintergreen used as the surrounding buffer. After sowing, the sites were treated by the grower as part of his crop, receiving the same fertiliser, pesticides, irrigation etc as his normal crop.

The trials were hand sown by seed and the information regarding sowing dates etc. are in Table 1.

Table 1. Summary of lettuce trials

	Trial 1	Trial 2
Number of varieties	18	18
Number of rows	18	18
Number of columns	4	4
Number of reps	4	4
Sowing date	31/3/2000	23/3/2000
Harvest date	13/7/2000	18/8/2000
Plot size	5m x 1.5m	5m x 1.5m

The yield potential at Hay for one hectare of lettuce is about 3800 cartons (45,000 plants per ha divided by 12 plants in a carton). This is rarely achieved with about a 30 to 40% of plants lost during the course of the growing season. A yield of about 2500 cartons per hectare is considered average. The main reasons for lower yields are poor germination, disease, insect damage and failing to form a marketable heart. The second trial was planted and used as a demonstration plot for the National Lettuce Conference held in June 2000.

Results

Five seed companies participated in these trials with Table 2 showing the yield achieved from the 18 varieties evaluated in trial 1. Trial 2 yield data was variable so has not been shown here. However disease data for both trials have been included in Tables 3 and 4.

Table 2. Yield results for Hay Lettuce variety trial 1

Variety	Seed company	Ctns per ha	Tonnes per ha	kg per ctn
Rubette	R/Zwaan	3333	37.3	11.2
Titanic	SPS	3244	39.6	12.2
Greenway	Yates	3155	39.8	12.6
Black Velvet	Hendersons	3125	37.1	11.9
Madraz	R/Zwaan	3066	35.4	11.6
Toronto	R/Zwaan	2887	35.5	12.3
Marksman	Yates	2768	39.3	14.2
Grenadier	Yates	2738	38.9	14.2
Lec 8550	Lefroy Valley	2679	34.2	12.8
Muskateer	Yates	2649	35.4	13.4
Morgan	Hendersons	2589	33.5	12.9
SPS 0619	SPS	2560	34.1	13.3
Kimba	SPS	2500	31.3	12.5
Magic	Yates	2470	30.6	12.4
Mr Mac	SPS	2470	32.4	13.1
Veronica	Hendersons	2381	24.0	10.1
Silverado	SPS	2232	22.9	10.3
Charger	Hendersons	565	5.7	10.1

Trial 1

The trial was harvested into cartons for the fresh market and Rubette yielded the highest with 3333 cartons harvested per hectare. If the varieties were harvested for processing then Greenway, Titanic and Marksman would have been considered better yielding with over 39 t/ha for each of these varieties.
Plant losses can occur during the season for a number of reasons. Table 7 shows the percentage of plant losses from the time of thinning through until harvest. Plants with the unformed and small hearts could also have been infected by big vein. Big vein infected plants may have hearts and be harvestable whereas others may not develop hearts.

Table 3. Percentage of plants with disease symptoms and hearts unsuitable for the fresh market from trial 1.

Variety	Unformed and small hearts %	Sclerotinia %	Necrotic yellows %	Big vein symptoms %
Titanic	11.5	1.5	4.7	1.5
Rubette	15.6	1.9	0.0	1.7
Toronto	16.2	1.0	1.0	3.3
Greenway	17.4	2.4	0.0	3.7
SPS 0619	17.5	2.6	6.4	5.9
Grenadier	17.8	4.0	1.7	7.5
Marksman	18.6	0.8	3.3	6.6
Black Velvet	20.6	0.7	0.8	4.4
Madraz	22.1	2.1	2.8	2.1
Lec 8550	22.5	0.7	4.2	3.2
Muskateer	23.1	1.7	1.8	5.1
Morgan	24.2	2.4	2.5	2.4
Kimba	24.5	0.7	4.1	5.4
Magic	27.7	0.8	4.5	5.5
Mr Mac	33.0	2.3	0.9	0.9
Silverado	37.7	3.0	0.9	2.3
Veronica	40.7	1.5	0.0	0.0
Charger	79.6	0.9	4.1	8.0

Titanic had the least problem in forming hearts with only 11.5 % of plants not harvested due to either a under sized or no heart being formed. Charger seemed to be way out of its time slot with nearly 80% of plants failing to form a marketable heart. Veronica and Silverado also appeared to be out of their timeslot with a high percentage of unmarketable hearts and probably would have performed better in an earlier planting. These three varieties had carton weights of less than 11 kg., which would also indicate they are suited to a warmer climate.

