Program 1: Development of effective pesticide strategies compatible with IPM management used on farm.

Peter Dal Santo
AgAware Consulting Pty Ltd

Project Number: VG07109

VG07109

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Level 7
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HAL

Know-how for Horticulture™

Development of effective pesticide strategies compatible with IPM management used on farm

Horticulture Australia Ltd

Project No: VG07109

Peter Dal Santo and Ross Holding

AgAware Consulting Pty Ltd and Classy Solutions

November 2009

Horticulture Australia project no:

VG07109

Project leader name:

Peter Dal Santo
AgAware Consulting P/L
21 Rosella Avenue
Strathfieldsaye Victoria 3551
Ph: 03 5439 5916
Fax: 03 5439 3391
Email: pds@agaware.com.au

Personnel:
Ross Holding
Classy Solutions
RSD B 812
Cardigan Victoria 3352
Mob: 0438 443978
Fax 03 5344 8313
Email: classysolutions@a1.com.au

Purpose of the report:

This project was funded by Horticulture Australia Ltd to development effective fungicide strategies compatible with IPM management used on farm.
The project involved listing the registered fungicides per target disease and crop and assessing the profile of each pesticide against certain parameters for their IPM compatibility.
Information was gathered from growers, consultants, government researchers and finding from other projects within the Vegetable Pathology Program to develop the overall strategies.
'Best Practice' documents for key diseases and crops were produced to assist the vegetable industry with their use of fungicides to minimise their impact on farm workers, consumers, the environment and beneficial organisms.

Funding sources:

- Horticulture Australia Ltd
- Australian Vegetable Research and Development Levy Scheme

Date of report:

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Disclaimer:

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Media and Technical Summary

With the growing interest of Integrated Crop Management (ICM), which includes Integrated Pest Management (IPM) techniques in the production of vegetables in Australia, there is a need to provide the vegetable industry with information that covers all components of ICM in vegetable production.

IPM principles are well known for insect control and insecticide use, but it is less well known for disease control and fungicide use.

The project, 'VG07109 – Development of effective pesticide strategies compatible with IPM management on farm' collated information to assist all sectors of the vegetable industry with their decision making to support the use of fungicides with an appropriate IPM profile.

The diseases and crops identified as high priority for investigation and reporting were:

- Downy mildew / all crops
- Fusarium, Pythium and Rhizoctonia / all crops
- Powdery mildew / all crops
- Sclerotinia / beans
- Sclerotinia / lettuce

Information on registered and permitted fungicides, fungicide use patterns, efficacy, impact on beneficial organisms, environmental and ecological impact were collated from Australian and overseas sources and presented in five easy to read 'Best Practice' documents for use by growers, grower associations, advisors, retailers, government agencies and researchers.

To improve the holistic approach to disease management, fungicide use and ICM, the Environmental Impact Quotient (EIQ) system developed by J. Kovach, et al. New York State Agricultural Experiment Station, Cornell University, New York, USA was selected as a support tool. EIQ rates fungicide impact on beneficial organisms, as well as:

- Applicator effects } Farm workers
- Picker effects } Farm workers
- Consumer effects
- Leaching (runoff, soil residues)
- Fish, birds & bees } Ecology
- Beneficial organisms } Ecology

The EIQ data was well supported by Australian data from:

- Horne P, et al 'VG06087 – Pesticide effects on beneficial insects and mites in vegetables.' This contained data on fungicide impact on beneficial organisms.
- Forsyth L, et al 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia. This contained data on the fungicide resistance status in various diseases.

To accompany each 'Best Practice' document, a 'Best Practice for Vegetables – Introductory Document' was prepared that expands on Integrated Crop Management, the structure of each report and references for additional information.

Introduction

There has been a significant growth in interest in the implementation of integrated pest management (IPM) techniques in the Australian vegetable industry in recent years due to:

- Resistance to existing pesticides
- Lack of effective alternative pesticides
- Impact of available pesticides on beneficial organisms
- Residues in produce
- Trade implications

Growers' interest in IPM has been reflected in the vegetable research undertaken where IPM is now an essential part of projects and outcomes. This has particularly applied to insect control and insecticide use; however growers, consultants, industry and the community now see a need to extend this knowledge and application to fungicides.

Strategies for IPM management of fungicides are a relatively less well developed science compared to IPM management of insecticides.

There is a need to understand the effects of commonly used fungicides on a wide variety of beneficial organisms such as predatory mites, ladybirds, lacewings, parasitoids, spiders etc. It is imperative that fungicidal effects be mapped out and taken into account when planning on-farm IPM programs.

There is incomplete knowledge about IPM usage of fungicides in Australia. There are Australian experts (involved in HAL and non-HAL projects) and other international IPM focused organisations that can provide information on the important beneficial organisms that need to be taken into account when analysing the current fungicides used in the Australian vegetable industry. An IPM fungicide profile will utilise the knowledge of a wide group of industry personnel including: private IPM consultants, state government fungicide and insecticide experts, chemical company experts and key growers who currently practice IPM farm management. It is recognised that knowledge is incomplete however by combining all available resources a management system can be constructed of the IPM compatibility of currently used fungicides as well as their pesticide residue and environmental profiles.

Field guides of diseases are available for selected vegetables and for selected states (e.g. 'Pests, Beneficials, Diseases and Disorders in Lettuce: Field Identification Guide' by NSW Agriculture and 'Diseases of Vegetable crops' by Dept of Primary Industries Qld) are currently available to growers. However linkage with fungicide (as well as insecticide) IPM safety is not readily available.

The use by growers of IPM specialist consultants in vegetable production is developing rapidly. Consultants such as Paul Horne (IPM Technologies, Victoria), Lachlan Chilman (Manchil IPM Services, WA) and Andy Ryland (Beneficial Bug Co, NSW) are now an integral part of the vegetable production scene.

In November 2006, the Victorian Department Primary Industries (VDPI) Knoxfield, lead by Dr Ian Porter's group conducted a national IPM Pathology Gap Analysis. The meeting involved leading growers, pathologists, researchers and consultants involved in the vegetable industry. From this workshop the following key issues were identified:

- Key diseases
- Key crops
- Information gaps
- Research gaps
- Innovation gaps
- Communication gaps

From this process a national 'Vegetable Pathology Program' was developed to address the issues identified from the workshop.

One project, 'VG07109 – Development of effective pesticide strategies compatible with IPM management on farm' was contracted to AgAware Consulting P/l and Xeron Consulting. The project started in late September 2007 and was a 2 year project. Xeron left the project after one year, with Classy Solutions (Ross Holding) then taking over the key role. The diseases and crops identified as high priority for investigation and reporting were:

- Downy mildew / all crops
- Fusarium, Pythium and Rhizoctonia / all crops
- Powdery mildew / all crops
- Sclerotinia / beans
- Sclerotinia / lettuce

The project liaised with a wide group of industry experts and organisations, from within and outside Australia, for the collection and collation of the information required. Organisations consulted included existing IPM consultants, international IPM organisations [Cornell University, IR-4 (USA minor-use program), IOBC (International Organisation for Biological and Integrated Control of Noxious Animals and Plant)], state departments of agriculture, other industry research organisations (grape and cotton industries), current HAL vegetable project leaders, key IPM growers and horticultural advisors from industry including chemical companies.

From a search of systems used internationally to rate pesticides for environmental compatibility, it was found that the Environmental Impact Quotient (EIQ) developed by Kovach, et al at Cornell University NY USA was the most appealing as its ranking system assessed pesticide impact on:

- Farm workers - applicators and pickers
- Consumers
- Environmental - leaching, runoff, soil residual
- Ecology - insects birds, fish & bees

EIQ took into account a complete understanding of the consequences of pesticide use, not just the inherent properties of the pesticide, but also properties related to the:

- Formulation
- Application rate
- Number of applications

This gave an 'EIQ Field' rating that can directly compare each disease management strategy.

'Best Practice' programs for each of the diseases/crops included current pesticide and non-chemical control practices. EIQ was used as the basis for the fungicide recommendation in each of the reports.

This project aimed to assist growers' and consultants with their plant disease management options:

- It is expected that within 2 years of this project that at least 80% of all vegetable growers and 100% of all consultants, researchers, advisors and resellers will be aware of IPM compatibility of the pesticides related to insecticides and fungicides.
- It is expected that within 2 years that at least 80% of growers and 100% of all consultants, researchers, advisors and resellers are aware of the 'Best Practice' methods of both fungicidal and non-fungicidal control of a number of key vegetable diseases.

Methodology

From the industry workshops conducted by Vic DPI in 2006, the following diseases and crops combinations were identified as high priority for investigation and reporting:

- Downy mildew / all crops
- Fusarium, Pythium and Rhizoctonia / all crops
- Powdery mildew / all crops
- Sclerotinia / lettuce
- Sclerotinia / beans

This project was principally involved with gathering data from a range of sources (Australian and international), collating the information into a logical order and then producing 'Best Practice' programs for each disease / crop combination.

