VEGEnote series: Practical science solutions for vegetable growers

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ARRIS Pty Ltd

Project Number: VG02116

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Know-how for Horticulture™

VEGEnote series: Practical science solutions for vegetable growers

Jim Kelly & Natasha Wojcik

Arris Pty Ltd

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Project Title: ***VEGEnote series: Practical science solutions for vegetable growers***

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Contents

Summary

Facilitating the adoption of research outcomes is a fundamental activity of an industry based research and development program. The Vegetable Industry Development Officers had identified a gap in the communication from research projects after feedback from growers and others in the industry. Often communication outputs from projects were either too scientific or indirect for any practical application or adoption of results. Easy to read facts sheets were seen as an effective and efficient tool to communicate outcomes from research projects. These were called VEGEnotes.

The preparation of a VEGEnote involved working with the project leader to ensure the relevant information was included in the fact sheet and highlighted the outcomes that growers would find beneficial.

Thirty titles were produced under the VEGEnote series over the three year project and distributed to growers by the industry development officers. A common branding was used to show that the outcomes of the research detailed in the VEGEnote involved the vegetable research and development levy as well as matching Australian Government funding through Horticulture Australia.

A survey was carried out with growers using a questionnaire. The responses indicated that the format of the VEGEnotes was popular with growers and that they wished to see the series continue.

Commercial sponsorship was used to fund ring back folder to allow growers to store VEGEnotes as a ready reference for future use.

There are three recommendations for future work:

Recommendation 1

Technical fact sheets such as VEGEnotes are an acceptable medium to communicate research outcomes to growers. They should continue to be produced and integrated with the Vegetable Industry's communication plan prepared by suitably qualified writer/editor working with the leader of the specific research project.

Recommendation 2

The preparation of a VEGEnote from a project should be agreed up front with the research organisation and Horticulture Australia and be in line with the Vegetable Industry's communication strategies. The VEGEnote should be an activity built into the project milestones.

Recommendation 3

All titles of VEGEnotes should be distributed to all growers rather than trying to select topics based on known grower preferences. VEGEnotes should be distributed as an insert in *Vegetables Australia* and placed on appropriate web sites as downloadable PDFs.

Introduction

Horticulture Australia's Vegetable Research and Development Program has supported several hundred projects since the national vegetable levy funding started in 1997. A wide variety of research projects has been completed for the Vegetable Industry while others are currently being undertaken.

The Vegetable Industry Development Officers (IDOs) had identified a gap in the communication from research projects after feedback from growers and others in the industry. Often communication from projects was either too scientific or indirect for any practical application or adoption of results. Growers often do not have time to read lengthy documents nor ready to receive information until the need arises for them.

As projects start and finish with no set regularity, a need was seen for compiling usable outcomes for growers in an easy to read format that was capable of being easily referenced. It was agreed that facts sheets known as *VEGEnotes* would go a long way in communicating usable outcomes to growers. VEGEnotes were not to be stand alone publications but seen as part of an overall multi tool approach to communicating research outcomes,

Another issue was that often growers do not associate research outcomes with the national vegetable levy to which they contributed. The 'branding' of the levy was usually lost amongst the research providers own intentions of promoting the research they carried out or was not thought important enough to publicise. By having a clear message on the VEGEnotes that the research was in fact supported by the levy would help overcome the lost of identity of the levy investment.

The research outcomes need to be presented in a user-friendly manner, easy to read, with simple graphics and overall presentation that is appealing and eye-catching and yet delivers the message to the users (growers). Growers want clear, concise technical advice that builds on existing knowledge and can be applied practically. They need 'real, practical' communication' that provides them with 'real, practical' solutions.

Horticulture Australia tendered out the project for $250,000 over three years for the writing, preparation and printing of the VEGEnotes. Arris Pty Lt was the successful company selected to undertake the project and started in January 2003.

Method

Once the project was successfully tendered, a steering committee was formed with the IDOs. The purpose of steering committee was:

- To provide suggestions on VEGEnote topics;
- Review draft copy;
- Agree to VEGEnote style and template;
- Develop *Author's guide to writing for VEGEnotes*. (see Appendix 1)

Researchers from selected projects were contacted to provide the original material for the fact sheet and to approve the final edited version. It was considered essential that the researcher be involved to ensure not only technical accuracy but to work together to identify the key messages that should be communicated in the VEGEnote. A spin off to the researchers involvement was the co ownership of the VEGEnote between the researcher and the editor.

One editor was used to ensure that a consistent style carried through all the VEGEnote issues. Information was also provided to guide the reader for further and more detailed information such as compact discs or project final reports where relevant.

A common and easily recognised letter head and style was chosen using the tag line *Your Levy @ Work* to promote the recognition of the grower levy and the research outcomes. Also included was appropriate recognition of those involved in funding the project (e.g. Horticulture Australia, national vegetable research and development levy, voluntary contributors and research organisations).

Draft versions were trialled with some growers to ensure that the style and level of information met the target audience needs. A larger than normal print size (Arial 12 point font) was deliberately chosen as it was recognised that most growers are middle aged or older and that long sightedness was a common problem with this age group.

Format of the VEGEnote was a maximum four page A4 format. The only exception was *Managing Cadmium In Vegetables* which was eight pages. Funding from the preparation and printing of this title came from the Horticulture Australia project, VX99042, *Coordination of the National Cadmium Minimisation Strategy*. This was also translated into Vietnamese.

While most of the VEGEnotes relate directly to projects supported by the vegetable research and development levy, some editions covered research outcomes from a number of projects or were of a general nature (e.g. Spray Application).

A key element of the VEGEnote was a break out box titled *The Bottom Line*. This was designed to highlight the key 'take home' message for the reader.

A ring back folder was also produced for readers to store the series for reference and later use. Sponsorship was successfully sought from a number of companies to cover cost of producing and distributing the folders. Funds were matched with Commonwealth funds as a voluntary contribution through another Horticulture Australia project, VG02126, *Preparation of VEGEnotes folder*.

Between four to six series of VEGEnotes were be printed at one time. All copies of VEGEnotes were sent to all growers and the IDOs distributed them using grower details from the IDOs' database.

It was intended that electronic versions (as Portable Document Format, PDF) be placed on vegetable industry development officer websites and future websites such as AUSVEG or Horticulture Australia but this has yet to occur at time of writing this report.

Towards the end of the project in February 2005, a written survey was conducted to ascertain feedback on the VEGEnotes and the usefulness to growers in communicating research outcomes. Questionnaires were posted out with a series of VEGEnotes with the request for readers to return by mail or fax. A scoring of 1 to 6 was used with a response indicator of '1' being in the negative and '6' being in the positive (See Appendix 2).

Results

While the overall response from researchers was enthusiastic, difficulties were encountered with some researchers who were reluctant to provide material. The common reason given was that the project had completed and they felt that they had adequately communicated with industry. Some expected additional payment for their time. These difficulties were overcome however using the IDOs or program managers from Horticulture Australia. Delays

were also encountered with researchers not providing material in a timely manner or tardiness in giving final approval of the edited version which impacted in distribution deadlines.

The 30 titles produced were:

1. Western Flower Thrips
2. Irrigation Management
3. Quality Washwater
4. Sweetcorn Integrated Pest Management
5. Australian Vegetable Industry Development Network
6. Spray Application
7. Slug Control In Vegetable Crops
8. Silverleaf Whitefly Management
9. Control of Sclerotinia Diseases
10. Irrigating Vegetable Crops With Recycled Water
11. Pesticide Storage Requirements
12. Pesticide Resistance Management
13. Nematode Control In Carrots
14. Minor Use Program
15. The National Vegetable Levy
16. Lettuce Aphid Threat
17. Lettuce Integrated Pest Management
18. Integrated Pest Management In Celery
19. Greenhouse Cucumber Extension Project
20. Greenhouse Cucumber Diseases
21. Freshcare
22. Quality Assurance For Growers & Packers
23. Cool Chain
24. Utilising Computers To Enhance Farm Business
25. Management Of Carrot Diseases
26. Capsicum Virus Diseases
27. Managing Cadmium In Vegetables
28. Brassica Integrated Pest & Disease Management
29. Biosecurity
30. Weed Management

(see Appendix 4 for copy of each VEGEnote)

One VEGEnote on Crop Protection Approvals Ltd, a company set up to facilitate the introduction of minor use pesticide permits, was prepared but withdrawn when the company went into voluntary liquidation in late 2003.

In response to the discovery of the currant lettuce aphid in Tasmania, there was flexibility in the publication schedule to produce *Lettuce Aphid Threat*. This rapid response allowed

growers to be informed of this exotic pest with its identification hints and management strategies to minimise its impact on the industry.

Production and distribution of the ring back folders was sponsored by Telstra, John Deere, Australian Perry Agricultural Laboratory, Primary Industries & Resources South Australia, Victorian Department of Primary Industries, Northern Territory Department of Business, Industry & Resource Development and Department of Agriculture Western Australia.

Feedback Survey

The survey questionnaire was distributed with a series of VEGEnote editions in February 2005 to all vegetable growers across Australia. A report was produced as part of Milestone 6 (see Appendix 3). The results were:

- More than 6000 copies of five editions of VEGEnotes were delivered across Australia and 100 completed surveys were received.
- Of all the surveys completed, only 11 included responses at a level of 4 or below. Of these, almost all were related to the fact that the respondents only have a small vegetable component to their business (ie only spring onions or small crop of potatoes additional to other business practices)
- The majority (80) found the series easy to understand (5 or above).
- A number of respondents (15) considered the series to be not highly relevant or beneficial. Of these respondents the majority 12 explained that this was because they only had small or limited vegetable crops as part of their business (vegetables not their core business).
- The overriding feeling from respondents was that this series was well presented and easy to understand.
- All respondents that received the whole series have used the folder to house and protect the series.
- A number of respondents have not received all editions and their requests have been forwarded to the appropriate industry development officer.
- There was one respondent who one seeing the series elsewhere, had requested they be added to the distribution list as they feel it is a valuable resource.
- There have been a number of enquires from other industries that have come across the series and believe it is very valuable communication tool.
- Only two respondents provided suggestions for the series (e.g how to gain organic accreditation).
- Of the growers who provided less than positive responses it is disappointing that none of them provided feedback or reasons for their displeasure.

The survey showed that the overwhelming feeling gained from the respondents is one of satisfaction. Respondents are satisfied that the series is providing them with relevant information in an easy to read, understandable and storable format. Some are even using it to store other industry information they receive.

Positive feedback also came from respondents who do not have crops directly related to the information that has been presented. It was an issue that was discussed initially with the Steering Committee whether or not to target certain VEGEnote titles to growers of certain crops. The decision to send all titles to all growers proved to be the right decision as readers were able to appreciate all the titles available.

Other communication surveys (unpublished) have been carried out under Horticulture Australia project VG03094 *Improving communication networks in the Australian Vegetable Industry*, has shown that VEGEnotes have been well accepted by growers. A communication plan was written in 2005 for the Vegetable Industry which recommended the continuation of technical fact sheets such as VEGEnotes.

Discussion and Recommendations

The feedback from the written survey shows that the concept of fact sheets designed in a simple yet informative style has been well accepted by growers. However, they need to fit in to an overall strategy to communicate research results to growers and facilitate the uptake of outcomes.

They have been shown to be a useful tool in communicating the technical issues of research results but should not be seen in isolation of other communication tools such as magazines, compact discs, videos, field days, workshops, etc.

The style should remain technical as other publications already provide less technical style with the aim of raising awareness of the research supported by the national vegetable research and development levy. As a technical publication, it is important that a suitably qualified writer/editor be used to ensure technical accuracy and industry empathy.

Recommendation 1

Technical fact sheets such as VEGEnotes are an acceptable medium to communicate research outcomes to growers. They should continue to be produced and integrated with the Vegetable Industry's communication plan prepared by suitably qualified writer/editor working with the leader of the specific research project.

Some difficulties were experienced with getting project leaders to be enthusiastic in supplying information for a VEGEnote. In some cases, the project had finished its administrative funding period and researchers had moved on to other work. Other excuses were that the researchers felt they had communicated sufficiently with industry on the outcomes of their project. As VEGEnotes are already included in the communication strategies for the industry, such researcher responses should no longer be an issue as an agreed communication strategy would be developed with each newly approved project.

Recommendation 2

The preparation of a VEGEnote from a project should be agreed up front with the research organisation and Horticulture Australia and be in line with the Vegetable Industry's communication strategies. The VEGEnote should be an activity built into the project milestones.

Feedback from the survey showed that growers valued receiving VEGEnotes that may not be applicable to their business (at the time). The distribution of all VEGEnotes to all growers has shown to be the correct approach rather than try to customise the distribution based on what was thought growers may like to see. Also growers may change the activities on farm as a response to market forces or life styles circumstance. The survey has shown that growers store VEGEnotes and have access to them when needed.

The use of computers is still low in the Vegetable Industry but this should not preclude placing electronic versions on web sites for easy downloading as the use of the internet will increase.

The magazine *Vegetables Australia* began publication in 2005 and would be a suitable cost effective distribution method for future VEGEnotes rathe than as a separate distribution.

Recommendation 3

All titles of VEGEnotes should be distributed to all growers rather than trying to select topics based on known grower preferences. VEGEnotes should be distributed as an insert in *Vegetables Australia* and placed on appropriate web sites as downloadable PDFs.

Acknowledgements

Arris Pty Ltd would like to thank the current and past Vegetable Industry Development Officers for their valuable participation in the project steering committee and assistance in distributing the VEGEnotes: Alison Anderson, Patrick Ulloa, Stephen Welsh, David Ellement, Craig Feutrill, Matt Dent.

Evonne Lovric, previously Program Manager, Horticulture Australia.

Special thanks to Jonathan Eccles, former Senior Program Manager, Horticulture Australia for his guidance, suggestions and support for the project.

Appendix 1 Author's guide to writing for VEGEnotes

Author's guide to writing for VEGE*notes*

Horticulture Australia

Author's guide to writing for VEGE*notes*

Compiled by
NATASHA WOJCIK
Communications Manager
ARRIS

ISBN 0 9750134 0 8

Graphic Design and Editing by
ARRIS Pty Ltd

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Horticulture Australia

Contents

Author guide for VEGE*notes*

Background

During the past decade, vegetable growers and Horticulture Australia Limited (HAL) have invested more than $20 million in the R&D program for the vegetable industry.

Research outcomes from related projects have been communicated to the growers in various forms. However, the Industry Development Officer (IDO) network identified a feeling of dissatisfaction amongst growers. The primary problem being that the information is too scientific to allow direct practical application. Growers want outcomes clearly detailed so as to allow practical applications.

Authors should be aiming to produce material similar to a magazine, rather than a scientific journal article. As the maximum size of any Vegenotes edition is four A4 pages, authors should keep text to a maximum of 1500 words.

The following guides have been prepared to enable Vegenotes to be produced with relative ease, whilst ensuring the grower obtains maximum benefit.

Your guide to writing for Vegenotes

Making it relevant

To ensure your article is relevant, try answering the following questions:

What do the readers want to know?

- What aspects of your topic matter to the reader?
- How does your topic relate to Vegetable farming?
- How can growers use your information?

What is the '*bottom line'*?

- What are the economic/dollar consequences of your topic?
- How will the grower benefit from your information?

Each edition of Vegenotes will include a highlighted section detailing the economic benefits of the information provided. Please include a paragraph that details how a grower will benefit from adopting the information contained in your article.

Is my article easy to read?

- Are scientific terms clearly defined?
- Are sentences short and simple?
- Can someone without a scientific background understand my article?

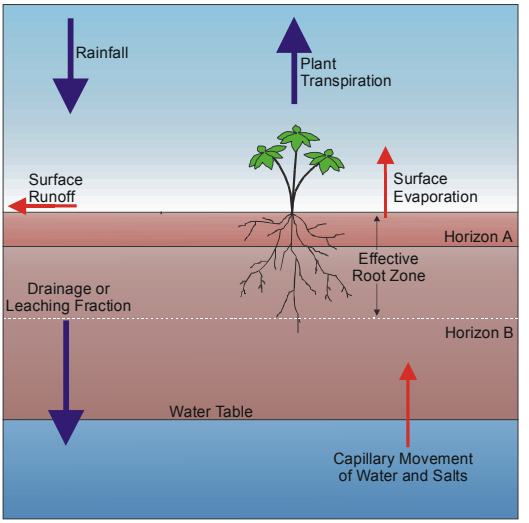
Can I break the information into clear sections?

- Introduction
- Background
- How to use this information
- What you get out of it

Appeal

Your article may contain all the information and be easy to understand, but is it also needs to be appealing to the reader. Graphics attract the reader's eye while providing information or backup to information in the text. **Pictures, tables, illustrations** and **cartoons** are all tools that you can use to make your article eye catching.

Can I use graphics to add interest to my article?



The fate of irrigation water

- Can I put that information in a table? *(only data relevant to growers)*
- Can a picture clearly show what I am explaining?
- Can a graphic be created to detail processes? *(graphics can be created by the editor. A clear sketch from the author is required and a published graphic as a guide would be useful).*

Further Reading

It is useful to provide a short list of further reading suggestions. This is not a reference list and can include other related final reports and website addresses. Please ensure your references are ones that are readily accessible by growers.

Further reading
Australian vegetable growing hanbook (1998)
Edited by J. Salvestrin, Scope Publishing
Vegetable Market Development Papers by PIRSA
Horticulture Australia website
http://www.hoticulture .com.au

How to prepare your Vegenotes

Preparation of Graphics

To gain maximum benefit from your graphics, please follow the guides below. Please ensure that you include captions will all graphics, as they are the most read part of the article, after headings. Captions should explain and enhance the graphic – tempting the reader to read further.

Tables to be included should be created in **Excel** or **Adobe Table**. Where tables are to be placed in the document, please advise by writing in **bold and underlined** with a **paragraph break** before and after.

Eg: **Insert Table 1 – Salinity Levels**

Table name **MUST** be the same as the file.

Pictures to be included should be sent at the highest possible resolution and should be in **TIFF**, **GIFF** or **JPG** format.
Pictures should be of good contrast and have obvious subjects. Cropping and size adjustment will be performed in-house. Where graphics are to be placed in the document, please advise by writing in **bold and underlined** with a **paragraph break** before and after.

Eg: **Insert Picture 1 – Salinity affected cucumbers**

Picture name **MUST** be the same as the file.

Preparation of text

When preparing text to be placed into a PageMaker document, there are a few simple guidelines that can be followed to make the process easier.

- Please provide **text only** in a word document
- Use **Arial 13pt**
- Leave a single **paragraph break** between paragraphs

- Leave two spaces after each **full stop**
- If text needs to be **bold**, underlined, *italicised*, please do so
- Avoid using **capitals** unnecessarily
- Write **dates** in full and without punctuation (25 April 2002)
- Spell out **numbers** one to nine and use digits from 10 onwards. Always use digits for measurements (e.g. 1 ha, 2 mm, 10 kg)
- Use **standard unit symbols** and leave one space between the number and the symbol, except for: 10c, 10%, 10°C and 10°
- Only use **metric** measurements
- **Scientific/proper names** should always be in italics with the first name starting with a capital. Cultivar/ variety names are not italicised, but do start with a capital
- Avoid **sexist language** and/or **stereotypes** in your article

Review your work carefully.
Authors are responsible for the information they provide for the Vegenotes series. They will need to sign-off on final copy before it goes to print.

Check your own work

Your writing checklist

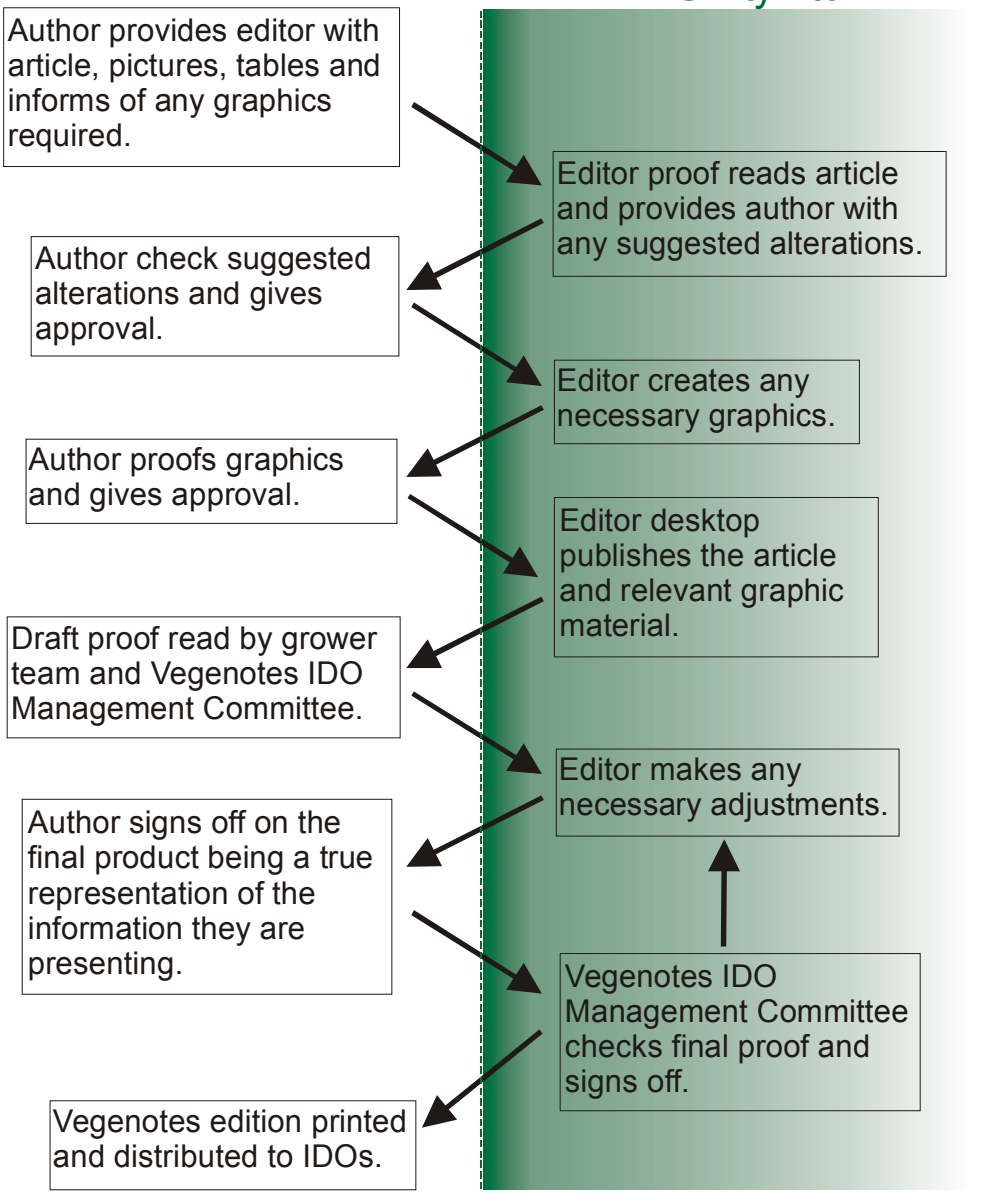
- ☐ Assign headings, subheadings, titles and captions
- ☐ Get approval from relevant people
- ☐ Check facts are correct and evidence is available
- ☐ Check names and numbers of further contacts
- ☐ Check that figures add up
- ☐ Check the length of sentences and paragraphs

Edit your own article

- Is it easy to read?
- Can readers apply the information?
- Will it give them confidence to apply it?
- Does it detail how to apply it?
- Is any information missing?

VEGE*notes* production process

ARRIS Pty Ltd



Colour code for the VEGE*notes* indexing system

Purple = Market Development

Green = Production

Red = Pest & Disease

Yellow = Farm Management

Light Blue = Soil & Water

Orange = Post Harvest

Dark Blue = General Industry

Horticulture Australia

Appendix 2 Grower survey questionnaire

Dear Grower

By now you should be familiar with VEGE*notes*, a series of fact sheets covering a wide range of topics from pest and disease through to product marketing. I hope you are finding the series useful. Please find enclosed six further editions of VEGE*notes*. These should be placed in your VEGE*notes* folder, behind the editions you have already received.

VEGE*notes* has been delivered to more than 7000 vegetable growers across Australia and the series is currently in its third year of production. We would like to know what you think of the series. We want your honest opinion, so it would be greatly appreciated if you could take the time to fill out this short survey and return it to us via fax or mail (details at bottom).

	Not		Somewhat			Very
Does the series contain useful information?	1	2	3	4	5	6
Is the information easy to understand?	1	2	3	4	5	6
Has the information been beneficial?	1	2	3	4	5	6
Has the series given you the opportunity to access information to assist with your business operations?	1	2	3	4	5	6

Have you received all editions of the series? Yes No

If yes, have you placed them in the folder provided? Yes No

If no, please tick the editions required and provide your mailing details below:

- ○The national vegetable levy
- ○Utilising computers to enhance farm business
- ○Irrigating vegetable crops with recycled water
- ○Quality washwater
- ○Irrigation management
- ○Lettuce aphid threat
- ○Western flower thrips
- ○Cool chain
- ○Lettuce integrated pest management (IPM)
- ○Brassica integrated pest and disease management
- ○Sweetcorn integrated pest management (IPM)
- ○Australian vegetable industry development network
- ○Biosecurity
- ○Management of carrot diseases
- ○Quality assurance for growers and packers
- ○Freshcare
- ○Spray application
- ○Integrated pest management in celery
- ○Managing cadmium in vegetables

We welcome your suggestions to improve the VEGE*notes* series:

Yours sincerely

Natasha Wojcik

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ph (08) 8303 7247 fax (08) 8303 6752
ARRIS Pty Ltd ACN 092 739 674 ABN 91 092 739 674

It would be appreciated if you could return this survey to ARRIS Pty Ltd
via fax: 08 8303 6752 or mail:
PO Box 206 HIGHGATE SA 5063

Appendix 3 Report on grower survey

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VEGEnotes Survey Summary

The final round of editions for 2004 was distributed to Vegetable growers across Australia in February 2005. This round was accompanied by a survey for recipients to provide feedback on the relevance and the success of the VEGEnotes series. The results have been compiled and are provided below.

- More than 6000 copies of 5 editions of Vegenotes were delivered across Australia and thus far we have received almost 100 completed surveys from all states (to date, responses still being received)
- Of all the surveys completed, only 11 included responses at a level of 4 or below
- Of these, almost all were related to the fact that the respondents only have a small vegetable component to their business (ie only spring onions or small crop of potatoes additional to other business practices)
- Encouragingly the majority (80) found the series easy to understand (5 or above)
- A number of respondents (15) considered the series to be not highly relevant or beneficial
- Of these respondents the majority 12 explained that this was because they only had small or limited vegetable crops as part of their business (vegetables not their core business)
- The overriding feeling from respondents was that this series was well presented and easy to understand
- All respondents that received the whole series have used the folder to house and protect the series
- A number of respondents have not received all editions and their requests have been forwarded to the appropriate State IDO
- There was one respondent who saw the series and has requested they be added to the distribution list as they feel it is a valuable resource (request forwarded to the appropriate State IDO)
- One respondent misplaced their folder and has requested a new one (request forwarded to the appropriate State IDO)
- There have been a number of enquires from other industries that have come across the series and believe it is very valuable
- Only a couple of respondents provided suggestions for the series (copies attached)
- Of the growers who provided less than positive responses it is disappointing that none of them provided feedback or reasons for their displeasure

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Respondent Quotes:

Excellent and Thank you!

This is the best series of tech notes ever – congratulations.

Great the way it is!

I have placed all my Vegenotes and newsletters in this folder.

Conclusions:

The overwhelming feeling gained from the respondents is one of satisfaction. Respondents are satisfied that the series is providing them with relevant information in an easy to read, understand and store format. Some are even using it to store other industry information they receive.

It is also interesting to note that we are receiving positive feedback from respondents who do not have crops directly related to the information that has been presented. An issue that was discussed during the initial development stages and the decision was made to send the series across the industry and not to targeted commodities – impressing people with information not specifically targeting them is a great achievement for the series.

The fact that some respondents have made suggestions for future editions and for improvement shows that the series is speaking directly to its audience. They have taken ownership and feel comfortable in providing input for their industry publication.

Examples of responses are including on the following pages.

Dear Grower

By now you should be familiar with VEGE*notes*, a series of fact sheets covering a wide range of topics from pest and disease through to product marketing. I hope you are finding the series useful. Please find enclosed six further editions of VEGE*notes*. These should be placed in your VEGE*notes* folder, behind the editions you have already received.

VEGE*notes* has been delivered to more than 7000 vegetable growers across Australia and the series is currently in its third year of production. We would like to know what you think of the series. We want your honest opinion, so it would be greatly appreciated if you could take the time to fill out this short survey and return it to us via fax or mail (details at bottom).

	Not		Somewhat			Very
Does the series contain useful information?	1	2	3	4	5	6
Is the information easy to understand?	1	2	3	4	5	6
Has the information been beneficial?	1	2	3	4	5	6
Has the series given you the opportunity to access information to assist with your business operations?	1	2	3	4	5	6

Have you received all editions of the series? Yes No

If yes, have you placed them in the folder provided? Yes No

If no, please tick the editions required and provide your mailing details below:

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- ○Utilising computers to enhance farm business
- ○Irrigating vegetable crops with recycled water
- ○Quality washwater
- ○Irrigation management
- ○Lettuce aphid threat
- ○Western flower thrips
- ○Cool chain
- ○Lettuce integrated pest management (IPM)
- ○Brassica integrated pest and disease management
- ○Sweetcorn integrated pest management (IPM)
- ○Australian vegetable industry development network
- ○Biosecurity
- ○Management of carrot diseases
- ○Quality assurance for growers and packers
- ○Freshcare
- ○Spray application
- ○Integrated pest management in celery
- ○Managing cadmium in vegetables

We welcome your suggestions to improve the VEGE*notes* series:

Suggestion: What about Excellent & doing a series on Organics - awareness raising for conv. grower. Helpful for Org growers eg certification gen. issues etc

Thank you!

Yours sincerely

Natasha Wojcik

ARRIS

It would be appreciated if you could return this survey to ARRIS Pty Ltd
via fax: 08 8303 6752 or mail:
PO Box 206 HIGHGATE SA 5063

Dear Grower

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VEGE*notes* has been delivered to more than 7000 vegetable growers across Australia and the series is currently in its third year of production. We would like to know what you think of the series. We want your honest opinion, so it would be greatly appreciated if you could take the time to fill out this short survey and return it to us via fax or mail (details at bottom).

	Not		Somewhat			Very
Does the series contain useful information?	1	2	3	4	5	6
Is the information easy to understand?	1	2	3	4	5	6
Has the information been beneficial?	1	2	3	4	5	6
Has the series given you the opportunity to access information to assist with your business operations?	1	2	3	4	5	6

(We only get spray onions)

Have you received all editions of the series? Yes **No**

If yes, have you placed them in the folder provided? Yes No

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- o The national vegetable levy
- ✓ Utilising computers to enhance farm business
- o Irrigating vegetable crops with recycled water
- ✓ Quality washwater
- o Irrigation management
- o Lettuce aphid threat
- o Western flower thrips
- ✓ Cool chain
- o Lettuce integrated pest management (IPM)
- o Brassica integrated pest and disease management
- o Sweetcorn integrated pest management (IPM)
- o Australian vegetable industry development network
- o Biosecurity
- o Management of carrot diseases
- o Quality assurance for growers and packers
- o Freshcare
- o Spray application
- o Integrated pest management in celery
- o Managing cadmium in vegetables

We welcome your suggestions to improve the VEGE*notes* series:

Dr. MIKE WALKER
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SPALFORD 7315

Yours sincerely

Natasha Wojcik

ARRIS

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Have you received all editions of the series? (Yes) No

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- ○Freshcare
- ○Spray application
- ✓○Integrated pest management in celery
- ○Managing cadmium in vegetables

We welcome your suggestions to improve the VEGE*notes* series:

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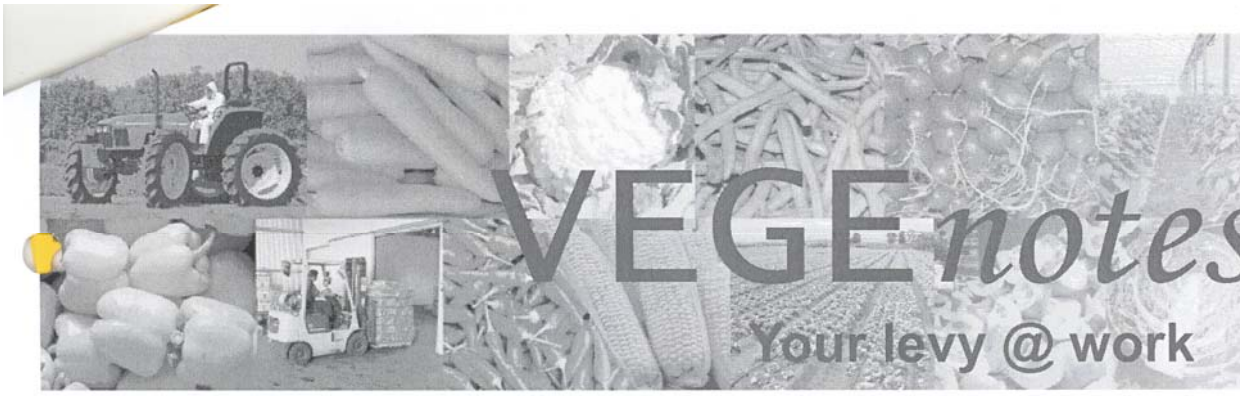

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Appendix 4 VEGEnotes

Western Flower Thrips

Western Flower Thrips (WFT), *Frankliniella occidentalis*, is one of the most damaging pests to confront the Australian vegetable industry. WFT causes damage by feeding on fruit buds (eg. cucumbers) and spreading Tomato Spotted Wilt Virus (TSWV) in many vegetable crops like lettuce, capsicum, potato and tomato.


A Western Flower Thrips.

This difficult pest often develops resistance to insecticides and is spreading into new growing regions and a wider range of crops, including stone and pome fruits.

Horticulture Australia (previously HRDC) has been funding research into the management of WFT and TSWV since 1995. Research work has included the following:

- monitoring the frequency of WFT resistance to commonly used insecticides
- generating data to support new chemical permit applications
- developing biological strategies for controlling WFT
- studying transfer of TSWV from infected plants to new crops
- surveying common weeds and native vegetation for their ability to host WFT and TSWV
- studying TSWV epidemics in potatoes
- observing seasonal changes in WFT levels in commercial crops


WFT damaged cucumber.

Australian vegetable producers have received the key outcomes of this research through a National WFT and TSWV newsletter and a three-year pilot extension project at Virginia.

Recommended WFT management strategies have been trialled 'on-farm', at Virginia and then transfered to growers through workshops and demonstrations.

The same basic management principles apply to greenhouses and field crops. However, well designed greenhouses are able to exclude some of the local environmental pest pressure, opening the way for additional management options including the inrtoduction of biological control agents.

Greenhouse and field crops can benefit greatly from area-wide strategies to limit WFT and TSWV levels, in a growing region at critical times. This is achieved by eradicating weeds and old crops before they become pest and virus hosts for other crops.

Results you can expect

Most growers gained immediate benefits from recommended practices, but all found they had to adopt a routine program for checking results and comparing with management records. Many of these growers have also substantially reduced their chemical use.

The bottom line

- Remove weeds and plants that host TSWV and WFT, including infected crop plants
- Assess and correct aspects of spray programs that can weaken insecticide effectiveness or encourage resistance
- Monitor pest and disease levels closely
- Improve greenhouse design to exclude pests while maintaining adequate ventilation
- Work together, as a region, to tackle WFT and TSWV control

Trials at Virginia combined chemical and non-chemical strategies. Positive results required regular pest and virus monitoring and diagnosis. This enabled clear and early identification of threats, as well as assessment of the effects of changes to management practices.

Basic Pest Management Cycle

Farm hygiene:

Thorough hygiene practices can prevent WFT and TSWV contamination of crops. Five frontiers must be protected:

- Only seedlings and plant material free of pests and disease can be brought into the area
- Vegetation near the crop (weeds or old crops) should be cleared at least 2 weeks before planting unless it is pest and virus free
- TSWV infected plants found in the crop should be detected early and removed without spreading the thrips
- Neighbours should communicate to help each other with their planting, clearing and spraying times to maximise crop protection
- Regional action may be needed to deal with uncontrolled weeds or green waste disposal

Note: if infested plants or weeds are pulled out or sprayed off any pests will seek new homes nearby.