No significant differences in plant losses were seen due to disease. All the head rots found in this trial were sclerotinia. No downy mildew was seen with only a low incidence of necrotic yellows as indicated in table 7. Varietal resistance is available with big vein and downy mildew but not for Sclerotinia or necrotic yellows. If symptoms of big vein become too severe, a heart is generally not formed and thus not harvested. Big vein symptoms in this trial were only slight and most of the effected plants were still harvested.

Trial 2.

Head rots found in these plots included both sclerotinia and botrytis. Big vein symptoms were more severe in this trial with higher losses due to under sized or no hearts being formed. Big vein levels between the varieties were significantly different with Titanic, Black Velvet and Veronica having more big vein infected hearts.

Again Charger and Veronica had more unformed and small hearts. No other diseases showed any significance difference between varieties.

Table 4. Percentage of plants with disease symptoms and hearts unsuitable for the fresh market from trial 2.

Variety	Unformed and small hearts %	Sclerotinia and Botrytis %	Necrotic yellows %	Big vein symptom %
Silverado	10.0	11.6	0.9	16.5
Rubette	12.2	14.4	1.7	15.3
Grenadier	12.9	4.9	0.9	24.7
Greenway	13.2	5.3	5.8	13.1
Madraz	14.6	2.5	2.0	11.4
Marksman	15.8	7.5	2.8	18.4
Mr Mac	16.0	17.6	2.5	17.3
Muskateer	16.5	7.0	1.0	18.8
SPS 0619	17.9	16.1	2.0	19.3
Magic	18.8	8.1	0.8	22.1
Kimba	19.0	6.7	1.1	17.9
Lec 8550	22.0	6.1	1.0	12.3
Titanic	30.2	5.3	0	35.8
Toronto	31.5	7.1	0	24.7
Black Velvet	37.6	11.0	0.7	36.2
Charger	37.8	1.9	2.7	24.8
Morgan	39.3	9.6	1.0	12.4
Veronica	52.1	6.0	2.1	44.8

Discussion

The variety trials gave some indication that varieties have differing levels of resistance to big vein. Trial 2 had higher levels of big vein than trial 1. This could have been related to site differences relating to paddock history or irrigation/rainfall effects. As an indicator of this Veronica was the best variety for big vein in Trial 1 but the worst in Trial 2. Titanic showed a similar pattern. Charger was also affected by big vein badly. Rubette the variety that yielded the highest in Trial 1 was also quite tolerant to big vein.

Variety trials are important for the main growing areas. It's an aspect of lettuce production that should be improved with more variety trials in the main growing regions.

Technology Transfer

Introduction

The traditional model of technology transfer is for scientists and funding agencies to decide the priorities, laboratory and field research are carried out at field research stations and new technology once developed is handed over to extension officers to 'transfer' to farmers (Chambers 1990). Typically individual problems of a particularly commodity are addressed with a technical solution that, ideally, can be applied uniformly on all farms in all regions. For the past 20 years there has been a debate on the merit of the traditional technology transfer model for agricultural research. Criticism has been that the model is biased towards capital intensive technology that favours more industrialized agriculture and agribusinesses, and tends away from sustainable solutions (Chambers 1990). In this model research disciplines tend to work in isolation focusing entirely on their own area of expertise. This can lead to development of solutions that cannot be adopted because they adversely affect some other part of the crop management system.

