Know-how for Horticulture™

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

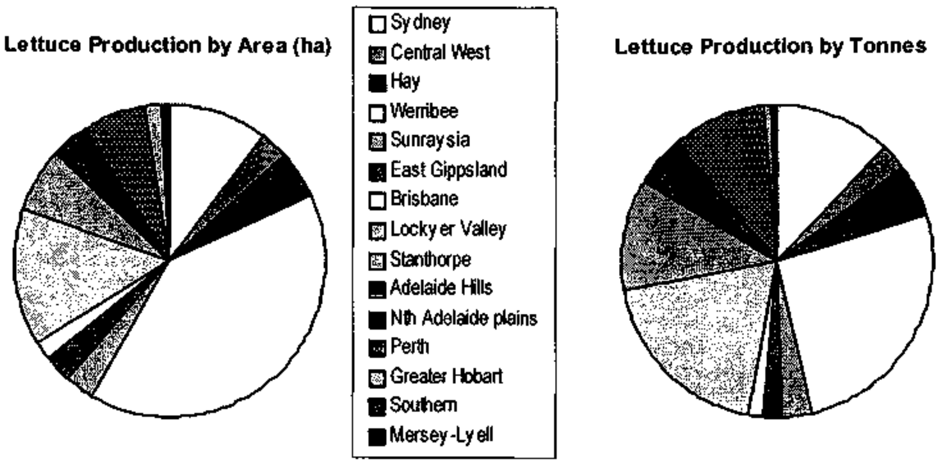
Australian Lettuce Industry

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.

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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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.