The process undertaken:

1. Prepare a list of registered and permitted fungicides for each disease/ crop combination. This gave us a list of all fungicides legally available to growers for disease control.

2. Tabulate the use pattern for each fungicide / disease / crop.

3. Obtain information from Australian sources on their perspective of IPM in vegetables, direction on how the 'Best Practice' programs should be presented and any new or local information:

   a. Liaise with State Department of Agriculture and company personnel
      - Dr Chrys Akem, Queensland Primary Industry and Fisheries
      - Tony Burfield, South Australian Research and Development Institute
      - John Duff, Queensland Primary Industry and Fisheries
      - Dr Leanne Forsyth, NSW Department of Primary Industries
      - Barbara Hall, South Australian Research and Development Institute
      - Dr Sandra McDougall NSW Department of Primary Industries
      - Dr Elizabeth Minchinton, Victorian Department of Primary Industry
      - Dr Leigh Pilkington NSW Department of Primary Industries
      - Dr Ian Porter Victorian Department of Primary Industry
      - Dr Hoong Pung, Peracto Pty Ltd Tasmania
      - Dr Len Tesoriero, NSW Department of Primary Industries
      - Dr Oscar Villalta, Victorian Department of Primary Industry
      - Andrew Watson, NSW Department of Primary Industries

   b. Liaise with vegetable growers and Vegetable Industry Development Officers:
      - Dr Alison Anderson, IDO New South Wales
      - Peter Cochrane, farmer Victoria
      - Melissa Frazer, IDO South Australia
      - Eddie Galea, farmer New South Wales
      - Roger Orr, IDO Tasmania

   c. Liaise with key horticulture advisors/experts from commercial organisations:
      - Lachlan Chilman, Manchil IPM Services, West Australia
      - Dr Stephen Goodwin, Biocontrol Solutions, New South Wales
      - Dr Paul Horne, IPM Technologies, Victoria
      - Andrew Meurant, Elders, South Australia
      - Karl Riedel, EE Muirs, Victoria
      - Scott Mathew, Syngenta, South Australia

4. Obtain information from overseas sources on IPM in vegetables and fungicide use:
    - IOBC 'International Organisation for Biological and Integrated Control of Noxious Animals and Plant' (European)
    - IR-4 Program (US)
    - University of California IPM Program (US)
    - Biobest (European)

5. Incorporate Australian and international information into fungicide lists for each disease/ crop combination.

6. Prepare draft 'Best Practice' program documents for each disease/ crop combination with the following sections:
    A. Introduction
    B. Integrated crop management
    C. Disease background
    D. Current fungicides (registered or permit)
    E. Other fungicides (chemicals)
    F. Environmental profile of fungicides
    G. Product application rates and other information
    H. Disease control programs incorporating IPM options
    I. Application
    J. Fungicide resistance
    K. Other ICM considerations
    L. Biofungicides
    M. Future directions
    N. Summary points

7. Draft 'Best Practice' program documents circulated to industry for comment on layout, accuracy and information provided.
8. Incorporate the latest information supplied by 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia' Dr Leanne Forsyth, NSW DPI and Barbara Hall, SARDI.
9. Final versions of 'Best Practice' program documents produced for:
    - Downy mildew / all crops
    - Fusarium, Pythium and Rhizoctonia / all crops
    - Powdery mildew / all crops
    - Sclerotinia / beans
    - Sclerotinia / lettuce

Results

Following the collation of data from Australia and overseas sources the following information could be summarised:

- Many fungicides are registered for Downy mildew control in a wide variety of crops. Copper is most commonly used in a protective fungicide programs.
- Other Downy mildew fungicides and biofungicides are under development and may achieve registration or permit use in the future. It is unknown at this time how many different vegetable crops will be included on these labels.
- Fusarium, Pythium and Rhizoctonia as disease 'complexes' are becoming increasingly important as soil-borne diseases in vegetable.
- Because of the nature of Fusarium, Pythium and Rhizoctonia, most fungicides (except for fumigants) are used as either seed dressings (applied to seed prior to planting) or post harvest dips (applied after harvest). Unfortunately, the number of different fungicides available is limited.
- Powdery mildew is the most serious disease of cucurbit in Australia. Powdery mildew also occurs in: carrots in south east Australia; peas (including snow peas) and capsicums/peppers in Western Australia and Queensland; parsnips in South Australia and radish, swedes, turnips and tomatoes throughout Australia.
- Powdery mildew resistance management is critical in cucurbits.
- Sulphur is the backbone of a preventative fungicide programs for Powdery mildew control in vegetables.
- Many Powdery mildew fungicides are registered or can be used under permit. Fungicides from a wide range of activity groups exist and provide ample opportunity for rotation to prevent fungicide resistance.
- Other Powdery mildew fungicides and biofungicides are under development and may achieve registration or permit use in the future. It is unknown at this time how many different vegetable crops will be included on these labels.
- *Sclerotinia* produces long lived sclerotes which can infest soil for many years. Reduction of the *Sclerotinia* inoculum is a key to the long term control.
- Iprodione (eg. Rovral®) and tebuconazole (eg. Folicur®) are the only currently registered active ingredients for Sclerotinia control in lettuce. Amistar® (azoxystrobin) and Filan® (boscalid) can be used under permit.
- Amistar and Filan are generally considered harmless to many beneficial organisms found in vegetables.
- From initial testing in the project, 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', 2 of 20 isolates of lettuce Downy mildew showed resistance to metalaxyl from the Sydney basin growing region. Further testing of isolates is underway.
- From initial testing in the project, 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', 45 of 47 isolates of *Sclerotinia sclerotiorum* received from Vic, SA, WA, NSW, Qld and Tas tested so far, 2 from NSW and 2 from Victoria were resistant to benzimidazoles (carbendazim, thiabendazole) with 6 showing reduced sensitivity and 5 were resistance to dicarboximides (iprodione, procymidone).

- From initial testing in the project, 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', 13 of 21 lettuce samples of *Sclerotinia minor* were resistant to benzimidazoles (carbendazim, thiabendazole) and 3 were resistant to dicarboximides (iprodione, procymidone).
- Further testing of isolates in the project, 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', is underway.
- CropLife Australia (formerly AVCARE) implements Fungicide Resistance Management Strategies (FRMS) for various crops and diseases in Australia. These strategies should always be followed.
- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.
- At present no biofungicides of a biological nature are fully registered in Australia for Downy mildew, *Fusarium, Pythium, Rhizoctonia,* Powdery mildew or *Sclerotinia spp*. control. The only exception is potassium bicarbonate eg. Ecocarb® which has a permit for Powdery mildew control in greenhouses for some crops. Although there are some products sold under various guises that claim disease control.

All this information was incorporated into 'Best Practice' program documents for:

- Downy mildew / all crops
- Fusarium, Pythium and Rhizoctonia / all crops
- Powdery mildew / all crops
- Sclerotinia / beans
- Sclerotinia / lettuce

Two versions of each document were produced:

- confidential versions containing registered and unregistered fungicides and biofungicides
- public versions containing registered fungicides only

Each document is presented in the Attachments:

1 - Best Practice for Vegetables – Introductory Document

2 - Best Practice - Downy mildew in vegetables

3 - Best Practice - Fusarium, Pythium and Rhizoctonia root rots in vegetables

4 - Best Practice - Powdery mildew in vegetables

5 - Best Practice - Sclerotinia in green beans

6 - Best Practice - Sclerotinia in lettuce

Discussions

The aim of the project, 'VG07109 – Development of effective pesticide strategies compatible with IPM management on farm' was to obtain relevant information to assist vegetable growers, advisors and researchers with their decision making to support the use of fungicides with an appropriate IPM profile. Basically we need to provide information on the current fungicides available for the control of selected diseases and their environmental compatibility.

The general method of controlling diseases in Australia is based on plant resistance, cultural practices or fungicides. When an agricultural chemical company registers a new product, they provide a range of information to the regulators, generally to do with efficacy, crop safety, residues, trade implications and OH&S. Often no information is required on IPM compatibility for registration. Agricultural chemical companies sometimes privately generate IPM data for their own use only. If the data is favourable, it is commonly used in their marketing information.

The need for fungicide IPM information is critical to the disease management in all vegetable crops, as this will assist the decision making of growers, advisors, retailers and researchers.

But the further you investigate the 'IPM profile' the vaguer the definition and support data becomes. The project was faced with various interpretations of 'IPM' depending on the source of information, limited reference to fungicides (most information was related to insecticides) and no information on a specific disease management program with IPM reference.

Following discussions with other project members involved in the Vegetable Pathology Program, it was determined that as idealistic IPM fungicide information is, that 'Good Agricultural Practice' (GAP) is just as important. Therefore the project extended its investigation to a holistic approach to fungicide selection and use.

The lists of registered and permitted fungicides for the specific diseases / crop combinations were obtained from the Australian Pesticides and Veterinary Medicines Authority. Information on current uses, local impact and market preferences were provided by growers, advisors, researchers and manufacturers.