Alternative models for agricultural research have been developed and they include: Farmer Participatory Research (Biggs 1980), Farming Systems Research (Shaner et al. 1982), Farmer Back to Farmer (Rhoades & Booth, 1982), On-farm Research (Lockeretz 1987), Farmer First (Chambers 1990), Participatory Action Research (Martin 1991) and Do Our Own Research (Hunter 1996). Each of these involve the farmer to varying degrees in the development, implementation, analysis and adoption of the research. All of these models involve at least some field trials on grower's land as part of the research process. The levels of involvement were classified by Ashby (1986) as nominal, consultative and decision-making. Nominal participation is when the researcher designs and implements the experiment or trial on the farmer's land without the farmer being involved. Consultative participation is when the farmer is involved in setting research priorities and in the evaluation of the results, and decision-making participation is when the farmers are active in all aspects of the research, including conducting the trial. Sumberg and Okali (1988) make the distinction between on-farm trials and on-farm research. On-farm trials compare two or more alternatives, with clearly defined differences between the alternatives, where as on-farm research incorporates farmers into the process of technology development. In the later process, the researchers role is to work with farmers to identify constraints and delineate potential research areas, run preliminary trials and then to re-disseminate the options within a broad definition of the technology.

By definition the greater the involvement of farmers in the research process the larger the commitment of time and resources, the greater the 'ownership' of the outcomes and therefore the greater the likelihood of adoption.

Methods

This project was written in collaboration with the Hay lettuce growers and the implementation of the project was envisaged to be an ongoing collaboration with at least some of the lettuce farmers or growers with a decision-making role. The proposal was deliberately left fairly open with broad research concepts that would be developed as the growers became more familiar with the process and took on an active involvement. The research team from NSW Agriculture was broad and had the potential of expanding or contracting as the project evolved.

The mechanisms for involvement were the well attended meetings of the growers as the project was initially conceptualized. The proposal was written by NSW Agriculture staff and then reviewed by some of the growers before being submitted to the funding body. Within the proposal was a consultative group of growers and the formation of a broader grower group involved in regular discussion meetings/workshops/field trips that covered topics of interest to the growers. The topics to be covered were to be collectively agreed upon and the role of the NSW Agriculture staff was seen as facilitators to gather appropriate resource material or people and attend to the logistics of the agreed activity. An active involvement in development of trials and the overview of the project direction was envisaged.

Many of the priority areas defined at the pre-project meetings were pest and disease management issues hence the broad focus of Integrated Pest and Disease Management. Other unrelated topics potentially could be addressed through the grower group activities and possibly through a Do Our Own Research model.

In conjunction with the grower group was to be the collation of a resource binder with relevant information relating to lettuce production and the topics raised by the group. This binder was to be available to the other lettuce growers in Hay and possibly to lettuce growers in other areas.

A series of meetings/workshops were planned for the Sydney basin as an extension tool for disseminating information gathered. Adoption rates were to be used as a comparison between the more collaborative approach with the Hay growers and the traditional extension approach in the Sydney basin.

After the project was initially supported two QLD researchers, an entomologist and a spray application engineer were included to complement the research project.

Once during the project a national conference of growers and researchers related to the lettuce industry was convened.

Results

A range of group extension activities were conducted during the course of this project (Table 1). Workshops focusing on pest and disease identification, crop monitoring and spray application were conducted in Hay, Sydney basin, Gatton and Canowindra (NSW). The workshops in Hay were hard to organize in the sense of getting commitment to come and were not well attended. Workshops and field days organized in the Sydney basin had much larger numbers and were too big for adequately doing hands-on work. As a response we organized smaller groups on 2 or 3 growers farms and having neighbouring lettuce growers join in with a paddock walk, looking at insect and disease specimens and address the issues of those growers more specificially.

Gathering the Hay lettuce growers together proved to be a very difficult task indeed. Although the pre-project meetings were attended by growers from virtually all the farm enterprises, it appeared that once the project was funded other issues between the growers came into play and meetings were poorly attended. The growers were canvassed as to why we were having so much trouble setting dates for meetings/workshops/field days and getting poor attendance on scheduled days. We also asked how they wanted us to proceed and the consensus seemed to be that for a range of reasons including: individual disagreements between growers, a culture of distrust and competition between the growers, as well as long work-hours and relatively little back-up support within the farming enterprises. The growers preferred to catch up with us individually on one of our regular weekly visits.