Spray program:

Improved pest control depends on ensuring the following things are completed:

- Planning to ensure effective spray timing and resistance control
- Maintaining spray equipment (fine jets and good pressure)
- Correct preparation of spray mixes (callibration, pH levles and chemical compatability)
- Application of spray mixture for best coverage
- Checking spray coverage results using dyes
- Recording chemicals used and results achieved

Monitoring:

Regular monitoring using yellow sticky traps or leaf and flower checks enables:

- Pest Identification
- A quick check of spray results
- Assessment of the success of pest program changes

This information helped growers achieve:

- Accurate, timely and effective use of all management strategies
- Better pest control outcomes
- A better handle on further problem solving
- Frequent reduction in chemical use

Greenhouse design:

Fine mesh, to exclude flying pests, helps reduce the entry of thrips (and whitefly). However, fine mesh can increase disease problems if ventilation is dramatically reduced. If WFT do enter they may breed rapidly, especially in warm weather. Double entry doors also assist in reducing pest entry.

Biological control of WFT:

A native predatory mite, investigated by NSW Agriculture, has successfully controlled WFT in several greenhouse crops including capsicum, cucumber and tomato. It requires very careful management to work effectively.

Further Information

For more information regarding this edition of VEGE*notes*, please contact your State Vegetable Industry Development Officer.

Acknowledgements

Tony Burfield, SARDI.

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Horticulture Australia

Irrigation Management

Good irrigation management is vital to achieve efficient use of water combined with high yields and quality in vegetable crops. Irrigation also has a direct influence on factors such as pack out percentage, shelf life and aesthetic or visual appearance of the product.

Irrigation application rate and timing depends on the moisture content in the root zone and the rate of water losses (evapotranspiration) from the plant and soil.

Evaporation + Transpiration = Evapotranspiration (ET)

Soil texture and structure, root depth, crop characteristics and climate are the main factors influencing the amount of water available to the plant.

Therefore, effective irrigation is crucial to eliminating over or underwatering, which can both reduce the yield and cause salinity and waterlogging problems.

Why improve irrigation management?

There are many reasons for improving irrigation management including:

Growing better crops

Providing crops with optimum soil water reduces exposure to periods of waterlogging and dryness, thus maximising crop growth and fruit quality.

Too little water can be as problematic as overwatering. For example, moisture stress in lettuce during head formation can result in tip burn, while in tomatoes blossom end rot will result if the crop is stressed in early fruit set.

Too much water can cause root rot in most vegetables.

Reduce pest and disease problems

Maintaining optimum soil water aids crop performance and health. It can also assist with reducing pest and disease impacts.

For instance, strategic spray irrigation can reduce the effect of downy mildew in onion crops.

Reduce environmental impacts

Avoiding excess irrigation minimises waterlogging, salinity, leaching of nutrients and chemicals, and rising watertables. This preserves local biodiversity, enhances river systems and saves on production costs.

Protect the value of the farm

Salinity, high water-tables and soil degradation reduce productivity and the value of land.

Increase overall crop production

Improved irrigation efficiency may provide surplus irrigation water, which can be used to grow additional crops or sold to other enterprises.

Reduce production costs

Efficient irrigation means applying the right amount of water at the right time. Making sure the crop uses all water applied and avoiding system losses and wastage through run-off or drainage.

Furrow irrigation is best suited to heavier textured soils such as clay loams.

The Bottom line

- Use soil moisture monitoring
- Use an accredited designer for new irrigation systems
- Match irrigation rate with soil infiltration rate
- Ensure good drainage during rainfall
- Conduct a whole farm plan including irrigation infrastructure

To irrigate your crop effectively and profitably you need to know:

Crop Water Requirements - Understanding crop water needs at various stages of development is critical. In carrots, soils that remain too wet at early growth stages can result in damping off, whereas later in the growth cycle hairy roots will result if soil becomes too dry.

Readily available water (RAW) - Plants cannot use all water held in soil. For practical irrigation planning, irrigators must work with the water that is readily removed from the soil by the plant, the *readily available water* (RAW).

RAW is expressed in millimetres per metre (mm/m) and indicates the depth of water (mm) held in every metre (m) of soil, which can be readily used by the plant. RAW can be calculated for the total profile depth, or more usefully just down to the depth of the plant's effective root zone.

To achieve high yields without creating excess drainage you need to know the RAW for each crop and block.

Effective root zone - The area of the plant's root zone where the main mass of roots is found. Encourage root growth below the effective root zone by withholding irrigations early in the season, being careful not to cause stress, so the plant extracts water from a larger volume of soil.

Vegetables vary in root depth. Table 1 is a guide to root depth of selected crops (Allen et al., 1998).

When to irrigate (refill point) - After the RAW has been used, it becomes harder for plant roots to extract water from the soil, referred to as the refill point. The drier the soil, the more water needed to return to field capacity.

Irrigation should occur before the refill point is reached because the plant is already struggling.

Table 1. Root depth guide

Crop	Root Depth (m)
Tomato	0.5 - 1.5
Onion	0.3 - 0.6
Watermelon	0.8 - 1.5
Carrot	0.5 - 1.0
Lettuce	0.3 - 0.5
Broccoli	0.4 - 0.6
Cabbage	0.5 - 0.8

Infiltration rate - Is highly variable, both within and between fields. Soil texture and structure determine infiltration rate. Soils such as sands that have large pore spaces have a high infiltration rate. Water infiltrates a well-structured soil with air spaces and root channels more quickly than a compacted soil.

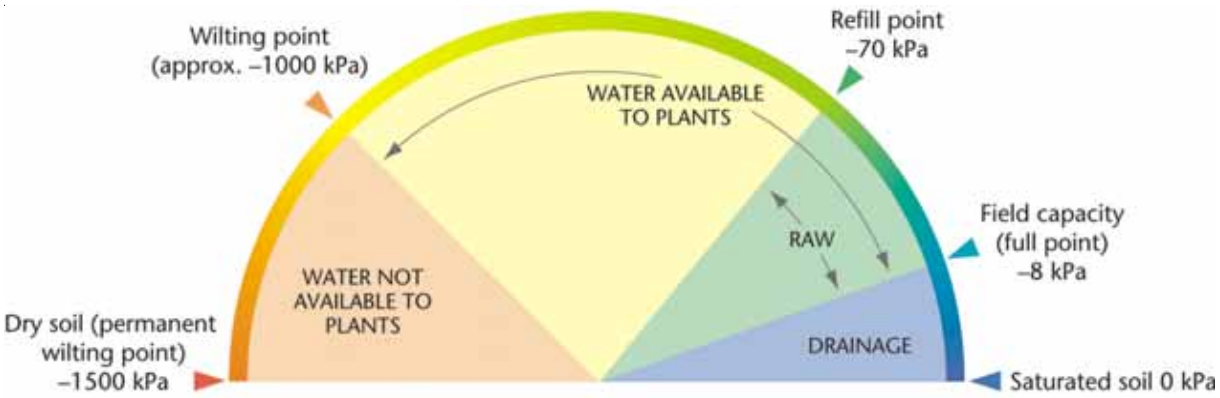
Infiltration can be improved by the following:

- open up the surface or break up crusts, hardpans and hard set layers
- use narrower beds
- add gypsum to sodic soils
- cultivate, core, spike or split to physically break compaction layers
- increase organic matter
- plant a pasture or cereal, such as rye grass or oats, over winter to increase levels of organic matter and allow roots to aerate the soil

Infiltration will be decreased by:

- exposing heavier subsoil during laser levelling
- working the soil when it is too wet
- using excessive cultivation

Figure 1. Different levels of soil moisture



Onions centre pivot - Irrigation application rates that exceed the infiltration rate can damage soil and produce excessive waterlogging and run-off.

Choosing the right irrigation system

It is wise to consider developing a whole farm plan to determine the best irrigation system for your situation.

Other considerations include:

- financial – detailed costing of the work and development stages
- farm management – development of fences and buildings etc
- engineering – sound design in hydraulic terms for automation, pressurised system design, re-use systems and on-farm storage
- environment – effect of surrounding landscape and watertable etc
- agronomy – crop types including rotations, soil types, paddock size and slope

Spray, drip or furrow irrigation?

Overhead spray irrigation is the most common form of irrigation used in vegetable crops in Australia. Spray irrigation:

- may be used on many soil types but is well suited to sandy, well-drained soils
- comes in many forms from fixed sprinklers, travelling guns and booms to centre pivot and linear move irrigators
- can be managed to minimise frost damage
- can be used with other crops in the rotation suited to spray irrigation
- is generally lower cost than drip
- allows more flexibility such as use on soils prone to crusting, regular irrigations to keep the surface soil moisture during plant emergence

Drip irrigation offers:

- better control of crop production
- less weed growth
- reduced risk of diseases such as fruit rots
- less labour (less hand weeding or moving the vines out of the furrow before irrigation)
- better control of the harvest schedule
- lower water use
- less drainage volume
- ability to use fertigation
- suitability to a variety of soils and landscapes

On the down side is the financial and environmental cost of disposing of drip tape, especially single-use tape, and black plastic, used to increase soil water. There is also a demand for better irrigation management, because the root volume is smaller (smaller margin for error).

Uniform wetting patterns of sub-surface drip is essential for even germination of crops.

As drip irrigation is expensive, rotations should comprise mainly high value crops. The other challenge for subsurface drip (buried drip tape) is bringing the water to the surface for crop emergance, while keeping the soil surface dry for the remainder of the season. Drip tape that is too shallow may keep the crown of the plant wet, encouraging disease.

A recent trial conducted by researchers at the Queensland Department of Primary Industries, Gatton, determined a lettuce crop yielding 4,150 cartons/ha could be grown using just 1.8 – 2.2Ml/ha of water (irrigation plus rainfall). This compares to 2.5 – 3 ML/ha budgeted by growers using well managed sprinkler systems.

Furrow irrigation is best suited to deep, moderately permeable soils with a uniform, relatively flat slope. Furrow irrigation:

- requires considerable skill, both in initial land grading and subsequent on-farm water management
- is viable on soils with good infiltration, such as self-mulching grey clays
- requires a good recycling system for efficient irrigation
- is cheaper to establish than drip, and so is suitable for long rotations, for example 1-in-4 years, or for growers who lease land for short periods
- requires little maintenance

Soil Moisture Monitoring

A recent study of irrigation in NSW vegetable crops revealed soil moisture monitoring is the most effective way to accurately meet vegetable crop water requirements.

By monitoring soil moisture, growers get a 'picture' of what is happening below the soil surface where the roots are exploring the soil and obtaining water vital for growth. The results provide information on the soil moisture changes after each irrigation.

There are several soil moisture monitoring devices available, which can be divided into two categories; soil moisture suction measuring (ie. tensiometers) and soil water content measuring (ie. Enviroscan®).

Whichever device is used, it is important to place it in a representative part of the paddock. Use sensors at different depths in the root zone (i.e. 15 and 30cms), in addition to a deep sensor (i.e. 50cms), which can monitor over-irrigation and watertable changes.

If the paddock is variable (ie. varies from clay on the flat rising to a sand hill) more monitoring sites may be required.

Many growers are already working towards better irrigation by taking these steps:

- developing a farm plan
- participating in an irrigation management course
- properly maintaining the irrigation system
- using a professionally designed irrigation system
- developing sound agronomic knowledge
- understanding soil and water relationships
- using soil water monitoring equipment
- determining irrigation and nutrient requirements

Further Reading

- "Best *management guidelines for irrigated vegetable crops*" (2004) M.Hickey et al, NSW Agriculture, Yanco (CD Rom and manuals)
- "*Managing yields and quality of lettuce cultivars*" (2003) Craig Henderson, Queensland Department of Primary Industries, Rural Water Use Efficiency Initiative.
- "*Irrigation scheduling for vegetable crops* : A growers guide" (2003) A.Qassim et al, Department of Natural Resources and Environment, Tatura, Victoria.
- *Crop evapotranspiration: guidelines for computing crop water requirements*" (1998) R.G Allen et al, FAO Irrigation and Drainage paper No 56, Rome
- "*Vegetable SoilPak*" (1998) B. McMullen, NSW Agriculture, Bathurst

Further Information

For further information on irrigation and water related issues in your state, contact your state Vegetable Industry Development Officer.

Acknowledgements

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NSW Agriculture

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Quality Washwater

A recent study on the quality of waste wash water used on Australian vegetable farms revealed some treatment would be needed for it to be safely re-used.

Some persistent herbicides were found in high enough concentrations to cause damage to future crops and organic matter levels were usually too high to effectively use disinfectants for the control of water and soil-borne diseases.

Water treatment depends on a range of factors such as intended use, quality of source water and quality after existing treatment or storage operations. There is no single answer and decisions should be based on careful consideration and advice for each situation.

Taking samples of washwater

Why treat water?

- Remove objectionable odours. Odours are derived from microbial degradation of organic matter in the absence of oxygen
- Improve water quality so current water disinfestation treatments are effective against human and plant pathogens
- Efficiently use a scarce resource and lower overall water consumption on farm

Removal of impurities

Water impurities vary in size and character from plant material, sand and soil to fungi, bacteria, viruses and chemicals. Coarse material, such as plant pieces, can be caught by coarse mesh in a sediment pit, where coarse and fine sand may also fall out depending on the settling time.

Extremely small particles (colloids) do not dissolve in water and are generally stable; they don't separate out or clump because each particle has a similar electrical charge, which repels like particles.

Chemically assisted sedimentation: colloids and fine particles (e.g. iron) take a long time to settle when not combined into larger, heavier particles (flocs). Chemically assisted sedimentation involves two steps, coagulation and flocculation, which neutralise the external charge and allow the colloids to combine into larger particles.

Coagulation destabilises a colloid through the addition of organic or inorganic substances: primary coagulants such as aluminium sulphate or a suitable cationic polyelectrolyte.

Flocculation is where destabilised particles are further clumped to form larger flocs. Flocculation is assisted by the addition of chemicals known as flocculants – polyelectolytes. The flocs either sink or float to the surface and are easily removed by skimming, settling or filtering the water.

Aeration: excess organic matter and metal ions may be removed by running water over a pebble or gravel trickle bed, providing a drop (1-2 plus metres) over a rough surface or bubbling air through water.

The Bottom line

- Washwater recycling cuts the water cost of washing to around $5/tonne of produce. This is based on an average use of 135,000L water/tonne of produce at a cost of $37/ML.
- However, low cost water treatment may be necessary to ensure the use of recycled water does not lower the food safety standards of the product due to contamination with bacteria or agrochemicals.

Removal of nutrients

Constructed wetlands are a low cost, low maintenance method which can reduce Biological Oxygen Demand, Total Suspended Solids and some pesticides, and remove excessive phosphorous. Nutrients are also removed by plants (the best is the common reed - *Phragmites australis)* and other wetland organisms.

A recent study on constructed wetlands (which incorporated horizontal flow sub-surface systems) showed that a hydraulic retention time (HRT) of five days allowed 86% of all nitrogen and phosphorous to be removed (Headley et al. 2001).

These systems involve water flowing through basaltic gravel fill in a trench lined with water (impervious barrier and planted with common reeds). This below gravel surface design stops mosquito breeding and wildlife polluting the water.

Surface water wetlands may be constructed so effluent is introduced into a series of ponds with a succession of shallow and deep water zones. Each zone has different types of vegetation. Wetland edges could have plants such as dwarf cyperus or common reed, while deeper water may be planted with water lilies and floating plants such as duck weed.

Treatment occurs through physical, chemical and biological processes: sedimentation, adsorption, volatilisation, filtration, plant uptake, and microbial action. Constructed wetlands of this type have been shown to degrade some agrochemical residues such as atrazine and linuron.

Constructed wetlands are cost competitive with other wastewater treatment methods and, depending upon land availability, may be a much less expensive option than other methods of water treatment. Operation and maintenance costs are often significantly lower than conventional advanced secondary treatment.

Water disinfestation treatments

Chemical disinfestation research for the Australian Nursery Industry has found fungal plant pathogens similar to those potentially causing problems in the vegetable industry.

A range of options are available for the control of human and plant pathogens in water. Recycled water is usually high in organic matter, which can act as a neutraliser, thus sodium hypochlorite is not recommended. Registered chlorine dioxide based chemicals are less likely to be affected by high organic matter load and more efficient in obtaining correct disinfectant concentrations.

Small settling dam for a carrot washing facility

Ozone can potentially provide a wide range of water treatment services. It breaks down organic matter, decolourises pigments and coloured compounds in water, decomposes agrochemicals, assists with metal ion removal, kills and flocculates algae and kills human and plant pathogens.

Further Reading

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Acknowledgements

Martin Mebalds and Andrew Hamilton
Department of Primary Industries, Victoria

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Sweet Corn Integrated Pest Management (IPM)

The Australian sweet corn industry has benefited from Integrated Pest Management (IPM) Research & Development (R&D) through the introduction of biological methods as opposed to broad-spectrum insecticides.

The conservation of naturally occurring parasitoids and predators is important as they, along with pathogens and some insecticides, are being used to manage helicoverpa (heliothis) in sweet corn.

Supersweet Sweet Corn

An integrated package of practices is more sustainable than one based on broad-spectrum insecticides alone. It involves a thorough understanding of pest-beneficial interactions, use of biological and narrow spectrum insecticides, spray decisions based on scouting information and pesticide application using improved equipment and techniques.

An IPM strategy aims to reduce the pest population to a minimum by taking into account the various components and how they might be manipulated. It then uses a range of tools and management options, which could include a combination of cultural, physical, biological and chemical control measures.

Helicoverpa (heliothis), a major pest of sweet corn.

The Bottom line

- **Scouting (monitoring) crops for pests and disease is critical.**
- **Cultural, physical, biological and chemical controls need to be considered.**
- **Be aware of new equipment and techniques for pesticide application.**
- **Target all pesticides at the cob and the silk to increase effectiveness.**

Management options in sweet corn

➢Scouting (Monitoring)

Monitoring for pests and diseases is a critical step in the crop protection cycle, without it you will have little evidence of the strategies needed or how well your current strategies are working.

A competent crop consultant can monitor sweet corn crops and provide assistance in making a spray decision. If you do not hire a professional crop consultant, the following procedures will help.

What to look for:

- Thoroughly examine a minimum of 20 to 30 plants per planting. In very large plantings you may need to sample several parts of the planting.
- A systematic sample should involve selecting a number of randomly spaced sites within the crop and assessing four to six plants at each site.
- The number of sites sampled will depend on the area of production and the time available for monitoring.
- Before tasselling look at the whole plant. From the start of tasselling, concentrate on the tassels and then the silks, from first appearance until they brown off. Intensive monitoring is usually no longer required once they have browned off. Monitor for aphids from the brown silk stage until harvest.
- Don't worry about not seeing a particular problem, you will. Choose plants randomly, being careful not to specifically target unhealthy plants while monitoring. If a plant doesn't look healthy and you don't know why, put it in a plastic bag and have the problem identified.

Carefully note and record the following:

- Number and maturity of heliothis eggs on the leaves and stems, particularly the top third of the plant, tassels and/or silks and wrapper leaves of the cob. White eggs are newly laid, brown eggs will hatch in about one day and shiny black eggs have been parasitised by a minute wasp, *Trichogramma*.
- Number of other pests such as armyworm, sorghum head caterpillar and yellow peach moth. Note the presence of thrips, aphids, mites and dried fruit beetles.
- Type and number of beneficial insects present. Exact number is essential for major pests.

Bronwyn Walsh, Entomologist, DPI - Monitoring a block of sweet corn.

For minor pests such as aphids, thrips and mites an approximate number is sufficient.

➢Naturally occurring beneficials

A large range of naturally occurring beneficials has been identified as important to managing Heliothis in sweet corn. They are now more effective in commercial fields due to the reduced use of broad-spectrum insecticides.

Trichogramma pretiosum is also a potential control agent for helicoverpa (heliothis) pests in sweet corn.

Telenomus, another parasite wasp species, also occurs naturally under field conditions and overwinters effectively, although its rate of parasitism is lower than the *Trichogramma* species, with only one wasp per egg being produced.

➢Biological & narrow spectrum insecticides

The 'Insect Pest Management in Sweet Corn' project produced data to support the registration of Success® (Spinosad) and Gemstar® (NPV) with the Australian Pesticides and Veterinary Medicines Authority (APVMA) for sweet corn in Australia.

These products effectively control Heliothis, when applied at the appropriate time and they preserve beneficial insects while being safe for the environment and end user.

Nuclear Polyhedrosis Virus (NPV) (e.g. Gemstar®) is an insect specific virus developed to control heliothis.

Late afternoon applications help prolong its effectiveness, as it is rapidly degraded by ultra-violet light. As it is specific to heliothis, beneficial insects are not affected.

Spinosad (for example Success®) is based on naturally produced metabolites of the soil micro-organism *Saccharopolyspora spinosa*. Although Spinosad is broken down in two to three days by UV light, its movement into the leaf results in the product having a longer residual effect. Spinosad has relatively low toxicity for most beneficial insects, although it can adversely affect *Trichogramma* wasps.

Bacillus thuringiensis (Bt) (for example Dipel®) is a bacterial biological insecticide used to control a wide range of caterpillar pests, including heliothis.

Standard Boom Spray modified with droppers

➢Pesticide application

Research has show that pest damage can be significantly reduced by targeting pesticides (both synthetic and biological) to the cob and silk area. Boom sprays modified with droppers have demonstrated a four-fold difference in the average deposit on silks compared to conventional boom sprays.

A number of growers in all districts are modifying boom sprays to take advantage of this improvement. Optimisation of aircraft application can be achieved through modification of spray patterns (eg reduced swath width), increased water volume, and the use of aids such as Global Positioning Systems (GPS).

➢Insecticide resistance management strategies

Resistance to one or more pesticides has been a problem in many vegetable crops, including sweet corn, for many years.

For example, heliothis has developed resistance to a wide range of carbamates and synthetic pyrethroids during the past two decades. Resistance management strategies, either for a particular crop or a growing region, help safeguard the effectiveness of new pesticides to ensure they will control heliothis and/or other pests for a number of years. Resistance management strategies are based on the principle of rotating products among chemical groups.

➢Making a pest management decision

First decide if action, such as pesticide application, is needed to avoid loss from pest damage. If action is required, remember the following important tips.

- Choose pesticides that will be the least damaging to beneficial insects
- Spray only when the pest level becomes economically damaging
- Spray at the stage in the pest life cycle when it is most susceptible
- Spray individual plantings and not the whole farm
- Target sprays on appropriate plant parts, i.e. the silks.

Monitoring and action thresholds help you make these decisions. The threshold you set will depend on the activity of beneficial insects and the risks you are willing to take in not controlling the pest.

Boom Sprayer fitted with Droppers

Weekly sampling for heliothis eggs will indicate parasitism levels present within the crop and guide you in your choice of insecticides. A high percentage of black eggs indicates a high parasitism level, reducing the need to take action against the pest.

Record all these in your monitoring log, as they can be used to judge when outbreaks may occur and what steps may be required to control them.

Further Reading

"Sweet Corn Insect Pests and their Natural Enemies" an IPM field guide
by Richard Llewellyn.

"Growing Sweet Corn" a NSW Agriculture Ag Note
by Clarrie Beckingham, NSW Agriculture.

"Heliothis in Sweet Corn"- a DPI Farm Note
by Peter Deuter, Brendan Nolan, and Bronwyn Walsh, Department of Primary Industries and Agency for Food and Fibre Sciences, Horticulture.

www.nre.vic.gov.au/agvic/ihd/projects/sc

Acknowledgements

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Australian Vegetable Industry Development Network

The Australian Vegetable Industry Development Network was established to assist the Australian vegetable industry in maximising the benefits of its investment in research and development (R&D).

This is achieved by enhancing communication and information flow between growers, researchers and other members of the vegetable industry.

The network began in 1998 and now comprises six Industry Development Officers (IDOs), with one officer in each state.

The National Vegetable Research & Development Levy is matched dollar for dollar by the Commonwealth Government (through Horticulture Australia Limited) and together they fund the network and the R&D program.

The IDOs' primary goal is to help bridge the gap between researchers and growers, and ensure maximum benefit is gained from the growers' levies and Government contributions that fund R&D programs. They do this by working closely with growers to determine the industry's R&D priorities, and then they pass this information on to researchers to ensure their future R&D work meets these priorities.

The IDOs also play a major role in coordinating the extension of information out from R&D programs, so that growers receive the information they need in a timely and useful manner.

In addition to regularly communicating with members of the vegetable industry, the IDOs also maintain frequent contact with the 50+ IDOs in other horticultural industries throughout Australia.

This allows them to tap into the latest knowledge, ideas and technologies from all facets of the broader Australian horticulture industry, and then make this information available within the vegetable industry.

The key objectives of the network are:

- *Facilitate transfer and adoption of new technologies and practices that increase sustainability and profitability*
- *Increase grower awareness of and access to information sources and services*
- *Identify impediments to the progress of the industry and suggest potential solutions*
- *Assist industry in identifying and accessing opportunities locally, nationally and internationally*
- *To assist implementation of the Australian Vegetable Industry Strategic Development Plan and develop further strategies for the industry*
- *Encourage and facilitate communication throughout the vegetable industry, with particular emphasis on improving linkages between researchers and growers.*

The Bottom line

- **Maximising the industry's investment in R&D programs through increased coordination and communication of R&D outcomes**
- **Stronger linkages forged between all members of the Australian vegetable industry**
- **More efficient transfer of technology and information, resulting in increased uptake and application of new technologies and practices**

The IDOs undertake a diverse array of activities to help them achieve these objectives, however as the Australian vegetable industry varies significantly from state to state, each of the IDOs tailor their activities to the individual needs of their state. These activities include:

- Production and distribution of information through a variety of media, such as newsletters, magazine articles, targeted mail outs, web pages, email broadcasts, fax streams and numerous industry publications
- Assisting the national R&D approval process, including facilitating commodity and key investment area groups
- Assisting in the determination of state and national R&D priorities, and communicating these throughout the industry
- Organising, facilitating and assisting with workshops, field days, conferences, seminars and other industry events which contribute to the effective transfer of R&D outcomes
- Acting as a central point in their own state for coordinating and distributing information from interstate and overseas R&D programs

The Australian Vegetable Industry Development Officers

Anyone requiring information about any facet of research and development in the Australian vegetable industry is encouraged to contact their local IDO.

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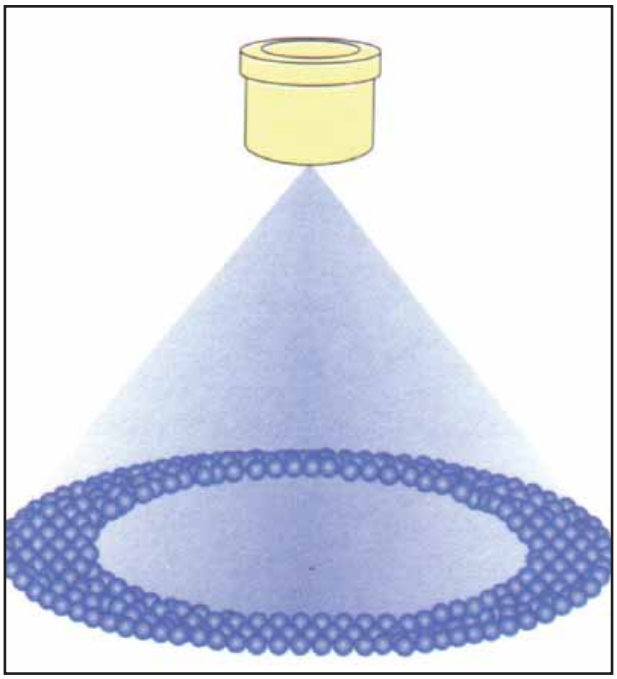
Spray Application

Chemicals are used in the vegetable industry to control pests, diseases and weeds. The majority of agricultural chemicals are applied in the form of droplets produced from different types of nozzles mounted on spray booms.

To maximise spray efficiency, droplets must be uniformly distributed on the target surface with minimum loss (usually caused by drift, evaporation and run-off). Poor spray application techniques waste chemicals, reduce control of pests and result in loss of yield and quality. This ultimately leads to lower returns for the grower.

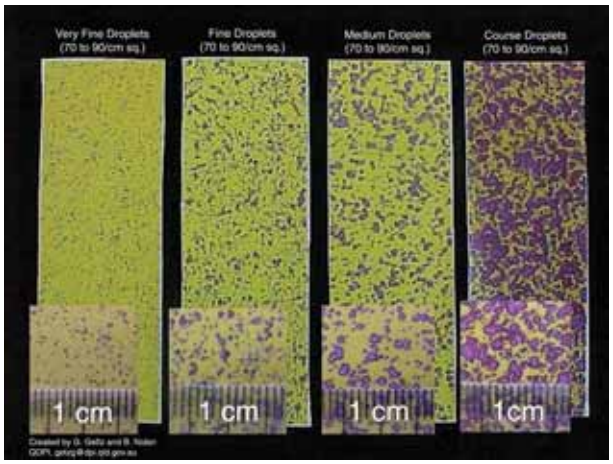


Hollow cone nozzles are still one of the most recommended types of nozzle for insecticide and fungicide use.

Droplet size

Droplets are very small and usually measured in microns (µm), with one micron equalling 0.001mm. When operating at any given pressure, hydraulic nozzles produce a range of droplet sizes.

The British Crop Protection Council (BCPC) has classified droplets into six different sizes (see Table 1). This classification is a useful guide for assessing the suitability of a nozzle for a particular spray job.



Water sensitive cards showing the difference between droplet sizes at the same density.

Spray volume versus droplet size

There is an important relationship between droplet size, volume and the number of droplets that can be produced from a fixed volume of spray application. As the size of droplets reduces, the number produced from the same volume of spray increases.

The bottom line

To achieve the best possible spray coverage you need to consider the following:

- Accurate pest and disease identification
- Suitable droplet size and water volume
- Application under the appropriate environmental conditions
- Using clean water of the correct pH
- Correctly calibrated and maintained spraying equipment

Table 1: BCPC classification of droplet size and their application

BCPC Category	Droplet size	Description	Uses
Very fine	< 150µm	Mist or fog	Insecticides and fungicides
Fine	150-250µm	Fine spray	Insecticides and contact herbicides
Medium	250-350µm	Medium spray	Residual herbicides
Coarse	350-450µm	Very fine rain	Residual herbicides and foliar fertilisers
Very coarse	450-550µm	Fine rain	Foliar fertilisers
Extremely coarse	> 550µm	Heavy rain	Foliar fertilisers

Note: Droplets smaller than 80µm cannot be readily seen by the naked eye.

For example, one 400µm droplet is equal, in volume, to 64 droplets each of 100µm. A far better spray coverage is achieved on a leaf surface with 64 droplets of 100µm than with one droplet of 400µm (see below).

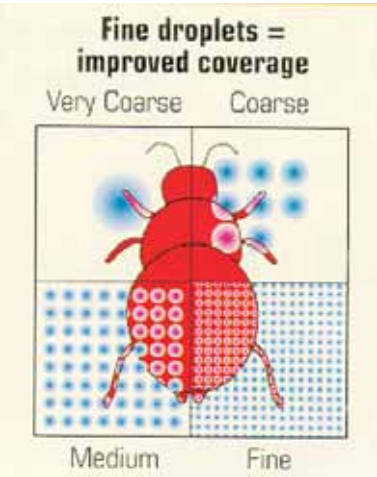


Photo courtesy of Hardi Australia.

Droplet density

To achieve good results, droplets not only need to be uniformly distributed over the target area, the density also needs to be sufficient. Different types of chemicals require a different droplet density. Systemic type chemicals require a droplet density as low as 20-30 droplets/cm^2. When targeting mobile insects or using contact fungicides, a higher density of 70-100 droplets/cm^2 is recommended. Table 3 gives a guide to the droplet densities required to ensure adequate levels of control.

Table 2: Number of droplets produced from 1ml of spray

Droplet size	Number of droplets produced
100µm	1909559
200µm	238732
400µm	29841
800µm	3730

Water Rate

Water rate as well as droplet size, help determine droplet density. A low water rate can lead to insufficient droplet density and poor coverage. If the water rate is too high, plants will be left dripping with excess pesticide, which can lead to environmental pollution. Good spray application aims to use a water rate that gives a uniform droplet distribution at the desired density. You may need to use more nozzles to maintain water rates with smaller droplets.

Table 3: The approximate droplet density required for adequate chemical control

Product	droplets/cm^2
Insecticides	
Mobile insects	60-100
Systemic	20-30
Contact	50-70
Herbicides	
Pre-emergent	20-30
Post-emergent	30-40
Fungicides	
Systemic	20-30
Contact	50-70
Foliar nutrients	20-30

The importance of droplet size

Knowing the importance of droplet size, droplet density and water volume will help spray operators get the best possible results. When targeting the plant, spray droplets should be distributed uniformly over the entire plant, which includes the underside of the leaves as well as the top of the plant. To achieve this, droplets need to be small enough that they swirl around as they are depositing onto the plant surface.

Large droplets

Large droplets, being heavier, tend to fall straight down and are not usually deflected by air movement. Therefore, their redistribution within the crop foliage is limited. Large droplets are also fewer in number and are more difficult to retain on the leaf surface as they tend to bounce or roll off, cascading down the foliage and onto the ground.

Smaller droplets

Droplet size is often reduced to improve spray coverage. However, droplets that are too small are more likely to drift or evaporate before reaching their target.

Small water based droplets evaporate rapidly in hot conditions. A 50µm droplet will evaporate over 250 times quicker than a 200µm droplet. On a hot day, a 50µm droplet may only travel between 0.1 and 1m before it evaporates.

Efficient spray application aims to achieve good target coverage, while reducing spray drift and any negative impacts it might have on the environment, public health and property.

Selection of nozzle type

Different operating pressures will change the droplet size and water rate of hydraulic nozzles. Therefore, when selecting a nozzle type you need to refer to the manufacturers catalogues. The catalogues give recommendations on appropriate nozzle types and a guide to the water rate and droplet size produced at various pressure settings.

Droppers on a conventional boom help direct the spray into the canopy from multiple angles.

Selection of sprayer type

Hydraulic spray boom

Conventional spray booms with hydraulic nozzles are the most common method of applying chemicals. The best results are achieved when spraying in a light breeze of about 7 km/h. This benefits application by creating turbulence to assist in carrying the droplets into the crop canopy.

A curtain of air directs the spray into the canopy to improve penetration and coverage.

The addition of droppers can improve spray penetration and coverage from this type of boom sprayer. These droppers are short lengths of semi-rigid plastic tubes attached to the boom, with modified nozzles positioned between plants at the lower end to direct spray from a lower angle.

Air assisted boom

In its most common form, this sprayer is a conventional hydraulic spray boom with the addition of a high volume output fan mounted centrally above the boom with an air duct extending the full length of both arms.

The slotted outlet of the air duct produces a curtain of air adjacent to the spray nozzles. This air curtain directs the spray down into the crop canopy, agitating the plants and improving spray coverage on both sides of the leaves. Air assisted booms also have the potential to reduce spray drift and allow the operator to spray in conditions unsuitable for conventional booms.

CDA sprayers

Controlled Droplet Application (CDA) is a method of spray application where 80% of all droplets produced are within a very narrow size range, usually about 100 to 150µm.

A rotating cage, inverted cone or a flat serrated disc produces droplets by means of centrifugal force when liquid is introduced at the centre of the rotating element. Most, but not all, CDA sprayers incorporate air assistance as part of their design. The air stream directs spray down into the plant canopy causing turbulence that assists in achieving better, overall coverage.

Focused research

Horticulture Australia has helped fund a number of projects, which have included improving spray application as a component of the project. The following recommendations have been generated from the results of two of these projects:

Sweet corn

When controlling heliothis with insecticides, at the reproductive stage of sweet corn, it is critical to target the silks. Trials have shown that a boom fitted with short droppers will give the best results. Droppers are fitted with flat fan nozzles that produce a droplet size of 150 to 200µm (BCPC 'Fine' category). A minimum water rate of 300 L/ha is recommended with a ground speed no faster than 10 km/hr.

When operating without droppers you can expect a reduced spray coverage, with up to 65% less chemical reaching the silks. The best nozzle types to use for a standard boom are hollow cones at 250mm spacing with 300 L/ha with a slightly faster ground speed if possible.

A well-optimised, air assisted boom can also give good results. When using these booms in sweet corn, it is best to have a high clearance boom, which is able to clear the top of the plants by at least 300mm. The nozzle setup should be the same as for a standard boom.

Lettuce

When controlling insect pests and disease in lettuce, it is critical to get good spray coverage on both the top and underneath side of leaves. To achieve adequate spray coverage on the underside of the lower leaves, trials have shown a boom fitted with short droppers can increase the spray coverage by threefold. An air assisted boom can also improve spray coverage to the underside of leaves, but care must be taken as the high air velocities can damage plant tissue.

Hollow cone nozzles are still the most recommended hydraulic nozzle for insecticides and fungicides as they can produce more droplets in the fine to very fine category of the BCPC classification table. A minimum water rate of 400 L/ha is recommended when trying to achieve 50-70 droplets/cm^2 for non-systemic chemicals.