For holistic GAP information, the Environmental Impact Quotient (EIQ) system developed by J. Kovach, C. Petzoldt, J. Degni and J. Tette of New York State Agricultural Experiment Station, Cornell University, New York, USA was selected as the most appropriate.

Each pesticide is assessed against all or some of the following criteria:

- Acute dermal toxicity
- Chronic health effects
- Leaching potential
- Mode of action
- Plant surface half life
- Plant surface health effects
- Runoff potential
- Soil residue half life
- Toxicity to bees
- Toxicity to beneficial insects
- Toxicity to birds
- Toxicity to fish

Therefore EIQ not only looks at the pesticides impact on beneficial organisms, but also:

- Applicator effects } Farm workers
- Picker effects } Farm workers
- Consumer effects
- Leaching (runoff, soil residues)
- Fish, birds & bees } Ecology
- Beneficial organisms } Ecology

For EIQ the higher the value associated with each fungicide, the poorer the environmental fit. Unfortunately, EIQ data was not available for all fungicides used in Australia. The authors were contacted regarding these 'gaps', but were unable to provide any additional data.

Of significant importance to the 'Best Practice' documents was the Australian information provided from Australian research, especially:

- The final report of 'VG06087 – Pesticide effects on beneficial insects and mites in vegetables.' By P. Horne, P. Cole and A. Cutler, IPM Technologies P/L, May 2009. This contained data on fungicide impact on beneficial organisms.
- The milestone reports from 'VG07119 – Identification and monitoring of resistance in vegetable crops in Australia.' by L. Forsyth, NSW DPI and B. Hall, SARDI. This contained data on the fungicide resistance status in various diseases.

With the lists of registered and permitted fungicides for each specific diseases / crop combination, the EIQ ratings and local research data were added as well as comments from local specialists.

The 'Best Practice' documents were constructed with the following sections:

A. Introduction
    - Provides an outline of the report
B. Integrated crop management
    - Provides an outline and scope of ICM
C. Disease background
    - Lists the diseases, symptoms and conditions favouring disease
D. Current fungicides (registered or permit)
    - Lists all available fungicides, permits, trade names, formulations, crops registered and cautions.
E. Environmental profile of fungicides
    - Provides EIQ information on each pesticide.
    - Lists the impact of fungicides on beneficial insects and mites – Australian data
F. Product application rates and other information
    - Information on fungicide use patterns
G. Disease control programs incorporating IPM options
    - Disease control programs under various scenarios
H. Application
    - Fungicide application information
I. Fungicide resistance
    - Fungicide resistance information for each disease, CropLife recommendations, resistance testing
J. Other ICM considerations
    - Disease management options other than fungicides
K. Biofungicides
    - Ratings of biological control agents and biofungicide currently available

L. Future directions
    - Future areas of research

M. Summary points

'Best Practice' documents were prepared for:

- Downy mildew / all crops
- Fusarium, Pythium and Rhizoctonia / all crops
- Powdery mildew / all crops
- Sclerotinia / beans
- Sclerotinia / lettuce

To accompany each 'Best Practice' document, a 'Best Practice for Vegetables – Introductory Document' was prepared that expands on Integrated Crop Management, the structure of each report and references for additional information.

Communication

The success of 'VG07109 – Development of effective pesticide strategies compatible with IPM management on farm.' was based on the projects' ability to communicate with industry.

The Methodology lists the people contacted during the construction of these reports. Contact was made with face-to-face meetings, regional meetings (as part of larger meetings), teleconferences and emails.

The stages where communication with Australian and overseas experts were critical was:

- In identifying the major disease / crop combinations
- In the sourcing of product lists and use patterns
- In the structure of the 'Best Practice' documents
- In providing scientific and regional information
- In the review of the final 'Best Practice' documents

Therefore, the information contained in the 'Best Practice' documents is the successful amalgamation of the registered fungicides and the comments, options and research of others.

The information from the 'Best Practice' documents have already been incorporated into the work of another project involved in the Vegetable Pathology Program – VG07110 – Best practice production models (lettuce, brassicas).

Promotion of the 'Best Practice' documents were prepared and produced by HAL and presented at the:

- Vegetable Industry Conference, Melbourne, May 2009 - poster
- Vegetable Field Days, Werribee, May 2009 - poster
- Vegetable IPM Disease Program, an overview – booklet
- Other vegetable field days – booklet and poster

Given that some of the key sources of communication with the vegetable industry were involved in the development and information gathering for this project, it is expected that these same sources will be the conduit that extends the 'Best Practice' documents to growers, grower associations, advisors, retailers, government agencies and researchers in the future.

Once the final report has been approved, the six documents that have been produced from this project; the 'Best Practice for Vegetables – Introductory Document' and five 'Best Practice' documents need to be circulated to industry for use. The best mediums to distribute the information are:

- Ausveg website – listing each 'Best Practice' document.
- Vegetables Australia – bimonthly magazine. As each 'Best Practice' document is too large to include in the magazine, an article detailing the reports should be included with reference to the Ausveg website.
- Distribution through the newly established Knowledge Management Subprogram of the Vegetable Industry Development Program and IPM Coordinator.
- Distribution to the other members/researchers of the Vegetable Pathology Program.
- Distribution to the vegetable contacts of AgAware Consulting Pty Ltd.

Recommendations

The following recommendations are made from the outcomes of 'VG07109 – Development of effective pesticide strategies compatible with IPM management on farm':

- Many of the fungicides available for diseases control in vegetables are very old and some are under review overseas and/or by the APVMA Chemical Review Program. This may lead to use restrictions in the future. This situation needs to be monitored and appropriate action undertaken when necessary.
- Some newer fungicides and biofungicides are under review and may achieve registration or permit use in the future. The vegetable industry needs to collaborate with these organisations to ensure vegetables are included.
- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.
- Correct application techniques are essential for the most efficient use of fungicides. Always read the label.
- The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur. Check state government agencies websites, retailers, consultants, etc. for pest management strategies.
- Incorporate Integrated Crop Management (ICM) into your farming practices. The effective control of disease requires the use of all management options; this includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicides be considered to: control / prevent / decrease / delay disease infection.
- Careful consideration of crop rotation is also a powerful management tool.
- At present no biofungicides of a biological nature are fully registered in Australia for disease control. The only exception is a permit for potassium bicarbonate (Ecocarb®) for powdery mildew control in greenhouse vegetable crops.

Recommendations for further research and activities are:

- For the vegetable industry to work with agricultural chemical companies to collaborate in new fungicide development and registration to ensure a wide variety of vegetable groups are included on existing and new fungicide labels.
- To continue to monitor for fungicide resistance in common vegetable diseases.
- To continually update the 'Best Practice' documents as new information becomes available – resistance, IPM compatibility, EIQ, etc.
- Biological fungicides to be evaluated for efficacy under Australian conditions and gain registration or permit if viable.

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APVMA:	Alan Norden
Consultants:	Domenic Cavallaro (SA), David Carey (Qld), Lachlan Chilman (WA), Stephen Goodwin (NSW), Paul Horne (Vic), Karl Riedel (Vic)
Government agencies:	Each state government agency as excellent sources of information
Horticulture Australia:	Leanne Wilson and Sarah Sullivan
Industry Development Officers:	All, especially the Alison Anderson and Melissa Frazer
Industry:	Andrew Meurant (Elders, SA), Scott Mathew (Syngenta, SA)
International agencies:	IR-4 (USA), IOBC (EU), University of California (US), Biobest (EU)
Growers:	Peter Cochrane (Vic), Eddie Galea (NSW)
Work colleagues:	Eileen Dal Santo, Rob Velthuis (Xeron) and Ross Holding (Classy Solutions)

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Attachments

Attachment 1 - Best Practice for Vegetables – Introductory Document

Attachment 2 - Best Practice - Downy mildew in vegetables

Attachment 3 - Best Practice - Fusarium, Pythium and Rhizoctonia root rots in vegetables

Attachment 4 - Best Practice - Powdery mildew in vegetables

Attachment 5 - Best Practice - Sclerotinia in green beans

Attachment 6 - Best Practice - Sclerotinia in lettuce

BEST PRACTICE FOR VEGETABLES

Introductory document

The documents prepared under the "Best Practice' series provide information essential for economic and sustainable control of a specific diseases in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VG07109.