Weekly visits to Hay usually involved conversations with one or more growers. In the last two years of the project 4-5 visits were made to lettuce growers in the Canowindra area. In late August 2000 growers in Werribee and Cranbourne areas were visited. 2-3 visits a year were made to the Sydney basin during which individual growers were visited in addition to the meetings or workshops conducted.

Table 1 Extension Group Activities of the Lettuce IPM project

Date	Location	Topic	Attendance
Field Days			
4th Sept 1998	Hay	IPM and irrigation best practice	10 growers and 15 others*
9th Sept 1999	Hay	Spray Application	7 growers and 5 others
11-12th May 2001	Richmond	Horticultural field days –lettuce IPM display	~60-100 growers
27th Nov 2001	Canowindra	Lettuce IPM	6 growers and 6 others
Workshops			
22nd July 1998	Hay	Pest and beneficial insect ID	10 growers and 4 others
15th Jan 1999	Sydney	Insect pest ID and crop monitoring	65 growers and 7 others
8 sessions in 1999	Hay	Quality Management and SQF2000 training	8 growers
7th October 1999	Yanco	Insect ID workshop	9 growers (2 lettuce)
10th Feb 2000	Sydney	Insect pest and disease ID	3 sessions with 6-8 growers each and 4 others
1st Nov 2000	Sydney	Insect pest and disease ID	2 sessions with 6-8 growers each and 4 others
28th August 2000	Werribee	Lettuce IPM, Pest & beneficial insect ID	15 growers and 8 others
6th June 2000	Hay	Spray Application	Conference delegates (~170)
7th June 2000	Hay	Pest, Beneficial Insect and Disease ID	Conference delegates (~170)
Discussion Meetings			
12th Oct 1998	Hay	General discussion of direction	4 growers and 6 others

		of Lettuce Project, coming season trials, marketing officer and cadmium issues	
28th Sept 1998	Camden	Pests and Diseases in lettuce, new project	36 growers and 11 others
1st July 1999	Hay	General discussion of direction of Lettuce Project, report back on trials.	6 growers and 6 others
16th Sept 1999	Hay	Marketing lettuce GSF and Costas' perspectives	8 growers and 4 others
17th Sept 1999	Warragul	Lettuce IPM	20 grower and 12 others
12th Oct 1999	Hay	Lettuce Conference organizing	1 grower and 5 others
Presentations			
15th Jan 1999	Sydney	1. Lettuce pests 2. Lettuce diseases	35 growers and 9 others
16th July 1999	Sydney	IPM in head lettuce	~80 growers and ~20 others
6-8th June 2000	Hay	Australian Lettuce Industry Conference	168 registrants (79 growers, 60 industry, 28 researchers)
11-12th May 2001	Richmond	Lettuce IPM	~60 –100 growers and others

* 'others' = researchers, industry people and consultants

The first national Lettuce industry conference was organized as part of this project and brought growers, researchers and industry people from each state together. It was held from 6-8 June2000, in Hay, NSW. 168 people attended, 79 (47%) were growers, 60 other industry people and 28 associated with State Departments of Agriculture. 74 (41%) were from NSW, 55 (33%) from Victoria, 31 (18.5%) from QLD, 4 from WA, 2 from Tasmania and 1 each from SA and NZ. See Appendix for evaluation results and R&D priorities listed by participants.

Some growers wanted written material and found the information folder useful many didn't find that they read the material, and copyright issues prevented us from distributing it more widely. Instead a resource list is included in the handbook. The handbook and ute guide formats of pest, disease, weed and spray information was liked by the growers. An IPM handbook for lettuce has as been published as part of this project. The Lettuce IPM guidebook is 160 pages long, full colour with lots of photos, and covering topics such as: Integrated pest mangement, insecticide resistance, information on insect pests, beneficial insects, diseases, weeds, spray application, useful resources and a glossary. This handbook is available to all lettuce growers and will be available for sale for other interested people.