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David White and Rod Eamens, 2000, *SMARTtrain Reference Manuals*, NSW Agriculture

Dr Sandra McDougall et al, 2002, *Integrated Pest Management in Lettuce*, NSW Agriculture

Peter Deuter et al, 1999, *Integrated Pest Management in Sweet Corn Milestone 4*: *Pesticide Application Techniques*, QLD Department of Primary Industries

Roger Broadley et al, 2000, *Pesticide Application Manual 3rd edition*, QLD Department of Primary Industries and Fisheries

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Slug control in vegetable crops

Slugs are a major economic pest in most horticultural crops. There are at least eight pest slug species in Australia, all of which have been introduced.

Slugs are primarily pests of vegetable and cereal crops. They feed above and below the soil surface, damaging seeds, shoots and roots. In some crops the main issue is at planting, while in others problems occur during the growing season and/or at harvest.

Deroceras reticulatum (below)

Milax gagetes (above)

Slugs favour heavier soil, surviving summer in cracks and under clods; they do not survive well in fine, light or compacted soils. Slugs are not active during the day and damage is often blamed on poor germination or other pests.

Environmental influences

The environment has a major impact on the life cycle of the slug. Air and soil temperature, wind-speed, humidity and soil moisture content are all correlated with slug activity. Slugs frequent moist shady places and their daytime resting site can be crucial to survival.

Slugs are active throughout the year, causing trouble whenever temperature and moisture conditions are favourable. The temperature range at which slugs are active varies with species.

The grey field slug, *Deroceras reticulatum*, is active at air temperatures of 11-25ºC and soil temperatures of 8-20ºC. Slugs are extremely susceptible to dehydration, but are able to rapidly rehydrate through skin absorption of water. Damp, mild and calm conditions are optimal for slug activity.

Slugs are hermaphrodites and both members of a mating couple can lay eggs. Mating usually takes place in autumn, however some species lay eggs whenever conditions are suitable.

Control methods

Slug management is difficult - often single agent control methods are ineffective and a combination of cultural, chemical and biological methods should be utilised to minimise damage. Unfortunately, soil management practices that increase soil water holding capacity and organic matter also favour slugs. Slug problems are also greatly influenced by crop rotations.

Sampling

The first step in any slug control program should be the use of sampling methods to determine numbers and species present. Sampling will also identify hot spots within paddocks and provide knowledge of slug life cycles.

The Bottom line

- At least 8 introduced slug species are in Australia
- Sampling is the first step in slug control
- A combination of cultural, chemical and biological methods are necessary for slug management
- Timing is vital when using chemical control methods
- Biological control agents are limited and easily killed by insecticides or tillage

Knowing how weather and environmental conditions affect slug activity and biological processes of both slugs and eggs can assist in planning control strategies.

The simplest way to sample slug populations is with refuge traps (shown above). These can be made from materials such as sacking, carpet squares, roof tiles, hardboard and corrugated iron. Layer mash (chicken feed) can be placed under the trap as a food source.

Cultural practices

Effective cultural practices include:

- reducing soil moisture,
- removal of materials/weeds that provide favourable habitats,
- soil cultivation to expose eggs and slugs,
- production of fine seed beds to reduce movement between habitat and crop,
- deeper drilling of seeds,
- selection of suitable cover crops,
- use of trap crops to keep slugs away from crops
- planting before slug populations build up,
- cultivating a weed free strip between crop and headland to prevent migration,
- keeping gully lines clean,
- minimising pesticide use to encourage build-up of predator populations.

Chemical control

Chemical baits can be effective, particularly when used in conjunction with cultural practices. However, timing is critical - baits need to be applied before populations reach damaging levels.

Use of refuge traps and regular monitoring will provide information on fluctuations in slug populations, allowing baits to be laid before slugs become a major problem. Once crop damage is evident it is too late to lay baits.

Bait choice is important. Those available in Australia are either methiocarb, methidathion, metaldehyde or iron based. Small, even sized pellets/granules will give better coverage, increasing the likelihood of slugs finding the baits. Under humid or wet conditions, metaldehyde baits are often less effective, as slugs can rehydrate. Some slug species are naturally tolerant to methiocarb.

Although slower acting, iron chelate baits appear to be more consistent in their effects than methiocarb or metaldehyde baits. They also have low toxicity to domestic pets and wildlife and are non-toxic to beneficial insects and earthworms.

Biological control

Biological control agents are limited. Birds, rats, frogs and lizards feed on slugs. Ducks, chickens and Guinea fowl can be effective in orchards and vineyards. Recent Australian research has shown carabid beetles and native earwigs feed on slugs. However they are easily killed by insecticides targeting insect pests or by tillage at critical times.

Physical barriers

Although not feasible in broadacre cropping, the use of physical barriers may be of assistance in high value crops. Lines of sawdust, ash, lime and copper sulphate are effective barriers, but efficacy is reduced on wetting. Copper bands or sprays, and aluminium oxide sandpaper are also effective barriers.

Further Information

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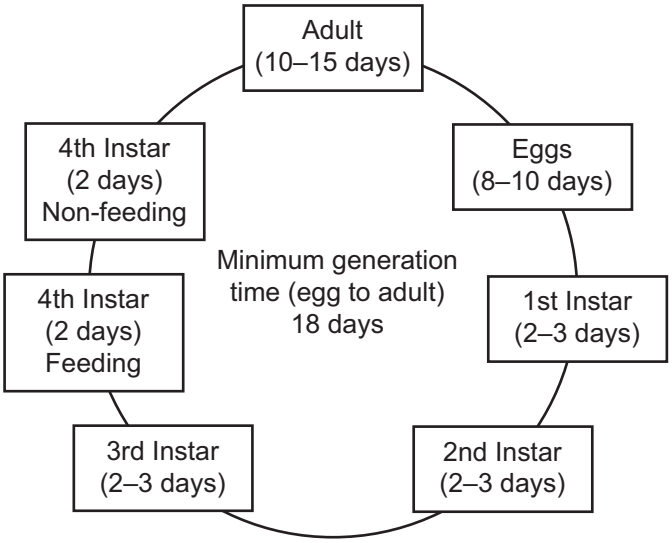
Silverleaf Whitefly Management

Silverleaf Whitefly (SLW) (*Bemisia tabaci biotype B*) is a major worldwide pest of cotton, vegetables and soybeans. It arrived in Australia in 1994 and is now causing severe problems in Queensland, northern New South Wales and parts of Western Australia. It is still spreading.

Silverleaf Whitefly adult and nymphs.

SLW has a similar life cycle to that of the common greenhouse whitefly (GHW) but favours warmer and drier environments, has the capacity to breed more quickly on a wider range of hosts and can develop resistance to insecticides rapidly. In warmer, more humid areas of Australia, SLW survives on native vegetation and roadside weeds, while in cooler areas it is more likely to be restricted to greenhouses.

Due to its ability to develop resistance to insecticides quickly, chemical control of SLW can no longer be taken for granted. Pest management overseas and experience from Australia has shown that effective management of SLW depends on the use of multiple management strategies.



SLW management strategies

There are a number of useful strategies for managing SLW, including cleaning up your property, adopting a crop-free summer break and using yellow sticky traps for early warning.

Clean up your property

Get rid of broadleaf weeds and the remnants of harvested crops. If you are serious about controlling SLW you cannot tolerate the presence of alternate hosts. Weedy areas and crop residues are often neglected and provide a perfect area in which SLW can breed.

The Bottom Line

- **Silverleaf Whitefly (SLW) favours warmer and drier environments and has the capacity to breed more quickly**
- **SLW can develop resistance to insecticides quickly, so a reliance on chemical control alone is unlikely to succeed in the long term**
- **To help manage SLW, clear weeds and crop residues from your property, adopt a crop-free summer break and use yellow sticky traps for early warning**

The weeds to watch out for in particular are milkweeds (*Euphorbia*), sow thistle, bell or cow vine, jute, bladder-ketmia, wild sunflower and burr-gerkin. Grasses are not hosts for SLW and, if managed carefully and kept short, can be used to exclude broad-leaved weeds. You will find that not only do SLW numbers fall with good weed management, but so do a number of other pests such as aphids and thrips.

Milkweed (Euphorbia).

Adopt a crop-free summer break

Adopting a susceptible crop-free summer break (early December to early February) will prevent the continuous availability of host plants for SLW. If adopted on a large enough scale (preferably whole districts), such a gap in production reduces SLW numbers and lowers the risk of widespread insecticide resistance development.

Ensure that seedlings are free of the pest

Seedlings are a major means for spreading SLW into new plantings. Young plants are generally more susceptible to damage and so early infestations need to be avoided. Clean seedlings should be your first line of defence against this damaging pest and others such as western flower thrips. Inspect seedlings carefully on arrival, look carefully under the top leaves of a minimum of 4–5 plants per tray. If more than 25% of those inspected have one large nymph or 2–3 adults then treat with insecticide.

There are no resistant cultivars available but some are less susceptible to SLW infestation. Check with your seed or seedling supplier for information on more tolerant varieties.

Prevent movement from older crops

Movement of adults from older crops is a primary source of infestation of young crops. Destruction of heavily infested crops often causes mass migration of adults into nearby crops. You should aim to control adults in crop remnants before destruction. Application of appropriate pyrethroid insecticides, either alone or in combination with an organophosphate insecticide, should give good control for up to three days. This will allow time for the residues to be thoroughly ploughed into the ground.

A pumpkin crop with Silverleaf Whitefly damage. Picture supplied by Paul De Barro, CSIRO Entomology, QLD.

Use yellow sticky traps

Yellow sticky traps can be used to detect and monitor whitefly activity, but should not be used to make spray application decisions. Around 3–5 traps should be placed in a block of 2–3ha, level with the tops of the plants since SLW are most attracted to young foliage.

Traps should be changed each week and the total flies counted. However, if numbers on the trap are very high, randomly select ten 1cm^2 areas, then multiply the count by 15. Whitefly numbers are recorded as the number of adults per trap per week. In young crops the warning threshold is 10 adults per trap per week.

Table 1. Guide to locating whitefly nymphs and adults within a plant.

Crops	Location of pest stage		
	Adults	Small nymphs	Large nymphs
Zucchini (young crop)	2–4 leaves FYL	4–6 leaves FYL	8–10 leaves FYL
Watermelon (mature)	2–4 leaves FYL	9–13 leaves FYL	17–24 leaves FYL
Tomato (determinate)	2–3 leaves FYL	2–3 leaves FYL	4–5 leaves FYL
Tomato (trellis)	2–5 leaves FYL	7–10 leaves FYL	11–14 leaves FYL

FYL - From Youngest Leaf.

Field sampling

SLW adults and eggs are mostly found on the underside of young leaves whilst larger nymphs are most obvious on older leaves. A 10 X hand lens is used when looking for eggs or small nymphs. The presence of large numbers of red-eyed nymphs indicates that adult numbers have the potential to increase rapidly within the next 2–3 days.

Adults should be sampled in the early morning (6–8am) and the edges of the field are usually infested first if the adults are moving from infested areas. Inspect at least 30–40 plants per 3–4ha block, walking through the block in a zig-zag or U-shaped pattern, randomly selecting plants every 8–10m. Also look for visual symptoms such as leaf silvering on zucchini, pumpkin and squash. Check each block at least twice weekly during the warmer months (key period is from August to December). Less frequent checking should be adequate at other times.

When to use insecticides

When whitefly numbers reach a point where insecticides must be used in order to avoid significant damage this is known as the 'action threshold'.

Close-up of Silverleaf Whitefly nymphs.

The secret to effective SLW management is to apply controls immediately when numbers reach this level. Monitor, act promptly and check on effectiveness. Thresholds will also help you decide the type of insecticide to use and the best timing.

In sensitive crops such as cucurbits, SLW populations should not be allowed to exceed three adults per leaf from seedling to fruit initiation. If 50% or more of leaves have three or more adults then apply an insecticide to prevent development of unmanageable numbers by harvest.

Table 2 (over the page) shows thresholds developed for a range of crops.

Insecticide choices

It is a legal requirement for you to check the registration status of any insecticide before use.

Overseas populations of SLW have developed resistance to nearly all available chemicals. Fully resistant whiteflies will be extremely difficult to manage. Few of the currently available insecticides provide excellent control, so a reliance on insecticides alone for control is unlikely to succeed.

Because SLW spend much of their time on the underside of leaves, correct spray equipment selection and use is critical to the success of many foliar insecticides. So-called 'soft insecticides' such as petroleum oils and soap formulations can be effective if SLW numbers are low.

Their use can help reduce the likelihood of insecticide resistance but take care as they can cause phyto toxicity in some crops in some situations.

Table 2. Action thresholds for Silverleaf Whitefly nymphs.

Crops	Threshold based on total nymph counts	Threshold based on large nymphs
Tomato (indeterminate gourmet)	5–8 nymphs/leaflet	2–3 nymphs/leaflet
Tomato (determinate round)	8–10 nymphs/leaflet	3–4 nymphs/leaflet
Zucchini (young crop)	3–4 nymphs/leaf	1 nymph/leaf
Zucchini (mature crop)	6–8 nymphs/leaf	2–3 nymphs/leaf

Synthetic pyrethroid insecticides applied as foliar sprays are used to control for SLW in vegetables. However, they are contact insecticides so small droplet sizes, high volumes and good crop penetration are necessary for good coverage of the underside of leaves, especially in older crops. Organophosphate insecticides give poor control and can lead to rapid increases in SLW numbers, probably due to suppression of natural enemies. However, tank mixtures of pyrethroid and organophosphate insecticides can be useful in some situations.

The neo-nicotinoid insecticide 'Confidor' can be used to control whitefly in some vegetable crops. It has systemic action, if applied around the root zone of the crops, and is mainly effective against feeding adults and nymphs. It has a short life in sunlight, so should be used quickly after mixing. Don't use it more frequently than every 3–4 weeks and be aware that resistance seems to be developing.

Resistance management

The keys to resistance management are:

- Identify your pests before spraying. Do not assume SLW until it has been positively identified.
- Minimise chemical use. Spray only infested areas and only as needed. Routine 'calendar' sprays applied as a precaution against infestation are a recipe for disaster.
- Use sticky cards and scouting to locate the population before it spreads.
- Spray an infestation thoroughly, then stop and monitor to assess the impact.
- If possible, rotate to a new chemical group every month to preserve the effectiveness of each chemical used.
- Apply chemicals only at the recommended rate.
- Maximise spray coverage. Calibrate sprayers, use the finest droplet size possible and make sure the under-surface of all leaves in the target crop is thoroughly covered. Hand pump knapsack type sprayers are totally inadequate. Poor spray coverage will necessitate repeat spraying and speed the development of resistance.

Biological control

In late 2004, CSIRO Entomology was granted permission by the Australian Government to release a very tiny, stingless parasitic wasp. *Eretmocerus hayati*, originally from Pakistan, is being used successfully against SLW in the Lower Rio Grande in south Texas (USA). With a similar climate to coastal and central highland areas of Queensland, this area was an ideal source for the wasp. Stringent testing in quarantine in Brisbane showed it would attack only SLW once released in Australia.

Further reading

The Nursery Papers
Issue no 1997/009, ISSN:1326-1495
www2.dpi.qld.gov.au/horticultureresearch/18362.html

Acknowledgement

Compiled from information supplied by Siva Subramaniam, QLD DPIF and Paul De Barro, CSIRO Entomology, QLD.

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Control of Sclerotinia diseases

Sclerotinia diseases cause major loss in many horticultural crops (e.g. lettuce, beans, carrots, brassicas and peas). Intense cropping and the use of Sclerotinia susceptible crops in rotations have led to a build up of Sclerotinia in soil.

There are new control options that have the potential to contribute to, when integrated with other control measures, improved and sustainable control of Sclerotinia lettuce drop, and other diseases caused by *S. minor*. These options include:

- non-chemical controls (e.g. biological control agents, biofumigant rotation crops)
- cultural strategies (e.g. rotation crops tolerant to Sclerotinia infection)
- procymidone, while an effective fungicide, has recently been withdrawn from use. Boscalid (Filan™) is a suitable alternative

Lettuce drop caused by Sclerotinia.

There are two species of Sclerotinia that cause Lettuce drop.

- *S. minor* usually infects through mycelium that comes in contact with lower leaves and stems. On rare occassions it also produces aerial spores.
- *S. sclerotiorum* usually infects through aerial spores landing on flowers and senescent or damaged tissues. The fungus spreads from these infected flowers or tissues to healthy leaves or stems. Sclerotia of *S. Sclerotiorum* can also produce mycelium, which can directly infect lower leaves and stems. In some places the pathogen is more aggressive under hot and humid conditions (eg Queensland).

Wet conditions favour disease development of both species and they can both cause disease on brassica crops (watery soft rot). Both species produce resting bodies (sclerotia) on infected tissue, which can survive in soil for up to 5 years (*S. minor* size up to 3 mm, *S. sclerotiorum* 5 - 15 mm).

S. sclerotiorum requires humid conditions to develop the fruiting bodies (apothecia) that produce aerial spores. *S. sclerotiorum* also infects carrots (soft rot), green and dry beans (white mold) and many other horticultural crops.

The Bottom line

- **Resting Sclerotinia bodies can survive for 5 years or more.**
- **Biofumigant green manure crops and crops more tolerant to Sclerotinia infection should be used to reduce and prevent build-up of Sclerotinia.**
- **The fungicide boscalid is a suitable replacement for procymidone, recently withdrawn from use.**
- **Better application, timing of fungicide sprays and the right volume of water is essential for effective disease control.**

Fungicides are the most common means of controlling Sclerotinia diseases. However, there is increasing pressure to produce vegetables with minimum to zero pesticide input and there are few fungicides currently registered for control of *S. minor* and *S. sclerotiorum* in Australia.

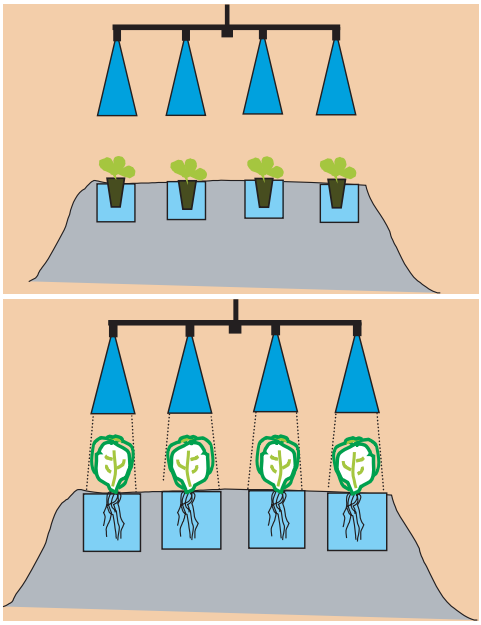
Note: Information on sclerotia numbers can be used as a general guide to predict the level of disease pressure in a given field and select the most appropriate strategy for disease control.

Action: Keep records of history of Sclerotinia disease and crops grown in each field. Use the records to help you select the most appropriate method of disease control.

The integration of non-chemical controls (e.g. biocontrol agents) and cultural strategies (e.g. biofumigation crops, rotation crops, soil amendments), in addition to fungicide applications, to control Sclerotinia diseases is essential to the sustainability of the horticultural industries.

Fungicides

The efficacy of registered fungicides is greatly affected by disease pressure, weather conditions, method of application, overuse and crop canopy size. Research in Victoria and Tasmania tested a range of fungicides for Sclerotinia control and found that boscalid (Filan ™) was an effective replacement for procymidone.



Strategic application provides a more reliable pattern and should be directed at the root zone and under leaves.

In fields with high incidence of Sclerotinia, two to three applications of registered fungicides at transplanting and repeated at a two week interval can be effective in controlling lettuce drop caused by *S. minor*. In low disease pressure sites, two applications of fungicide can provide excellent disease control.

Fungicides must be directed at the base of young plants and repeated before plants become too large. Irrigation after spraying can help to distribute the fungicide into soil and around the base of plants. For *S. sclerotiorum* (airborne spores), fungicides should be applied preventatively at flowering, ensuring good coverage of all flowers.

Biological control agents

Biocontrol agents have been proposed as potential alternatives to fungicides. Biocontrols are fungi or bacteria, commercially formulated, which can destroy *S. minor* sclerotia.

These agents use mechanisms such as competition for nutrients and space, production of antimicrobial chemicals (antibiosis) and parasite sclerotia in soil (specialised sclerotial mycoparasite) to reduce their viability.

To be effective, biocontrol agents must be applied strategically to colonise the soil, or the root zone, quickly and at high levels. They should be applied so as to directly parasitise sclerotia in soil to reduce viability (incorporate into soil prior to planting) and/or to colonise in the plant's root region (apply into seedling mixes or seedling plugs prior to field transplanting) to protect from mycelium of sclerotia.

HAL project VG00048 focused on improving the formulation, shelf life and application of biocontrol agents (Table 1). Dry powder preparations of biocontrol agents can be incorporated into seedling mixes at sowing. Liquid preparations can also be applied to mixes and as a drench to the seedling transplants.

Trials showed commercial seedling mixes with a high percentage of composted pine bark were better substrates to incorporate *Trichoderma* species into because they had less naturally occurring non-pathogenic microbes, and therefore more space and food sources for *Trichoderma* biocontrol agents to grow.

Tabel 1: *Biocontrol agents proven to be effective against sclerotia of Sclerotinia minor and/or suppressing infection in root zone of lettuce plants in overseas trials.*

Biological control agent (isolate)	Mode of action[A]
Coniothyrium minitans (Contans™)[B]	Specialised mycoparasite of sclerotia of *S. minor*
Coniothyrium minitans (A69)[C]	Good competition for nutrients and mycoparasite
Trichoderma hamatum (6Sr4)[C]	Good competition for nutrients and antibiosis

[A] As reported by manufacturers.
[B] Prophyta, Germany.
[C] Lincoln University and Agrimm Technologies Ltd, New Zealand.

Biocontrol agents can also be incorporated into soil, but this method is only effective if they are delivered into the region of soil where the roots grow. For example, a maize-perlite method of inoculum incorporation has delivered good levels of the biocontrol agents (*T. hamatum 6Sr4*) to the root region of lettuce plants.

An added effect of biocontrol agents, and some other microbes sold as soil conditioners, is they may promote better growth of seedlings. This has been observed on seedling roots in nurseries where there were high levels of biocontrol agent colonisation. For example, high levels of Trichoderma 6Sr4 and Trich-A-Soil™ promoted better lettuce seedling root growth, and high levels of *B. subtilis GB03* (Companion™) promoted better lettuce seedling growth.

Biological control agents must be registered with the Australian Pesticides and Veterinary Medicines Authority (APVMA) before they can be used specifically for the control of Sclerotinia diseases in Australia.

Note: Researchers are continually developing and testing new biocontrol products for use in horticultural crops as soil conditioners, growth promoters and for improved management of soil-borne diseases. For updates on new products contact your local pesticide supplier, agronomist or State Agricultural Department.

Biofumigants

Another promising non-chemical measure for Sclerotinia control is the use of inherent properties of some plants for 'disinfecting' soil or suppressing infection. For example, some Brassica crops (e.g. mustard) release volatile compounds (biofumigants) that are toxic to some soil pathogens.

Green manure Brassica crops that produce high plant biomass and high concentrations of biofumigant compounds offer advantages over low biomass manure crops and non-manure rotation crops for the control of soil-borne diseases.

A green manure crop is a crop grown in a crop rotation system for incorporation into soil to improve soil conditions, such as water infiltration and nutrients and organic matter levels. Information on different types of green manure crops (legumes, brassicas, grasses) suitable for rotations is available from Government agencies and agronomists.

Research in Tasmania showed BQ-Mulch™ (*Brassica napus*) and Fumus™ (*Brassica juncea*) crops, when used in rotation with lettuce, reduced Sclerotinia lettuce drop incidence by 89% and 46%, respectively. BQ-Mulch™ produces high levels of biofumigants (isothiocyanates or ITCs) in the roots and appears to be more effective in suppressing Sclerotinia lettuce drop infection than Fumus™ (mustard), which produced high levels of ITCs in its foliage.

Other organic soil amendments can produce similar volatile compounds when incorporated into soil. For example, 'mustard meal' and 'neem-cake' are two commercially available soil amendments with reported biofumigant properties.

Cultural and soil amendment strategies

Management practices such as crop rotations and soil amendments are becoming important tools for managing soil-borne diseases, including Sclerotinia. Rotations with crops less susceptible to Sclerotinia can prevent the build up of inoculum in soil.

Where possible, practice 3-4 year crop rotations to prevent the build up of Sclerotinia inoculum in soil. The use of Sclerotinia non-hosts, such as small grains and corn, and green manure crops can be useful in reducing the build up of inoculum and the incidence of Sclerotinia diseases in high disease sites.

Another example of the damage caused by Sclerotinia.

Incorporating a manure crop.

Some soil amendments with high content of nitrogen have shown potential to reduce inoculum carry over of some soil-borne pathogens.

Sclerotinia minor has a wide host range, which restricts the choice of a suitable rotation crop. In Tasmania, research showed that *S. minor* infection is closely correlated with plant architecture.

Adoption of these practices may be limited by cropping practices, availability of suitable rotation crops and soil amendments, and loss of income from not growing a commercial crop.

Summary and future research

Project VG00048 endeavoured to provide lettuce and other vegetable growers with information on the development of non-chemical control methods (biocontrol agents, biofumigant green manure crops), cultural and soil amendment strategies, and improved application of fungicide sprays for better management of Sclerotinia diseases in Australia.

The project found that control of Sclerotinia diseases can be improved by:

- using green manure Brassica crops in crop rotations
- selecting rotation crops more tolerant to Sclerotinia infection, especially in high Sclerotinia pressure sites
- the fungicide boscalid is a suitable replacement for procymidone

This project has identified new methods to produce, formulate and deliver biological control agents into cropping systems. The results thus far indicate some biocontrol agents have the potential to contribute to improved and sustainable disease control, only when integrated with other control measures. Thus, biocontrol agents should be considered an important component of an integrated control program for Sclerotinia diseases.

More information is required on the compatibility of biocontrol agents with farm practices (e.g. fertilisers, pesticides) and their survival in Australian soils growing vegetables under a variety of rotational cropping systems.

The use of crop rotations with Sclerotinia tolerant and non-host crops can prevent the build of inoculum in soils.

Soil amendment strategies such as the use of pre-planting applications of organic and nitrogenous soil amendment materials have the potential for making soil conditions suppressive to sclerotia and disease development. Soil amendment strategies investigated by this project require further development to optimise their use for Sclerotinia control. The effectiveness of other chemical and non-chemical treatments available for inoculum reduction should also be investigated.

Further Information

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Irrigating Vegetable Crops with Recycled Water

Reclamation and reuse of a variety of treated wastewaters on food crops has been practiced for more than 50 years around the world.

Any reuse scheme developed now is by no means a 'world first'. For example, recycled water has already been used for many years in the United States, Israel and Australia for irrigating a range of food and fodder crops.

Recycled water quality

Most Australian states have guidelines for irrigation with recycled water; there are also national guidelines.

These guidelines have been developed from extensive research, and risk management principles from Australia and around the world.

Users and consumers can be confident that the quality of produce grown with recycled water is as high as produce grown from any other source.

To ensure recycled water is fit for purpose, scheme operators, managers and practitioners should consult state and national guidelines for detailed information regarding the appropriate water qualities required for a particular reuse scheme.

Pipes carrying recycled water are obvious from their lilac colour

Benefits

Recycled water irrigation schemes offer substantial environmental benefits:

- Reduction of nutrient loading into sensitive aquatic environments
- Replacement of drinking water sources, freeing up our limited water resources for urban uses or environmental flow

There are also potential benefits to agricultural enterprises:

- Guaranteed water supply and quality
- Recycling of valuable nutrients
- Security for investment where water is scarce

The Bottom line

- Recycled water is used around the world for vegetable production.
- Recycled water schemes must be approved by health and environment related departments in your state.
- Recycled water irrigation schemes offer substantial environmental and agriculture benefits to the community.

Recycled water can be produced through different types and degrees of treatment, to supply a defined quality of recycled water.

There is now technology to produce safe potable (i.e. drinking) water, if there is ever a demand. In fact, recycled water for potable use is currently being undertaken in some countries.

Can you grow vegetables?

In Australia, Class A is the highest rating for recycled water used for irrigation and is equal to the most stringent guidelines worldwide. Australian standards for Class A recycled water exceed those recommend by the World Health Organisation for irrigation of food crops[1].

Fresh produce crops can be grown with Class A recycled water

State Departments of Human Service and Environmental Protection Authorities (or the equivalent) set these strict guidelines to ensure the safety of growers irrigating with recycled water and the produce grown with it. Every reuse scheme requires the approval of these departments and must show that appropriate safeguards are in place (before the reuse scheme is commissioned). This guarantees a particular water quality to growers, which is fit for purpose.

These extensive safeguards ensure the microbiological and chemical safety of recycled water, and the quality of food and salad crops grown with it.

Guidelines for recycled water

There are extensive guidelines for use of recycled water in most states of Australia. Contact your Environmental Protection Agency for a copy (details on back page).

Food quality and safety

There should be no difference in the quality of food irrigated with recycled water. There have been hundreds of scientific research projects and trials completed around the word to ensure it is safe.

For example, a ten-year project in Monterey, California has been the subject of a landmark study on crop irrigation with recycled water[2].

The Monterey study investigated and compared crops grown with recycled water (Class A equivalent) and those irrigated with water from other sources.

In terms of health and nutrition, the findings confirmed that food produced with high quality recycled water is the same as any other produce.

The research found no significant difference between the two types of produce in terms of heavy metals or the presence of bacteria.

The research also examined a number of other issues. In terms of crop yields, few differences were recorded, although higher yields from celery and broccoli crops were noted when they were irrigated with recycled water.

The quality and shelf life of produce was also put under the microscope. It was found to be as good, and in some cases, superior to, produce grown with the bore water used in the area.

There are no restrictions on irrigation methods or the types of crops that can be grown when using Class A recycled water. Restrictions only apply when using a lower class of recycled water such as Class B, C or D.

Potential issues

All crops grown with recycled water must adhere to the strict guidelines mentioned above. These

cover classes of water, types of crops and irrigation methods used, and are designed to ensure all produce is safe for consumption. If guidelines are not followed, despite inbuilt safety barriers, health concerns may arise and should be directed to your State Environment Protection Agency (or equivalent).

Salinity

Recycled water often has higher salinity levels than surface or groundwater commonly used for irrigation, although this is site specific. The important point to remember is that the salinity of recycled water must still be matched with the:

- crop to be grown
- soil to be irrigated
- leaching required

Salinity of irrigation water is generally measured by electrical conductivity (EC), which indicates the total dissolved salt content (TDS).

Saline soil

Plant tolerance to water salinity varies considerably between species and can range from sensitive crops (EC < 650 µS/cm) to tolerant crops (EC ranges from 2900 to 5900 µS/cm). Note: 1 dS/m = 1000 µS/cm = 640 mg/L of TDS (TDS value can vary from 550 to 950 depending on water chemistry)[3].

Sodicity

Sodicity refers to the amount of sodium in the soil or water. For soil, this is measured as the Exchangeable Sodium Percentage (ESP), which is the proportion of sodium as a percentage of all the exchange cations (e.g.

Sodic soil *Source: Pichu Rengasamy*

calcium, magnesium, potassium, etc) adsorbed on the soil.

The sodicity of water is measured as the Sodium Absorption Ratio (SAR). Put simply, the SAR is the amount of sodium present in a solution, relative to the amounts of calcium and magnesium.

SAR can be used for measuring soil sodicity by measuring the SAR in soils by mixing (extracting) water with soil and measuring the concentration of calcium, magnesium and sodium in the extract.

Use of irrigation water with a high SAR can lead to soil structural and drainage problems.

Boron

Higher concentrations of boron are often found in recycled water compared with bore and surface waters (site specific). Sensitivity of plants to boron varies significantly between species and baseline soil concentrations of boron. Both need to be considered before irrigating with the recycled water.

Heavy metals

Heavy metals concentrations in recycled water are usually low and not a significant factor in preventing its use in horticulture. However, it is still important to check that no guideline values are exceeded[3].

Nutrients

Significant amounts of nutrients can be applied when irrigating with recycled water. The amount applied depends on the source of the water being recycled, treatment process (e.g. if nitrogen and phosphorus are removed) and the amount of recycled water irrigated per crop. Simple loading calculations can be used to estimate the nutrients applied in each irrigation.

Recycled water vs reclaimed water

These terms are often used interchangeably according to the terminology that different states have adopted.

- **Recycled water** – is a generic term for water that is suitable for a controlled use as a result of treatment of waste. This use would otherwise not occur.
- **Reclaimed water** – is a more specific term for water going to waste that is reclaimed to be used in a different industry (e.g. agricultural irrigation of treated urban sewage effluent which would normally go out to sea).

Recycled water storage

Acknowledgements

Coordinator Recycled Water Development Horticulture (www.recycledwater.com.au)
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dstevens@arris.com.au

State contacts for more information on recycled/reclaimed water and state guidelines

New South Wales
NSW Department of Environment and Conservation
ph (02) 9391 9000
www.epa.nsw.gov.au

Queensland
Department of Primary Industries and Fisheries
ph (07) 3404 6999 or 13 25 23 (within QLD)
www.dpi.qld.gov.au

South Australia
EPA South Australia
ph (08) 82042097
www.deh.sa.gov.au/epa/contact.html

Tasmania
Department of Primary Industries, Water and Environment
ph (03) 6233 6518
www.dpiwe.tas.gov.au

Victoria
EPA Victoria
ph (03) 9695 2722
www.epa.vic.gov.au

Western Australia
Department of Environment
ph (08) 9278 0427
www.wrc.wa.gov.au

Northern Territory
Project Manager Water Recycling
ph (08) 89517218

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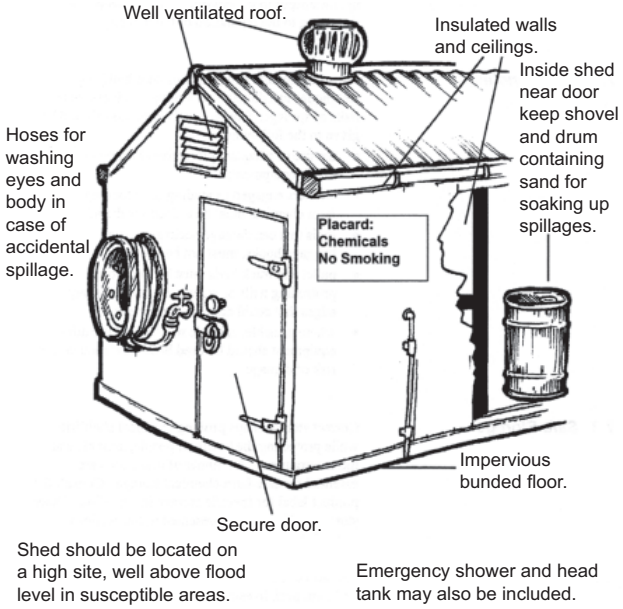
Pesticide storage requirements

Correct pesticide storage is important as it prolongs chemical shelf life while protecting the health of people, animals and the environment.

Currently, pesticide storage requirements differ across Australia and it is the responsibility of individual growers to determine how to meet the legislative requirements in their State or Territory.

It is expected that 'The National Standard for the Storage and Handling of Workplace Dangerous Goods' and the 'National Code of Practice for the Storage and Handling of Dangerous Goods' will form the basis of a uniform legislative framework for the storage and handling of dangerous goods. In the meantime this VEGEnote provides general information.



Storage facility diagram.

A number of conditions are essential for safe storage however, product labels should always be referred to for specific storage information.

The following can be used as a checklist when establishing a pesticide storage facility:

- A fireproof construction with sealed cement bunded floor is the best.
- Use metal shelving: it will not absorb spills and is easier to clean than other surfaces.
- Maintain a well ventilated facility, relatively free from temperature extremes, which can cause chemical deterioration: check labels for guidance.
- Place warning signs on walls, doors and windows to warn of hazardous chemicals. Check legal requirements for signage ('No Smoking' signs should also be displayed).
- Store products in a cool, dry place out of direct sunlight.
- Keep soap and water close to the facility.
- Store products away from food, feeds, veterinary supplies, seeds and protective equipment: to prevent contamination and reduce the likelihood of accidental human or animal exposure.
- Approved chemical fire extinguishers, first aid equipment and emergency telephone numbers should be readily available.

The Bottom Line

- **Correct pesticide storage can prolong shelf life.**
- **Seek advice/assistance when establishing a pesticide storage facility.**
- **Consult pesticide labels for specific product information.**
- **Pesticide storage is currently the responsibility of the individual grower.**

- Clean safety equipment, in sealed plastic bags should be readily accessible (not inside the facility).
- Up to date storage records should be readily accessible in an emergency (not inside the facility).
- NEVER use drink/food containers, maintain original containers: poisoning could result.

A bad example fo pesticide storage.

Licencing

A licence is not necessarily required for the storage of pesticides. However, some States/ Territories require licencing and/or specific placarding if pesticides are above a certain limit.

Establishing a storage facility

Storage areas should be located where environmental damage is unlikely. Soil and land surface characteristics should be considered to prevent contamination of surface or groundwater by drainage, run-off or leaching.