This document covers the principles of Good Agricultural Practice (GAP) that have been incorporated in the following documents:

- Downy mildew in vegetables
- Fusarium, Pythium and Rhizoctonia in vegetables
- Powdery mildew in vegetables
- Sclerotinia in beans
- Sclerotinia in lettuce

These diseases and crops were selected as those of greatest concern to growers in regards to:

- current control options
- effective control mechanisms
- impact on production

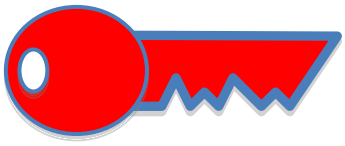
A theme that will be discussed throughout the documents is:

- Integrated Crop Management (ICM)
- Integrated Pest Management (IPM)

ICM is becoming increasingly important for vegetable production to control diseases and insect pests. ICM includes the principles of IPM including the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimise the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

For each of the diseases/crops reviewed in the documents, there are one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-



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DOCUMENT STRUCTURE

1. INTRODUCTION
Introduces the scope of each Best Practice documents.

2. INTEGRATED PEST MANAGEMENT
A short general introduction /description of ICM and IPM and its relevance to vegetable production. As there is a huge quantity of information already available to growers on IPM: the principles, mechanisms and practice (eg. Ausveg website), they are not elaborated any further in this section.

3. DISEASE BACKGROUND
This section provides a brief background to each disease within each document. It includes crops, correct names, symptoms and variety susceptibility. It is not intended to be a comprehensive précis of each disease as this information is available from other sources (eg. state agriculture department websites).

4. CURRENT REGISTERED AND PERMIT PRODUCTS
A list of all registered and permitted fungicides is listed for each disease. This includes all registered formulations for each active (eg. all registered copper products). It provides any precautions that are listed on labels or reported from field use.

Before any fungicide is used, the label or permit should be thoroughly read to determine if the use and situation is appropriate to the growers needs. The latest information on labels and permits is also available on the APVMA website.

Information and labels on registered fungicides can be obtained from the APVMA Pubcris website at: http://services.apvma.gov.au/PubcrisWebClient/welcome.do;jsessionid=vskyFtjLZKvxGrpbpnfpZXLRLqj9Z390Z9Gk5JWF2nQBccpBXFFw!546591743

Information and copies of permitted fungicides can be obtained from the APVMA Permit website at: http://www.apvma.gov.au/permits/permits.shtml

5. ENVIRONMENTAL PROFILE OF FUNGICIDES
One of the main aims of the project was to provide growers with information to rate each fungicide on their applicator, worker, IPM, environmental and consumer fit. After considering different methods and databases used worldwide, we adopted the Cornell University, New York, USA, Environmental Impact Quotient (EIQ) system: http://www.nysipm.cornell.edu/publications/EIQ/

EIQ assess each fungicide for:

- Applicator effects } Farm worker effects
- Picker effects } Farm worker effects
- Consumer effects
- Leaching
- Fish effects } Ecology effects
- Bird, bee & beneficials } Ecology effects

EIQ rates each of these factors and gives a rating that can be used to compare one fungicide with another for its environmental profile.

The EIQ data for each of the disease/fungicide combinations is presented in table format to give a quick concise summary for comparison. Unfortunately, not all fungicide data was available.

6. IMPACT OF FUNGICIDES ON BENEFICIALS INSECTS AND MITES- AUSTRALIAN DATA

In order to provide the best available local data; information from other projects was included, eg. VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

Only data relevant to each particular fungicide was included. Unfortunately, not all fungicide data was available.

7. PRODUCT APPLICATION RATES AND OTHER INFORMATION

To support the EIQ data it was necessary to summarise all other relevant information for each fungicide. This information is available on product label, but is presented in summary form – chemical group, maximum number of applications, rate per hectare, spray intervals and product concentration.

Before any fungicide is used, the label or permit should be thoroughly read to determine if the use and situation is appropriate to the growers needs. The latest information on labels and permits is also available on the APVMA website.

8. DISEASE CONTROL PROGRAM (EXAMPLE)

This section provides a diagrammatic representation of the crops growth cycle and critical stages when fungicides and other disease control options can be employed.

This representation is a guide only.

9. APPLICATION

General details on fungicide application are described, including droplets, coverage and spray adjuvants. More detailed information on application is available on product labels, the fungicide manufacturer or sprayer manufacturer.

10. FUNGICIDE RESISTANCE

The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Throughout the Best Practice documents, chemical groups are listed (eg. Group M1 - copper). These should be used as a guide to fungicide rotations between the different groups to minimise any resistance developing.

The CropLife Australia Fungicide Resistance Management Strategies for various crops and diseases are listed, where appropriate. These strategies provide the appropriate use patterns for most fungicide / disease combinations. Further CropLife Australia information can be found at: www.croplifeaustralia.org.au

Some Best Practice documents make reference to HAL Project VG07119 (Barbara Hall, SARDI and Leanne Forsyth, NSWDPI) who are investigating fungicide resistance by testing diseased samples collected in the field. From initial testing, Hall and Forsyth have found resistance in some diseases to commonly used fungicides. Further testing is underway.

11. OTHER ICM CONSIDERATIONS

To reduce the emphasis on thinking disease control is dependent only on use of fungicides, a list of other management options (eg. resistant varieties, rotations, site selection, etc) is provided to assist growers in their decision making.

12. BIOLOGICAL CONTROL OF FUNGICIDES

The information on the availability and use of biological control agents (BCA) to control diseases in vegetables in Australia is limited as there are very few or no BCA registered.

Although there appears to be a lot of interest in BCA by growers and researchers, very little scientific validated information is available.

13. SUMMARY POINTS

The key points for each disease / fungicide / crop are summarised.

14. AUTHORS

Peter Dal Santo
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Ross Holding
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

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Best Practice – Downy mildew in vegetables

Introduction

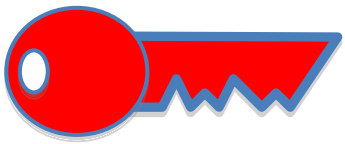
The following document incorporates information essential for economic and sustainable control of a specific disease in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VGO07109.

This document is one of a series of documents intended to provide information on "best practice" control of diseases of vegetables. As a result it conforms to the strategy of Integrated Crop Management (ICM) where the "whole" crop is managed to achieve our aim of disease control. However, there is a bias in this document towards fungicide control options with other strategies blended in to the mix of disease control.

The following are the main principles of ICM used in this document for best practice:-

- To select from the available range of economically effective methods to manage plant pathogens below the threshold for disease
- To manage these methods to prolong their effectiveness as long as possible
- To use these methods to minimise adverse effects on users, environment and other crop management systems eg IPM for insect control

For each disease there is one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-



Downy mildew cucurbits
(Photo Courtesy of K Ferguson SARDI)

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Integrated Crop Management (ICM)

There is increasing attention on incorporating Integrated Crop Management (ICM) systems for vegetable production to control diseases and insect pests. ICM includes the principles of Integrated Pest Management (IPM) that relates specifically to the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimise the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

An ICM/IPM program needs to be developed for all the major crop-disease combinations included in this project. Traditional methods of disease management including crop hygiene, crop rotation and irrigation management remain important elements of ICM. Today a range of fungicides treatments are also available to assist in the management of crop diseases as are some disease resistant crops varieties.

Pesticide treatments vary in cost, efficacy, withholding period, re-entry period and environmental impact. It is accepted that knowledge in this area is incomplete and dynamic.

This document presents a summary of the IPM compatibility of the fungicides currently used in Australia to manage foliar diseases caused by **Downy mildew** as well as their pesticide residue and environmental profiles.

For further information on ICM and IPM research initiatives in the Australian vegetable industry can be found on the Ausveg website: www.ausveg.com.au.

Downy mildew cucurbits
(Photo courtesy of C Akem QDPIF)

Table of Contents

1. Disease background

The disease title "Downy mildew" describes a wide array of individual genus and species which can attack many different vegetable crops in Australia.

The following are examples of the common Downy mildew diseases observed on vegetable crops covered by this document.

Crop	Common name	Scientific names
Brassica	Brassica downy mildew	*Peronospora parasitica*
Lettuce	Lettuce downy mildew	*Bremia lactucae*
Cucurbits	Cucurbit downy mildew	*Pseudoperonospora cubensis*
Capsicums	Capsicum downy mildew	*Peronospora tabacina*

As an example, symptoms of 'Lettuce downy mildew' appear initially as chlorotic yellow spots on the upper leaf surface. Under favourable conditions, a white cottony-like fungal growth that is indicative of sporulation (formation of fungal spores) generally appears on the lower leaf surface within 24 to 48 hours following initial symptom development.

Downy mildew (*Bremia lactucae*) on lettuce
(Photo courtesy of R Holding)

During the early stages of disease development, spots are often delineated by the veins of the leaf, giving lesions a rather angular appearance. As the disease progresses, only larger veins obstruct lesion expansion. Lesions become increasingly chlorotic with time and eventually turn brown.

Although Downy mildew is usually most severe on the older outer leaves, the disease may become systemic over time, infecting mature plants and colonizing even the roots. Downy mildew lesions may also serve as portals for secondary invaders, such as the fungus Grey mould (*Botrytis cinerea*.)

Cultivar resistance (when available) is the most economically feasible form of Downy mildew control. However, fungicides should still be applied to these varieties as Downy mildew is highly variable in Australia and frequently adapts mid season and overcomes one or more resistant genes in resistant cultivars.