Some written material was produced as listed below. Material included conference posters and papers, press releases that resulted in newspaper, radio and television interviews. A newsletter was not initially written into the project and started as some informal information leaflets sent to local growers and available at workshops/discussion evenings and via extension officers. Seven newsletter style letters were sent out over the life of the project and three, "Lettuce Leaf" newsletters were sent to all the lettuce growers we had on our Lettuce Conference data base (360 growers and 28 researchers) in all.

Publications/Posters

Watson, A and Snudden, M. (1999). Sclerotinia minor control in lettuce in the Hay region of NSW. Poster at the Australasian Plant Pathology Conference, Canberra 1999

S McDougall "Integrated pest management in head lettuce" *Proceedings of inaugural Sydney basin field-grown vegetables conference* Richmond July 1999

Watson A., M. Snudden (2000). Diseases of Lettuce and their control in the Hay region of NSW, *Australian Lettuce Industry Conference 6-8 June.* pp. 100-101

McDougall, S., J. Valenzisi and T. Napier (2000) Evaluation of Beneficial-Friendly insecticides for management of *Helicoverpa* spp. in lettuce. In the Proceedings of the *Australian Lettuce Industry Conference 6-8 June.* pp.91-95

Duff, J (2000) Insecticide evaluation trial for *Helicoverpa* spp. in lettuce during the 2000 growing season. In the Proceedings of the *Australian Lettuce Industry Conference 6-8 June.* pp.96-99

S McDougall "IPM of Heliothis in Vegetables" *Farmers' Newsletter* IREC 184 June 2000 pp 28-33

Media

Press Release on Lettuce Conference [interviews local ABC, ABC TV, The Land]

TV story on Lettuce Conference June 2000 (Riverina)
TV story on Lettuce IPM April 2000 (Riverina, Central West)

Discussion

Bimonthly project meetings were attempted with the Hay lettuce growers in the first year. Only three discussion meetings/workshop/field days were held and attendance was low, especially at the meeting where we were planning the program for the coming year. A survey of growers was conducted and the feedback that we got was that they were pleased the project was funded and were keen for us to conduct research, they felt that the insecticide trials were particularly useful and more registrations of products were of immediate practical benefit. They were happy for any work on beneficial insects or pathogens or anything else that may aid them. Although they saw a benefit in crop monitoring it was another activity to fit into an already very busy cropping schedule. Some form of calender spraying was still seen as being easier to manage. Some of the growers confessed to not having had "a holiday" or day-off in a decade, hence their non-attendance at meetings was not a reflection on the project but their tight schedule. Certainly most of the growers were keen to talk lettuce pest and disease management when we visited their farms. Some read the material provided and came back with questions. After the spray application night one grower modified his hydraulic boom sprayer and appeared to get immediate improvement in pest and disease control. This grower also was quick to adopt other recommendations of timing and chemical choice.

Attendance was much greater in the Sydney basin but there are a lot more growers to draw from, however the proportion of growers we saw at the organized events was relatively greater than at Hay. We were not visiting the growers on a weekly basis so essentially their only contact with us was via the meeting/workshops/field days and later through the newsletter. Both trips to Victoria on request from industry people resulted in good attendance. They were both in response to difficulties in controlling Heliothis, so there was an immediate need and potential benefit for the growers to attend. Crop monitoring as a routine practice was adopted by many growers and a crop monitorer was employed by GSF to service the growers who supply them in Victoria.

Clearly growers have to want to participate in group processes for them to exist let alone thrive. Since most growers are small enterprises with year-round production there is not much latitude for taking time out. What time they take out has to be of obvious and generally immediate benefit. The concept of an 'adult-learning-circle' or participatory research takes time for trust and a working relationship to develop. In this situation there was not the luxury of time. Many grower groups that have been successful have been in crisis, for example brassica growers in the Lockyer Valley and Diamond-back moth control. Or if not in crisis then having relatively greater 'down-time' in the year, for example citrus and rice grower groups. Perhaps if the Hay growers were in greater crisis around pest management or they were only growing lettuce and had the summer months as a quiet time we may have had greater success with group activities.

This project is not yet finished, a continuing project has been funded that will focus on IPM strategies for insect pests, another two national conferences with some IPM workshops associated with the conferences and in WA, SA and Victoria in non-conference years, and a UTE guide.