Wind direction should also be considered and in certain situations bunding may be warranted, i.e. a raised lip to contain liquid. For outdoor storage, a fence should restrict entry. Keep an inventory of all products in storage and mark each container with a purchase date. A label indicating shelf life allows you to know when products are no longer useable. If there are doubts, two years is a reasonable shelf life. Although, many products will remain safe for a number of years, call the retailer or manufacturer for further information.

Excessive clumping, poor suspension, layering or discolouration can indicate deterioration. However, deterioration from age or poor storage may only be apparent after application and poor pest control and/or damage to the treated area.

There are other rules when storing chemicals. Never lend or give away any product in unmarked or unlabelled containers.

Close containers securely as dry formulations tend to cake when they are wet or subjected to high humidity.

Store products packaged in glass bottles in cool locations on lower shelves. Too much heat can cause containers to break or explode. Containers should not be put where they could be knocked off shelving.

Containers of liquids should be stored below powders so any leaks do not affect the powder products.

Store chemicals in their separate chemical groups e.g. insecticides away from herbicides. Some animal health products like vaccines will need to be refrigerated.

A clean, secure storage cupboard with clear placading.

Acknowledgements

ChemCert
www.chemcert.com.au

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Pesticide resistance management

Insecticide resistance is a problem of modern agriculture. Since the 1950s and the introduction of synthetic organic insecticides, insect resistance to insecticides has required more frequent applications, higher doses and the substitution of newer, more expensive compounds.

While chemical insecticides remain the mainstay method of pest control (and they will continue to into the foreseeable future), resistance will continue to threaten sustainable agriculture.

Insecticide resistance is an evolutionary phenomenon caused by a genetic change. It results directly from insecticide use and its evolutionary selection for resistance. Management requires the slowing and preferably stopping of resistance. Resistance management currently aims to reduce the resistant individual's fitness when insecticide is applied or reduce the total amount of selection pressure applied.

Effective resistance management is complex, requiring the integration of many disciplines including pest ecology, farming systems and crop/pest phenology, bioassay, statistics, chemistry, application technology, formulation technology, biochemistry and most recently molecular biology. For this reason, resistance management is often best tackled by a team. The amalgamation of the various disciplines is essential to understand the many aspects of the evolutionary process and to implement successful resistance management.

With the progressive introduction of more stringent government regulations worldwide, insecticide development costs have increased exponentially and chemical development has slowed.

Tanya James, Technical Officer Scientific, prepares to test thrips for insecticide resistance with the aid of a Potter precision spray tower.

It was clear by the 1960s that there would be a time when there would be no chemicals left to control specific pests without documented resistance. This occurred in Australian horticulture for the two-spotted mite in the late 1980s, western flower thrips in the early 1990s and melon (cotton aphid) in the late 1990s.

The Bottom Line

- **Resistance management is a National, across comodity issue.**
- **Synergists can help in the fight against resistance.**
- **Resistance management is best tackled by a team.**
- **Monitoring is a vital element of any resistance management program.**
- **Resistance management programs evolve over time.**

Williams Pears were made uneconomic when cyhexatin resistance was first dected in twospotted mite and replacement chemistry was still being developed.

Resistance in these three major agricultural pests has caused whole cropping systems to be abandoned. The sustainability of modern agriculture is now intricately linked to effective resistance management.

The rapid development of insecticide resistance to various pesticides after 1950 stimulated an interest in the genetic basis of resistance. Some consider that understanding the genetics of resistant mite populations will allow the development of improved integrated controls.

Studies of the genetic basis of resistance in insects and mites are often complicated by their method of reproduction. For instance, the major agricultural pests, two-spotted mite and western flower thrips, reproduce through virgin-birth (males are not needed for reproduction), which may favour the rapid development of resistance.

In this method of reproduction virgin females produce eggs that develop into males, while mated females deposit a mixture of eggs that develop into males and females. Male offspring always possess the genotype of the mother.
The degree of fertilisation or non-fertilisation determines the sex ratio of the offspring.

For managing resistance, it is important to know how dominant or recessive the resistance is, as well as the number of genes involved.

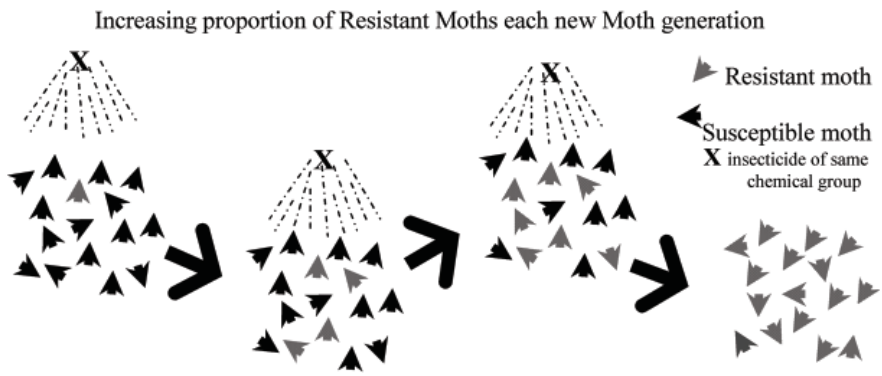
A completely recessive resistance allele will increase in a population at a much slower rate than the dominant allele.

It has long been considered that resistant genotypes must be at some fitness disadvantage, however small.
In the absence of the test pesticide or resistant alleles this would be very common prior to selection. The relative fitness of each genotype is environment dependent.

In the presence of pesticide the resistant genotype has a selective advantage over the susceptible. Conversely, newly evolved resistant strains reportedly show disadvantages in the absence of selection.
If pesticide use continues until resistance is widespread, it is probable that resistant genotypes, with high fitness, will evolve making reversion unlikely when pesticide use is discontinued.

Most fitness studies compare the resistant genotype with the susceptible genotype. However, it is more critical to know if differences in fitness exist. This is because heterozygotes will be the most common carriers of resistance during the early stages of its development.

Arthropods have three basic resistance mechanisms: decreased cuticular penetration, increased metabolic detoxification, and target site insensitivity. Decreased cuticular penetration usually confers resistance



Insecticide resistance develops in target insects when a larva carrying a resistance mutation survives the application of a particular insecticide and subsequently breeds as a resistant insect. If a large proportion of the breeding population is then exposed to an insecticide of the same group, then selection for the resistance mutation will increase and the population of resistant insects will increase with time.

Source: McDougall, Sandra (2002) Integrated Pest Management in Lettuce: Information Guide.

levels less than three times. However, it is to a wide range of compounds and probably only delays the onset of symptoms.

Enzymatic detoxification is achieved by mono-oxygenases, hydrolases, glutathione-S-transferases and DDTases. Target site insensitivity reduces the amount of toxin reaching the vulnerable target.

Target site insensitivity is common in pyrethroid and organophosphorus pesticide resistance. Organophosphate insensitivity involves alterations of acetylcholinesterases, leading to decreased sensitivity to acetylcholinesterase inhibitors. Another mechanism of organophosphorus insecticide resistance is increased metabolism of insecticides, which can often be blocked by adding synergists. Synergists are compounds that enhance the toxicity of a pesticide, although they are relatively non-toxic.

Jeanette Rophail, Senior Technical Officer, scores a resistance test under a stereo microscope.

Synergists can be useful when comparing susceptible and resistant strains. By testing the response to the test chemical with or without synergist, it may be possible to narrow down which metabolic pathway is involved in the resistance. Synergism data can then be confirmed with biochemical assays.

This is essential when selecting alternative chemicals. For example, as pyrethroids are often detoxified by mono-oxygenases, a pyrethroid would not be selected as an alternative chemical if the established resistance mechanism involved mono-oxygenases. Adding the appropriate synergist to the particular pesticide may render the resistance mechanism ineffective.

Rick Roush defines resistance management as “the use of methods that extend the number of generations that a given pest population can be controlled economically by a pesticide”. An earlier management strategy proposed by Georghiou was based on insecticide use, and divided management into three use categories:

1. Moderation (dosage to give less than 100% mortality of susceptibles);
2. Saturation (overwhelm the resistance mechanism with high doses or synergists);
3. Multiple attack (mixing or alternating pesticides).

Later strategies, such proposed by Roush, consider resistance management from a genetics perspective and consider underlying genetic similarities in pesticide use, rather than how pesticides are employed (operational factors). They propose ten management strategies to either reduce the fitness of resistant individuals or reduce total selection pressure:

1. Increase insecticide dose to kill heterozygotes or resistant homozygotes;
2. Use compounds that confer lower levels of resistance;
3. Treat the most vulnerable life stage of the pest;
4. Use synergists to suppress detoxification mechanisms;
5. Mix pesticides with differing modes of action and metabolism;
6. Decrease concentration of insecticide to ensure some of the susceptible individuals exposed to the pesticide survive;

7. Reduce the number of pesticide applications;
8. Use pesticides with short residual activity and avoid slow release formulations;
9. Use spot treatments;
10. Rotate pesticides so not all generations are exposed to the same chemical.

The implementation of such strategies can require very detailed information to be effective. The whole strategy requires that the heterozygotes are killed by the pesticide. However, without detailed knowledge of the genetics of resistance it may be difficult to work out what the dose should be, and if all the heterozygotes are not killed, resistance is aggravated.

This strategy also requires that susceptibles migrate from a refugium to breed with the surviving resistant homozygotes, thus diluting resistance. Without immigration, resistance is again exacerbated. Additionally, it is necessary to know the reproductive potential of the pest, because this management strategy is not effective against pests with high reproductive potential.

Even so, resistance management programs can be effectively implemented based on relatively little information. As more information on the pesticide and pest becomes available, the initial resistance management program can be improved and fine tuned. Roush believes a resistance management program can evolve over time, without ever making a serious error in recommendations.

This is certainly the case for western flower thrips management, where resistance management was implemented without resistance being confirmed.

Resistance monitoring then detected ubiquitous pyrethroid resistance and subsequently the management strategy was changed so pyrethroids were no longer recommended.

Monitoring still underpins the recommended resistance management strategy for western flower thrips. Abamectin, methiocarb and pyrazophos are now the only chemicals recommended for use against western flower thrips for which resistance is not detected.

Unfortunately, monitoring has recently detected resistance to the Group 2B GABA gated compound fipronil and the Group 5 acetylcholine receptor modulator spinosad.

This research has shown that, except for the newly emerging fipronil and spinosad resistances, there is little variation in response to the older chemistries between crops. This possibly relates to these resistances already being present in the western flower thrips that arrived in Australia.

The practical outcome is that individual industry sectors (e.g. vegetables, ornamentals, cotton etc) cannot isolate themselves when considering western flower thrips, and resistance management should continue to be considered on a national and across-commodity basis.

Further Reading

G.P. Georghiou and T Saito eds (1983) Pest Resistance to Pesticides. Plenum Press, NY

R.T. Roush and Tabashnik, B.E. eds (1990) Pesticide Resistance in Arthropods. Chapman and Hall, NY.

Acknowledgements

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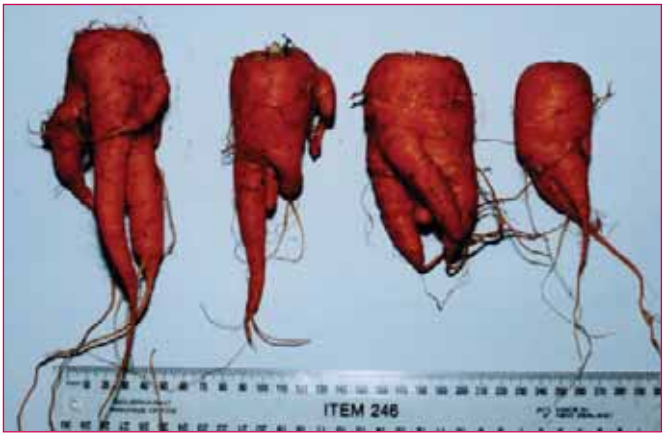
Nematode control in carrots

In Australia there are 330,000 tonnes of carrots produced annually, from approximately 7500 ha, with a farm gate value of A$150 M. Some species of plant-parasitic nematodes are a significant constraint to carrot production.

What is a nematode?

Nematodes, or 'eelworms', are small (invisible to the human eye) worm-like organisms that live in soil and feed on plant cells. They have a simple lifecycle; hatching from an egg as a worm-like organism that feeds and moults as it grows to become an egg-laying adult. This process takes about one month, and while most nematode species are important to soil ecology (e.g. feeding on fungi and bacteria), some plant-parasitic species are harmful to vegetable crops.



Nematode feeding can cause distortion of carrot shape including; galling, forking, hairiness, and thumb-like branch roots.

Nematodes harmful to carrots

Root knot nematode (RKN) (*Meloidogyne spp.*) is the most damaging to many crops in Australia. The main species affecting carrots in Australia are *M. javanica*, *M. hapla* and, to a lesser extent, *M. fallax*.

RKN can cause seedling death, stunting of young plants, branching of tap roots and galling in older plants, which reduces quality and yield. RKN is particularly damaging due to its high reproduction rate, which allows populations to build up rapidly.

Lesion nematode (*Pratylenchus spp.*), and other nematodes such as *Hemicyliophora saueri* and *Neodolichodorus australis,* can also cause crop losses when present in high numbers.

Control of nematodes

Nematode control in Australia is heavily reliant on general soil fumigants (e.g. metham sodium, 1,3, dichloropropene (1,3 D) or 1,3 D/chloropicrin mixtures) and non-fumigant nematicides (e.g. fenamiphos). These can be effective when applied according to label recommendations and with proper soil preparation. However, they should be used as part of an integrated program, e.g. along with soil testing. Nematicides should be used judiciously as they tend to be costly, highly toxic and potentially environmentally harmful. Additionaly, continual use of the same chemical can lead to microorganism build-up that can rapidly render them ineffective – a process known as 'enhanced microbial degradation'.

The Bottom line

- **Know your enemy and conduct a soil test.**
- **Sample intensively to get a representative count.**
- **Use nematicides in conjunction with a soil test.**
- **Plan rotations with crops that are poor nematode hosts or with biofumigant crops.**

Soil testing gives an indication of the risk of planting a particular field and the necessity for chemical treatment. Samples are taken with a trowel or soil corer, at an intensity of around 50/ha, to a depth of 20-30 cm across the field. Samples are bulked, gently crumbled, mixed well and 0.5 kg is sent to the laboratory. Samples should be kept cool (10°C) and sent soon after collection; testing relies on nematodes migrating out of soil prior to counting - those that die in transit are not counted! Samples are often collected prior to planting however, a sample taken prior to harvest of the previous crop in the rotation (soil is undisturbed and nematode numbers at their peak) can provide more accurate results. Test results need to be compared with local information on how many nematodes constitute a crop risk (i.e. the damage threshold. Nematode numbers higher than the threshold cause yield losses suffecient to warrant the costs of control).

Root knot on a carrot in WA. Courtesy E. Davison

The RKN threshold is often a single RKN, as soil tests often underestimate nematode numbers and carrots are particularly susceptible to RKN. However, for lesion nematode, the threshold may be 200-400 per 400 ml or grams of soil; thresholds can vary widely between geographical areas. As nematodes often have a patchy distribution, it may be possible to split the field into sections and send a sample from each; increased testing costs may be offset by the need to treat only those sections with high nematode numbers.

Rotations and break crops are best chosen with accurate soil counts of particular nematode species. For example, RKN *M. hapla* and *M. fallax* both cause damage to carrot crops. Grass or cereal crops are often used to control *M. hapla*, but they can be hosts of *M. fallax*. Consult your local agronomist or Department of Primary Industries on suitable rotation or break crops. Biofumigant brassicas and mustards have been shown to be effective against nematodes if sufficient biomass is grown and incorporated into soil.

Some biofumigants host nematodes, and unless a good kill is obtained following incorporation, nematode populations may increase. Planting biofumigants in autumn and incorporating in early spring, prior to increased soil temperatures and nematode activity, reduces nematode build up under the biofumigant.

Fallow periods of more than six months can reduce populations of some nematodes, but may not reduce numbers below damage thresholds. It is important to maintain a bare fallow, as weeds can act as hosts and allow nematode numbers to increase.

Planting in late autumn or early spring can allow crops to become established when soil temperatures are cool and less conducive to invasion and reproduction of nematodes.

Future

Carrot varieties resistant to RKN are being developed overseas, however it may be some time before they are available. DNA based techniques of quantifying nematodes in soil and identifying specific species are likely to become important. This technology is available to cereal growers and may be available to vegetable growers in the future.

Further Information

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Acknowledgement

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Minor Use Program

Growers of horticultural crops frequently suffer from a lack of legal access to crop protection products. The problem is that whilst their crops are valuable, individually they are too small for agrochemical companies to bear the high cost of registering products for use on them. For larger crops it is also difficult when the pest or disease is only localised or infrequent.

Growers are increasingly trapped in a situation where they face severe loss (from diseases, pests and weeds) if they do nothing to protect their crops, or face penalties if they use a product that is not registered.

Purple Blotch disease on an onion crop.

Horticulture's access to pesticides through minor-use permits is now coordinated and managed by AgAware Consulting Pty Ltd, under the Horticulture Australia Ltd project: AH04009 'Coordination of minor use permits for horticulture'.

The project aims to assist all horticulture industries (including vegetables) to protect their crops from diseases, insects or weeds, by providing access to pesticides that wouldn't otehrwise be legally available for use. This will be via minor-use permits and/or new registrations. The project will undertake the assessment of chemical suitability, resistance, IPM, residues and exports in its evaluations.

Specifically, the project aims to assist growers to:

- Protect their crops from pests, weeds and diseases
- Solve crop protection problems
- Manage chemical resistance
- Meet legal requirements regarding chemical use
- Ensure produce does not contain unacceptable chemical residues
- Meet the requirements of quality assurance systems and export markets

The project will do this by:

- Undertaking a coordinated approach to permit acquisition across all horticultural industries in association with stakeholder and regulatory authorities
- Determining data requirements and costs to obtain registrations/permits for pesticides
- Setting up cost sharing arrangements and funding across horticultural industries regarding data generation
- Coordinating registrations/permits with the regulatory authorities (APVMA)
- Providing feedback to individual industries on registrations and permits granted.

The Bottom line

- Growers are required to only use registered or permitted pesticides on their crops.
- Not all vegetables have the range of pesticides available to maximise production and quality.
- The project allows growers to access pesticides currently not available.
- The pesticides selected will give consideration to chemical suitability, resistance, IPM, residues and exports in its evaluations.
- The vegetable industry needs to become more proactive in managing diseases, insects, weeds and pesticides.

Permit Number	Permit holder	Crops	Active	Problem	Expiry date	States applicable
PER4402	Ausveg	Tomatoes	Abamectin	Western Flower Thrips	30/09/2005	All states
PER6792	Ausveg	Broccoli, Brussels sprout, Cauliflower	Copper oxychloride	White Blister (*Albugo spp*)	31/10/2005	All states
PER7416	Ausveg	Lettuce	Imidacloprid	Lettuce Aphid	30/06/2005	All states
PER7629	Ausveg	Cucurbits, eggplant, tomato, lettuce, broccoli	Pymetrozine	Silverleaf Whitefly	31/03/2006	NSW, QLD, NT, WA
PER8186	Ausveg	Leafy vegetables	Phosphorus acid	Downy Mildew	24/01/2010	All states

There are many examples where this approach to permits has helped the vegetable industry. The above shows just a few examples.

If you, as a vegetable grower, manager or consultant have any requests for pesticides to control diseases, insects or weeds, please provide your requirements to the project management, your industry development officer or industry representative. Or the information required can be simply added to the table and forwarded to AgAware.

Please note that all information provided will be treated with strict confidence.

The vegetable industry is very aware of the possible consequences that can occur from the use of unregistered or non-permitted pesticides. These can include:

- Produce with unauthorised chemical residues present
- Rejection of produce from local markets
- Temporary exclusion from market access
- Rejection of produce from export markets
- Jeopardising of export trading arrangements
- Fines and penalties

It is not worth the risk to your crop and income to use unregistered or non-permitted pesticides on your vegetables. Your involvement in this project will assist you to access the pesticides you require and address the chemical residue issues.

There is also an opportunity for growers to highlight any pesticides they are currently using that are causing or may cause concern in export markets.

The vegetable industry needs to become more proactive in the way it manages diseases, insects, weeds and pesticides. If there are any diseases, insects or weeds you believe are a problem now, or may be in the future, or you are using pesticides that may cause trade, environmental, worker or consumer concerns now or in the future, please let us know by recording them in the table.

Further information

If you have any queries or require any assistance, please contact Peter Dal Santo on Ph: 03 5439 5916 Fax: 03 5439 3391 or email: pds@agaware.com.au

Acknowledgement

Peter Dal Santo, AgAware
This is a national project funded by Horticulture Australia Limited.

Crop eg. vegetable	Product eg. Vermitec	Active eg. abamectin	Problem eg. Two spotted mites	Rate required eg. 100 g/100L	Any current control methods	Damage eg. fruit blemish	Impact eg. loss of value

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The National Vegetable Levy

The National Vegetable Levy was introduced in 1996, after considerable nation-wide consultation, at the request of AUSVEG (the national organisation representing Vegetable & Potato growers).

Having a levy allows for planned Research and Development (R&D) rather than uncoordinated and sporadic R&D that produces few practical outcomes.

The Commonwealth Government matches industry investment for R&D on a dollar for dollar basis, doubling the amount of money that is invested back into the industry for R&D.

How is the levy calculated?

The levy is calculated at 0.5% of the value of produce at the first point of sale. This equates to 50 cents out of $100 of produce sold.

How is the levy collected?

The levy is collected at the first point of sale. This is usually at the wholesale market or processing company. If it is a direct sale it is collected via the retailer. The levy is applicable to both fresh and processed vegetables.

It is the responsibility of the growers to ensure the levy is paid at the first point of sale, regardless of the type of sale - direct or wholesale.

The collected levy is then forwarded to the Levies Revenue Service (LRS), a designated Commonwealth Government section under Department of Agriculture, Food and Fisheries, responsible for collecting all agriculture levies.

The LRS forwards the money to Horticulture Australia, an industry owned company which coordinates, invests and manages R&D and promotional programs on behalf of Australia's horticulture industries.

The LRS can be contact for further information on freecall: 1800 625 103.

Horticulture Australia Limited was formed in 2001 following the merger of Commonwealth statutory organisations, Horticultural Research and Development Corporation and Australian Horticultural Corporation.

Not all vegetables are levied

Potatoes, onions, processing tomatoes and mushrooms have separate levy arrangements and are not included in this program.

Fresh tomatoes, garlic, melons and asparagus currently have no national levy arrangements.

How are the funds allocated?

Like all good business investments, strategic planning is vital to the future direction of the industry. The vegetable industry determines the Strategic Investment Plan (SIP), which highlights the priority areas and maximises the return on the funds invested in R&D.

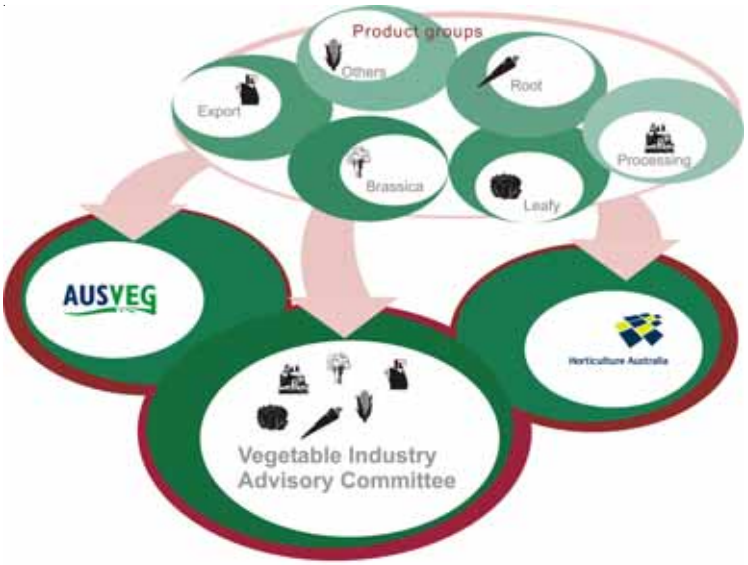
Horticulture Australia and AUSVEG have set up an industry based advisory group responsible for recommending where funds should be allocated.

Even though they use the SIP as a guide, there is still flexibility to support R&D for unexpected issues, such as the appearance of White Blister on Brassica or Lettuce Aphid.

The Bottom line

- **Growers benefit through having greater resources to invest in R&D**
- **Grower driven R&D that directly benefits industry**
- **Ability to attract greater research funding for the vegetable industry**
- **Like with any investment, a reasonable return is expected**

It should be noted that while Horticulture Australia is responsible for both industry funds and commonwealth matched funds, it is the industry's responsibility to make recommendations on how the funds should be allocated.



Who makes the decisions?

Due to the complexity of the vegetable industry, six product groups have been established. Each group has a representative from each State, totalling 36 members.

The product groups are: Export, Processing, Brassica, Root Vegetables, Leafy Vegetables and Other Vegetables.

The 36 members also consider projects under the following key investment areas: domestic market development, sustainability, industry communication, product development, and supply chain development.

One member from each of these groups, together with the AUSVEG Board form the Industry Advisory Committee (IAC). It is through the IAC that Horticulture Australia receives recommendations.

Funding R&D with Voluntary Contributions

An additional and complementary mechanism for investing in vegetable R&D is Horticulture Australia's ability to match voluntary contributions (VCs) dollar for dollar from any sector of the industry with commonwealth funds. This allows the non-grower sectors of the industry to access commonwealth funding for research that complements the vegetable levy. VCs from growers can also be matched provided they meet certain criteria.

How much is invested annually?

The levy collects approximately $4M per year that funds an R&D program worth more than $7M annually.

Since 1996, the levy has funded approximately 450 projects, resulting in a combined value of $60 million.

Key projects include:

- National strategy for Western Flower Thrips Management
- National Diamondback Moth Integrated Pest Management Program
- National Cool-Chain Management Strategy
- National Greenhouse Projects
- National IDO Network
- Sweetcorn IPM
- Carrot Virus Y
- Minor Use Chemicals

Advantages of statutory levy

A statutory levy indicates vegetable industry commitment to research, which is important to research providers and state agricultural departments when gaining additional leverage.

Levy funds are an investment in the future of the industry through R&D, not an expense.

Further Information

For more information regarding this edition of VEGE*notes*, please contact your State Vegetable Industry Development Officer:

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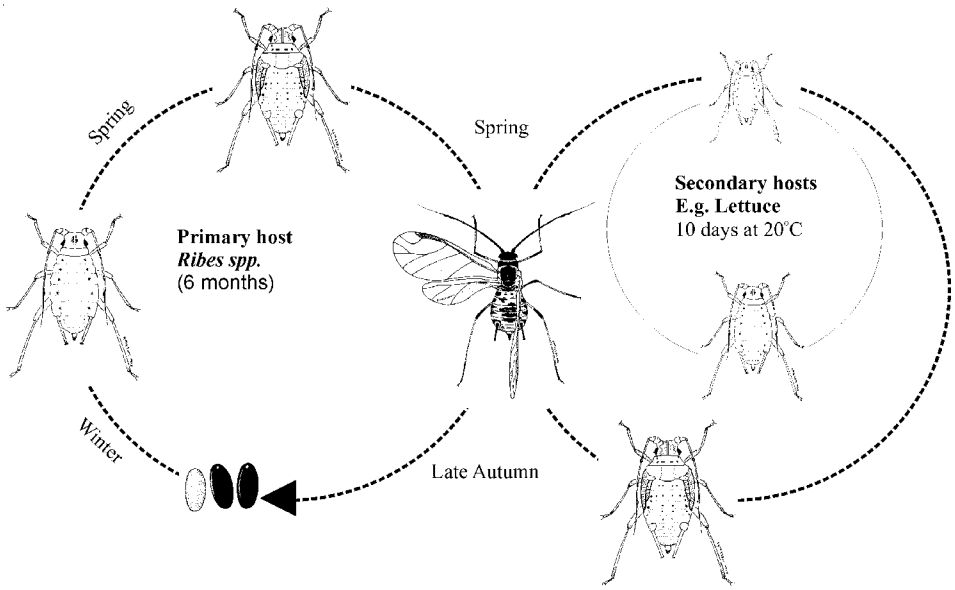
Lettuce Aphid Threat

The lettuce aphid (also known as currant-lettuce aphid) is a major pest of salad crops, particularly lettuces. Originating from Northern Europe, it was confirmed in Tasmania mid-March 2004.

A current theory is that it arrived in Tasmania from New Zealand via an extreme and unusual weather event in late January.

Lettuce aphid is now found in Europe (Belgium, France, Germany, Greece, Italy, Netherlands, Poland, Russian Federation, Switzerland, United Kingdom), North America (Canada, United States of America), South America (Argentina), New Zealand and Tasmania.



Life cycle of the Lettuce Aphid.

Eggs are only laid on *Ribes* spp., including red, white and black currants, and gooseberries.

A dangerous feature of the aphid breeding cycle is that most species do not need a male to reproduce. Parthenogenesis is the process that allows female aphids to give birth to smaller editions of themselves, bypassing sexual activity and egg laying.

Immature aphids are yellow-green and wingless while adults can be winged or wingless, ~2-2.5 mm in length, greenish to yellow-green with irregular narrow dark patches on their back.

Hosts

Lettuce (*Lactuca sativa*), *Ribes* (gooseberry, and red, black and white currants), endive, chicory, Hawksbeard (*Crepis*) and Hawkesweed (*Hieracium)* are all hosts that the lettuce aphid is found to breed on in New Zealand.

Nipplewort (Lampsana), Speedwell (Veronica), Sowhistle (Sonchus), Artichoke, Tobacco, Petunia and other members of the hairy thistle family are hosts recorded in international literature.

Damage

Lettuce aphid is primarily a contamination pest. In general, the direct damage from the aphid is limited on lettuces, though large numbers of aphids may stunt young plants and cause leaves to become pale in colour and slightly deformed.

The Bottom line

- **Lettuce aphid has been confirmed in Tasmania**
- **Hosts include lettuce, gooseberry currants and some weeds**
- **It is a contamination pest**
- **Management is using resistant lettuce varieties or chemical control**
- **Confidor® 200 SC has been issued a permit as a lettuce aphid control**

Lettuce head contamination by lettuce aphid makes them unsaleable. Lettuce aphid can also transfer cucumber and lettuce mosaic virus.

Contamination damage caused by Lettuce Aphids.

Management options

1. **Resistant varieties** - Some seed companies have utilised an aphid resistance gene in some of their lettuce varieties. Lettuce aphid does not feed or reproduce and immatures do not reach adulthood on resistant plants.

   Other seed companies are now also using this gene and have a range of fancy lettuce ready for commercialisation, but head lettuce varieties are not yet available.

2. **Source control** - Care should be taken that lettuce aphid is not introduced via transplants or movement of other plant material.

3. **Monitoring** - Crops need to be closely inspected. In seedlings and prehearted lettuce, attention needs to be paid to the innermost leaves and in folds or crinkles in the leaf. Once the lettuce has hearted some destructive sampling is needed. Since lettuce aphid may occur non-uniformly across paddocks, a number of widely dispersed sites need to be sampled. Weed hosts should be sampled, including Hawksbeard and wild lettuce if nearby.

4. **Beneficial insects** - Aphids are eaten by a range of beneficial insects which are likely to be more efficient at reaching and killing them than insecticides, particularly in hearted lettuce. However the use of broadspectrum insecticides is likely to kill many beneficials.

5. **'Soft' foliar insecticides** - Pirimicarb (Pirimor®) is a 'soft' aphicide registered for use on aphids in lettuce in Australia. Although resistance has been reported to pirimicarb in Europe, tests in NZ show that their lettuce aphid is not resistant. There are some newer potentially 'softer' chemistry that is not currently available that may get permits or registration.

6. **Broadspectrum insecticides**. Dimethoate, maldison, methidathion (e.g. Supracide®), and pyrethrins are the other registered aphicides for lettuce in Australia. In Europe resistance to cypermethrin, dimethoate, and endosulfan has been recorded.

   Broadspectrum insecticides are undesirable in an IPM system as they kill most, if not all, beneficial insects.

7. **Seedling drenches**. An emergency permit has been granted for imidacloprid (Confidor®) as a seedling drench in lettuce. Seedling drenches have been proven to control lettuce aphid for the life of the crop in New Zealand. Imidacloprid seedling drench is not fully compatible with IPM programs. Overuse of imidacloprid for lettuce aphid control raises concerns with resistance developing. A resistance management strategy is being developed and should be followed when introduced.

8. **Sanitation.** Control surrounding weeds. Any infested lettuce, including recalled product, should be buried as soon as possible.

9. **Post harvest washing.** Washing of head lettuce will not disinfest. Loose leaf lettuce washing processes with fine water filtration systems can reduce numbers of aphids present in packed lettuce.

Growers with a strong IPM strategy and good populations of beneficial insects are in a better situation to manage lettuce aphid populations, particularly when they first arrive in a district.

A winged Lettuce Aphid.

Confidor® 200 SC (imidacloprid) Lettuce Aphid permit

The Australian Pesticide and Veterinary Medicines Authority (APVMA) has issued a permit for Confidor® 200 SC Insecticide (200 g/L imidacloprid) to control lettuce aphid (*Nasonovia ribis-nigri*) in lettuce.

A copy of the permit can be obtained from the APVMA website: www.apvma.gov.au/permits/permits.shtml

The information in this document should be reviewed in conjunction with the permit:

EMERGENCY USE PERMIT
PERMIT NUMBER – PER7416

This permit is valid from 24 March 2004 to 30 June 2005. All persons who require Confidor for lettuce propagation and production can use the permit.

The only product that can be used is Confidor® 200 SC Insecticide (200 g/L imidacloprid).

Confidor is a Group 4A Insecticide.

Directions for Use

APVMA has issued several 'Critical Use Comments' in relation to this permit, which must be strictly adhered to whenever the permit is used.

- Apply only one application via spray or drenching equipment, in a sufficient volume of water to ensure complete coverage or drenching of the cell (seedling and soil). Ensure even distribution.
  - Only apply imidacloprid seedling drench to lettuce aphid susceptible varieties. Imidacloprid should not be used on lettuce aphid resistant varieties.
  - It is vital for the application process to be carried out correctly, otherwise optimum control may not be obtained.
  - Each plant cell (seedling and soil) must be saturated with the Confidor solution, but not to run-off.
- The higher rates may be more effective under conditions highly favourable to aphid infestation.
  - Information obtained from New Zealand shows that 35 to 55 mL per 1000 plants is effective in controlling lettuce aphid, but in aphid favourable conditions the higher of these rates is most effective.
- Application should occur as close to the time of planting out as possible. If watering is required, avoid or minimise leaching from the cells.
  - Confidor treatment applied to each plant cell must remain within the cell until the seedling has planted out.
  - The seedling must take up the drenching solution from the cell soil to maximise the concentration of chemical within the seedling.
  - Where possible, apply Confidor within 24 hours prior to transplanting.
  - If treated, seedlings require watering prior to transplanting. Ensure that only enough water is applied to wet the cells without leaching through the cell.
- Users must take care to minimise potential run-off, either during or following application. Only apply sufficient solution to fill the cell.
  - Run-off must be avoided or minimised, as this represents product not taken up by the seedling for lettuce aphid control.
  - If run-off occurs, ensure the solution is captured, retained and disposed of appropriately.
- Persons handling treated trays and seedlings should wear chemical resistant gloves.
  - Nurseries supplying imidacloprid treated seedlings should advise purchasers that the seedlings have been treated and of the need to wear chemical resistant gloves.
- Only a single application should be made to any one batch of seedlings.
  - If there are delays in planting out of seedlings, another application of imidacloprid provides no additional control.
- No other application of Confidor or other Group 4A Insecticides should be made during the entire life of the crop.
  - All lettuce seedlings purchased from nurseries should be identifiable as being treated with imidacloprid. This will determine aphid management actions by the grower.
  - To minimise potential imidacloprid resistance developing, no other Group 4A Insecticides should be used for the life of the crop.

- Confidor is the only Group 4A Insecticide currently permitted for use in lettuce.
- If growers are required to control Lettuce Aphid or other aphids during the life of the crop, insecticides such as dimethoate and pirimicarb should be used. Always monitor the effectiveness of these insecticides.

APVMA has also issued several 'Advisory information' points in relation to this permit, which must be strictly adhered to.