With the onset of favourable environmental conditions, fungicide applications can begin early eg. at about the 1or 2-leaf stage of lettuce, and continue throughout the crop life. Fungicide applications must be in place prior to infection if adequate control is to be maintained. If Downy mildew is known to be present in the area, do not wait until symptoms appear in your crops to begin your fungicide program.

Cultural practices, such as:

- the establishment of a susceptible crop free period,
- crop rotation, and
- the destruction of possible weed hosts,

have also been recommended as control measures. Related to sanitation, these measures are targeted at reducing the potential of or at least delaying an initial outbreak of Downy mildew.

The incorporation of infected crop residues into the soil immediately after harvesting may also help to slow the spread of the disease to other areas.

Since moisture and/or high humidity are required for infection and sporulation of Downy mildew, irrigation practices minimising leaf wetness or soil moisture should also be utilise. The use of overhead irrigation in vegetable production should be avoided as it promotes the development of Downy mildew.

A new pathotype of Lettuce downy mildew was identified from lettuce in Australia during 1998 (named AUS 2). Currently there are estimated to be more than 20 cultivars that have resistant to the various Downy mildew races.

2. Current registered and permitted fungicides for Downy mildew control in vegetables

Downy Mildew control programs on farm are based mainly on preventative spray programs used the fungicides, copper and mancozeb.

(a) Copper (Cu) products (Group M1 multi-site activity)

Many copper based products are registered in Australia including the following actives and trade names:

Active Ingredient	Trade Name/s	Formulation
copper as ammonium acetate (93 g/L)	LiquiCop	Liquid
copper as cuprous oxide (400 g/L)	Norshield	Liquid
copper as cuprous oxide (500 g/kg)	Nordox 500	Wettable powder
copper as cuprous oxide (750 g/kg)	Norshield WG	Wettable granule
copper as hydroxide (350 g/kg)	Kocide Blue Xtra	Wettable powder
copper as hydroxide (350 g/L)	Cung Fu	Liquid
copper as hydroxide (360 g/L)	Kocide Liquid Blue	Liquid
copper as hydroxide (375 g/kg)	Champ Dry Prill	Wettable granule
copper as hydroxide (400 g/kg)	Blue Cop 400 DF	Wettable granule
copper as hydroxide (500 g/kg)	Blue Shield DF, Blue Mantel	Wettable granule & other
copper as oxychloride (375 g/kg)	Neoram 375 WG	Wettable granule
copper as oxychloride (500 g/kg)	Oxydul DF and 14 others	Wettable granule & other
copper as sulfate (tribasic) (190 g/L)	Tri-Base Blue	Liquid

Caution is required when using copper based fungicides as:

- Some crop damage is possible if frost is likely after application.
- Some crops/cultivars are copper sensitive eg lettuce.

NOTE: All of these copper based fungicides are also registered to control 'other' diseases in each of the nominated crops. Check the individual label for full details.

Copper as ammonium acetate

Only one copper ammonium acetate product is registered in Australia - LiquiCop. This product is a 93 g/L liquid formulation and is registered for Downy mildew control in the following vegetable crops:

- Brassicas
- Cucurbits
- Lettuce
- Onions
- Red Beet
- Rhubarb
- Silverbeet
- Spinach

Copper as cuprous oxide

There are three copper oxide products registered for Downy mildew control in vegetables;

- Norshield - a liquid formulation with 400 g/L of cuprous oxide
- Nordox 500 - a wettable powder with 500 g/kg of cuprous oxide
- Norshield WG - a wettable granule with 750 g/kg of cuprous oxide.

Cuprous oxide products registered for Downy mildew control in vegetable crops:

Vegetable Crop / Product	Norshield	Nordox 500	Norshield WG
Brassicas			
Brassica leafy vegetables		PER8538	PER8538
Cucurbits			
Endive & chicory		PER8538	PER8538
Lettuce			
Red Beet			
Rhubarb			
Silver Beet			
Snow peas & sugar snap peas		PER8538	PER8538
Spinach			

	= registered or permit
	= not registered or no permit

Copper as hydroxide

There are four copper hydroxide products for Downy mildew control in vegetables:

- These are either wettable powders or wettable granules.
- Have active ingredient concentrations ranging from 350 to 500 g/kg.

Registration status for key copper hydroxide products by vegetable crops is as follows:

Vegetable Crop / Product	Kocide Blue Xtra	Champ Dry Prill	Blue Cop 400 DF	Blue Shield DF	Cung Fu	Kocide Liquid Blue
Active ingredient	350 g/kg	375 g/kg	400 g/kg	500 g/kg	350 g/L	360 g/L
Formulation	WP or WG				Liquid	Liquid
Brassicas						
Brassica leafy vegetables		PER8538		PER8538		
Cucurbits						
Endive & chicory		PER8538		PER8538		
Lettuce						
Red Beet						
Rhubarb						
Silver Beet						
Snow peas & sugar snap peas		PER8538		PER8538		
Spinach						

	= registered or permit
	= not registered or no permit

Copper as oxychloride

Copper oxychloride is a very commonly used fungicide for Downy mildew control in vegetables which reflects the 14 brand names sold in the market.

Registration status for key copper oxychloride products by vegetable crops is as follows:

Vegetable Crop / Product	Neoram 375 WG	Oxydul DF
Active ingredient	375 g/kg	500 g/kg
Formulation	Wettable granules	
Brassicas		
Brassica leafy vegetables		PER8538
Endive & chicory		PER8538
Leeks	PER3850	PER3850
Lettuce		
Red Beet		
Rhubarb		
Silver Beet		
Snow peas & sugar snap peas		PER8538
Spinach		
Cucurbits		

	= registered or permit
	= not registered or no permit

Copper as sulfate (tribasic)

Copper sulfate (tribasic) is a relatively new fungicide formulation for Downy mildew control in vegetables.

Registration status for key copper sulfate (tribasic) products by vegetable crops is as follows:

Vegetable Crop / Product	Tri-Base Blue	Cuprofix Bordeaux Mixture
Active ingredient	190 g/L	200 g/kg
Formulation	Liquid	Wettable powder
Brassicas		
Brassica leafy vegetables	PER8538	PER8538
Endive & chicory	PER8538	PER8538
Lettuce		
Red Beet		
Rhubarb		
Silver Beet		
Snow peas & sugar snap peas	PER8538	PER8538
Spinach		
Cucurbits		

	= registered or permit
	= not registered or no permit

(b) Mancozeb products (Group M3 multi-site activity)

Many mancozeb products are registered in Australia including the following actives and trade names:

Active Ingredient	Trade Name/s	Formulation
mancozeb (420g/L)	Penncozeb 420SC	Liquid
mancozeb (430g/L)	Dithane 430SC	Liquid
mancozeb (750g/kg)	Dithane Rainshield Neo Tec & others	Wettable granule
mancozeb (800g/kg)	Dithane M-45	Wettable granule

Caution is required when using mancozeb based fungicides as:

- Some negative impact on beneficial insects is possible.

Registration status for key mancozeb products by vegetable crops is as follows:

Vegetable Crop / Product	Penncozeb 420SC	Dithane 430SC	Dithane Rainshield	Dithane M-45
Formulation	420g/L	430g/L	750g/kg	800g/kg
Beetroot				
Brassicas				
Cucurbits				
Leeks & shallots			PER10088	
Lettuce				
Rhubarb				
Silver Beet				
Spinach				

	= registered or permit
	= not registered or no permit

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

(c) Other products available for Downy mildew control in vegetables

Active ingredient	**azoxystrobin** (250 g/L)	**chlorothalonil** (500 g/L)	**chlorothalonil** (720 g/L)	**copper hydroxide + mancozeb** (300 +150 g/kg)	**copper hydroxide + metalaxyl-M** (390 + 50 g/kg)	**dimethomorph** (500 g/L)
Product	Amistar 250 SC	Chlorothalonil 500 SC	Bravo Weather Stik	ManKocide DF	Ridomil Gold Plus	Acrobat SC
Activity Group	11	M5	M5	M1 and M3	M1+4	40
Brassicas						
Brassica leafy vegetables						
Capsicum, chillies, paprika						
Carrots	PER10914					
Cucurbits					Cucumber	
Endive, chicory, radicchio						
Fennel			PER9043			PER10902
Horseradish	PER10816					
Leeks	PER10914					
Lettuce						PER7935 (field only) Reg – head only
Peas						
Red Beet						
Root vegetables – radish, swede, turnip						
Rhubarb						
Rocket						
Silverbeet						PER10905
Snow peas and sugar snap peas			PER8608			PER9485 (snow only)
Spinach						PER10906
Spring onions/Shallots		PER9775 (Sp-on only)	PER9775 (Sp-on only)			PER9666

	= registered or permit
	= not registered or no permit

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

(c) Other products available for Downy mildew control in vegetables (cont)