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Ashby, J.A. (1982) Methodology for the participation of small farmers in the design of on-farm trials. *Agricultural Administration* 22 pp. 1-19

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Recommendations

Insect pest management

Although calender spraying is the most commonly used management technique it can result in:
unnecessary use of chemical and labour
poor timing of sprays
inappropriate choice of sprays
insecticide resistance in target insects.

The range of control options for insects was very limited at the beginning of this project. The efficacy trial work that was carried out assisted with the registration of three products, a permit for a forth and the potential registration of another two products for the key insect pest, Heliothis.

Conclusions

1. Routine monitoring of lettuce crops in Hay indicated that insect species and numbers varied from paddock to paddock, week to week and with crop stage.
2. Crop monitoring can identify which pests are present, at what stage in their lifecycle and in what numbers, hence help with decisions of whether control may be necessary, what to spray and when.
3. Heliothis pheromone traps are not an accurate indication of egg numbers in the neighbouring paddock
4. Spinosad, indoxacarb, *Bacillus thuringiensis*, emamectin benzoate and chlorfenapyr are as effective against Heliothis as methomyl, endosulfan or a synthetic pyrethroid.
5. The newly registered products are more expensive than the older products
6. Growers are not very familiar with the pests in their fields, their lifecycles, mortality factors or behavioural patterns.

Further Research

1. Draft thresholds developed in this project need to be trialed in a range of crops and situations to assess resilience.
2. New chemistries or biological insecticides need to be tested for relative efficacy against lettuce pests and impact on non-target organisms. Companies with products that work well against the target insect and have better environmental or human health impact profiles than existing registered broad-spectrum insecticides should be encouraged to seek lettuce registration.
3. A best management strategy for insects needs to give as good or better control as the existing broad-spectrum insecticide program, reduce the likelihood of developing resistance in the target insects, have less negative impact on beneficial insects or other non-target organisms, be less potentially toxic to the applicator, potentially produce less residues in the harvested product, and be cost neutral.
4. Guidelines for an IPM program need to be clear, easily understood and applied by growers.

Disease management

Conclusions

1. Variability in knowledge of lettuce diseases, from grower to grower.
2. A wide range of diseases found which varied with growing region and often from farm to farm.
3. Irrigation contributes to many fungal diseases such as Downy mildew and Anthracnose. Drip irrigation, a useful option for some areas.
4. Sclerotinia control possible with current fungicides sprayed at the correct time. However more fungicides for Sclerotinia control should be available to reduce chances of resistance.
5. Monitoring for some diseases e.g. Downy mildew is very important.
6. Projects looking at diseases are too short term.

Further Research

1. Varnish spot and Big vein (with other viruses) were two of the main areas for future research.
2. Improved diagnostic methods eg for corky root.
3. Variety trials should be ongoing for all growing regions especially for the new lettuce growing area in the

central west.
4. Further develop the management of irrigation and its effect on diseases (especially overhead irrigation and Downy mildew).
5. Further drip irrigation work needs to be done especially to indicate the reduction in disease.
6. Establishment problems associated with direct seeding including an evaluation of seed dressings for the lettuce industry.
7. The role of green manures in reducing sclerotial numbers.
8. Further extension on disease management important for growers.

Spray Application

Many commonly used spray application techniques have been evaluated for their efficiency in targeting pesticides to leaves. Using fluorescent tracers, spray deposits on leaves have been collected for a range of equipment types. Some of the techniques tested have produced improvements to conventional application methods. Even though the equipment used is important when applying insecticides to lettuce the lettuce canopy also has a large influence on the spray penetration and spray distribution on the plant. The distribution on the plant is difficult to manipulate when spraying over the top with a boom.

Conclusions

1. Calibration of ground based sprayers used in lettuce is very important.
2. Spray penetration and uniformity of spray deposition across a paddock may be improved by using reduced nozzle spacings and/or reduced speeds.
3. Boom sprayers fitted with droppers have the ability to direct more spray onto bottom part of the plant canopy compared with conventional over the top boom sprayers types.