- The use permitted by this permit alone will not prevent the general movement, spread or colonisation of Lettuce Aphid.
  - Growers should regularly monitor crops and other host plants for lettuce aphid and contact their local Agriculture Department for information about correct sampling techniques.
  - Monitoring will determine the need for the imidacloprid seedling drench treatments on susceptible crops.
  - If lettuce aphid has not been detected in your area, it may be possible to grow susceptible varieties successfully. Also consider growing lettuce aphid resistant varieties that do not require imidacloprid.
- Growers should develop and implement IPM and Insecticide Resistant Management (IRM) strategies to complement the seedling drench treatment.
  - In New Zealand and Tasmania soft chemical options, encouraging aphid predators, play a vital role in the control of lettuce aphid. This allows for minimal and selective chemical use.
  - It is essential that imidacloprid is only used once for each crop to minimise resistance developing. Use other products (non Group 4A insecticides), if foliar control is required.
  - To minimise the risk of resistance developing, growers using imidacloprid should aim for an imidacloprid free growing period at some stage during the year.

According to research from New Zealand, imidacloprid will provide season long control of lettuce aphid when used as a seedling drench. Under lettuce aphid favourable conditions the high rate (55 mL per 1000 plants) is required.

The Confidor seedling drench treatment has not been evaluated under Australian conditions and may provide the following control, based on limited information:

- Season long control (achieved in New Zealand under cool growing conditions)
- Imidacloprid maybe less effective in warmer climates

A withholding period is not required for the use of imidacloprid as a seedling drench, when used as directed.

APVMA has set a temporary MRL of 5.0 mg/kg for imidacloprid in head and leafy lettuce.

This permit is valid in all states except Victoria, as their 'control-of-use' legislation does not require a permit to legalise this off-label use.

Contact

If you find suspect aphids in an area where lettuce aphid is not previously known, clearly mark the collection site, so it can be easily found later, and call either your:

1. Vegetable Industry Development Officer
2. Local department of agriculture or primary industry
3. Exotic Plant Pest Hotline 1800 084 881

Acknowledgements

Sandra McDougall
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NSW Agriculture

Greg Baker
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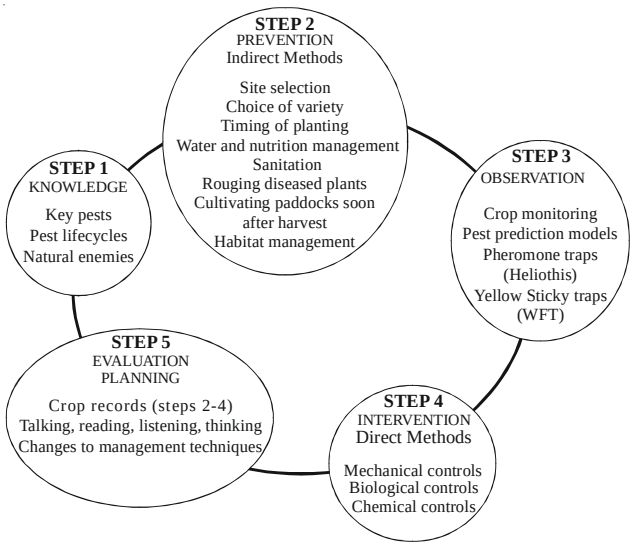
Lettuce Integrated Pest Management (IPM)

Lettuce Integrated Pest Management (IPM) helps growers select the best tool to manage pests. There are five steps in this strategy:

1 - identify key pests and understand their lifecycles, including what naturally eats/kills them (natural enemies and climatic conditions).

2 - prevent pests from being in your crop or increasing in numbers to the point of causing economic damage. It may be that the pest is: not present at particular times of the year, unable to develop on specific varieties (best choice for disease prevention), or is worse when crops are over or under watered or fertilised.

3 - monitor crop for pests and numbers. Pheromone traps help identify which of the two heliothis species is dominant (*Heliocoverpa armigera* is resistant to synthetic pyrethroids and carbamates but *H. punctigera* is not). Yellow sticky traps help monitor thrips species and numbers. Prediction models should be used to indicate periods when pests or diseases are most likely to be present if available.



4 - control the pest when numbers are causing economic damage. This can involve: mechanical methods (chipping weeds or diseased plants); biological methods (introduce a beneficial insect or use biological spray - Bt or NPV); or chemical methods (pesticides).

5 - evaluate immediate effectiveness of direct controls and overall success of the program. Identify potential areas for improvement and develop a plan for future plantings.

The bottom line

- Select disease resistant varieties
- Understand and identify key pests
- Monitor crops for pest and numbers regularly
- Control pests with mechanical, biological or chemical interventions
- Record all controls used
- Evaluate the effectiveness of controls
- Plan to improve pest management for future crops

KNOWLEDGE

Develop an understanding of key and minor or occasional pests that are found in lettuce in your area. The most likely candidates are in the table below.

Key Pests		Minor or Occasional Pests	
Insects:	Diseases/Disorders:	Insects:	Diseases:
Heliothis	Sclerotinia	Cutworm	Anthracnose
Western Flower Thrips	Big Vein virus (cool wet conditions)	Loopers	Downy Mildew
Silverleaf whitefly (QLD)	Tomato Spotted Wilt Virus (TSWV)	Cluster caterpillars	Damping-off
Aphids (when virus levels high)	Tipburn (Werribee)	Wireworm	Septoria spot
Other Thrips (when virus levels high)		False Wireworm	Botrytis or Grey Mould
		Rutherglen bugs	Black root rot
		Leafhoppers	Bottom rot
		Aphids (when virus levels low)	Bacterial leaf spot
		Other Thrips (when virus levels low)	Varnish spot
		Vegetable Weevils	Bacterial soft rot
			Corky root
			Lettuce Mosaic Virus
			Necrotic Yellows Virus

Lettuce pests.

PREVENTION

Where possible prevent pest problems. The measures used will depend on the particular situation and which pest or disease is most serious. Potential prevention strategies for lettuce and other leafy vegetables:

- Select disease resistant varieties is the best option for prevention. Contact seed companies for the best varieties for your growing window and the diseases they are resistant to.
- Avoid having lettuce in the ground when populations tend to peak in your area. Heliothis caterpillars tend to be in large numbers in late summer, with some local variation, so avoid if possible.
- Remove flowering weeds to assist with reducing thrips numbers, especially in areas where thrips, particularly WFT, is a problem. Flowering plants and unsprayed vegetation may provide a nursery for beneficial insects but they can also be a source of thrips.
- Remove sow thistles to reduce the potential for infection with Necrotic Yellows virus.
- Source seedlings from nurseries with an active pest management strategy to reduce the likelihood of introducing pests and diseases.
- Chip out and remove (roughing) diseased plants.
- Cultivate paddocks immediately after harvest or if abandoned to reduce the potential of harbouring pests and diseases and spreading to other plantings.
- Use crop records to identify practices that may encourage pests or diseases.

OBSERVATION

Routine crop monitoring is important to record pest and beneficial numbers and assess crop health.

This can be completed by a contract professional or yourself, with the following factors in mind:

- When identifying key pests, beneficials and diseases send specimens away if in doubt.
- Keep crop monitoring records.
- Follow a systematic protocol for monitoring so direct comparisons can be made of numbers found between monitoring dates and plantings.
- A basic protocol involves visually assessing: four lettuce at ten sites within a crop, from seedling to pre-heart stage; two lettuce at ten sites from hearting until harvest. Spread the sites widely throughout the crop, include some near paddock edges and change sites each monitoring.
- Monitor at least once a week.

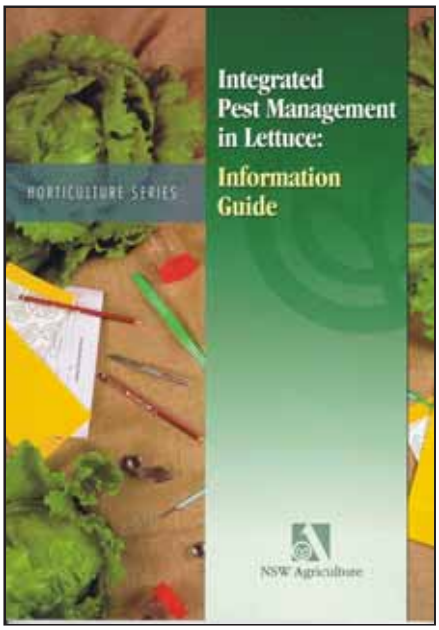
Other monitoring tools include: Pheromone traps for assessing the proportion of each of the two Heliothis species and to indicate flights. Be aware, the traps attract male moths but female moths deposit the eggs into the crop. Yellow sticky traps are also useful for accessing thrips species and pressure, particularly important for crops in or near areas with Western Flower Thrips.

Yellow sticky trap, used particularly in areas prone to Western Flower Thrips.

Doing a visual preharvest assessment of 100 plants for key insects or disease types can give a better indication of planting quality to compare with other years or blocks than actual marketed product, given the market can accept differing quality depending on supply.

INTERVENTION

Crop monitoring information, past crop records and any pest action thresholds (some are contained in the IPM in Lettuce Information Guide) will help with deciding if pest numbers warrant active intervention.



The factors most likely to affect disease control decisions are: varietal susceptibility; disease found; if weather conditions favour spread or development; if transmitted by an insect, the numbers and source of the insect; crop vigour; irrigation methods; crop destination (export, domestic, fresh, processing); and effectiveness of control options.

Disease	Prevention	Environmental	Management
Sclerotinia	Rotate with non-sclerotinia hosts Apply fungicide at thinning or transplanting stage when crop is likely to be infected		Roughing early infected plants
Tomato Spotted Wilt (TSWV)	Removing surrounding weeds that may harbour TSWV		Controlling thrips will reduce within-paddock transmission of the virus
Big Vein	Some varieties are less susceptible than others Good drainage	Cold-wet conditions favour Big Vein	None

Diseases that affect lettuce.

Insect Pest	Crop Vulnerable Stage	Environmental influences	Beneficials	Control options
Heliothis	Larvae burrow into lettuce hearts, so once lettuce has hearted, control is difficult Ploughing in paddocks immediately after harvest	Eggs hatch more quickly in warmer weather, Rain and frosts may wash off or kill eggs	Specific wasps parasitize eggs, larvae or pupae; Generalist predators (spiders, some shield bugs, nabids etc) may eat eggs or small larvae,	*H. armigera* is resistant to SPs (alphacypermethrin or permethrin) and methomyl particularly medium to large larvae. Some resistance to Success® has been reported. SPs & methomyl will also kill most beneficials. NPV virus & Bts need to be eaten by caterpillars, & are degraded by light and dry conditions.
Western Flower Thrips (WFT)	Seedlings tolerate less direct feeding damage than older plants Younger plants are less likely to be marketable if infected by TSWV	Haying-off of nearby weeds can be major source of WFT in regions with WFT	Currently no important ones	WFT develop insecticide resistance quickly therefore, a strict resistance management strategy needs to be followed (see resource box)
Aphids (not including Lettuce aphid*)	Tend to be found on the undersides of outer leaves, seedlings more vulnerable to direct feeding	Survive best in mild conditions. Frosts, rain and high temperatures reduce populations	Ladybird beetles (especially larvae), Hover fly larvae and Lacewing larvae are key predators of aphids. Parasitic wasps can also kill many aphids	Pirimor – is less effective when temperature is below 15 C Dimethoate – effective but will kill beneficials

1. *Lettuce Aphid or Nasanovia is not currently found in Australia but quickly sprea d throughout New Zealand in 2002. Lettuce Aphid quickly infests lettuce heads but some lettuce varieties are resistant.

Insects that affect lettuce.

Other factors that can influence pest control decisions include: crop stage (Heliothis are more difficult to control once lettuce has hearted), number of beneficial insects known to predate the target pest, and regional resistance management strategies.

The control method chosen will be the one with the least negative impact on other strategies (won't kill beneficial organisms) and will accomplish the goal within the constraints. Constraints can be: product registration, market requirements, cost, resistance management strategies and current conditions. If a pesticide is selected, every effort should be made to maximise its efficacy.

EVALUATION

All spray applications should be evaluated. SPs and Carbamates should show immediate effects however, new chemisty (ie. Success® and Avatar®) and biologicals (ie. NPV and Bts) take a few days to kill caterpillars. Feeding usually ceases quickly after application.

Pre-harvest assessments are recommended for the purpose of comparing crops and seasons. Counting the number with grub or sclerotinia out of 100 will give a better basis for comparison than simply what is sent to market.

A lettuce crop with Sclerotinia damage.

Packouts won't explain why lettuce wasn't picked and in times of low supply the market will accept poorer quality than in periods of high supply.

It is very useful to spend some time, each year, examining crop records to evaluate why some plantings did well while others did not. The records may show that a necessary spray was missed but beneficial insects or adverse weather did the job, or alternatively the missed spray allowed grubs through and weren't able to be cleaned up at a later date.

Talking to other growers about current conditions and crop quality can provide information on how a crop is preforming in comparison to others and provide ideas on ways to improve management.

Comparing records over a number of seasons may show patterns or paddock variations that weren't noticed previously, which then allows the problem to be addressed and overall performance improved.

Integrated Pest Management in Lettuce, as in any crop, continually develops as those who adopt it develop their skills, gain a deeper understanding of their situation, and in response to changing environmental, market or economic conditions.

Further Reading

Pests, Beneficials, Diseases and Disorders in Lettuce: field identification guide* (2003) S. McDougall *et al*., NSW Agriculture

IPM in Lettuce: information guide* (2002) S. McDougall *et al*., NSW Agriculture

Pests, Beneficials, Diseases and Disorders in Greenhouse Vegetables: field identification guide (2002) S. Goodwin *et al*., NSW Agriculture

IPM in Greenhouse Vegetables: information guide (2002) S. Goodwin *et al*., NSW Agriculture

The Good Bugs Book 2nd Edition (2002) R. Llewellyn *et.al.* Bugs for Bugs

Insect Pests of Fruit & Vegetables (1992) G. Swaine *et al.* QDPI

Lettuce Agrilink (1997) Editor: G. Ayling, QDPI

*all Australian lettuce growers should have complimentary copies.

Further Information

Further information regarding Lettuce IPM can be gained by contacting your State IDO.

More information and back copies of the bimonthly lettuce industry newsletter can be accessed at: www.agric.nsw.gov.au by following the links: Horticulture>Vegetables>Publications or by contacting:

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NSW Agriculture

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Integrated Pest Management in Celery

What is IPM?

IPM stands for 'Integrated Pest Management' and is used to control pests without relying on pesticides alone. With an IPM approach, pesticides provide support for other control measures such as weed management, variety selection, crop rotations and biological control, and the protection of beneficial insects (or allowing naturally occurring insects to survive). Identification of both pests and beneficials is important and there are several guides that growers can use.

Key beneficials

The most common species of beneficial insects found in celery crops are:

- ladybirds which feed on aphids
- brown lacewings which feed on aphids, small caterpillars and moth eggs
- damsel bugs which feed on caterpillars and other soft bodied insects
- *Aphidius*, a small wasp that is an aphid parasite

All of these can be found in very large numbers when pest pressure is high. When pest pressure is low, beneficials are present but there is not enough food supply to support a large population.

Left: Ladybird larva

Below: Damsel bug

All graphics courtesy of Denis Crawford - Graphic Science.

Key pests

Heliothis (*Helicoverpa punctigera* and *Helicoverpa armigera*) are considered the main pests affecting celery crops. Depending on the district, flights of *H. punctigera* usually occur around spring whereas flights of *H. armigera* are more common during summer. Both cause the same type of damage but because *H. armigera* is resistant to many insecticides, it is much harder to kill.

Cutworm damage to celery

Cutworm, which is often considered an establishment pest, can become a problem when flights occur during summer, much in the same way as Heliothis.

Green peach aphid, which is a vector for celery mosaic virus, is also common, as well as vegetable weevil, which can either breed on weeds or move in from the edge of the crop.

Minor pests

A variety of insects exist in any IPM crop, some of which will have no effect and others, such as

The bottom line

- **Beneficial insects provide better control than most insecticides, which often target specific pests**
- **An IPM program greatly reduces the cost of pesticide, even though more expensive products are used (cheaper broad spectrum insecticides kill beneficial insects, which can result in other pest problems)**

European earwigs, loopers and thrips, can cause minor damage. Some thrips, including onion, tomato and Western Flower Thrips (WFT) can carry Tomato Spotted Wilt virus (TSWV). The most common thrips found in celery are Plague Thrips. These insects do not carry TSWV and cause little feeding damage, except in extreme cases on very young plants. All these minor pests can be controlled by insecticides, beneficial insects or through cultural control methods.

Other beneficials

Native earwigs, parasitic wasps, predatory mites and predatory beetles are all found in small numbers in IPM crops and when combined, play a significant role in pest management.

Monitoring

For IPM to be successful, regular, usually weekly, monitoring is required. This is done by going into the crop, looking for pests and beneficial insects and then making a decision on what, if any, action needs to be taken. Monitoring allows growers to target the most vulnerable life stage of a pest and discover when an insecticide is most effective. Monitoring will also tell a grower if an insecticide, which can sometimes fail because of weather conditions, spray equipment or the expiry date of the chemical, has worked.

Brown lacewing larva attacking aphids

How is monitoring achieved?

On a farm, monitoring sites are chosen according to vulnerable areas and age of planting. Three sites are chosen as representatives of each age group of plants, young (two weeks old), middle and old (near harvest). Fifty plants from each site are selected and checked on the outer leaves for moth eggs, the lower leaves for aphids or in the centre for grubs, as well as for beneficials. Suction samples that will collect anything living on the leaves, including beneficials, are taken from the younger plants. Pheromone traps are also used to count the number of moths present.

These methods, if done weekly, will monitor the number of beneficials, the flight of aphids or moths and tell the grower if aphids are breeding, if an insecticide has worked, if a problem is throughout the crop or just the edge, or if the pests are under control.

How are decisions made?

Growers need to assess the information collected through monitoring, along with other factors such as the age of the crop or growth stage of the plants, weather conditions, age of pest, withholding periods and crop value. From this, the relative number of pests to beneficials needs to be determined, and the likelihood of damage, given all of the above variables.

What is the role of pesticides?

Pesticides in an IPM program should support other non-chemical control measures and be used in a way that will have the least impact on other beneficial insects and mites. Large flights of pests can overwhelm the resident population of predators and parasites. Using a selective insecticide that will reduce the number of pests allows the beneficial insects to “catch up”, while avoiding damage to the crop. This approach will not kill the beneficial insects, which will eventually reinvade the sprayed areas.

In general, the herbicides and fungicides used in celery production are acceptable in an IPM strategy. However, growers are warned that frequent use of mancozeb could kill populations of beneficial mites.

Further Information

For further information contact IPM Technologies on (03) 9710 1554

Acknowledgements

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IPM Technologies

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Greenhouse Cucumber Extension Project

The development of the Australian greenhouse cucumber industry relies heavily on good communication of relevant, practical scientific outcomes and general industry information to growers.

A Greenhouse Cucumber Extension Project was established to assist industry development by creating better industry networks; providing education and training opportunities; helping growers access information on improved horticultural practices; and facilitating the dissemination of project outcomes.

Due to the complexity of establishing good linkages and networks in a demoraphically diverse industry, a three point strategy was adopted. This strategy aims to:

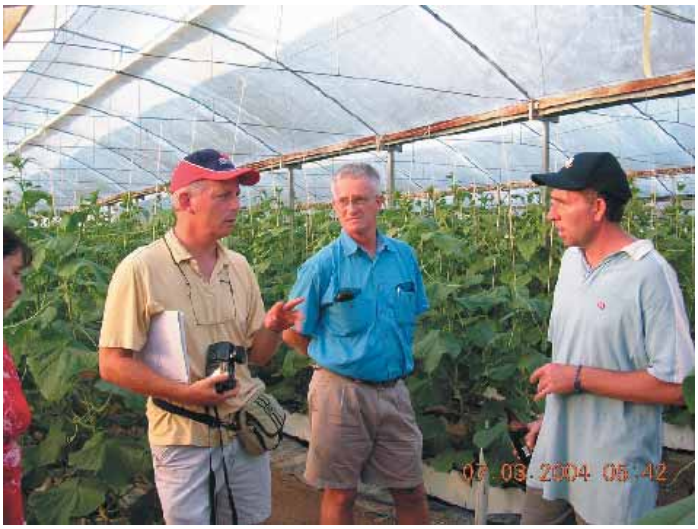
- Support effective relationships between research and development (R&D) providers and the State Vegetable Industry Development Officer's (VIDO's). These relationships assist growers by improving their awareness of and access to information about improved greenhouse cucumber horticultural practices.

- Undertake a range of extention activities to increase industry awareness of: R&D, sources of information and training opportunities and also extend exisiting information regarding good agricultural practices (GAP).
- Develop, and make available, distinct sources of information that offer growers opportunities for long-term further education.

Underpinning and complementing this project was a research component conducted at the National Centre for Greenhouse Horticulture (NCGH), Gosford.

The bottom line

- The National greenhouse cucumber and vegetable industries are now better linked and enjoy improved communication
- Growers have access to a range of greenhouse cucumber and vegetable resources and training
- Improved horticultural practices are being adopted by Australian greenhouse cucumber growers



A series of demonstrations featured crop and system management of GAP greenhouse cucumber crop production (conducted by Dr Sophie Parks, NCGH). Full demonstration details will be in this project's final report, available in early 2005.

Complementary Projects

A unique aspect of the Greenhouse Cucumber Extension Project was its integration with two other greenhouse cucumber research projects being conducted by NSW Agriculture, at the NCGH in Gosford. The two projects are:

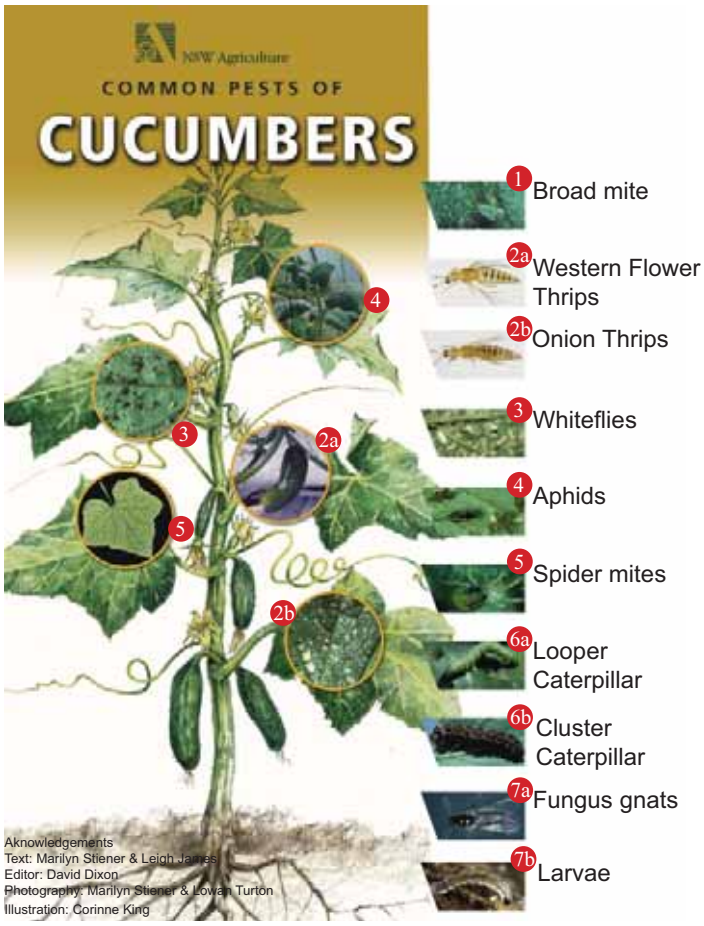
- *Improvements to biological control systems and development of biorational chemicals for IPM in the greenhouse vegetable industry* (conducted by Dr Stephen Goodwin and Marilyn Steiner - National Centre for Greenhouse Horticulture).
- *Integrated management of greenhouse cucumber and capsicum diseases* (conducted by Len Tesoriero - Elizabeth Macarthur Agriculture Institute).

Pest and disease management practices and outcomes from these two research projects formed an important part of a series of workshops held for growers across Australia.

Extension Activities

A range of extension activities were undertaken throughout the project to increase industry awareness, including:

- A survey of greenhouse vegetable growers established industry needs and goals. It also provided a forum for growers to voice their opinions on the industry.
- Feature articles outlining R&D activities appeared in national industry magazines.
- Growers in Queensland, New South Wales, Victoria, South Australia, Western Australia and the Northern Territory participated in workshops which outlined the latest R&D outcomes for: improved pest and disease management; implementing Integrated Pest Management (IPM) programs; crop nutrient disorders; and greenhouse hydroponic cucumber production.
- An award winning display booth by the NCGH team (encompassing all three projects) was set-up at the Australian Hydroponic and Greenhouse Conference in Melbourne in 2003.
- 'Grower Days' have been held at the NCGH, as well as on-farm, to provide growers with GAP information on IPM, disease and nutrient disorders, irrigation and media, hydroponics and crop management.



The meetings and workshops have provided a greater number of greenhouse cucumber growers with access to training and accredited courses. In NSW these courses include *SMARTtrain*, *WaterWise* and *IPM Basics* and a new package for greenhouse growers called *The Business of Greenhouse Hydroponic Vegetables.*

These gatherings have also given growers the latest information on IPM and disease management practices.

The project also involved promoting the availability and use of a range of existing resource materials to help growers get the best information possible.

These resources include:

- Pests, Diseases, Disorders and Beneficials in Greenhouse Vegetables: Field Identification Guide
- Integrated Pest Management in Greenhouse Vegetables: Information Guide
- Disease Management for Greenhouse Cucumbers (NSW Agriculture Agfact publication)
- Nutrient Disorders of Greenhouse Lebanese Cucumbers (NSW Agriculture Agfact publication)

New Information Resources

In addition to those already available, several new resources relevant and useful to growers have been developed. This includes a comprehensive and easy to read Commercial Greenhouse Cucumber Production Manual, available in early 2005.

In addition to the manual, two up-to-date informative wall posters, entitled *Common Diseases of Cucumbers* and *Common Pests of Cucumbers,* have been produced and disributed. The posters are designed to provide growers with a pest and disease reference and include information on a new disease called Beet Pseudo-Yellows Virus, as well as Western Flower Thrips.

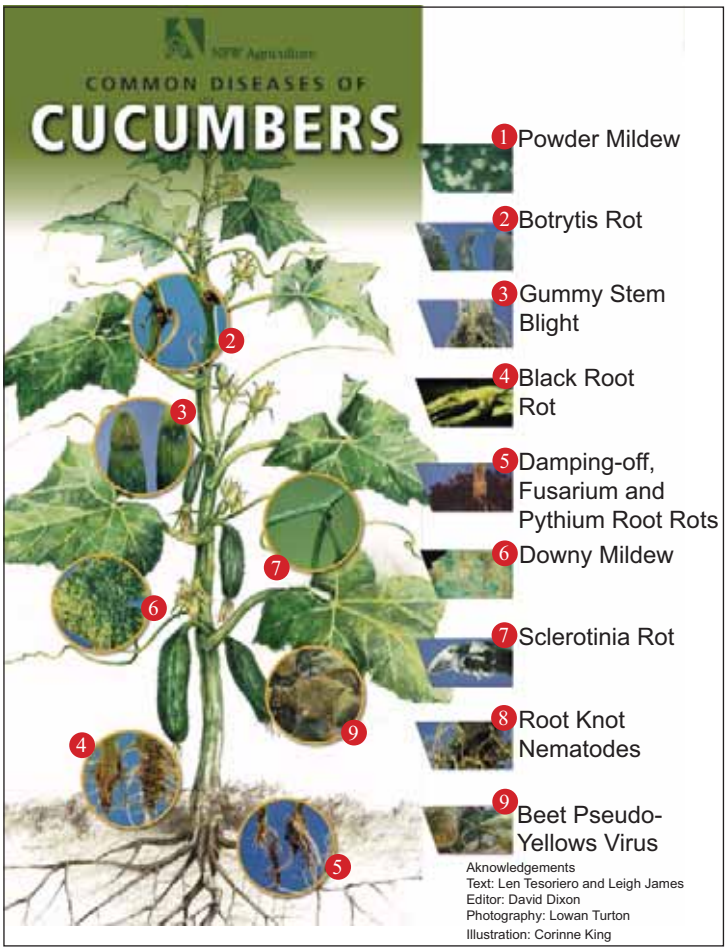
In NSW, the project interacts with an industry providers group comprised of resellers, company representatives, researchers and extension people. The group is aims to improve industry cohesion and communication in the Sydney basin (home of the largest Lebanese cucumber production area in Australia).

It also provides on-going support to the State greenhouse growers' association, Greenhouse Vegetables NSW. These two groups address issues affecting intensive horticulture in the region, including greenhouse vegetables.

Finally, a national greenhouse vegetables email chat line, *ListServe*, has been established. While the use of the internet and email is still relatively new to many growers, the technology has been utilised to provide an on-going opportunity for growers to network and source information. This resource, like the manual and posters, will continue to provide opportunities for growers to learn well beyond the conclusion of this project.

This project has not only established better access to commercial greenhouse cucumber production information, it has also helped industry members gain a better understanding of Industry roles, needs and opportunities. For example:

- better knowledge of the AusVeg levy
- understanding the pesticide permits process
- the need to promote R&D priorities.



The development of good relationships and industry linkages has enabled growers around Australia to meet researchers, learn about what they do and gain an understanding of R&D and how it improves greenhouse cucumber practices and profitability.

Futher Information

For further information, contact The NCGH
Ph 02 4348 1900 www.agric.nsw.gov.au
OR contact you State Vegetable IDO

Acknowledgements

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Greenhouse Cucumber Diseases

In an effort to develop effective management strategies, research project VG00069 studied greenhouse cucumber diseases and their causes.

The most important disease detected across Australia was a root rot, stem and wilt that frequently caused one third of plants to die prematurely.

Plants wilt and die soon after transplanting and right throughout the life of the crop, particularly when plants are carrying a heavy fruit load.

Many growers suffering losses from this disease terminate crops early as their yields diminish.

Plants collapsing from Pythium and Fusarium root rots.

What is a disease complex?

Many textbooks and factsheets on plant diseases describe individual diseases with a single causal organism, such as Powdery Mildew or Downy Mildew diseases of cucumbers.

A disease complex is where more than one causal organism act together. In some cases, they can interact so their combined effect is greater than the sum of their individual effects.

For example, let us say Fungus A causes 5% of plants to wilt and die, and Fungus B has a similar effect. We would expect 10% of plants to be lost if both fungi were present.

However, in practice it was found that plant losses exceeded 50%. This is called a synergistic interaction and, as can be seen from this example, can lead to far more serious losses than when the effects are simply added together.

What causes this disease complex?

There are many different fungal pathogens that can cause cucumber seedlings to wilt and die, known as ‘damping-off’.

The Bottom Line

- The most common greenhouse cucumber disease detected across Australia is root rot, stem and wilt
- A disease complex is where more than one causal organism act together
- There are currently no chemicals for this disease, however it can be managed with certain farming conditions and good hygiene practices

Environmental conditions and crop hygiene play an important role in the incidence and severity of 'damping-off' losses.

In cucumbers, *Pythium, Phytophthora, Fusarium, Rhizoctonia* and a few less common fungi are associated with these losses. They may occur individually or as a combination.

The more serious losses found during this research project occurred when a combination of *Fusarium oxysporum* and various *Pythium* species continued to cause plants to wilt and die throughout the life of the crop.

The major *Pythium* species found causing root rots in greenhouse cucumbers in Australia include:

- *P. aphanidermatum* and *P. deliense*, which favour warm temperatures and can grow at temperatures in excess of 40ºC
- *P. spinosum* and *P. irregulare*, which favour cool to moderate temperatures and can grow at 5ºC
- *P. ultimum*, which favour moderate temperatures between 10-30ºC

What symptoms distinguish this disease?

Infections occurring through roots cause them to turn from white to a creamy-yellow colour.

Initial symptoms above ground are pale-yellow to brown rots at the base of stems (Picture 1). In the middle of the day, leaves may tilt downwards or be slightly wilted. If left untreated, plants permanently wilt and die.

Fusarium infects the water-conducting tissue (xylem) and moves into stems from root infections. *Pythium* generally remains in the outside ring of root tissue, and can also move into lower stems (Picture 2).

F. oxysporum has one distinguishing feature in that it causes a stem rot, the outside of which becomes covered in powdery orange spore masses (Pictures 3 and 4). Maggots of sciarid flies (fungus gnats) can become numerous in the crown and larger roots as the disease develops.

Picture 1: Early symptoms of Pythium *and* Fusarium *infections are pale bleached tissue near the stem bases.*

Picture 2: Pythium *and* Fusarium *infections develop into a watery brown rot at the base of stems.*

Picture 3 (above) and 4 (below): Typical symptoms of Fusarium *stem rot are reddish-brown rotted areas on which salmon-pink masses of fungal spores form that spread through the air or through handling.*

Pythium *root rot causing a young cucumber plant to collapse.*

Where do these fungi come from and how are they spread?

Pythium species are widely distributed in nature and can infect a wide range of plants. They are commonly known as water moulds and can enter untreated water supplies.

Some species produce minute motile spores that rapidly swim towards and infect roots.

Other types of spores have thickened walls that can survive drier conditions and become soil and air-borne. *Fusarium* have a more restricted host range but also produce spores that are very resistant to drying out.

F. oxysporum can be spread through the air or easily spread when plants are handled from the orange spore masses on stems. The adult sciarid flies can also spread spores of both *Fusarium* and *Pythium*.

What management strategies can be used to control this disease?

The choice of management options partly depends on correct diagnosis and the production system currently being used. Use a reputable diagnostic laboratory to give you an accurate diagnosis, and remember there are other diseases and disorders that can cause plants to collapse which should not be confused with this disease complex.

Also, there are no chemicals (excluding soil fumigants) currently registered for controlling these pathogens. Therefore, cultural controls feature heavily in this list of strategies:

- Use clean seed that has good vigour and has been stored correctly. Old seed is more susceptible to these pathogens.
- Avoid stress to plants by optimising timing of fertiliser applications and irrigation. Avoid long irrigation periods and high fertiliser rates.

  High rates of soluble fertilisers burn the surface tissue of roots and allow these fungi to infect. Root tips and root hairs are killed when soluble nutrient levels have an EC measurement of 3.5–5.0 mS/cm.

continued over page

- Avoid low oxygen conditions developing in the root zone. Excessive watering and high temperatures can cause these conditions. Similar conditions can result from poorly aerated root substrates or soils. These conditions predispose plants to infection.

  Reusing substrates or repeatedly cultivating soils can change their structure, which results in poorer structures and low oxygen levels in the root zone.

- Cold and wet soils or root substrates also predispose plants to infection, particularly to certain *Pythium* species.

- Practice good farm and crop hygiene. If possible, have concreted or sealed paths that can be cleaned of organic matter and disinfected. Remove crop residues and infected plants carefully to avoid spreading spores and infecting surrounding plants.

  Use trolleys with plastic liners and put infected material directly into them rather than allowing organic matter to sit on the ground or dragging crop residues through the house.

  Schedule 'dirty' operations so that workers do not enter 'clean' areas afterwards without washing up and changing clothes.

  Disinfect pruning tools and use footbaths at greenhouse entrances. Ensure that disinfectants are changed regularly, particularly when they become dirty, rather than on a calendar basis.

- Disinfect and regularly test the water supply to ensure it does not carry these fungal pathogens.

  This may not be necessary where sanitised town water is used, but remember any stored water can be contaminated, and reused water is likely to require disinfection.

- Soil can be fumigated before planting. Ensure fumigation treatments are applied correctly because these fungi can quickly recolonise soils.

  Do not bring dirty machinery or contaminated footwear into greenhouses or allow untreated soil to come into contact with sterile soil soon after fumigation. Remember these fungi can blow in and recolonise fumigated soil.

- Quality composted organic matter used as root substrates or incorporated into soils can suppress this disease.

- Certain commercial microbial products (biocontrols) can be added to soil or substrates and suppress this disease.

  Note that they are preventative treatments and are less likely to succeed after the disease has occurred.

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Freshcare

The fresh produce industry is recognised as being proactive in implementing effective food safety programs throughout the supply chain. From primary production to retail shelf, the fresh produce industry is ahead of many other Australian agribusiness sectors.

Freshcare has been developed as a national, industry-owned food safety program suitable for all growers of fresh produce, including organic growers. Freshcare Limited was formed in 2000, as a not-for-profit company, to manage the Freshcare Program on behalf of the horticultural industry.

The program aims to:

- provide a simple, cost effective option for fresh produce producers to implement their own on-farm food safety systems
- support the industry as a whole with a program that, through independent third party assessments, provides confidence in the food safety status of fresh produce
- support retailers, wholesalers, packers and processors with an upstream (on-farm) program, focused on food safety, that integrates effectively with their own quality and food safety systems

On-farm, Freshcare has become the industry's most widely adopted food safety program, with membership exceeding 3000 growers nationally.

Freshcare components

The Freshcare Program is based on Hazard Analysis Critical Control Points (HACCP) principles (refer to 'Quality Assurance' VEGE*note*).

In developing the HACCP plan that underpins Freshcare, potential on-farm food safety risks for the fresh produce sector were identified and assessed.