Active ingredient	**mancozeb + metalaxyl-M** (640+40 g/kg)	**metiram** (700 g/kg)	**oxadixyl + propineb** (80 + 560 g/kg)	**phosphorus acid** (600 or 400 g/L)	**propineb** (700 g/kg)	**zineb** (800 g/kg)
Product	Ridomil Gold MZ WG	Polyram DF	Rebound	Agri-Fos 600 Agri-Fos 400	Antracol	Zineb
Activity Group	M3 and 4	M3	4 +M3	33	M3	M3
Brassicas	PER10674			PER10152		
Brassica leafy vegetables	PER10674					PER10845 Rego – cauli & cabb
Capsicum, chillies, paprika	PER10760					
Carrots						
Cucurbits	PER9916 (cucumber)					
Endive, chicory, radicchio				PER8186		
Fennel						
Horseradish						
Leeks	PER9916					
Lettuce				PER7905 (leafy & hydroponic)		
Peas				PER8187		
Red Beet						
Root vegetables – radish, swede, turnip	PER9916					
Rhubarb				PER9922		
Rocket	PER10674					
Silverbeet	PER10727			PER8186		
Snow peas and sugar snap peas	PER7897					
Spinach				PER8186		
Spring onions/Shallots						

	= registered or permit
	= not registered or no permit

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

(d) Other products available for Downy mildew control in vegetables – seed treatments

Active ingredient	**metalaxyl-M (350 g/L)**	**metalaxyl (350 g/kg or 350 g/L)**
Product	Apron XL 350 ES	Mantle or Mantle Flowable
Activity Group	4	4
Brassicas		
Brassica leafy vegetables		
Capsicum, chillies, paprika		
Carrots		
Cucurbits		
Endive, chicory, radicchio		
Fennel		
Horseradish		
Leeks		
Lettuce		
Peas		
Red Beet		
Root vegetables – radish, swede, turnip		Radishes only
Rhubarb		
Rocket		
Silverbeet		
Snow peas and sugar snap peas		
Spinach		
Spring onions/Shallots		
Sweet corn		

	= registered or permit
	= not registered or no permit

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

There are many protectant and systemic/curative fungicides registered for the control of Downy mildew. But not all products are registered in all crops. Always check the label for directions. Careful use of these products is required to ensure their useable life.

3. Other possible fungicides for Downy mildew control in vegetables

On investigating the currently available fungicides registered for Downy mildew control in all horticultural crops, it was found that all appropriate chemical groups are already available in various vegetables crops.

Although there may be new product options available, the activity of these chemical groups is already available to vegetables by registered products or permitted products.

Therefore growers need to be careful in the fungicide use to ensure that Downy mildew fungicides are only used when absolutely necessary to preserve their effective life.

4 (a) Environmental profile of fungicides

The choice of fungicide should not be based on efficacy or price alone as other considerations need to be taken into account when employing an ICM/IPM based best management practice.

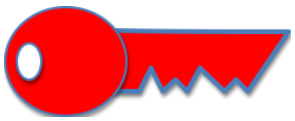
The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

EIQ assess each fungicide for:

- Applicator effects } Farm worker
- Picker effects } effects
- Consumer effects
- Leaching
- Fish effects } Ecology
- Bird, bee & beneficials } effect

EIQ rates each of these factors and gives a rating that can be used to compare one pesticide with another for its environmental profile.

Further information on EIQ can be found on their web site - see reference (2).



The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems. The lower the EIQ rating the better the environmental profile.

The following table includes information for those products that could be considered for *Powdery mildew* control in vegetables. Some of the information can already be found on product labels (eg. chemical group, withholding period, re-entry period, etc).

Below are the explanations for terms used in the table.

1. WHP = withholding period for harvest
2. REP = re-entry period after spraying
3. EIQ = Environmental Impact Quotient. Rating system which provides a relative rating for pesticides active ingredients based on worker consumer and environmental effects. The lower the rating indicates a better environmental profile.
4. EIQ field rating = EIQ x product formulation concentration x application rate (kg or L/ha). A lower rating indicates a better environmental profile.
5. Effect on beneficials - Individual component of EIQ.
6. NIFWR = no information further work required

Product	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4](per app)	Effect on Beneficials[5] (IPM fit)	Comments
copper as ammonium acetate eg Liquicop	M1	1	>Spray dried	NIFWR	NIFWR	NIFWR	
copper as cuprous oxide eg. Norshield	M1	1	>Spray dried	NIFWR	NIFWR	NIFWR	IPM fit- see 4(b) Aust data
copper as hydroxide eg. Kocide	M1	1	>Spray dried	33	19	22	IPM fit- see 4(b) Aust data
copper as oxychloride eg. Oxydul	M1	1	>Spray dried	NIFWR	NIFWR	NIFWR	IPM fit- see 4(b) Aust data
copper as sulfate eg. Tribase blue	M1	1	>Spray dried	48	27	6	
mancozeb eg. Dithane DF	M3	14	>Spray dried	15	25	8	IPM fit- see 4(b) Aust data
mancozeb + metalaxyl M eg. Ridomil Gold MZ	M3+4	7-14	>Spray dried	15	25	8	
dimethomorph eg. Acrobat	40	14	>Spray dried	24	4	4	
phosphorus acid eg. Agriphos 600	33	1					Permit only
metiram eg. Polyram	M3	7		40	62	71	IPM fit- see 4(b) Aust data. Claimed to be safer to mite predators than mancozeb.

Product	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4](per app)	Effect on Beneficials[5] (IPM fit)	Comments
propineb eg. Antracol	M3	3	>Spray dried	NIFWR	NIFWR	NIFWR	Claimed to be safer to mite predators than mancozeb.
oxadixyl + propineb eg. Rebound	M3+4	3	>Spray dried	NIFWR	NIFWR	NIFWR	Shorter WHP in lettuce &cucurbits than metalaxyl based products

(See page 14 for explanations of terms used in this table-consult individual product labels for full details)

4 (b) Impact of fungicides on beneficial insects and mites - Australian data

Research work funded by HAL and AUSVEG into the effects of pesticides on beneficial insects and mites in vegetables in Australia has been ongoing for 3 years. The following table summarises results of relevant *fungicides*.

These results show the short term (or acute) effects using adults. Potential long term effects such as impact on reproduction are not shown as they were not conducted. However, it is hoped that with further funding this aspect may be evaluated.

Product	**Beneficial insect or mite (their target pest)**							
Fungicide Active ingredient	**Brown lacewing** (Aphids)	**Transverse ladybird** (Aphid)	**Common spotted ladybird** (Aphid)	**Variegated ladybird** (Aphid +Thrips)	**Damsel Bug** (Caterpillars)	**Trichogramma wasp parasitoid** (Caterpillars)	***Gallendromus occidentalis*** (Mites)	***Predatory Staphilinid beetle*** (Thrips)
azoxystrobin eg. Amistar								
metiram eg. Polyram								
cuprous oxide eg Norshield								
mancozeb + petroleum oil								
chlorothalonil eg. Barrack								
propineb +oxadixyl eg. Rebound								
cuprous oxide eg. Norshield								
copper hydroxide eg. Kocide								
copper oxychloride eg. Oxydul								

	=Harmless- less than 30% acute mortality		=Mod harmful. 30 to 70% acute mortality		=Harmful: greater than 70 %mortality