Further Research

1. Trials comparing nozzle types (hollow cones, twin-fans and even fan nozzles) is needed to determine whether they produce better spray deposit levels on lettuce target sites compared to tapered flat fan nozzles.
2. Further testing is required with air-assisted sprayers to determine if there are significant differences in the spray deposit for the different settings (air velocity and angle) that can be used on this equipment.
3. Additional spray application trials need to include bioassays to be able to relate deposit to mortality. And also to test the different application methods to see if any of the application methods give greater control over the season
4. Work on the ability of shrouds to improve spray penetration and reduce drift is needed.
5. Also work needs to needs to be done to assess which water volumes give the best coverage and control.

Technical Transfer

Conclusions

1. A variety of technology transfer methods need to be used to cater to the wide range of stakeholder preferences and needs
2. Immediate tangible results are what growers want
3. Research with less immediate results is not strongly supported.
4. This project was not truly as collaborative with growers as was intended. The reasons include: it not being a familiar model for either the researchers or growers; growers are busy; many of the growers seeing us regularly individually.
5. Intentions are not always followed by action.

Further Research/work

1. A UTE guide be produced to complement the Lettuce IPM information guide.
2. Workshops be conducted in as many lettuce growing regions to address the specific pest management questions of the area and work with small groups of growers to identify their pest and beneficial insects and diseases
3. Spray nights be conducted in as many lettuce growing regions so growers can see first hand the differences in the spray coverage by the available spray application equipment.

Appendix 1

AUSTRALIAN LETTUCE INDUSTRY CONFERENCE 6-8 JUNE 2000, HAY, NSW

CONFERENCE EVALUATION

- 73 participants completed the evaluation forms
- numbers given below are actual numbers (not all participants filled in all sections)
- comments included in this summary are fairly specific. There were many positive comments of the value of the conference overall and this is reflected in the fact that the majority of people would be interested in attending another conference in the future.

Question	1 poor	2	3	4	5 excellent	Comments
1. Opportunity to make contact			1	23	48	
2. Format		6	19	29	14	• have more field visits • field activities needed to be "punchier" • open forum should have been earlier on day 2 (too many people left) • increase number of field visit options – growers want to see things other than research • first afternoon not informative – too basic • more field visits would have balanced the format • field visits disappointing – would have liked more machinery methods e.g. bed forming etc. • field visits could have been longer and more exposure to local practices/problems • more grower presentations to compare state growing strategies • field visit on day 1 shorter • farmer/grower presentations to complement technical presentations • more time at IPM stations – ring a bell to move on to next one • venue too dark, microphone didn't work, no laser pointer
3. Quality of presentations			13	41	18	• some not grower/applied enough i.e. what does this work mean to me in practice? • some information a bit dated • some of the research papers needed to be a bit more grower friendly • keep talks to less than 20 mins (keynote speakers 30 mins) • speakers need to be outcome focussed
4. Value of information		1	18	36	17	•
5. Timing	2	2	8	34	26	• good to have regional town during production season • time of week is good
6. Length			5	27	36	• optional day of farm tours post-conference • conclusion of conference should take into account travel timing and logistics • suggest 2.5 days finishing at noon
7. Attendance - growers			7	29	35	• more seed companies present

- scientific officers - industry reps		 3	7 11	41 38	24 21	
8. Location		1	11	32	27	• regional good , but maybe closer to national airports
9. Attend another conference?		1	2	20	41	•

Where?

- rotate around growing regions 19
- Gatton, Qld 19
- Werribee, Vic 11
- WA 3
- Sydney Basin 3
- Shepparton, Vic 2
- Adelaide, SA 1
- Stanthorpe, Qld 1

When?