This information was used to establish farm practices and requirements to control potential problems. The Freshcare Code of Practice was then developed from this plan. The Code requires risk assessments to be completed for inputs such as water, chemicals, fertilisers and soil.

The Code of Practice describes the on-farm practices growers need in place to ensure they are meeting the food safety and quality requirements of both customers and consumers.

Freshcare is just one of the many Quality Assurance systems available to help ensure the quality of fresh produce in Australia.

The bottom line

- **Freshcare is industry owned**
- **Implementing the Freshcare Program costs approximately $1000-$1200* in year one. The cost of maintaining the program is about $550-$650 per year**
- **Most growers take 3-6 months to undertake training, implement changes and achieve certification**

*(Farmbi$ or alternate funding may be available to assist with costs)

While the basic Freshcare Program addresses food safety issues, optional modules are being developed for the management of environmental practices as well as on-farm safety and welfare issues. This will ultimately lead to providing an option for EurepGAP equivalence for those members for whom EurepGAP compliance is an export market requirement.

How is Freshcare managed?

The Program was developed with the support of key industry associations and with initial funding from Horticulture Australia Ltd, under the AUSHORT Program.

Freshcare Limited's ownership is made up of national and state industry associations, including AUSVEG. A Board of Directors is selected from the owner associations. The Freshcare office, located in the Sydney Fresh Produce Markets, undertakes the day-to-day management of the program.

How to get involved in Freshcare

Training is key to the effective implementation of the Freshcare program on-farm. The aim is to ensure there is a clear understanding of the issues impacting on food safety and the practices required to manage them.

Access to the Freshcare Program is designed to be as simple as possible, from initial registration to full certification.

The trainers are responsible for Freshcare enrolment and program administration (Farmbi$ funding if/when available), leaving participants to focus on training and the implementation and adoption of Freshcare.

Training is designed to best meet the needs of the individual grower and can be scheduled as one-on-one, group sessions or distance education. Prior learning will be acknowledged when growers have participated in other recognised food safety programs or training.

On completion of training, an Initial On-Farm Assessment is scheduled to ensure the delivery of the training has been effective and the program has been successfully implemented on-farm. In subsequent years an Annual Third Party Audit is conducted by a Freshcare approved auditor.

Having successfully become Freshcare Certified, growers are issued with a Freshcare Certificate with their own unique number. The Freshcare Certification Number and logo can be used for marketing products and to demonstrate to customers that the grower is effectively managing food safety.

Grower Andrew Braham (cucumbers, capsicums and tomatoes), from Virginia in South Australia, became a certified Freshcare member in July 2004.

"I decided to become Freshcare certified because it gives you that little bit more recognition within the industry. Some of my wholesalers supply Woolworths and Coles (who require Freshcare or another approved QA system). As for my other wholesalers, if they can say that their grower is Freshcare certified then this would obviously benefit them, and me, in the long run. Being certified also makes you feel like you are taking more of a part in the industry. I had no problems implementing the Freshcare system. The team were very helpful and have provided on-going assistance. I will definitely be renewing my membership in the future. It might mean more paper work, but this also gives you accurate records to look back on in the future."

Further Information:

For Freshcare Trainers and upcoming training courses in your area, visit www.freshcare.com.au or contact:

Clare Hamilton-Bate
National Program Manager
Freshcare Ltd
ph: (02) 9764 3244

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Quality Assurance for Growers and Packers

The new National Food Safety Standards, enforceable since February 2001, apply to processors, wholesalers and retailers, while also implicating growers and packers. Currently growers and packers are exempt from meeting these standards, unless processing on-farm or selling direct to the public.

However, as businesses handling food are required to ensure they only accept uncontaminated produce, growers and packers will also need to implement Quality Assurance (QA) systems in the near future.

Retailers such as Woolworths/Safeway, Coles and Metcash/IGA have largely met the requirements with more than 90 percent of direct supplying packers and wholesalers certified to an acceptable system.

Apart from meeting legal and/or customer requirements, QA systems also reduce waste, downtime, rejects and repacking. The cost of implementing and maintaining the system can be easily justified if just one problem is avoided each year.

There are a range of options available when choosing a QA system, including:

Approved Supplier Programs

Developed by wholesale, food service or processor customers to address specific food safety and quality hazards. Some of the lower end programs are becoming unsuitable for fresh produce because they do not meet retailer requirements, even though they still meet processor requirements. A guide for developing a program is available from the author.

QA ensures that the best produce reaches the consumer

Freshcare

An externally audited Code of Practice based on a generic HACCP Plan rather than requiring a HACCP Plan for each business. A prescriptive approach designed for growers who supply packers, wholesalers and processors. Freshcare is being sought by many wholesalers and is owned, managed and endorsed by most of the major peak industry associations. Further information can be found at www.freshcare.com.au.

Hazard Analysis Critical Control Point (HACCP)

An internationally recognised preventative approach to managing food safety hazards, it is auditable in its own right and forms the basis of a number of other codes. HACCP requires an analysis of all production processes (planting, pest management, harvest, storage, packing, etc) to identify food safety hazards (chemical, microbiological and physical contaminants). This is followed by identification of critical points in the processes to determine where and how hazards will be controlled. Further information can be found at www.codexalimentarius.net.

The Bottom line

- Growers and packers will have to implement systems in the near future, if they haven't already
- The system chosen must meet the needs of the business, as a direct or indirect supplier, while also being acceptable to customers
- Most QA systems articulate well, thus moving up a level (or down if necessary) can be done with relative ease

SQF 2000CM and SQF 1000CM

These both incorporate HACCP with some additional requirements from ISO 9000 (the international QA benchmark). SQF 2000CM is suitable for packers, while SQF 1000CM is more appropriate for growers. The SQF programs focus on both quality and food safety, with quality hazards also identified in the HACCP Plan. SQF 2000CM is now gaining recognition from European retailers. Further information can be found at www.sqfi.com.

Woolworths Quality Assurance Standard (WQA)

Mandatory for all direct fresh food suppliers and indirect suppliers who pack Woolworths-branded produce, it focuses on individual product quality and safety. Although WQA is available on the Woolworths website, vendors participate by invitation only. WQA includes a HACCP Plan, significant support programs and the need for certified suppliers. Further information can be found at www.woolworths.com.au/vendors.

ISO 9000 and ISO 9000 plus HACCP

Apply to larger processors and packers. There are 80 horticultural businesses, including wholesalers, certified to ISO 9000 in Australia. Further information can be purchased at www.standards.com.au.

Further Information

Richard Bennett, Horticulture Australia
03 5825 3753 or richard.bennett@horticulture.com.au
The new food standards can be found at www.foodstandards.gov.au.

Acknowledgements

Richard Bennett, Horticulture Australia Limited

There are other programs that encompass environmental management and farm safety currently being considered for use in Australia.

EurepGAP

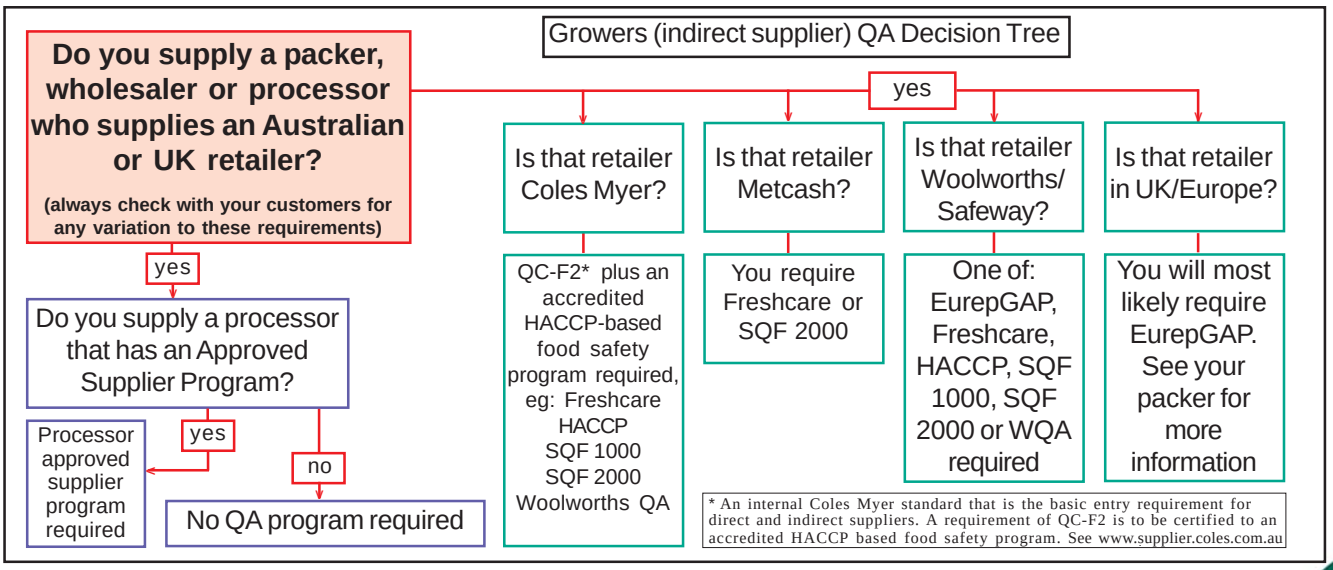
The European retailers Good Agricultural Practice protocol (EurepGAP) is of increasing interest as a significant number of Australian horticultural businesses are certified, or are working towards certification, to meet compliance deadlines stipulated by UK/ European retailers and importers. A guide for Australian growers is currently being compiled and should be available soon. Further information can be found at www.eurep.org.

Enviroveg

A self-assessment tool, which allows growers to compare current farming practices with a set of realistic and practical environmental performance measures. Growers complete the checklist annually, allowing them to see progress over time. Growers assess the areas where they would like to improve their performance and then implement the relevant practices. Further information can be found at www.enviroveg.org.

Managing Farm Safety

A program developed by Farmsafe Australia to develop skills in risk management of farm safety - an approach in line with the way other farm business risks are managed. Further information can be found at www.farmsafe.org.au.



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Cool Chain

What is the Cool Chain?

Every process in the journey of delivering vegetables, right from the field through to the consumer, can be thought of as a link in a chain. When the optimum temperature of the vegetables is maintained from start to finish it is a 'Cool Chain'.

The Cool Chain: vegetable temperature management from Grower through to Consumer.

The *aim* of the Cool Chain is to:

- Deliver vegetables in fresh-picked condition
- Guarantee customer satisfaction
- Ensure consumer confidence and repeat purchases

By meeting the *aims*, the following *benefits* can be delivered:

- Increased sales of vegetables
- Higher prices and better margins
- Better profits for everyone involved
- Reduced wastage

Consumers want vegetables that look, smell and taste fresh.

This is achieved by harvesting vegetables at their optimum in the field. However, as soon as they are harvested quality begins to deteriorate.

To deliver the fresh vegetables consumers are looking for, deterioration must be slowed. The best way to achieve this is to quickly cool vegetables and maintain the temperature throughout the marketing chain.

Managing the correct temperature of vegetables through the Cool Chain benefits vegetable quality by minimising:

- weight loss
- wilting
- softening
- limpness
- bruising
- texture degradation
- colour changes
- the growth of rots, moulds and other organisms

The Cool Chain in Action

The Cool Chain is working when the optimum temperature of the vegetables is maintained at every step, between the grower and the consumer. Vegetables change hands many times during the journey and each change is a potential break in the Cool Chain.
Everyone who handles fresh vegetables during

The bottom line

- **Produce quality is directly related to Cool Chain management**
- **Produce must be handled correctly from the beginning of the chain**
- **Probe thermometers are a vital tool for temperature monitoring**
- **Temperature data loggers collect temperature details throughout the chain and allow timely improvements to be made when necessary**

this process needs to be actively aware of the Cool Chain, including:

- growers and their workers
- packers and staff
- transport companies and truck drivers
- wholesalers and distribution centres and staff
- retailers and staff at retail shops
- consumers

The Produce Handling Guidelines poster shows the optimum storage and transport conditions for a wide range of vegetables.

Without cooperation from all of these groups, the vegetables would not reach the consumer in the best possible condition.

People often wonder how vegetables can look so good in the field yet so bad by the time they get to the shop. Each sector (grower/packer, transporter, wholesaler, retailer) often blames the other. A small break in the Cool Chain can create a big problem in product quality when it reaches the consumer.

Starting the Cool Chain

Quality vegetables for the consumer starts with good quality in the field. With all the time, effort and expense required to grow vegetables it is critical that the final steps of harvesting, packing, cooling and transporting do not cause damage or premature deterioration.

Growers need to follow best practice methods of harvesting to preserve the physical appearance and condition of the vegetables, these include:

- careful harvesting
- picker instruction & supervision
- using clean picking containers
- placing, rather than dropping vegetables
- gentle handling and transportation

The Cool Chain needs to start the moment vegetables are harvested. Harvesting vegetables when they are cool gives the Cool Chain a good start.

One technique is to harvest early morning or at night, with some vegetables benefiting from using sprinklers prior to harvest to keep them cooler.

Once harvested, it is sensible to avoid letting the vegetables heat up. They should be kept in the shade (or covered) to avoid an increase in temperature. Regularly transporting harvested vegetables back to the shed for cooling and/or packing will also help maintain temperature.

Research shows that vegetables not at the appropriate temperature before being transported to the market are rarely ever properly cooled.

Transport vehicles are not designed to cool but only to maintain the temperature of pre-cooled produce. It is the responsibility of the grower/packer to start the Cool Chain by properly cooling the vegetables at packing.

Growers may be tempted to send produce to market without proper cooling to save time but it should be a priority. Harvest, packing and cooling times need to be organised to allow sufficient cooling time prior to transportation.

Growers can gain even more flexibility by using rapid cooling techniques, which can drastically cut the cooling time compared with simply standing vegetables in a cool room. Rapid cooling also benefits product quality by quickly reducing the rate of deterioration.

Rapid Cooling

Forced-Air Cooling is a Breeze

Forced-air cooling is fast. It can easily cool most vegetables within 6 to 8 hours, and often considerably faster. Forced air cooling can be used on just about any container type, from the field or as a final packed product providing the container has suitable ventilation.

A forced-air cooling system can be set-up within many existing cool rooms.

Basically, a dedicated fan draws cold air through the containers and directly over the individual vegetables in each container. It is much more efficient than simply leaving the boxes of vegetables on pallets sitting in a draught of cold air.

Forced-Air cooling is a rapid cooling method that is simple to set-up and run. More information on cooling methods is available at the SARDI Cool Handling website.

Rack Cooling

Rack cooling is a variation of basic room cooling that increases the air flow over each container of vegetables. Each container is placed onto a racking system so air can flow around each container. There is a requirement of extra handling in the system to re-stack the produce in the cool room. For most situations forced-air cooling is a better option.

Hydro-cooling

Hydro-cooling is the process of cooling produce by immersion or exposure to cold water. There are two main types available, shower or immersion type coolers. Both systems can be performed in-line along a conveyor belt or loaded as a batch. Only vegetables tolerant to water contact are suitable. Cooling is very fast, although it is dependent on product size and type. Water must be free from decay organisms and pathogens. As most systems recirculate water, a sanitation system is usually required.

Vacuum Cooling

Vacuum cooling is another very rapid cooling technique. The mode of cooling is quite different from the other systems listed.

It works by placing produce in an airtight chamber, reducing atmospheric pressure inside the chamber, which consequently reduces produce temperature by evaporating water from within the produce itself. It is typically used on leafy vegetables where there is a high surface to volume ratio.

Specially designed vacuum coolers can also shower water through the vegetables. The introduction of water into the system enables other vegetable types (such as carrots) to be successfully vacuum cooled.

One of the key advantages of the vacuum cooling is that vegetables can be rapidly cooled, even when they are packed (provided the packaging is not airtight).

Package icing and Liquid icing

Placing a layer of ice on top of warm produce will not adequately or evenly cool vegetables. This process should only be used to assist in maintaining vegetable temperature. To properly cool produce, the ice needs to come in contact with all the vegetables in the container. This can be achieved by liquid icing, where a water/ice slurry is injected into containers of vegetable to cool them.

Measuring Temperatures

Instinctively, when we want to check the temperature of something, we feel it. But touching vegetables isn't a very good way to establish temperature.

That will only give a rough indication of its surface temperature. Furthermore, simply looking at the temperature read-out on the outside of the cool room doesn't give the product temperature either. To properly understand what is happening in the Cool Chain we need to measure vegetable temperatures.

Probe to the middle

The only way to be really sure of pulp temperature is to measure it with a probe thermometer that pierces to the middle of the vegetable. This is particularly important with larger vegetables. Digital probe thermometers are cheap and every packing operation should have at least one. Only by probing produce can you really understand what the temperature of your produce is in the field, during packing and in the cool room.

Probe thermometers are the only way to properly measure vegetable core temperature.

Data Loggers

There are also continuous temperature monitors, known as temperature data loggers. There is a large range available; loggers with probes are particularly useful.

Temperature loggers are very compact and can easily fit in a box along with the produce. To retrieve the results the logger is attached and downloaded to a computer.

Loggers can be placed with produce in the field and temperatures tracked right through to the destination market.

The information collected can then be used to identify if and where any breaks in the Cool Chain are occurring. The results collected are often quite surprising, and with the decreasing cost of loggers, it is something all vegetable producers should be involved with.

Summary

The Cool Chain is important for delivering high quality vegetables to the consumer. Consistent high quality will help to drive sales and encourage repeat purchases. To achieve this, everyone involved with handling vegetables must ensure that the temperature is maintained through good postharvest practices.

The chain will only ever be successful if the product is handled correctly from the start. Vegetables should be handled carefully and cooled quickly and thoroughly prior to shipment.

To ensure good temperature management is in place, vegetable temperature should be measured with a probe thermometer.

Temperature data loggers can measure temperatures right through the chain, and the information gathered used to implement improved Cool Chain procedures.

Further Reading

SARDI Cool Handling website: http://www.sardi.sa.gov.au/coolchai

Available from the PIRSA Resource Centre, 1800 356 446:

- Produce Handling Guidelines poster, SARDI
- *Vegetables: Quality is Cool* (1999) by M. Palmer and A. Dahlenburg, SARDI

SARDI

SOUTH AUSTRALIAN RESEARCH AND DEVELOPMENT INSTITUTE

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Horticulture Australia

Management of Carrot Diseases

Common leaf diseases

Leaf blight

Leaf blight is an extremely common, quickly spreading fungal disease that initially occurs as patches within crops. The symptoms of leaf blight are small brown, dead spots on the leaves and petioles (leaf stalks). These spots grow rapidly and eventually join so that the leaf yellows and dies. The petioles also break during harvesting.

There are two types of leaf blight, Alternaria and Cercospora. Alternaria leaf blight is caused by *Alternaria dauci* and/or *A. radicina* and usually first appears on the oldest leaves. Cercospora leaf blight is caused by *Cercospora carotae* and appears on the youngest leaves first.

Disease cycle

Both Alternaria and Cercospora can be carried on carrot seeds and once introduced into an area will survive on carrot debris. They can spread easily during rain or irrigation and can also be carried on machinery.

Control

- Disease control is difficult on farms where carrots are planted sequentially
- Some carrot varieties are more tolerant of leaf blight than others
- Use seed that has been treated with fungicide
- Use fungicide sprays, such as chlorothalonil, copper, difenoconazole, mancozeb, metiram and zineb. Start the spraying program when the first sign of blight appears


Symptoms of leaf blight.

Common root diseases

Sclerotinia or cottony rot

Sclerotinia is a common fungal disease that affects many vegetables. It affects carrots both in the field and in storage and is caused by the fungus *Sclerotinia sclerotiorum*.

In the field, the first symptoms are water-soaked spots at the base of the petioles and at the crown. The outer leaves redden and wilt. There is often a white, cottony fungal growth in the surrounding soil. Eventually the top of the carrot becomes soft and slimy.


Symptoms of sclerotinia.

The Bottom Line

- Fungal, nematode, viral and bacterial diseases can affect carrots at any stage of the crop, from seedlings to cold storage
- Root and post-harvest diseases affect marketability of carrots, while foliar diseases affect the yield of crops
- For export, growers should ensure that chemical use complies with the maximum residue limits of the importing country

If slightly infected carrots are harvested the rot continues to develop during storage and can spread to adjacent carrots.

These carrots then develop a soft, watery, slimy rot at the crown. A white cottony fungus develops from this rot; it often contains small black sclerotes that look like mouse droppings.

Disease cycle

Sclerotinia is a common and widespread soil borne pathogen, with a host range that includes both commercial crops and weeds. Black, hard sclerotes form on infected plant debris and these persist in the soil for up to five years.

Sclerotes close to the soil surface infect old leaves and petioles. The infection spreads down the petioles to the crown, resulting in rotting at the top of the roots.

Control

- Deep ploughing buries sclerotes formed on the soil surface
- Check at www.apvma.gov.au to determine which fungicides are registered for controlling sclerotinia
- Post harvest losses are minimised by reducing mechanical damage during harvesting, by rapid cooling and storing carrots at 0°C

Cavity spot, damping off and root forking

Cavity spot is a widespread problem in Australia. It is particularly severe when carrots are grown with limited rotation. Affected carrots have small brown spots (usually less than 10mm in diameter) on the surface. Cavity spot develops rapidly on carrots that are close to harvest or over mature.

Cavity spot is a fungal disease caused by either *Pythium sulcatum* or *Pythium violae*. *Pythium sulcatum* occurs throughout all carrot growing regions of Australia. *Pythium violae* only occurs along the River Murray and in South Australia.

Seedling infection by pythium is a common cause of damping off.

Tap root infection is a cause of root forking.

Symptoms of cavity spot.

Disease cycle

Pythium spp. are soil borne pathogens that persist as resting spores between crops.

Pythium sulcatum only infects carrots and closely related plants, it can survive for at least two years between carrot crops. *Pythium violae* has a much wider host range and can survive for at least five years between carrot crops.

Cavity spot caused by *Pythium sulcatum* is most severe in summer and autumn harvested crops, while cavity spot caused by *Pythium violae* is most severe in winter harvested crops.

Control

- Cavity spot control is difficult on farms with limited rotation
- Grow varieties such as Stefano and Navarre that are tolerant to cavity spot
- Do not allow carrots to become over mature
- Metalaxyl will reduce pythium diseases when used at, or shortly after, seeding. If used frequently, metalaxyl may become ineffective due to enhanced microbial degradation
- High soil pH can suppress cavity spot, however enhanced microbial degradation develops more rapidly on soils with high pH. Maintain soil pH in the range 6.5-7 in water (5.8-6.3 in $CaCl_2$)
- When *P. sulcatum* is present, rotate carrots with unrelated crops e.g. broccoli, lettuce and onions. Where *P. violae* is present rotate carrots with non-hosts e.g. onions, maize, potatoes and beans

Root knot nematode

Carrots are very susceptible to root knot nematode. This is a serious soil borne disease that is difficult to control and symptoms include root forking and galling. Infection is usually patchy within a crop; plants are uneven and wilt easily.

There are several species of root knot nematode that infect carrots in Australia. The most common species is *Meloidogyne javanica*, which occurs in South Australia, Victoria and Western Australia. Other species include *M. hapla* which is found in Victoria and Western Australia, while *M. fallax* occurs in Tasmania.

Disease cycle

Root knot nematodes are difficult to control because they have wide host ranges. They are more usually a problem in sandy soil. Root knot nematodes survive between crops on alternate hosts and in egg masses in the soil.

When conditions are suitable, the eggs hatch and juvenile nematodes penetrate root tips. Female nematodes mature within the roots and a gall develops around the nematode. These females lay eggs into a gelatinous matrix on the root surface. The eggs either hatch immediately or become dormant.

Control

- Soil sampling to assess nematode numbers before seeding is not always a reliable indicator of whether a nematicide needs to be applied
- Preplant fumigation with 1,3-dichloropropene, 1,3-dichloropropene + chloropicrin, fenamiphos or metham sodium. If these chemicals are used frequently they may become ineffective because of enhanced microbial degradation
- Use a bare fallow between susceptible crops
- Rotate carrots with a non-host crop. The choice of non-host will depend on which *Meloidogyne* sp. is present
- Where *Meloidogyne javanica* is present, seed carrots in winter

Symptoms of root knot nematode.

Root lesion nematode

Root lesion nematode causes reddish and brown patches on tap and lateral roots. The mature carrots are stunted.

Symptoms of root lesion nematode: the two seedlings on the left have reddish patches caused by nematode infection, the two seedlings on the right have healthy roots.

The four species of root lesion nematode in Australia that infect carrots are: *Pratylenchus crenatus*, *P. neglectus*, *P. penetrans* and *P. thornei*.

Disease cycle

Like root knot nematodes, *Pratylenchus* are difficult to control because they have wide host ranges, including cereal nurse crops. They are a problem in sandy soils and survive between crops either on alternate hosts or as eggs in the soil.

When conditions are suitable, the eggs hatch and juvenile nematodes penetrate carrot roots. The nematodes migrate and multiply within the roots.

Control

- Sample soil to assess nematode numbers before seeding to determine whether a nematicide needs to be applied
- Preplant fumigation with 1,3-dichloropropene, 1,3-dichloropropene + chloropicrin, fenamiphos or metham sodium. Minimise use due to the potential for enhanced microbial degradation

Carrot virus Y (CarVY)

CarVY is a serious disease, spread by aphids and occuring throughout Australia. It infects carrots at any stage and is most severe where carrots are grown all-year-round.

The leaves of infected plants develop a mild feathery mottle. The most severe symptoms are stunted and distorted roots, which occur when young plants are infected.

Symptoms of carrot virus Y.

Disease cycle

CarVY is difficult to control on farms where carrots are planted sequentially all year because infected volunteer carrots and adjacent crops provide inoculum sources for new crops.

CarVY is spread non-persistently by aphids, i.e. the aphids acquire the virus rapidly when feeding on infected leaves, but rapidly lose it when feeding on healthy plants.

CarVY only infects carrots and closely related plants e.g. parsnip, coriander and chervil.

Control

- Avoid planting sequential side-by-side crops and separate crops by planting non-hosts, such as brassicas, between them
- Remove volunteer carrots and harvested carrot crops promptly
- Use a fallow period to break the infection cycle

Common post-harvest diseases

Bacterial soft rot

This is a soft, slimy, orange rot that can occur on any part of the carrot, although it is often associated with the eyes. The rot can penetrate deeply. It does not usually smell unpleasant unless there is secondary infection caused by other bacteria.

Soft rot is caused by either *Erwinia carotovora* subspecies *carotovora* or *E. carotovora* subspecies *atroseptica*.

Symptoms of bacterial soft rot.

Disease cycle

Erwinia spp. are common soil bacteria that survive on crop residues. Carrots are likely to be contaminated with soft rot bacteria in the field before harvest. However, these bacteria are readily spread in washing water during post-harvest handling.

Soft rot bacteria enter carrots through wounds, but they can also be forced into the eyes if warm carrots are dumped into deep cold water tanks. Once the bacteria are in the carrot root they cannot be killed by sanitisers such as chlorine.

Control

- Losses caused by soft rot bacteria can be minimised by cooling carrots as soon as possible after harvest and then storing them at 0°C
- Minimise mechanical damage during harvesting and in the packing shed

Black root rot

Two fungi cause black root rot: *Thielaviopsis basicola* (*Chalara elegans*) and *Chalaropsis thielavioides*. Roots affected by black root rot have large black superficial patches on them. These patches are often circular and sometimes surrounded by a matt white halo.

Disease cycle

The fungi that cause black root rot have a wide host range and occur in soil. Carrots are likely to be contaminated with these fungi in the field before harvest.

After harvest the fungi infect carrots through wounds or abrasions. They develop rapidly on carrots stored at 25°C and in high humidity.

Symptoms of black root rot.

Control

- Losses caused by black root rot can be minimised by rapid cooling of harvested carrots and storing them at 0°C
- Minimise mechanical damage during harvesting and in the packing shed

Sclerotinia rot or cottony rot

See Sclerotinia above.

Further Information

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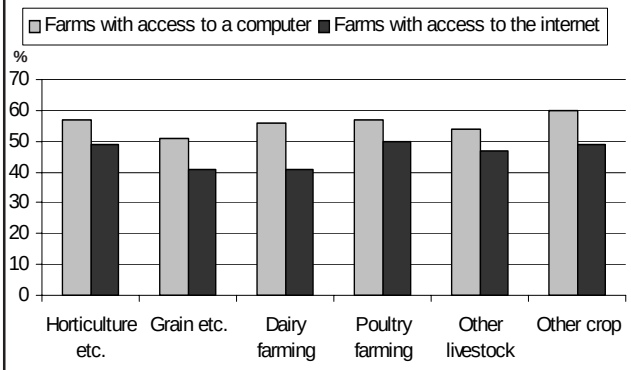
Utilising Computers to Enhance Farm Business

The use of computers on farms for business such as E-commerce (buying and selling goods), banking, emailing, information recording (paddock records, bookkeeping) and research (using the internet) is increasing at a record rate.

Used in conjunction with specialist programs to help with forward planning, finances and production issues, a computer can greatly improve farm profitability. Initially, computing (particularly the internet) can seem daunting, but it can be a very rewarding experience.

Internet usage by primary producers has increased from about 10% in 1998 to more than 50% in 2002 (Australian Bureau of Statistics). Horticulture is similar to other production industries for farm computer and internet usage.

Farms using a computer or the internet, by industry



From Australian Bureau of Statistics, Use of Information Technology on Farms. 8150.0, page 11 June 2002

Choosing a computer

If you have limited computer or program knowledge it is important to ask for advice. You don't always need the latest technology, but new computers are entering the market constantly and the range can be very confusing.

Connecting to the internet

To send and receive email, and search for information on the internet, your computer will need to be connected to the telephone system (as with a fax) and you will need an account with an Internet Service Provider (ISP) such as Telstra Bigpond.

If using a normal telephone line, you will need a modem to connect the computer and the telephone socket. This may be a separate unit or built into the computer. If you do not have a separate line for your computer, then you will have to share with a fax or telephone. Sharing with the fax line is preferable if you have a dedicated line as you will still be able to make and receive calls on your other line while connected to the internet.

When choosing an ISP, ensure you can connect for the cost of a local call, otherwise you will be charged STD rates. You will usually pay by the hour, although there are many deals available. Choosing an ISP is similar to choosing a mobile phone provider – lots of confusing deals, so make sure you seek advice if unsure.

If connecting using ADSL or ISDN, which provide a faster and better service, seek advice as to what you require, as modems are not used.

For people in very remote areas, satellite connections are possible where normal landlines

The Bottom line

- Computers, like any other farm tool, are invaluable if used to benefit the business.
- Establishing a computer system takes time and effort, but is worth it in the long run.
- You must remember to gain the skills required to use your computer.
- Aways ask for advice if unsure. Your state IDO can help you get started.

are not available or are of such poor quality that they are unable to be used.

It is also possible to access the internet via a wireless connection, which utilises mobile phones equipped with GPRS or an equivalent service. However, these are sometimes slower and more expensive than landline options. They tend to be used by people who work in the field.

The internet

Searching the internet can be as daunting as buying your computer, but with a little experimentation with search engines such as Google (www.google.com), you will find information with ease. Remember, particularly with respect to overseas information, that information may not always be relevant to your farming practices. Are the chemicals mentioned registered in your state? Are the pests the same ones? Are the soil types, rainfall and temperatures in the regions mentioned similar?

Farm programs

There are a few programs to aid the business of farming, including property management planning, Integrated Pest Management and financial planning. Talk to someone who is using the program to see if it fits your needs and has the support needed. There are also websites, such as farmcentre.com, which have linked much of the farm software available. The Rural Industries Research & Development Corporation (RIRDC) have published two books, 'The Farmers Guide to the Internet' and 'The Rural and Regional Guide to E-commerce'.

Email

Email is fast becoming a major method of communication for businesses and information exchange. There are, however, some simple rules to follow:

- etiquette - get to the point and keep it simple
- email - avoid sensitive information in email
- do not type in UPPER CASE (this is the same as yelling), send junk mail (Spam - which is simply unsolicited information) or send large file attachments.

Protecting your computer

Computer viruses are the "common cold" of modern technology and are designed to interfere with your computer and frustrate users. They are normally sent by email, usually in attachments, so it is important that you install a virus protection program and personal firewall. A firewall stops people trying to gain access to your computer.

"I don't know how people survive without a computer these days. We have three different businesses that we can easily keep track of through MYOB, and this software can also be used to pay creditors. We have several customers who pay us electronically so our bank software helps keep track of this. We also use Excel for our production and quality assurance records. The internet has been great for researching new equipment and email has been invaluable. Customers can now contact us via email and send us pictures of their problems. This allows us to better assess their needs and offer a better service. I'm also able to email my brother who lives 40kms away so we can liaise with planting and harvesting."

John Cranwell - brassica grower

Remember to keep your antivirus software up to date. Also use a personal firewall – (hardware such as a router or software such as ZoneLabs free program Zone Alarm. See www.zonelabs.com/store/content/home.jsp); keep regular backups of important data (assume that your computer may be stolen, destroyed and you will lose all data – keep backed up data in a safe place) and fit a surge protector to minimise electrical surges.

What computer is right for you?

For more information on computers, virus protection, firewall and other necessary programs, talk to your state Vegetable Industry Development Officer or visit the South Australian Vegetable Industry Development website www.arris.com.au/vidp/index.html and follow the links to Farm Computers.

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Capsicum virus diseases

Diseases caused by viruses are among the most common cause of loss to capsicum growers across Australia.

Vital information on the symptoms, spread, hosts and control of these diseases are clearly detailed in the table over the page (Table 1).

A healthy capsicum crop.

The symptoms outlined for each virus disease are a guide to the range of symptoms usually seen. In reality, the symptoms of several virus diseases often appear to be very similar in the field, and more than one virus disease may be present in a crop at one time.

Diagnosis on symptoms alone is very difficult and often misleading. If a virus disease is suspected, it is advisable to arrange to have samples sent to a plant pathology laboratory for accurate diagnosis.

Most thrips species are unable to transmit tospoviruses tomato spotted wilt and capsicum chlorosis. The species that transmit tomato spotted wilt virus (TSWV) in Australia are western flower thrips (*Frankliniella occidentalis*), tomato thrips (*F. schulzei*), melon thrips (*Thrips palmi*) and onion thrips (*T. tabaci*).

Capsicum chlorosis virus is transmitted by tomato thrips (*F. schulzei*) and melon thrips (*Thrips palmi*). Thrips species such as plague thrips (*T. imaginis*) and greenhouse thrips (*Heliothrips haemmorhoidalis*) do not transmit the viruses.

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Key control method considerations for virus diseases are:

- Use healthy transplants
- Destroy harvested capsicum and tomato crops before planting new blocks nearby
- Maintain high crop and farm hygiene standards
- Do not over use insecticides: insects can develop resistance and insecticides are often of limited use in reducing virus spread
- Use virus resistant varieties in disease management strategies, where possible

Further Information

Compendium of pepper diseases. (2003) APS Press, St Paul ,Minnesota, USA.

Diseases of vegetable crops (1994) Department of Primary Industries and Fisheries, Queensland.

Management of thrips and tomato spotted wilt virus. Department of Agriculture, Western Australia Farmnote 69/2004.

Plant Pathology Sections in each State Department of Agriculture or Primary Industries

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The Bottom Line

- **Virus diseases cause frequent economic losses in capsicum.**
- **Symptoms of different viruses can be similar and accurate diagnosis is essential before deciding on control options.**
- **Infected plants cannot be cured: control depends on prevention.**

Table 1 Virus diseases in capsicums

Virus	Symptoms	Spread	Hosts	Importance	Control
Tomato spotted wilt virus (TSWV)	Ringspots, mottling, yellow blotches, line patterns on leaves. Fruit distorted with blotches/ ring patterns.	Thrips with only a few species able to transmit. Virus acquired in larval stage and insect then able to transmit for life. Not seedborne. Not spread by contact and does not survive in soil or debris.	Many crop, weed and ornamental plants.	High.	Control weed hosts. Destroy old crops. Plant healthy transplants. Control thrips. Use resistant varieties.
Capsicum chlorosis virus (CaCV)	Yellowing (chlorosis) of leaf margins and areas between veins on younger leaves. Plants stunted. Fruit distorted with dark spots and scarring.	As for TSWV.	Capsicum, chilli, tomato, peanut, several weed species.	Common in capsicum in Queensland.	Destroy old crops. Plant healthy transplants. Control thrips resistant varieties being developed.
Cucumber mosaic virus (CMV)	Mosaic, mottling on leaves. Fruit have wrinkled, bumpy appearance, uneven colour and ripening with dark spots sometimes developing.	Aphids. Many species can transmit the virus from plant to plant during very short feeding periods.	Many. Include tomato, grain legumes, weed species.	Generally low in Australia.	Crop and farm hygiene. Healthy transplants.
Pepper mild mottle virus (PMMV)	Fruit small, mottled, deformed with sunken or raised areas on skin. Mild leaf mottling may occur.	Virus contaminated seed and infected plant debris are major sources. The virus is easily spread from plant to plant by handling and touching.	Capsicum, chilli.	Can be important in protected cropping situations, e.g. glasshouses, tunnels.	Use healthy seed from a reputable source. Good crop hygiene. Resistant varieties available.
Potato virus Y (PVY)	Narrow bands of dark green tissue along the leaf veins. Yellow-green mottled areas between veins.	Aphids. Virus spread from plant to plant during very short feeding probes by insects. Not carried in seed or spread by handling plants.	Range of crop and weed hosts, including tomato, tobacco and weeds in potato family.	Once very common and damaging. Outbreaks still occur.	Grow resistant varieties. Crop hygiene.
Tobacco mosaic virus (TMV)	Leaf distortion and mosaic, sometimes with leaf drop. Disfigured fruit.	Contaminated seed, plant parts and debris are major sources. The virus is easily spread on tools, farm implements, stakes and by handling plants.	Weeds and crop plants in the potato family, including tomato and tobacco.	May be important in glasshouse crops.	Many capsicum and chilli varieties are resistant.