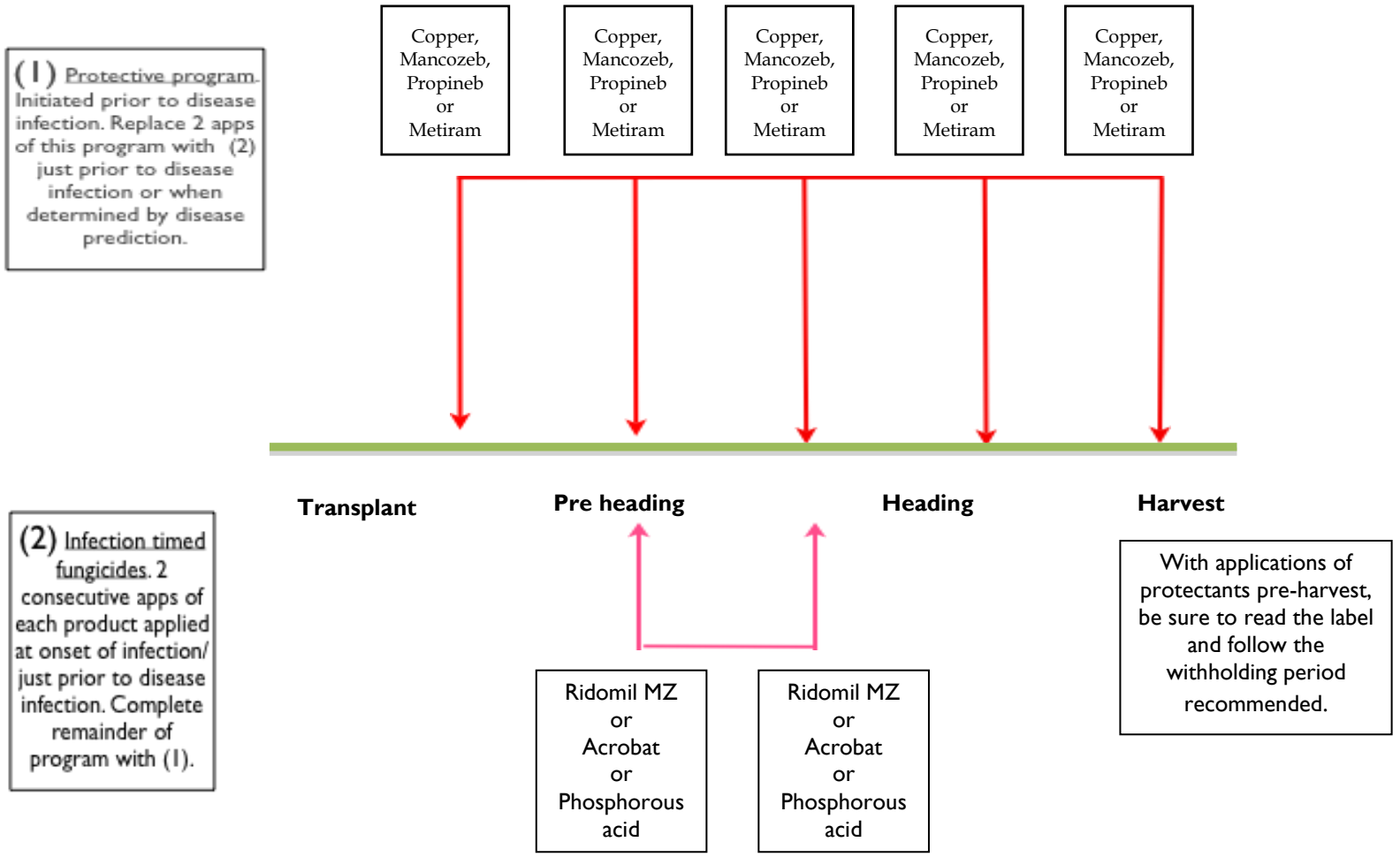
This work was performed by IPM Technologies Pty Ltd and the Department of Primary Industries (Vic). Funding by Horticulture Australia Ltd (HAL) and the Australian Vegetable Grower's Research and Development Levy (AUSVEG), Project VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

5. Product application rates and other information

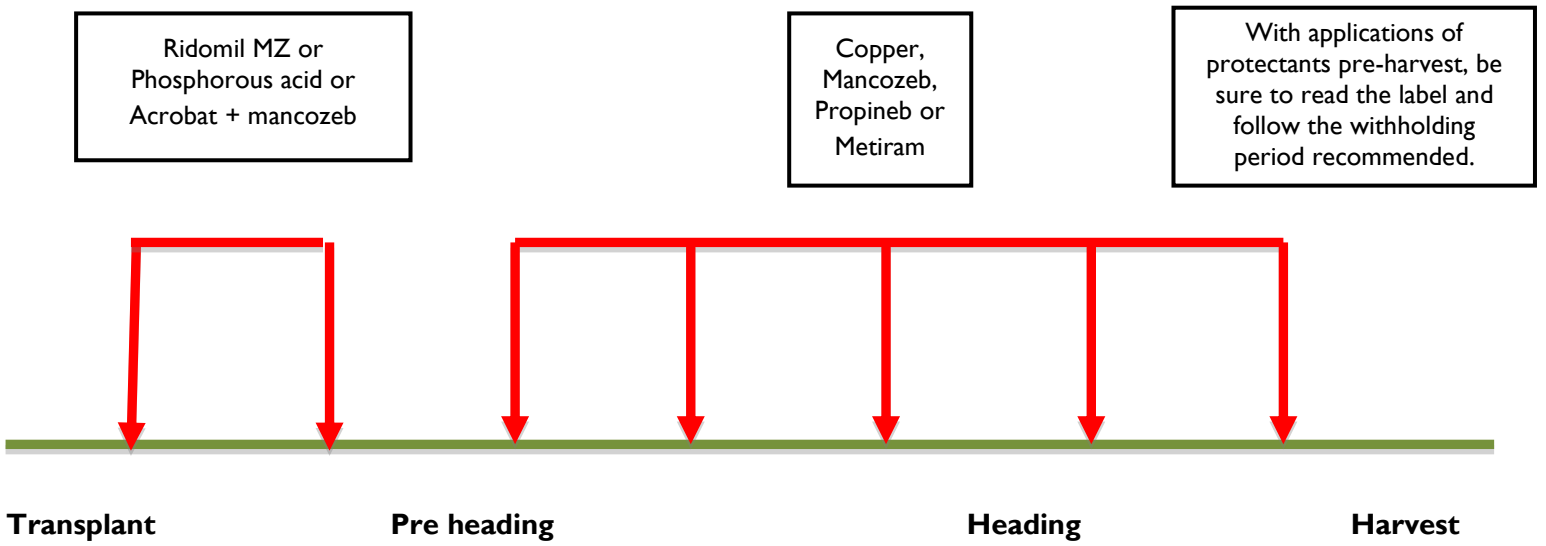
Fungicides presently registered or used under permit.

Product Name	Concentration	Group	Rate per ha	Maximum number of applications per crop	Spray interval (days)
copper as ammonium acetate eg. LiquiCop)	93 g/L	M1	1.0-2.5L/ha	No limit	7-14
copper as cuprous oxide eg. Norshield WG	750 g/kg	M1	1.2 kg/ha	No limit	7-10-14
copper as hydroxide eg. Kocide Liquid Blue	360 g/L	M1	1.65-1.9L/ha	No limit	7-10-14
copper as oxychloride eg. Oxydul	500 g/kg	M1	250 g/100L	No limit	7-10-14
copper as sulfate eg. TriBase Blue	190 g/L	M1	3.0 L/ha	No limit	7-10-14
mancozeb eg. Dithane DF	750 g/kg	M3	1.7-2.2 kg/ha	No limit	7-10
mancozeb + metalaxyl M eg. Ridomil Gold MZ	680 g/kg	M3+4	2.5 kg/ha	4	7-10
metalaxyl M + Copper hydroxide eg. Ridomil Gold Plus	440g/kg	40	2.0 kg/ha	4	7-10
dimethomorph eg. Acrobat	500 g/kg	33	360 g/ha + protectant	4	7-10-14
phosphorous acid eg. Agri-Fos 600	600 g/L	M3	3.0 L/ha	No limit	7
metiram eg. Polyram	700 g/kg	M3	2.2-3.5 kg/ha	No limit	7-10
propineb eg. Antracol	700 g/kg	M1	2.0 kg/ha	No limit	7-10
oxadixyl + propineb eg. Rebound	640g/kg	4+M3	2.5 kg/ha	No limit	7-10

5 (a) Disease control programs example incorporating ICM options - Lettuce downy mildew - susceptible cv. Low / moderate disease conditions



5(b) Disease control programs example incorporating ICM options - Lettuce downy mildew - susceptible cv. High disease conditions



The efficacy of common lettuce fungicides on Downy mildew

Product	Downy Mildew
copper	√
mancozeb	√
mancozeb + metalaxyl-M	√
dimethomorph	√
metiram	√
phosphorus acid	√
propineb	√

6. Application of fungicides

Downy mildew lettuce

Successful spraying applications depend on the thorough coverage of the target with evenly distributed individual droplets. Good disease control will result if the application yields an average of the following droplets per cm^2 on the target.

- 20-50 droplets per cm^2 for systemic and translaminar fungicides
- 50-70 droplets for cm^2 for protectant type fungicides

Combine these two elements – good coverage and product deposit with the correct choice of nozzle pressure and sprayer speed. It is generally recommended that application volumes in the range 200- 500 L/ha are adequate for field grown crops sprayed with boom sprays using hydraulic nozzles. The advent of air assist /air blast equipment to boomspraying offers many advantages -

- Better coverage in dense or complete canopies where turbulence is required to achieve droplet coverage on both sides of plant leaves.
- Better management of drift

The addition of an air blast nozzles is beneficial particularly when the crop grows large enough to form a complete canopy.(6)

The addition of spray adjuvants to fungicides is important where directed by label recommendations. Spray adjuvants reduce surface tension/assist droplet formation and provide other benefits such as drift minimisation.

For other cropping situations, eg. greenhouse, the same principles can be applied with the choice of appropriate equipment - thorough coverage with evenly distributed individual droplets.

However, efficacy can be more variable on the lower leaf surface with protectant type fungicides. Better control of disease on lower leaf surfaces can be achieved with fungicides of systemic or translaminar activity .

Spraying a young vegetable crop
(Photo courtesy of R Holding)

7. Fungicide Resistance

The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Never use more than the label recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action /activity group.

Always use fungicides according to the label directions:

- If the fungicide is to be used preventatively, then apply prior to the onset of main disease infection period.
- If the fungicide is to be used curatively, then apply as soon as possible after the onset of main disease infection period.
- Never use fungicides after infection has fully established and is visible.