- 1 year 6
- 2 years 33
- 3 years 3
- April 2
- May 1
- June 17
- September 2

Other comments:

- please contact Harvest Freshcuts for sponsorship of future conferences
- have somewhere a bit more accessible by plane
- turnout of attendees shows confidence and acceptance of the need for this sharing of information
- include a session by a government rep re funding availability etc
- very few of the R&D issues came from growers – seemed to be more from Ag people and consultants
- HRDC seemed to shut down discussion on projects they felt were being done or were not relevant (during open forum)
- more chief investigators could have attended as well as more junior staff
- all HRDC projects currently funded could have reported on progress of their work

CONFERENCE EVALUATION – TRADE DISPLAYS

Question	1 poor	2	3	4	5 excellent	Comments
1. Opportunity for access to you/your site			5	8	1	
2. Siting of display within venue		1	4	8	1	• would have been more accessible in main hall
3. Area (space) available		1	6	7	1	
4. Attendance - growers - scientific officers - industry reps			 5 4 5	 5 6 5	 3 2 2	

Other comments: "would like to display product from the processed industry"

Appendix 2 R&D Strategy for Lettuce Industry

Open Forum at First Australian Lettuce Industry Conference *facilitated by Tony Biggs*, Thursday 8 June 2000

R&D ISSUES	***INDUSTRY ISSUES***
Salinity of Irrigation Water • Groundwater problems – Werribee, Lockyer, WA. **Crop Models (incl. water & nutrition) for Different Establishment (Seeds/Plants)** • Best practice guidelines for each production system • Also placement & frequency of water & nutrient applications **Integrated Production Systems (inc. Rotations)** • What combination of crops in a production system • Predictive Farming techniques eg. - GPS use to guide production of crops x geographical location x farm location x water & nutrient application in field, - molecular probes for disease ID (big vein). **Organic Production** • Info/guidelines on how to enter the industry • Develop specification/best practice guidelines for organic lettuce production (ref Domonic McPhee, QDPI, Robyn Neeson, NSWA) **Mechanical Harvesting** • Leave for private enterprise. **Heliothis** • Assess neem • Assess further range of products - chemical/organic/IPM • Current project finishes 2000 • Carry over pest pressure from other crops eg. Sweet corn. • Use of trap crops • What crops go well together in a cropping system. **Treatment of Manures** • Robert Premier AgVic has project. • Develop industry standard 'treatment of manures' **Tipburn in QLD/Pinking in Cos (No work done in QLD)** • Physiological disorders project. **Product Presentation** • Aim is to improve consumer appeal & sales success. • USA - excellent product presentation/attractiveness. • What can Aust do to improve?	**National Coordination** • Refer to HRDC Website / Horticulture Australia. • Some coordination occurring with SDA's in some areas. • No involvement by educational institutions, eg. University projects (this needs to change). **Advertising** • No issue raised **Conference Frequency** • TB advised organisers to consider – must be something new to present to keep interest & effectiveness. **Prohibitive Costs of QA Assessments (Audits)** • AUSVEG to address. • Mushroom industry (HACCP Plan) negotiated ¼ usual costs for auditing. **Consistency of QA Systems** ❖ No issue raised

R&D ISSUES

Balanced Nutrition
- Individual element approach to issue
- Needs holistic approach to nutrition program.
- Interaction of nutrients - antagonism/synergism.

Better Analysis Standards (Nutrients)   Soil & Leaf
- Private companies have data.
- Terry Pigott's publication is comprehensive.

Classification of *Trichoderma*
- Clarify the uses/applications of the several strains ie. they do different things (uses) not all the same.
- Clarify what uses the strains are for.
- Ian Porter's project will cover this (IHD, Vic)

Best Practice Information Via Technology Transfer
- Package information appropriately and disseminate.
- Consider information from other crops (eg. cotton) and locations (countries) and incorporate into Lettuce Best Practice.
- It was suggested the problem is adoption of information - Role for IDO's.

Product Screening and Development
- Private company to go for VC with HRDC to screen products.

***Botrytis* and Basal Rots**
- No issue raise

Processor Involvement in R&D
- Via VC's.
- Include processors in setting of R&D priorities.

Tomato SWV and WFT
- Covered by vegetable and strawberry projects.

Consumer and Service Sector Market Research
- Yes – do this as a project.

Product Description Language Manual
- Yes – do this as a project.

Nutritional (Essential) Components of Lettuce/Vegetables
- Determine essential nutritional status.
- Use to educate consumers