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Managing Cadmium in Vegetables

Consumer demand for quality products is increasing.

Concern about the presence of chemical impurities has resulted in monitoring and research into food quality in Australia.

Cadmium has been identified as a potential concern.

This publication is an initiative of the National Cadmium Minimisation Committee

www.cadmium-management.org.au

The bottom line

- Cadmium is a potential problem for horticultural growers
- Crops should be monitored for cadmium
- Cadmium can be managed by reducing inputs or by using sound agronomic practices

July 2003

The Australian Vegetable Industry is the largest section of the horticulture industry and is vital to the national economy. In 1999-2000 it produced more than three million tonnes of product, which had a gross value of $1.8 billion.

To protect this industry Australia's National Cadmium Minimisation Committee (NCMC) was established in 2000 to oversee a strategy to minimise cadmium concentrations and inputs into agricultural soils and crops.

What is cadmium?

Cadmium is a widespread, naturally occurring, element that is present in soils, rocks, waters, plants and animals. The chemical symbol for cadmium is Cd. It occurs naturally with deposits of zinc and phosphorus but, unlike these nutrients, it is not considered essential for life.

Cadmium can accumulate in humans and high levels can affect human health, through bone disease and kidney damage. Therefore, it is crucial to limit our long-term exposure.

Why is cadmium a problem?

Increased daily intake of cadmium can lead to health problems.

Human intake of cadmium is through food consumption, smoking and occupational (workplace) exposure.

Cadmium is concentrated in particular parts of plants. As a general rule, leaves contain the most, followed by storage roots and tubers, seeds or grain and fleshy fruits.

Surveys have shown that the levels of cadmium in some foods have occassionaly approached regulatory health limits.

Greater use of rocl phosphate from the united states, Africa and the Middle East has reduced cadmium inputs to soil.

Sources of cadmium

- Natural levels in Australian soils range from less than 0.1 to 0.5 milligrams per kilogram, or about 0.1 to 0.7 kg cadmium per hectare in the top 10 centimetres of soil.
- Rain and irrigation water generally have very low cadmium concentrations.
- Some sewage sludges (biosolids) may contain a significant amount of cadmium as an impurity. However, phosphorus, nitrogen, copper and zinc concentrations are generally the rate limiting factors in the application of biosolids to soils for beneficial use.

  Consequently, there are comprehensive state guidelines governing the application of biosolids to soil. Contact your state Environmental Protection Agency for more details.
- Other organic wastes and manures may also contain cadmium.
- Cadmium in the atmosphere may be high in the vicinity of industrial activities such as smelting. In most agricultural regions the amounts added to the soil from the atmosphere are minimal.

- Phosphorus containing fertilisers can contain high levels of cadmium depending upon the source of rock phosphate used in manufacturing.
- Trace element fertilisers and phosphogypsum may also contain high cadmium levels. Consequently, these fertilisers can be a major source of cadmium in horticultural soils. The maximum permitted concentration of cadmium, in trace element fertilisers, ranges from 50 - 80 mg per kg and in phosphogypsum it ranges from 10 - 80 mg per kg (check with your local fertiliser representative for state standards).

  Normally, nitrogen and potassium fertilisers have very low cadmium contents.

A regular testing program of the harvested crop is recommended.

Currently all states are aiming for a Maximum Permitted Concentration (MPC) of cadmium in phosphatic fertilisers of 300 mg cadmium per kg phosphorus .

The concentrated phosphatic fertilisers currently used in Australia, i.e. DAP, MAP and TSP are generally low in cadmium (less than 100 mg cadmium per kg phosphorus). It is recommended that fertilisers used have cadmium concentrations as low as possible.

Pasture grades of single superphosphate are generally higher in cadmium, typically containing less than 250 mg cadmium per kg phosphorus. Premium grades developed for horticulture contain less than 100 mg cadmium per kg phosphorus and are available in some states.

The Fertiliser Industry Federation of Australia Inc. (FIFA) initiated a program in the early 1990s to progresssively reduce the levels of cadmium in phosphatic fertilisers. They achieved this by using low cadmium phosphate rock in the manufacturing of superphosphate and importing low cadmium, high phosphorus analysis fertilisers.

FIFA member companies are replacing the voluntary limit, of 300 or 350 mg cadmium per kg of phosphorus for horticultural fertilisers, with products generally containing less than 100 mg cadmium per kg of phosphorus.

High phosphorus users, like horticulturists, could apply as much as 35 grams of cadmium per hectare annually, if they are using fertilisers with a high cadmium concentration. This is equivalent to approximately 0.01 to 0.03 mg per kg soil.

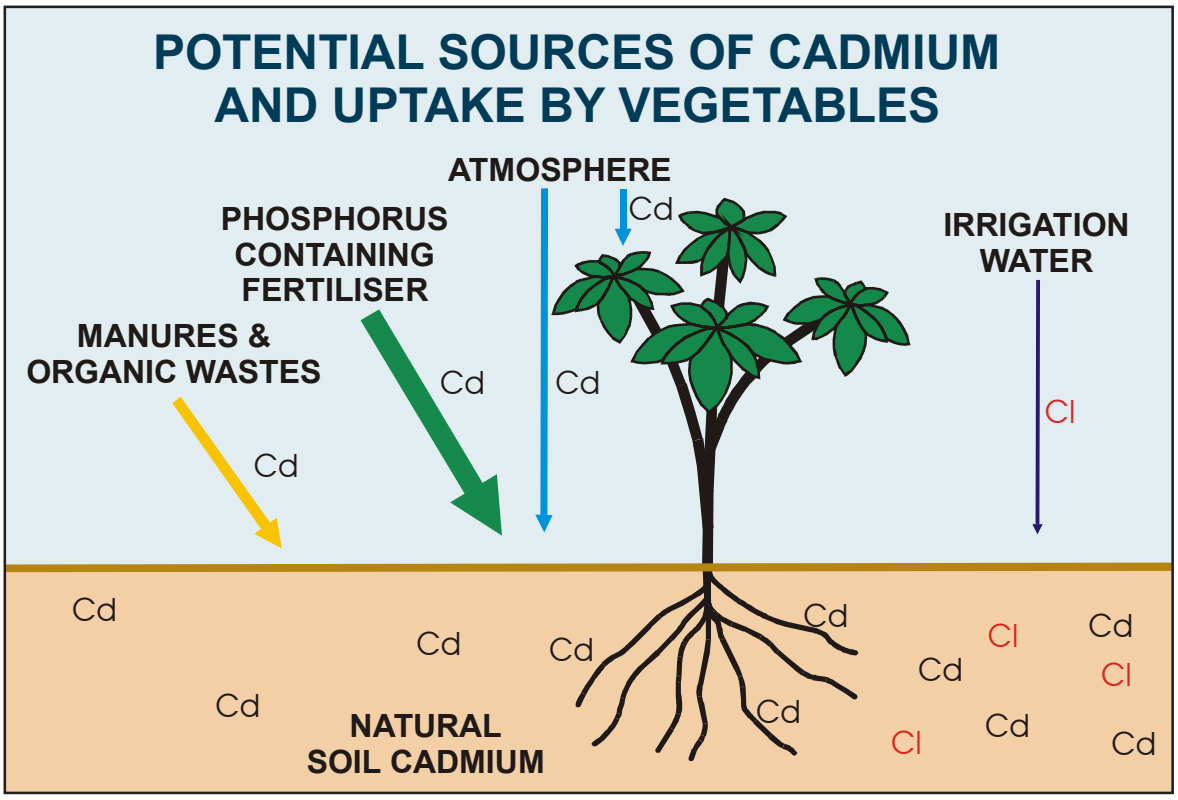
Cadmium levels in Australian food and exports

- Dietary intake of cadmium in Australia is low in comparison to world standards and our food exports have a "clean" reputation worldwide. To maintain this quality advantage we need to minimise any potential cadmium accumulation in food products.
- Food Standards Australia New Zealand (FSANZ) sets the maximum levels of cadmium in various food products by considering public health, food safety and consistency between domestic and international food standards.

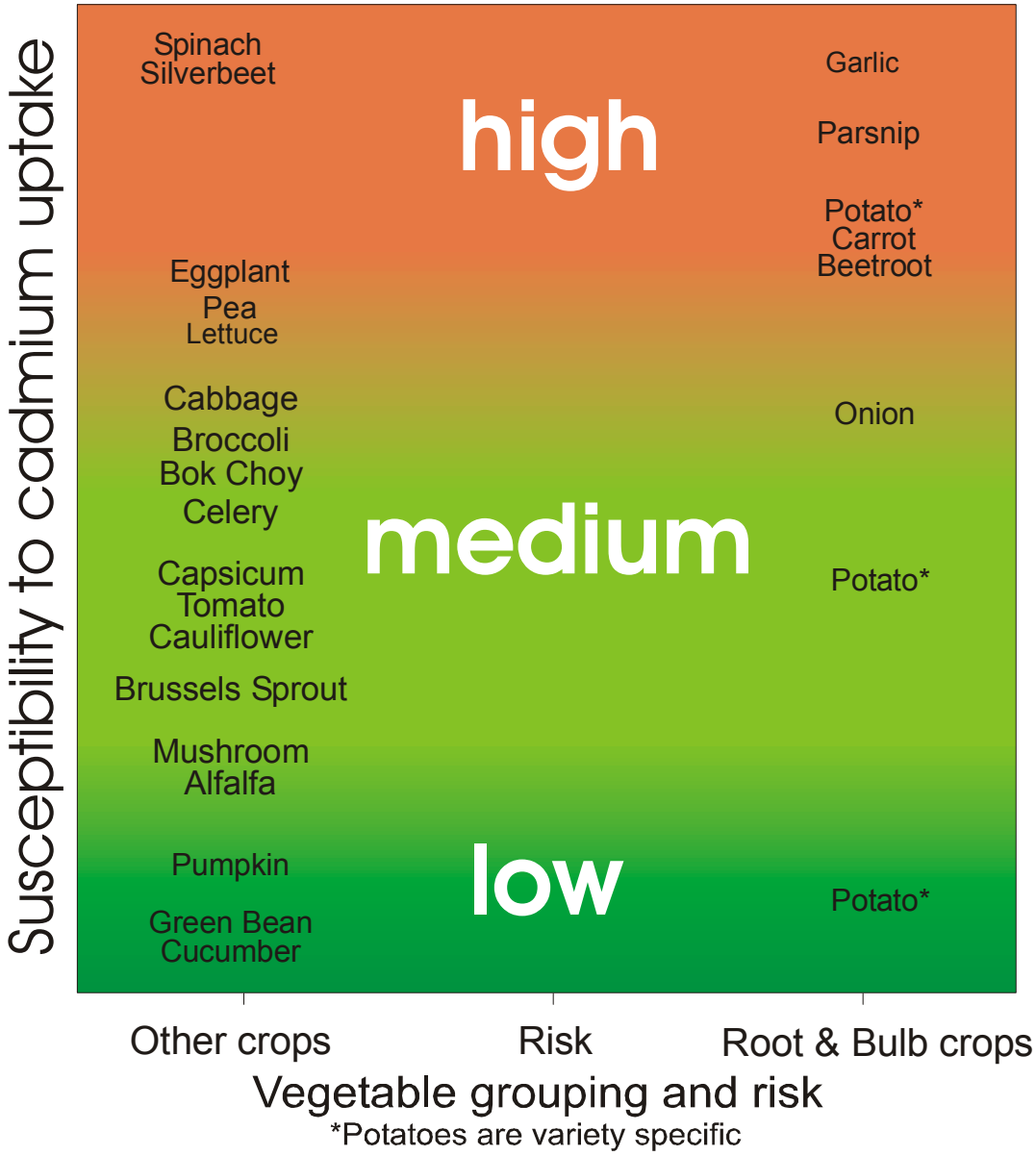
  The Maximum Level (ML) of cadmium for leafy (including leafy Brassicas), root and tuber vegetables, as set by FSANZ (www.foodstandards.gov.au), is currently 0.1 mg per kg, on an 'as consumed' basis. However, the ML is a good guide for all vegetables to manage cadmium.
- If State, Territory and New Zealand Health Departments enforce the standards contained in the Food Standards Code. Where an ML for cadmium is exceeded in vegetables, they would take action to alert the supplier and have the product removed from the market.
- Australia has several residue survey programs which include cadmium. Some of these programs have detected a very small number of samples exceeding the ML.

How plants take up cadmium

- Plants absorb most of their cadmium from soil through their roots.
- Cadmium in soil readily attaches to clay particles and organic matter, making it less available for uptake by plants. Sandy soils, with low clay content, and organic matter are likely to result in a higher uptake of cadmium.
- The availability of cadmium to plants decreases as soil pH increases - as soils become more alkaline.
- Zinc and cadmium uptake by plants occurs in a similar way and research suggests that if soil zinc levels are low then more cadmium will be taken up.
- Cadmium in soil tends to remain in the cultivated layers, where it is potentially available to plants. It can be removed from soils by erosion, or from very light sandy acid soils, by leaching.
- Higher concentrations of chloride in the soil appear to mobilise cadmium and increase uptake by plants. Soil chloride can be high after irrigation with saline water, (eg. in areas subject to dryland salinisation) or after the intensive use of chloride based fertilisers (eg. potasium chloride or muriate of potash).



Generally, vegetables are very low in cadmium. If your vegetables are high in cadmium, other plant species can be grown that take up less cadmium. The chart below will assist in the selection of crops that will minimise the risk of cadmium uptake.



*Potatoes are variety specific

- Uptake varies considerably between different plant species and between varieties or cultivars. Refer to the diagram above.
- Cadmium present in farm produce can also be as a result of soil or dust contamination, either in the field or during processing.

How to recognise a cadmium problem

Visual symptoms can be evident when plants are grown in grossly contaminated soils in industrial or urban areas. However, you cannot tell visually if a plant has high cadmium when grown in normal agricultural soils - the concentration needs to be measured. This is because the level of cadmium in plant tissues that may affect human health could be well below the level that may damage the plant.

A regular plant analysis program is recommended for growers. Edible samples of the harvested crop should be forwarded to accredited laboratories, as cadmium analysis is a specialised service. You can find accredited laboratories listed on the National Cadmium Minimisation Strategy website: **www.cadmium-management.org.au**

Conventional soil tests are also of value in soil and crop management. Soil tests for pH, organic carbon, salinity, phosphorus and zinc provide valuable information in managing cadmium accumulation by plants (consult with your local agricultural adviser).

Irrigation water should be checked for its salinity as chloride stimulates plant uptake of cadmium (see table page 7). Plant tissue tests for cadmium are best performed on the marketable or edible portion of the produce and are reported on a fresh weight basis.

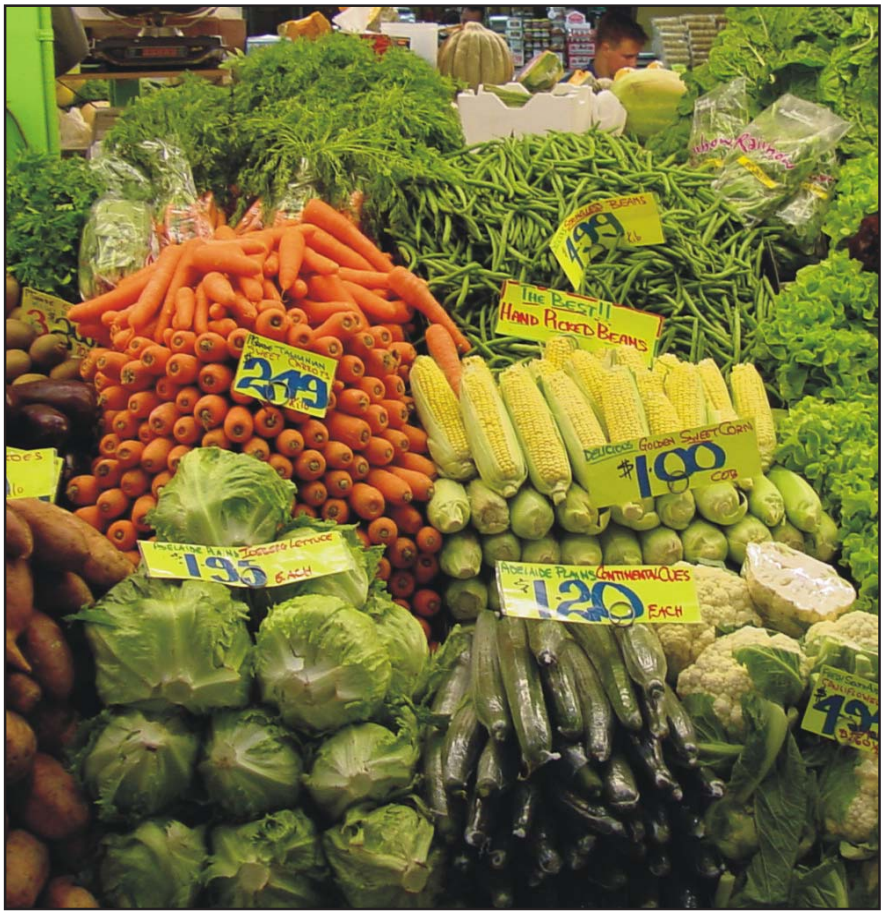
Managing cadmium in produce

There are three approaches to reducing the cadmium content of produce:

1. **Reducing the input of cadmium into soil.**
2. **Using agronomic practices that minimise plant uptake of cadmium.**
3. **Monitoring cadmium concentrations in produce to assess the impact of cadmium minimisation strategies.**

Reducing inputs

- As discussed previously, superphosphate fertilisers can be a major contributor of cadmium inputs in horticultural soils. Growers need to be aware of cadmium impurities in specific fertilisers and should use fertilisers low in cadmium.
- Ensure you have a soil test performed and only add phosphorus to soil when the test indicates a deficiency, increasing the likelihood of a crop response.
- Organic wastes (e.g. biosolids) and manures may also contain cadmium. If these are used, check that cadmium concentrations are below acceptable limits.



Agronomic practices

- Reduce chloride additions to soils through the use of irrigation water and fertilisers with low chloride concentrations. Elevated soil chloride concentrations increase the plant availability of soil cadmium. See table, page 7.
- If high chloride concentrations are present in irrigation water, it is recommended that cadmium concentration in the edible portions (e.g. tubers for potatoes, leaves for leafy vegetables, etc) be tested more frequently.

- Choose low risk crops or varieties (if known). Certain crops are more susceptible to cadmium uptake and selection of crops and varieties (if known) which minimise cadmium accumulation in the edible portion can be used if unacceptable cadmium levels in produce are detected (See risk graph, page 5).
- Soil pH affects the uptake of cadmium by crops. Soil pH of less than 5.5 (measured in water) or 4.8 (measured in calcium chloride) should be amended upwards to pH levels of between 6.2 - 6.7 (measured in water) and 5.5 - 6.0 (measured in calcium chloride), through the addition of lime.

  As a **guide**, lime rates of high quality agricultural lime needed to raise soil pH by one unit in the top 15 cm of soil are:

Sand	1.5 - 3 tonnes of lime/ha
Loam	3 - 4.5 tonnes of lime/ha
Clay	4.5 - 6 tonnes of lime/ha

A liming program is needed in highly acidic soils.

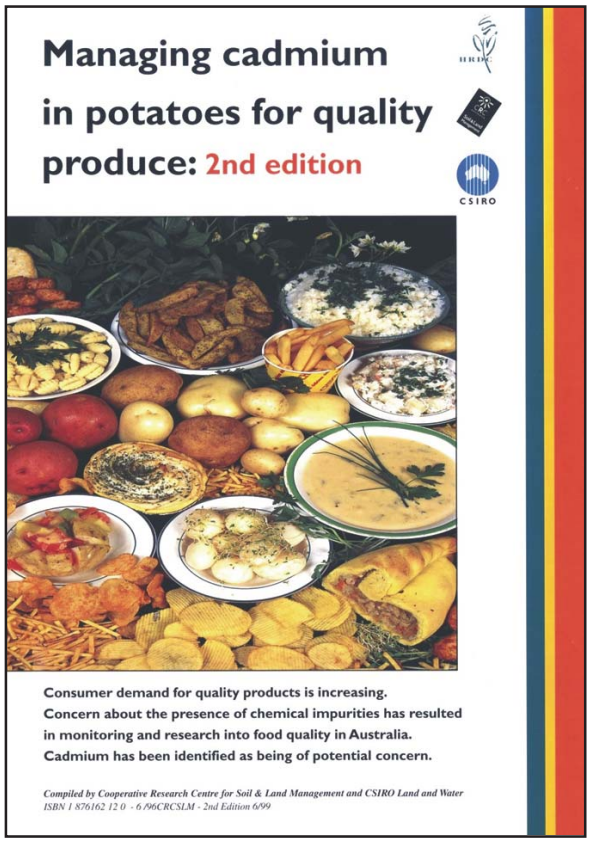
Interaction between chloride in irrigation water and cadmium in soil

Irrigation water chloride concentration (mg/L)	Risk of increasing crop cadmium concentrations
0-350	Low
350-750	Medium
>750	High

For best results, use finely ground, high quality lime and incorporate it into the soil.

- Maintain or increase soil organic matter, which is thought to reduce the availablity of cadmium in plants, therefore reducing plant uptake of cadmium. If you do this by importing compost or other off-farm organic material, use only high quality (low cadmium) sources.
- Addition of zinc at nutritional rates to overcome zinc deficiency, at planting, has been found to reduce cadmium levels in crops in some field trials.
- Cadmium is generally more available to plants grown in sandy soils than in soils with high clay content. Therefore, the risk of high cadmium levels in produce is greater for sandy soils in comparison with clay soils.

Further information can be found in the 'Managing



cadmium in potatoes for quality produce; 2nd edition' at:

www.cadmium-management.org.au/publications.html

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FIFA

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Managing Cadmium in Vegetables

Nhu cầu người tiêu dùng cần sản phẩm chất lượng cao ngày càng tăng.

Lo lắng về sự hiện diện của hoá chất độc đã dẫn đến việc theo dõi và nghiên cứu chất lượng thực phẩm ở Úc.

Cadmium đã được đánh giá là chất có tiềm năng đáng lo ngại.

This publication is an initiative of the National Cadmium Minimisation Committee

www.cadmium-management.org.au

Những điểm nhấn mạnh

- **Cadmium là một vấn đề tiềm năng đối với nông gia trồng vườn.**
- **Cây trồng cần được theo dõi về hàm lượng cadmium.**
- **Cadmium có thể điều chỉnh bằng cách giảm lượng bón vào đất hoặc bằng biện pháp nông học hữu hiệu.**

Spring 2003

Trồng rau là lĩnh vực lớn nhất trong ngành trồng vườn của Úc và có vai trò quan trọng trong nền kinh tế quốc dân. Trong năm 1999-2000, ngành đã sản xuất được 3 triệu tấn sản phẩm với tổng giá trị là 1.8 tỷ Úc kim.

Để bảo vệ ngành, Uỷ ban quốc gia về việc giảm thiểu lượng Cadmium (Australia's National Cadmium Minimisation Committee (NCMC) đã được thành lập trong năm 2000 để xem xét một kế hoạch giảm thiểu hàm lượng và sự nhiễm cadmium vào đất nông nghiệp và cây trồng.

Cadmium là gì?

Cadmium là một nguyên tố phổ biến trong thiên nhiên: trong đất, đá, nước, thực vật và động vât. Công thức hoá học của cadmium là Cd. Nó có mặt trong thiên nhiên cùng với các hợp chất tự nhiên của kẽm và photpho, nhưng không giống các dưỡng chất này, cadmium được cho là chất không cần thiết cho sự sống.

Cadmium có thể tích tụ trong cơ thể người, và nếu đạt tới nồng độ cao, nó có thể ảnh hưởng đến sức khoẻ như gây bệnh về xương, làm tổn hại thận. Cho nên, hạn chế việc tiếp xúc lâu dài với cadmium là điều cực kỳ quan trọng.

Cadmium gây ra vấn đề gì?

Lượng cadmium đi vào cơ thể hàng ngày tăng cao có thể làm tổn hại sức khoẻ.

Cadmium đi vào cơ thể qua việc ăn uống, hút thuốc lá và qua tiếp xúc trong khi làm việc.

Cadmium tích tụ trong các phần đặc biệt của thực vật. Theo nguyên tắc chung, lá chứa nhiều cadmium nhất, sau đó là các loại củ, hạt và các loại trái cây nhiều phần mềm (thịt)

Các nghiên cứu cho thấy rằng lượng cadmium trong một số thức ăn đôi khi lên tới giới hạn được cơ quan quản lý sức khoẻ cho phép.

Tăng sử dụng đá phosphat nhập từ Mỹ, Nam phi và Trung đông đã làm giảm lượng cadmium bón vào đất.

Nguồn cadmium

- Hàm lượng cadmium tự nhiên có trong đất của Úc từ dưới 0.1 đến 0.5 mg /kg, hay khoảng 0.1 đến 0.7 kg/ha trong lớp đất dầy 10cm trên cùng
- Nước tưới và nước mưa nói chung có hàm lượng cadmium thấp.
- Một số loại bùn cống thải (biosolids) có thể chứa một lượng cadmium đáng kể do bị nhiễm bẩn. Tuy nhiên, nói chung, để đánh giá lợi ích sử dụng của các loại bùn này khi dùng bón cho đất người ta chỉ tính mức giới hạn của các nhân tố phốt pho, nitơ, đồng và kẽm.

  Vì vậy, người ta đã đưa ra nguyên tắc chung cho toàn tiểu bang để chỉ đạo việc bón phân bùn cho đất. Xin liên hệ với Cơ quan Bảo vệ Môi trường tiểu bang để biết thêm chi tiết.
- Một số chất thải hữu cơ và phân gia xúc cũng có thể chứa cadmium.
- Lượng cadmium trong không khí ở các vùng sản xuất công nghiệp cũng có thể đạt mức cao, như xung quanh lò luyện kim. Trong đa số các vùng nông nghiệp, lượng cadmium từ không khí nhiễm vào đất là rất nhỏ.

Một chương trình bón vôi là cần thiết cho đất có độ axit cao (đất chua nhiều - ND).

- Các loại phân bón có chứa phốt pho (lân) có thể chứa nhiều cadmium, điếu này phụ thuộc vào nguồn đá phốt phát được sử dụng trong sản xuất phân.
- Các loại phân vi lượng và lân thạch cao (phosphogypsum) cũng chứa nhiều cadmium. Do vậy, các loại phân này là nguồn cadmium chính trong đất nông nghiệp. Nồng độ cho phép tối đa của cadmium trong phân vi lượng giao động từ 50-80mg/kg và trong lân thạch cao là từ 10 đến 80 mg/kg (xin quí vị hỏi chuyên viên phân bón ở địa phương để biết tiêu chuẩn của tiểu bang).

  Thông thường, phân đạm (nitơ) và phân kali (potassium) chứa ít cadmium.

Hiện nay tất cả các tiểu bang đang nhắm tới việc qui định Nồng độ Cho phép Tối đa (Maximum Permitted Concentration - MPC) của cadmium trong các loại phân lân (phosphatic) là 300mg/kg.

Các loại phân lân đậm đặc đang được sử dụng ở Úc, như DAP,MAP và TSP nói chung có chứa ít cadmium (dưới mức 100 mg/kg). Người ta đề nghị nên sử dụng các loại phân lân có lượng cadmium càng ít càng tốt.

Nói chung, loại super lân dùng bón cho đồng cỏ có lượng cadmium cao hơn, thường là dưới 250 mg cadmium/ kg lân.

Loại phân lân cao cấp dùng cho ngành trồng vườn chứa ít hơn 100 mg cadmium/kg và sẵn có ở một số tiểu bang.

Hiệp hội sản xuất phân bón của Úc (Fertiliser Industry Federation of Australia Inc.- FIFA) đã đưa ra một chương trình vào đầu thập niên 90' nhằm giảm bớt nhanh chóng lượng cadmium trong phân lân. Họ đã đạt được việc này bằng cách sử dụng đá photphat có hàm lượng cadmium thấp để sản xuất phân super lân và nhập khẩu các loại phân lân có hàm lượng phốtpho cao và hàm lượng cadmium thấp.

Các công ty thành viên của hiệp hội này đã tự nguyện thay các loại phân lân dùng trong nghề vườn mà có hàm lượng cadmium cao ở mức 300 hoặc 350 mg /kg phân lân bằng các loại phân có chứa dưới 100 mg Cd/kg phân lân.

Những người dùng nhiều phân lân, như người trồng vườn, có thể bón một lượng cadmium nhiều đến 35 gam trên một hecta một năm nếu họ dùng các loại phân lân có hàm lượng cadmium cao. Lượng này tương đương với khoảng 0.01 đến 0.03 mg Cd /kg đất.

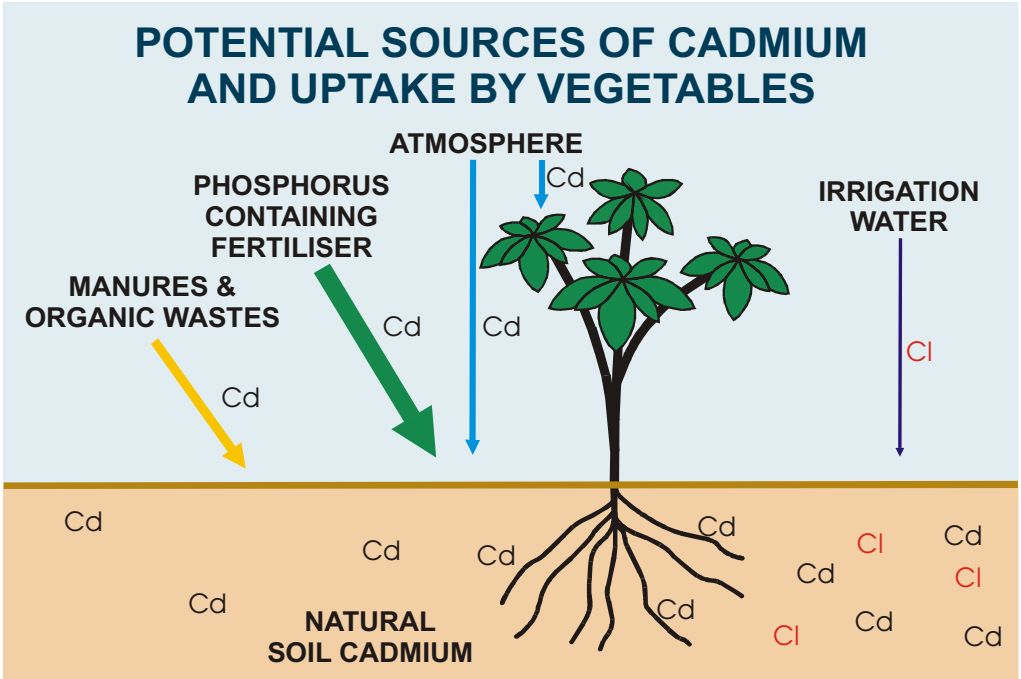
Lượng cadmium trong thực phẩm trong nước và xuấu khẩu của Úc.

- Lượng Cd trong khẩu phần ăn ở Úc thấp hơn so với tiêu chuẩn thế giới và thực phẩm xuất khẩu của chúng ta nổi tiếng là "sạch" trên thế giới. Để giữ được ưu thế chất lượng này, chúng ta cần giảm thiểu khả năng tích luỹ cadmium trong thực phẩm.
- Cơ quan Tiêu chuẩn Thực phẩm Úc và New Zealand (Food Standards Australia New Zealand -FSANZ) qui định mức Cd tối đa trong các loại thực phẩm dựa trên việc xem xét sức khoẻ cộng đồng, việc an toàn thực phẩm và sự nhất quán giữa tiêu chuẩn thực phẩm nội địa và quốc tế.

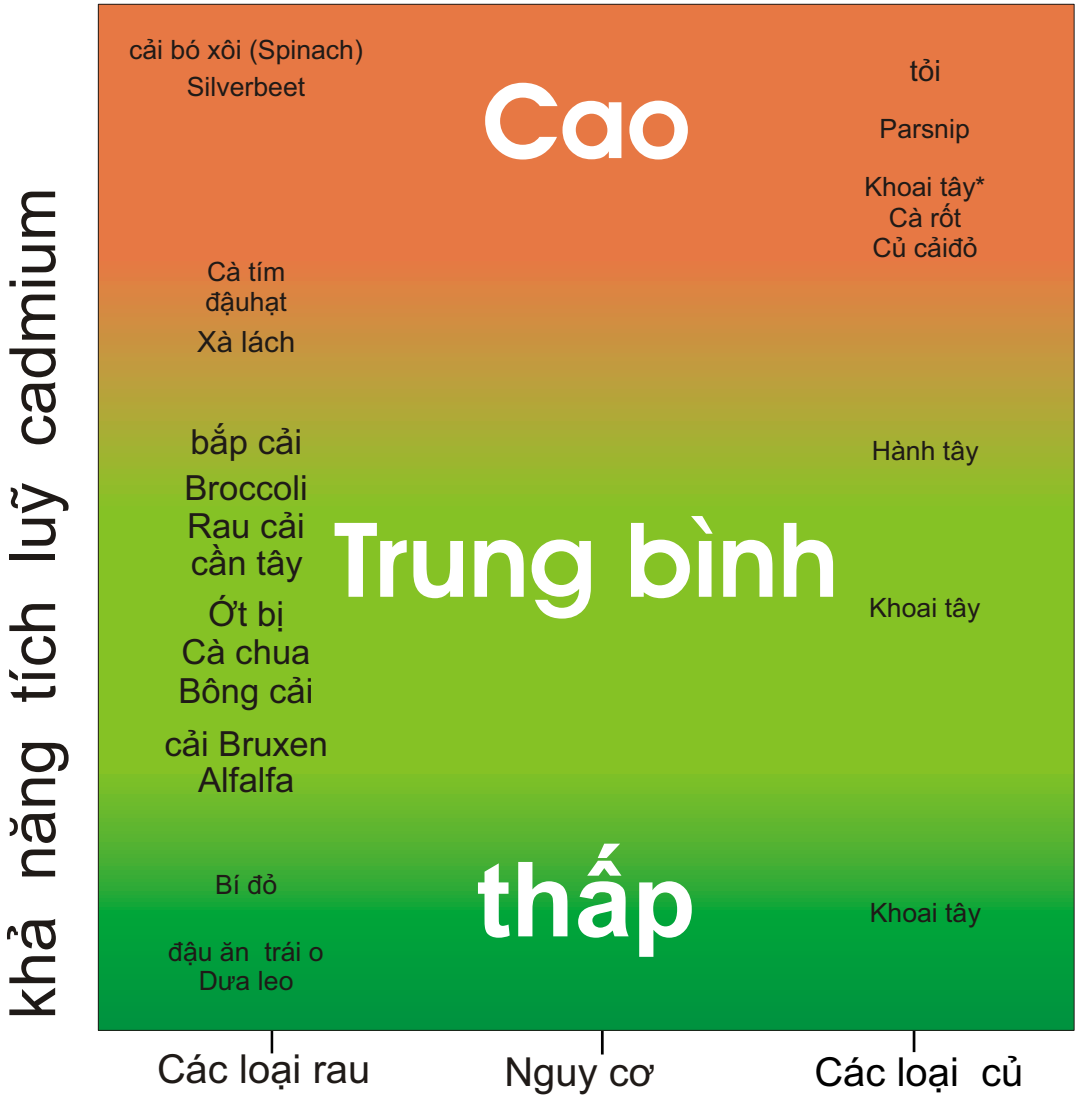
  Lượng Tối đa (Maximum level - ML) của cadmium trong rau ăn lá (kể cả các loại rau cải), rau lấy củ, như đã được FSANZ (WWW.foodstandards.gov.au) qui định hiện nay là 0.1mg/kg nông sản ở dạng " để dùng". Tuy nhiên, ML là chỉ số tốt để điều chỉnh lượng cadmium trong tất cả các loại rau.
- Nếu lượng cadmium trong rau vượt quá múc cho phép, Sở Sức khoẻ của các tiểu bang, khu vực lãnh thổ và New Zealand có quyền thi hành Qui định về Tiêu chuẩn Thực phẩm. Các sở sẽ thông báo cảnh cáo người cung cấp và buộc họ phải thu hồi sản phẩm trên thị trường.
- Úc có một số chương trình kiểm tra lượng tồn dư hoá chất trong đó có cadmium. Một số chương trình đã phát hiện một số lượng nhỏ của mẫu thực phẩm có lượng cadmium vượt quá MứcTối đa.

Cây hút cadmium như thế nào?

- Cây hấp thụ phần lớn cadmium từ đất qua rễ.
- Trong đất, cadmium dễ dàng liên kết với các hạt đất sét và vật chất hữu cơ. Việc này làm cho cây khó hút được cadmium hơn. Đất cát có thành phần sét và vật chất hữu cơ ít hơn, và kết qủa là cây hút nhiều cadmium hơn.
- Khi độ pH của đất tăng thì lượng cadmium tự do cho cây hút sẽ giảm đi - do đât trở lên kiềm hơn
- Cây hút cadmium và kẽm theo cách giống nhau và các nghiên cứu cho rằng nếu lượng kẽm trong đất thấp thì cây sẽ hút nhiều cadmium hơn.
- Cadmium thường nằm trong tầng đất canh tác, nơi mà cây dễ hút. Cadmium có thể rửa khỏi đất do bị xói mòn, hoặc bị rửa trôi từ đất cát rất nhẹ và chua.
- Nồng độ clorua cao trong đất có thể làm cho cadmium năng động hơn và cây hút dễ dàng hơn. Hàm lượng clorua trong đất có thể cao sau khi đất được tưới bằng nước mặn (ví dụ như ở các vùng bị mặn do hạn) hoặc sau khi sử dụng nhiều các loại phân bón có chứa clorua (ví dụ như phân clorua kali hoặc muriat bồ tạt).



Nói chung, rau củ chứa rất ít cadmium. Nếu rau của quí vị chứa nhiều cadmium, có thể trồng loại rau tích luỹ ít Cadmium hơn. Sơ đồ dưới đây giúp quí vị chọn lựa loại rau Có khả năng giảm thiểu nguy cơ tích luỹ nhiều cadmium.



PHÂN NHÓM RAU VÀ NGUY CƠ TÍCH LUỸ CADMIUM

*** Khoai tây có các giống riêng biệt**

- Khả năng hấp thu cadmium của các loại cây, các giống và các loại cây trồng là khác nhau. Xin tham khảo sơ đồ trên đây.
- Cadmium có trong nông sản còn có thể là do bụi và đất bị nhiễm độc, cả trên đất vườn cũng như trong quá trình chế biến.

Làm sao có thể nhận biết được vấn đề về cadmium?

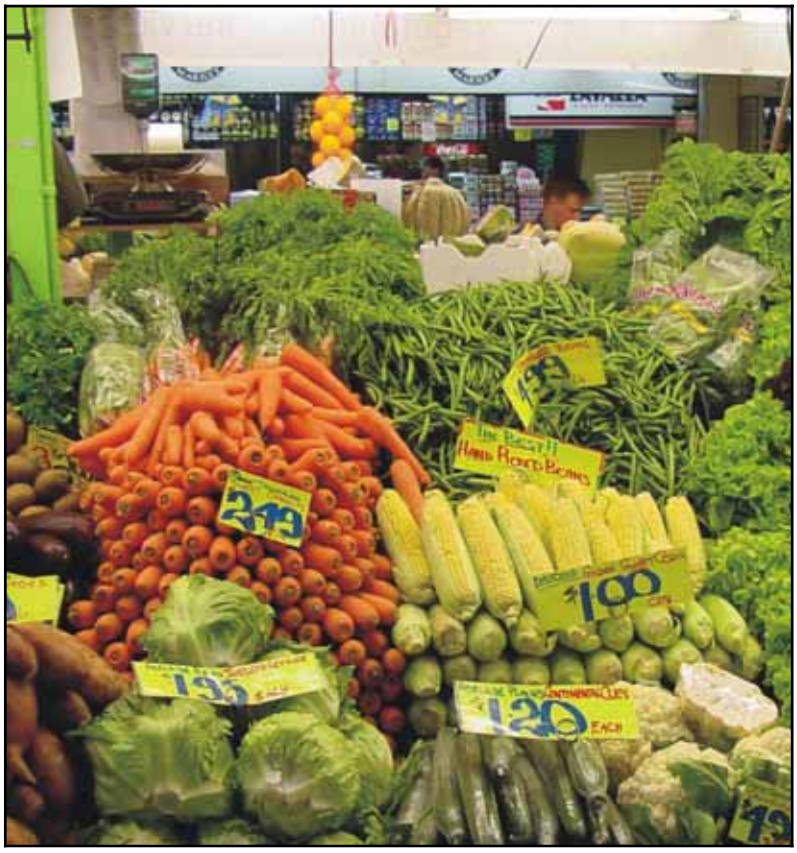
Các triệu chứng nhìn thấy thể hiện rõ khi cây được trồng trên đất bị nhiễm độc nặng trong các vùng công nghiệp hay vùng đô thị. Tuy nhiên, người ta không thể nhìn thấy các chứng cớ nếu cây có hàm lượng cadmium cao khi cây được trồng ở đất nông nghiệp bình thường - Người ta cần phải đo hàm lượng cadmium. Đó là do lượng cadmium trong cây có thể ảnh hưởng tới sức khoẻ con người nhưng còn xa mới tới mức gây hại cho cây.

Các nông gia nên có một chương trình phân tích cây trồng thường xuyên. Những mẫu nông sản của các vụ thu hoạch nên được gửi tới các phòng thí nghiệm được công nhận, vì phân tích lượng cadmium là một nghiệp vụ chuyên môn. Quí vị có thể tìm thấy các phòng thí nghiệm được công nhận trong danh mục trên trang web của chương trình Chiến lược Quốc gia về giảm lượng cadmium (National Cadmium Minimisation Strategy website):

www.cadmium-management.org.au

Các xét nghiệm đất thông thường cũng có giá trị trong quản lý đất và cây trồng. Các xét nghiệm kiểm tra độ pH, lượng cácbon hữu cơ, độ mặn, lân và kẽm cung cấp các thông tin có giá trị trong việc tìm cách giảm bớt lượng cadmium tích tụ trong cây trồng. (hãy tham khảo ý kiến chuyên viên nông nghiệp địa phương).

Nước tưới cần được kiểm tra độ mặn vì clorua kích thích cây trồng hấp thụ cadmium (xem bảng 7). Các xét nghiệm về hàm lượng cadmium trong mô cây nên đươc thực hiện trên các phần ăn được hoặc bán được của nông sản và được báo cáo theo trọng lượng tươi.



Quản lý cadmium trong nông sản
Có ba cách làm giảm lượng cadmium trong nông sản:

1. **Giảm lượng cadmium được bón vào đất.**
2. **Sử dụng các biện pháp nông học làm giảm việc hút cadmium của cây trồng.**
3. **Theo dõi nồng độ cadmium trong nông sản để đánh giá ảnh hưởng của chương trình giảm thiểu cadmium.**

Giảm lượng bón

- Như đã nói ở phần trên, phân super lân có thể là nguồn chủ yếu để đưa cadmium vào đât vườn. Nông gia cần biết các loại phân đặc biệt có lẫn nhiều cadmium và nên sử dụng các loại phân chứa ít cadmium.
- Cần bảo đảm rằng quí vị có làm xét nghiệm phân tích đất và chỉ bón lân cho đất khi xét nghiệm cho thấy đất thiếu lân và việc bón lân có khả năng làm cây trồng tốt hơn.
  - Các chất thải hữu cơ (như bùn cống thải) và phân gia súc có thể cũng chứa cadmium. Nếu sử dụng chúng, quí vị hãy kiểm tra để biết rằng hàm lượng cadmium trong phân này ở dưới giới hạn chấp nhận được.

Biện pháp nông học

- Giảm lượng clorua được đưa vào đất bằng cách dùng nước tưới và phân bón có nồng độ clorua thấp. Nồng độ clorua trong đất cao sẽ làm tăng lượng cadmium tự do cho cây hút. Hãy xem bảng ở trang 7.
- Nếu nước tưới có hàm lượng clorua cao, người ta khuyên nên nên kiểm tra hàm lượng cadmium trong các phần ăn được của cây (ví dụ như củ của khoai tây, lá của các loại rau ăn lá v.v) thường xuyên hơn.

- Một số cây trồng hấp thụ cadmium dễ dàng hơn các cây khác . Nếu phát hiện thấy hàm lượng cadmium trong nông sản cao ở mức không chấp nhận được, hãy chọn loại cây trồng và giống (nếu biết) tích luỹ ít cadmium hơn trong các phần ăn được (hãy xem đồ thị về nguy cơ, trang 5).
- Độ pH của đất ảnh hưởng đến việc hấp thụ cadmium của cây trồng. pH đất nhỏ hơn 5.5 (đo trong nước) hoặc 4.8 (đo trong clorua canxi) nên được điều chỉnh lên tới mức pH 6.2 - 6.7 (đo trong nước) và 5.5-6.0 (đo trong clorua canxi) bằng việc bón thêm vôi.

Sau đây là **chỉ dẫn** về cách tính lượng vôi nông nghiệp chất lượng cao cần thiết để tăng pH của đất lên một đơn vị trong tầng đất 15 cm trên cùng:

đất cát	1.5 - 3 tấn vôi/ha
đất mùn	3 - 4.5 tấn vôi/ha
đất thịt	4.5 - 6 tấn vôi/ha

Để đạt kết qủa tốt nhất, hãy sử dụng vôi nghiền nhỏ chất lượng cao và trộn vào đất.

Một chương trình kiểm định nông sản mới thu hoạch đã được đề nghị.

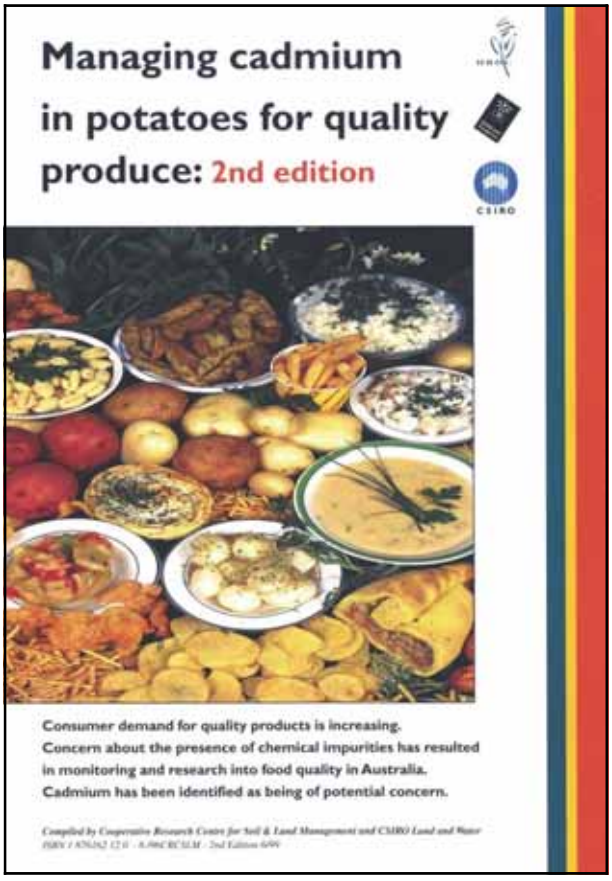
Tương tàc giữa ciorua trong nước tưới và lượng cadmium trong đất

Nước tưới Hàm lượng chlorua (mg/L)	Nguy cơ tăng hàm lượng cadmium trong cây trồng
0-350	Thấp
350-750	Trung bình
>750	Cao

- Duy trì và tăng các vật chất hữu cơ trong đất. Người ta nghĩ rằng chúng sẽ làm giảm cadmium tự do cho cây, và như vậy cây trồng sẽ hút được ít cadmium hơn. Nếu quí vị làm việc này bằng cách bón thêm phân cây ủ (compost) hoặc những vật chất hữu cơ từ bên ngoài vào thì chỉ nên dùng những loại phân có chất lượng cao (ít cadmium).
- Một số thử nghiệm ngoài đồng cho thấy việc bón kẽm vào lúc trồng, ở liều lượng bồi bổ cho cây thiếu kẽm sẽ làm giảm lượng cadmium trong cây trồng.
- Nói chung, trong đất cát có nhiều cadmium tự do để cây hút hơn là trong đất có thành phần đất thịt cao. Do vậy, nông sản trồng trên đất cát có nguy cơ chứa nhiều cadmium hơn so với nông sản trồng trên đất thịt.

Quí vị có thể tìm thêm thông tin trong " Quản lý cadmium trong khoai tây để có chất lượng cao"(Managing cadmium in potatoes for quality produce); Xuất bản lần thứ 2, trên địa chỉ mạng:

www.cadmium-management.org.au/publications.html



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An initiative of the National Cadmium Minimisation Committee:
www.cadmium-management.org.au

Funded by:

Horticulture Australia

GRDC Grains Research & Development Corporation

FIFA

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Brassica Integrated Pest & Disease Management

Managing Diamondback Moth

Diamondback Moth (DBM), *Plutella xylostella*, is a major pest of Brassica vegetable growing in Australia and it has the ability to rapidly become resistant to insecticides.

The National Diamondback Moth Project Team was established to research and communicate an integrated approach to managing this pest.

During the six years of project work the team has focused on limiting DBM's development of insecticidal resistance and facilitating the implementation of effective alternatives to insecticide-based control.

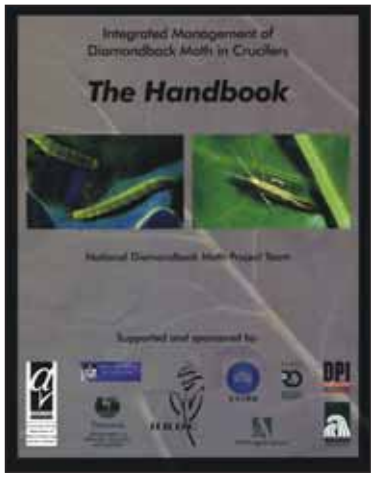
Significant tools have been developed to assist growers and consultants to better manage DBM and they are outlined below.

The Handbook

'Integrated Management of Diamondback Moth in Crucifers' was created by the team and distributed to all Brassica growers nationally.

The handbook has been evolving with insertable sections mailed out as they are developed.

The following modules are either included already, or nearing completion:



- Integrated pest management – what does it really mean?
- Crop monitoring – the key to informed decision making
- Insecticide resistance management – getting the best from your sprays
- The role of *Bacillus thuringiensis* in managing DBM
- Ensuring good spray coverage
- How fast does DBM develop
- Brassica information on the internet – pests, diseases & agronomy
- Information sources for Brassica crops
- Natural enemies of DBM
- Other Brassica pests
- Dispersal and movement of DBM
- Impact of insecticides on natural enemies chart.

The bottom line

- Follow the Insecticide Resistance Management (IRM) Strategies developed for your State (see overleaf).
- Practise the pest management tactics as outlined in the 'Handbook of Integrated Management of Diamondback Moth in Crucifers' (discussed above).
- Monitor (scout) crops, preferably using a Monitoring Guide (discussed overleaf) to allow well-informed control decisions.

Monitoring and Action Guide

It is well known that inspecting (monitoring) crops regularly is one of the most important activities that allows a grower to make sound pest control decisions.

A crop sampling guide, consisting of five different charts for different situations, has been developed to enable growers and advisors to be more cost efficient with their monitoring time.

The guide asks questions regarding – type of crop to be monitored (eg. cauliflower or broccoli), growth stage of the crop, market destination (eg. processing or fresh), chemical use in the crop and wasp parasitism rates of grubs. Once answered, the guide leads to a sampling chart that advises how many plants to sample for an accurate decision about whether to spray, not spray, or monitor again in five days.

Below a certain level of DBM presence, control will often cost more than the damage. The aim of the guide is to minimise insecticide sprays and time spent monitoring, while delivering a high quality crop. It is hoped that the guide will also 1) reduce spraying costs and 2) help growers move forward in integrated pest management (IPM) practice by providing them with a reliable tool to confidently advance.

The guide has been trialed around the country and will be available in Summer 2003 in both computer based and portable flip charts versions.

Insecticide Resistance Management (IRM) Strategy

An important component of the team's work is the development, distribution and updating of a 'two window' insecticide resistance management strategy, in collaboration with the Avcare Insecticide Resistance Action Committee.

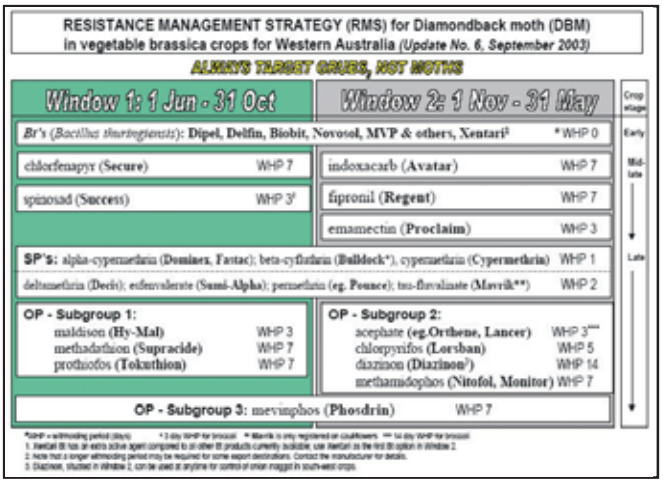
If adhered to, this strategy is likely to extend the effective life of insecticides by at least 2–2.5 times.

The strategy works on the principle of only using particular insecticides for a certain period of time in a year, before switching to those of a different mode of action.

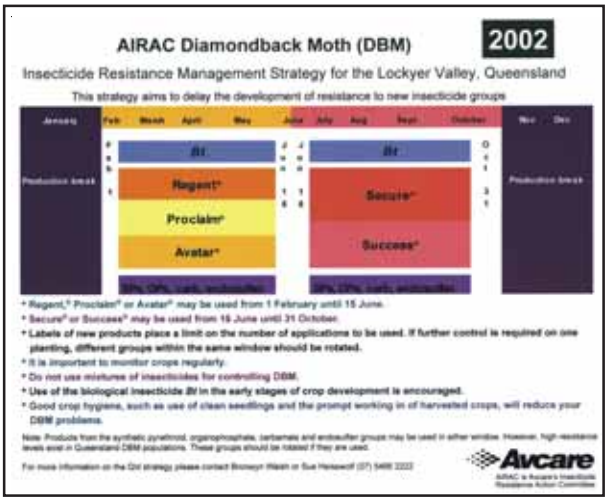
Using insecticides in this way limits the exposure of the pest to products, since prolonged use can allow the pest generations to build up defences and become resistant.

The strategy has been customised for different regions to accommodate different growing conditions.

Examples of the IRM Strategies for the different States.



WA



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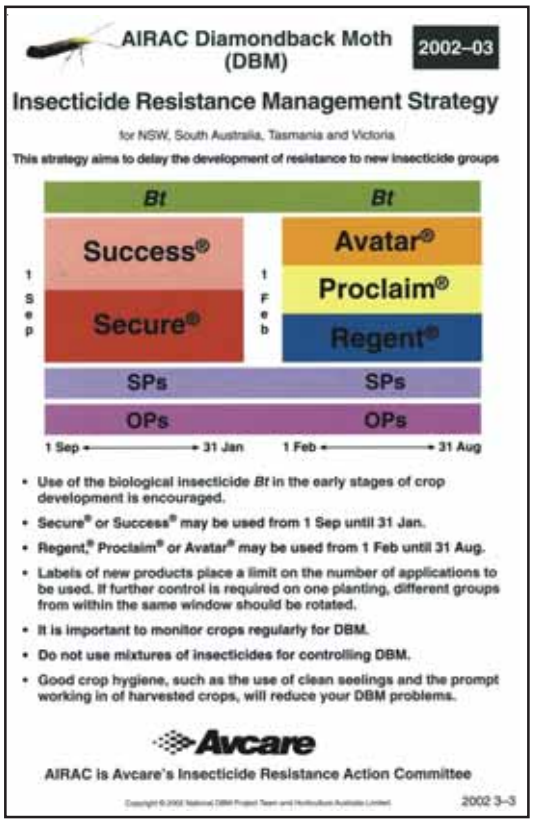


NSW, SA, Tas, Vic.

Acknowledgements
Dijana Jevremov, South Australian Research and Development Institute.

Managing Clubroot

Clubroot, caused by the organism *Plasmodiophora brassicae,* affects crucifer plants including broccoli, cauliflower, Chinese cabbage, Brussels sprouts, bok choy, cabbage, Swedes, radish and turnips. It can also infect cruciferous weeds (eg wild turnip and wild radish).

Symptoms include wilting of plants during warm weather and the formation of enlarged galls on the roots. The galls prevent the uptake of water and nutrients, reducing the potential yield of the crop.

Above: Crop wilting due to clubroot infection.

Below L to R: Uninfected and infected roots of a broccoli plant.

Integrated management of clubroot

A minimum of approximately 1000 spores per gram of soil is required to cause root galling. The threshold can vary according to soil type and climatic conditions. Below the threshold symptoms become difficult to detect and yield is unaffected.

Integrated management of clubroot aims to achieve a soil environment that ensures the spore population remains below the threshold required for the disease. This is best achieved using a combination of management techniques.

1 Improve hygiene - nursery and farm

Spores can be transported by anything carrying soil or water including machinery, shared/contract labour and equipment, boots, livestock, pallets, transplants and dams receiving run-off from affected paddocks.

As a result, hygiene must focus on minimising soil movement and be practiced both on and between farms. High pressure washing of machinery and equipment is the most effective method of removing soil that may harbour clubroot spores.

2 Modify the soil

Environmental factors can be managed to create soil conditions that restrict disease development.

- Clubroot is less virulent in high pH soil. Apply lime to maintain a soil pH of 7.0 – 7.5. Burnt lime (quicklime) reacts quickly in acid soil, while agricultural lime (lime sand or ground limestone) takes at least three months to increase soil pH levels. Take care applying lime to soils with a low buffering capacity (eg. sands) and soils already close to pH 7.0.

  When soil pH is greater than 7.0, lime application is unnecessary. Excessive lime may increase soil pH too much (making it alkaline), which may affect the availability of some nutrients.
- Calcium and boron affect the growth and reproduction of clubroot and application should occur at transplanting and during the first four weeks of the life of the crop, to protect the vulnerable roots.
- Clubroot requires free water to assist with movement through the soil. Thus, good drainage in cropping areas is vital. Improve drainage by using raised beds for cropping or laser grading low lying areas. Avoid overwatering.

3 Rotate crops

Increase the duration between successive brassica crops to allow natural decay of the spores. Rotate with non-brassica crops and maintain crops free of cruciferous weeds.

Chinese cabbage is most susceptible to clubroot, followed by cauliflower, cabbage and broccoli. However, some cultivars within a species are tolerant (eg. Yates broccoli - 'Dome' is tolerant to some Australian isolates of clubroot).

The bottom line

- Australian growers have the world's first molecular diagnostic test to detect the clubroot fungus in soil and water.
- This test has helped trace and eliminate clubroot contamination in nurseries.
- Integrated management strategies have been developed for all States.
- On high risk soils, fluazinam alone (incorporated in transplant row) can increase yield by up to 80% or $10,200 per hectare (for cauliflower).
- Modified planters are now used to incorporate base fertilisers into the transplant row at planting.

Transplant equipment modified to include two small rotary hoes for incorporation of product into the transplant row.

4 Use fungicides wisely

Application of fungicide may also be necessary in paddocks with previously high levels of disease. It is important to evenly distribute fungicides around the transplant root zone.

This is best achieved by incorporating the fungicide into the transplant row at planting. In trials, this method increased the marketable yield of broccoli and cauliflower by at least 80%, compared with other commercial methods. It also required 80% less water and was more reliable and effective in a range of soil types.

5 Know the disease risk

Effective on farm application of integrated management techniques will require some estimation of likely disease risk and will depend on:

- Spore load - a commercial diagnostic test is available to determine the presence or absence of spores. Evaluation of a quantitative test (that provides an estimate of spore numbers) is under way. Until then, spore load must be estimated based on the severity of last infection, time since last infection and management strategies used. Consider:
  - Sowing time (high risk in warm months)
  - Soil type (clay - high, loam - medium and sand - low risk)
  - Drainage, soil pH, crop (including variety) and cruciferous weeds.

Risk

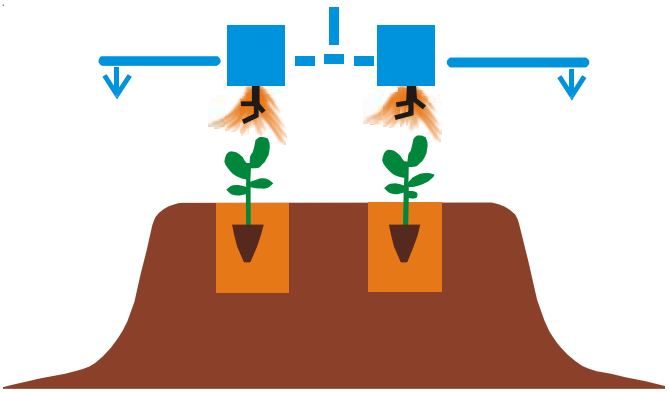
Low - no or mild infection in the past, with at least 5 years since the last infection.

Medium - moderate infection in the past with between two and five years since the last infection.

High - severe infection with less than two years since the last infection.

Acknowledgements

Caroline Donald, Ian Porter (Department of Primary Industries VIC) and Rachel Lancaster (Department of Agriculture WA).



Even distribution of fluazinam around the root zone prevents phytotoxicity, minimises product waste and increases efficacy.

Further Reading

A guide to the prevention and management of clubroot in vegetable brassica crops

Clubroot Galls and All – the newsletter of the National Clubroot Project

Integrated Pest Management for Brassicas (Computer CD and Video)

www.dpi.vic.gov.au

Further Information

For more information regarding the information contained in this edition of VEGE*notes* please contact your Vegetable Industry Development Officer.

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Biosecurity

"Biosecurity" is a general description for a series of measures designed to protect individual farming properties, businesses and the nation as a whole, from the entry and spread of exotic pests. This is done by using exclusion, eradication and control measures.

As an island continent, Australia has remained relatively safe from the serious plant pests including insects, diseases and weeds, which are found elsewhere in the world. This benefits plant industries, including the vegetable industry, by giving growers a valuable competitive advantage in terms of securing market access and maintaining reduced production costs.

Protecting Australia's crops is important to ensure the long-term survival of the industry.

Effective pest management is essential in protecting Australia's economy. Exotic pests could cost the industry millions of dollars through job losses, reduced export opportunities and increased control costs. The gross value of vegetable crops is around $2.3bn[1] and exports (mainly to Asian countries) are worth, on average, $200m annually[2]. Direct employment in the industry stands at approximately 15,000 jobs[3].

The current level of strict quarantine is an essential part of protecting Australia's vegetable industry from new pests. However, these measures will not provide total protection. For example, the currant-lettuce aphid, recently discovered in Tasmania, appears to have entered Australia from New Zealand after unusual weather conditions.

The potential for natural incursions from near neighbours and increasing international movement of passengers, cargo and mail is an ongoing threat to Australia's favourable plant health status.

A sign promoting hygiene as a biosecurity measure.

Plant Health Australia (PHA) is working with AUSVEG, Horticulture Australia, representatives from the federal, state and territory governments and other experts to develop national biosecurity plans for the vegetable and potato industries.

The bottom line

- Industry, government and the community are all responsible for maintaining Australia's plant health status
- Prevention is the key
- Growers can use simple biosecurity measures to protect the industry; keeping cropsp pest free and preventing movement of pests between regions

The development of the vegetable industry biosecurity plan will include:

- identification of high-risk pests
- development of risk management measures
- contingency plans to ensure any exotic pest outbreaks are efficiently managed

Practices that minimise the risk of exotic pests are key aspects of any biosecurity plan. This is not only important for the profitability and sustainability of individual businesses, but for the whole vegetable industry.

Potential pests

There are a number of pests that affect vegetable crops around much of the world that are currently not present in Australia. For example, the American Serpentine Leafminer (*Liriomyza trifolii*) could have a significant impact on the Australian vegetable industry. It attacks plants by burrowing into the leaves of a range of vegetable crops including cucurbits, alliums, brassicas, capsicums, celery, lettuce, potatoes and tomatoes. The vegetable biosecurity group is currently working to identify other high priority exotic pests that could cause significant impact in Australia.

Lirionmyza trifolii.
photo: Mike Parrella

Biosecurity strategies

There are several practical steps growers can take to ensure better biosecurity for their individual business, and the wider industry, including:

- regularly inspect crops and report suspicious insects, diseases and weeds to the nearest agriculture department as soon as they are detected (Exotic Plant Pest Hotline freecall - 1800 084 881)
- learn about local and common pests so that any new pests can be identified
- clean dirt and plant material from any footwear, equipment or vehicles entering your property (this includes your own footwear, vehicles or machinery if taken off-farm)

Washing down bins.

- put systems in place to deal with contractors and visitors to minimise the introduction of new pests to your property. This can be done by restricting the movement of people and machinery on your property
- use signage to inform visitors to your property of biosecurity and hygiene measures in place
- buy accredited seed or planting stock where possible
- identify any areas on the property that are infested with weeds, insects or diseases so they can be managed and precautions can be taken to prevent further spread

Further information:

More information on the vegetable industry biosecurity plan, it is available on the PHA website:
www.planthealthaustralia.com.au/vegetables

Acknowledgements

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Know-how for Horticulture

Weed Management

Australian vegetable production is characterised by a diversity of crop types, grown in intensive rotations, across the wide range of environments Australia has to offer.

Basic strategies used to manage weeds are adapted and integrated to suit the different production systems. The overall aim is to develop a system that combines all of the appropriate weed control options.

Fat Hen (chenopodium album) is a common weed of vegetable crops.

Weed management systems employ combinations of physical, ecological, biological, chemical and genetic methods to obtain effective and economical weed control, with minimal effect on non-target species and the environment.

History has shown weed populations can adapt to weed management systems that rely on few or single control options. Thus, the adoption, and continued development, of weed management programs incorporating a diverse range of management methods is essential for cropping systems to remain productive.

Herbicides

Herbicides are currently the predominant control option for weeds in intensive vegetable production. In a number of vegetable crops, such as capsicums and cucurbits (pumpkins, melons etc.), there are few, if any, suitable herbicides registered for broadleaf weed control.

Even in some of the more significant vegetable crops, such as potatoes, the availability of new herbicide technology is limited, which has created a number of weed management issues.

On a global scale, companies are primarily interested in the major crop markets such as: cereals, rice, soybeans, corn, cotton, canola, grapevines, pome fruit and potatoes. In Australia, crops such as cereals, canola, pulses and cotton have a strong influence on development decisions.

To develop new herbicides, companies are faced with increasing costs to satisfy the data requirements prior to registration. Companies cannot justify the expense to develop products for most intensive horticultural uses.

The Bottom Line

- **Weed management requires a combination of physical, ecological biological, chemical and genetic control methods.**
- **Herbicides for vegetable weed management are limited.**
- **Intensive horticulture in Australia needs to be proactive and seek new technologies from non-traditional sources.**
- **Research is delivering new weed managemen options for Australian vegetable growers.**

Thus, smaller more intensive crops are often overlooked in relation to chemical development.

Historically, herbicides were the compounds every company wanted to discover. However, the advent of genetically modified (GM) crops that could tolerate very cheap, patent-expired herbicides, required companies to change their strategic direction.

Insecticides, fungicides and plant growth regulators also increased in importance to companies. As a result, chemical companies previously targeting herbicide development diversified into the seed business, so as to remain viable. The development pipeline for herbicides has also been quite low in recent times, in comparison to fungicides and insecticides.

Intensive horticulture in Australia needs to be proactive in identifying suitable products and raising the priority of development programs for new agricultural chemicals to control pests, diseases and weeds. It also needs to seek out new, potentially beneficial, technologies from non-traditional sources.

Current Research

Serve-Ag Research is currently conducting valuable weed management research for the Australian vegetable industry. Weed management projects have been completed in crops such as:

- pumpkins;
- green beans;
- sweetcorn;
- lettuce;
- processing peas;
- potatoes;
- brassicas;
- processing tomatoes;
- Kabocha;
- carrots; and
- capsicums.

The principle aim of these projects has been to develop new herbicides for these crops, to address specific weed management issues. The work is principally funded by Horticulture Australia Ltd, with voluntary contributions and in-kind support from a number of herbicide manufacturers.

All the projects are conducted nationally with replicated trials in key production regions throughout Australia.

Some of the herbicides developed in these projects are now becoming commercially available to growers throughout Australia.

New Herbicide Registrations

Trial information collected as part of these projects was used to gain registration of the herbicide Command in a range of horticultural crops including potatoes, green beans and cucurbits.

This was a significant achievement for the Australian vegetable industry, particularly as it is the only herbicide registered for broadleaf weed control in cucurbit crops.

Baron 40 WP trial site.
Left: Wild radish in transplanted broccoli. Right: Transplanted broccoli treated with Baron 40 WP.

The commercial availability of Command also provides an alternative chemical mode of action in crops such as beans and potatoes. This product can also be used as part of an integrated control strategy for weeds such as black nightshade (*Solanum nigrum*) in potatoes, which are typically very difficult to successfully control. Furthermore, Command is also particularly active on other problem weeds such as hogweed (*Polygonum aviculare*) and potato weed (*Galinsoga parviflora*), for which few chemicals are registered.

Serve-Ag Research is currently working on further herbicide development projects including:

- A new active dimethenamid-p for registration in crops (including processing peas, green beans, sweet corn and pumpkins) for the management of a range of grass weeds and broadleaf weeds, including Amaranthus (*Amaranthus spp.*).

  Grower scale trials conducted with this product have shown very promising results. These include significantly reduced costs of handweeding in pumpkins and control of amaranthus in beans; and reducing the need for post emergent herbicide application, which can reduce yield and quality.

- Bioefficacy trials on Baron 40 WP, which is a new formulation of oxyflourfen (Goal®). Baron 40 WP can be applied over the top of brassica seedlings to control wild radish and other weeds.

The bottom line for the Australian vegetable industry is that while it may be a slow and expensive process, registration of new herbicides, employing new actives and environmentally sound practices, are being successfully obtained through current research.

This is resulting in the development of more efficient and effective weed management strategies for sustainable Australian vegetable production.

Top: Grass weeds in sweetcorn.

Bottom: Control of grass weeds in sweetcorn with dimethenamid-p.

Novel weed management ideas

New crop protection products do not necessarily need to be agricultural chemicals, they can be new technologies for weed control.

Generally, these technologies do not require the extensive data needed for herbicide registration. As a result, smaller companies can develop these technologies as the financial development 'hurdle' is lower.

One example is degradable mulch being developed in the UK by Terraseed. This is a great example of a practical solution to weed management and is an alternative to heavy agricultural chemical reliance.

This system involves the crop seed being impregnated between a layer of paper and plastic. The plastic is laid in the field on beds and then watered using overhead or drip irrigation. The paper absorbs the water and the crop seed germinates through slits in the plastic.

Weeds are physically prevented from growing through the plastic and, furthermore, the mulch has additional benefits, such as ensuring even crop germination, retaining soil moisture and preventing soil contamination of crops. Also, mulch is fully biodegradable: the remaining mulch can be cultivated into the soil following harvest.

Kabocha planted into mulch.

Another novel alternative to chemical weed management is the use of mulches such as cereals. Cereal mulch is grown, then killed off and rolled. Crops such as cucurbits and brassicas are then planted into the stubble. The mulch provides effective suppression of weeds throughout the growing season.

Cereals such as wheat and ryecorn are very effective mulches for controlling weeds, possibly due to alleopathic effects (compounds released from the cereals which inhibit weed germination). The ability of cereal crops and stubble to suppress weed emergence is well documented. Banded applications of herbicides and cereal mulches can be used to further improve the weed control in the planted row, as soil disturbance at planting stimulates weed germination.

The use of mulches requires some changes in crop management. For example, the decaying cereal stubble can affect soil nitrogen levels and some insect pests populations may build up in the mulch.

AHR CropScience has worked for several years on the use of mulches as part of an integrated crop management program, and the final report on this work is available from Horticulture Australia Ltd.

The future of weed management

The challenge facing Australian vegetable producers is to develop weed prevention and management strategies that are: effective and profitable (in both the short and long term); sustainable and safe for the community and the environment; and adaptable for individual land management situations.

The three main issues facing agriculture are a dynamic and expanding weed flora, environmental and ecological sustainability and the integration and adoption of weed management systems.

To be able to tackle these issues there is a need for an increased understanding of the biology and ecology of weeds, advances in and integration of control methods, as well as greater use of emerging technologies.

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Acknowldgements

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