There have been reported losses of effectiveness of some fungicides in vegetable crops. In many situations it was found that poor commercial results may have been due to poor application by growers rather than fungicide resistance/tolerance.

CropLife Australia (3) (formerly AVCARE) implement Fungicide Resistance Management Strategies (FRMS) for various crops and diseases in Australia.

For Downy mildew in vegetables the following FRMS exists:-

Crop:	Lettuce
Pest:	Downy Mildew
Resistance Management Strategy for:	Group 4 (Phenylamide) and Group 40 (dimethomorph) fungicides

1. Start disease control early and maintain a regular program using a fungicide from groups other than Group 4 or 40.
2. When conditions favour disease development, DO NOT wait for disease to appear, but apply two consecutive sprays of a Group 4 or 40 product at the interval recommended on the label. Then resume the program of sprays using products from a different group to the Group 4 or 40 products just applied.
3. DO NOT apply more than four sprays of a Group 4 or 40 product per season.

Crop:	Cucurbits
Pest:	Downy Mildew
Resistance Management Strategy for:	Group 4 (Phenylamide), Group 11 (Quinone outside Inhibitor) and Group 40 (dimethomorph) fungicides

1. Start disease control early and maintain a regular program using a fungicide from groups other than Group 4, 11 or 40.
2. When conditions favour disease development, DO NOT wait for disease to appear, but apply two consecutive sprays of a Group 4 or 11 products, at the interval recommended on the label, or a single spray of a Group 11 fungicide. Then resume the program of sprays using products from a different group to the Group 4, 11 or 40 products just applied.
3. DO NOT apply more than four sprays of a Group 4 or of a Group 40 product per season.
4. DO NOT apply more than three sprays of Group 11 fungicides per crop.
5. Continue alternation of fungicides between successive crops.

HAL Project VG07119 (Barbara Hall, SARDI and Leanne Forsyth, NSWDPI) is investigating fungicide resistance by testing diseased samples collected in the field.

From initial testing in VG07119, 2 of 20 isolates of lettuce Downy mildew showed resistance to metalaxyl from the Sydney basin growing region. Further testing of isolates is underway.

Sending diseased plant samples in for testing for chemical resistance

If you suspect that the applications of pesticides that you are applying to your crop are failing to control/suppress disease, the pathogen present on your farm may have fungicide resistance. Currently a resistance testing project funded by HAL and the Vegetable R&D Program being undertaken across Australia is assessing Sclerotinia, Botrytis, White blister, Downy mildew and bacterial pathogens for resistance to fungicides. If you are encountering spray failure you should have the pathogens tested to ensure you aren't wasting time and money applying fungicides which may not work as well as they should.

To have the pathogens present on your farm tested for resistance:

- Collect plants or parts of the plant showing the disease. It is important that the diseased plant isn't dead.
- Wrap the diseased plant tissue in slightly moist paper, and then wrap further in dry paper, then in a plastic bag. It is important not to wrap the diseased plant directly in plastic as it can cause the plant to "cook".
- It is important to collect the plant/plant parts on the day that you are going to send the sample in, and samples should not be sent on a Thurs/Friday.
- Samples should be sent preferably early in week eg. Monday or Tuesday to allow transit to destinations prior to the weekend.
- Send the plant sample either by courier or by overnight post.
- Include with the sample information stating what plant cultivar is being used, what pesticides have been applied and any additional information e.g. more severe than in a regular season.

For **Downy mildew** test samples should be sent to:

Leanne Forsyth
Department of Primary Industries NSW
Plant Health Research
Elizabeth Macarthur Agriculture Institute
PMB 8, Camden, NSW 2570.
Ph: (02) 4640-6428
Email: leanne.forsyth@dpi.nsw.gov.au

Prior to sending please advise the above researchers by email or phone that samples are in transit

8. Other ICM considerations

Management Option	Recommendation
Scouting/thresholds	Record the occurrence and severity of Downy mildew. No thresholds have been developed. Use history to make your decisions on paddock selection and spray timing.
Resistant varieties	Moderately resistant lettuce varieties should be utilised as this strategy would reduce the need for fungicides by at least 40%.
Crop rotation	A minimum of three year rotation with non-hosts crops such as grains is needed, if practical.
Site selection	Aim to select planting sites to minimise disease inoculum carryover especially for susceptible crops like lettuce.
Seed selection	Seed treatment may provide short term protection for a period soon after planting.
Rouging	Removal of diseased plants during the life of the crop may reduce disease inoculum for crop and following years. (labour intensive)
Fungicide resistance	Always follow the fungicide resistance warnings on product labels. Never use more than the recommended maximum number of applications per crop and where possible rotate to fungicides with a different mode of action (different chemical group). Where appropriate use fungicides preventatively (prior to the onset of main disease infection). Overuse of fungicides from only one chemical group could lead to the development of resistance. Where possible rotate chemical groups. Monitor all fungicide application for effectiveness and make future fungicide selections based on previous performance. Using fungicides in a curative manner can increase the risk of fungicide resistance.
Disease modelling	In development and evaluation in Australia. Based on overseas research.

9. Biological control agents and biofungicides

Biological control includes any organism or extract from an organism of biological origin which exhibit biofumigant, biostimulant or biofungicidal activity on fungi. At present there are no biological control agents that are registered in Australia for **Downy mildew** control, although there are some products sold under various guises that claim disease control. Some biological control products are registered for **Downy mildew** control overseas.

Many different biological control agents have been trialled over many years in Australian conditions. A common observation from these trials is that the results are inconsistent from trial to trial and year to year.

It is the authors understanding that no manufacturer has presented appropriate efficacy data to APVMA to seek full registration for any biofungicide in vegetables.

10. Future directions

Additional fungicides may be registered for use or available via permit for Powdery mildew control in vegetables in the future.

Biological fungicides may also be evaluated for efficacy under Australian conditions and gain registration or permit if viable.

11. Summary Points

- A wide range of fungicides are registered for Downy mildew control in a wide variety of crops. Traditional copper fungicides are more commonly used in protective fungicide programs.

- Other fungicides and biofungicides are under review and may achieve registration or permit use in the future.

- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.

- Correct application techniques are essential for the most efficient use of fungicides.

- The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.

- Careful consideration of crop rotation is also a powerful management tool.

- At present no biofungicides of a biological nature are fully registered in Australia for Downy mildew control.

12. References

1. Australian Pesticides and Veterinary Medicines Authority: www.apvma.gov.au
2. New York State Integrated Pest Management Program, Cornell University, New York, USA: www.nysiPowdery mildew .cornell.edu
3. CropLife Australia Ltd: www.croplifeaustralia.org.au
4. University of Arizona College of Agriculture 2001 Vegetable Report: http://ag.arizona.edu/pubs/crop/az1252/

13. Authors Information

(1) Peter Dal Santo B Agr Sc MAIAST AAAC CPAg
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Peter has been involved with Australian agricultural since 1983. Peter's experience has included sales, marketing, research and development roles with major agchem multinational companies and Executive Officer for Crop Protection Approvals, which managed data collation and minor-use permits for the vegetable industry. Since 2003, Peter has been the Director and Principle Scientist of AgAware Consulting P/L which is a project management consultancy. AgAware manages the HAL funded project, 'MT07029 - Managing pesticide access for horticulture' to accessing minor-use permit for horticulture as well as other HAL projects. In 2009, Peter received the 'Ausveg Industry Recognition Award' for servicies to the vegetable industry.

(2) Ross Holding B Agr Sc
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

Ross has worked in the Agchem industry since 1985. First as Technical Officer/Manager Research and Development with a major multinational company (1985-1996) and then as Product Manager with an Australian agchem manufacturer(1997). Since 1998 has worked independently as a contract agricultural consultant specialising in field efficacy and residue trials in both horticulture and broadacre.

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

HAL Know-how for Horticulture™ AgAware Consulting Pty Ltd Classy Solutions

Best Practice – Fusarium, Rhizoctonia, Pythium root rot diseases in Vegetables

Introduction

The following document incorporates information essential for economic and sustainable control of specific diseases in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VG07109.

This document is one of a series of documents intended to provide information on "best practice" control of diseases of vegetables. As a result it conforms to the strategy of Integrated Crop Management (ICM) where the "whole" crop is managed to achieve our aim of disease control. However, there is a bias in this document towards fungicide control options with other strategies blended in to the mix of disease control.

The following are the main principles of ICM used in this document for best practice:-

- To select from the available range of economically effective methods to manage plant pathogens below the threshold for disease
- To manage these methods to prolong their effectiveness as long as possible
- To use these methods to minimise adverse effects on users, environment and other crop management systems eg IPM for insect control

For each disease there is one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-

Fusarium rot of greenhouse cucumbers
(Photo courtesy of K Ferguson SARDI)

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

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Integrated Crop Management (ICM)

There is increasing attention on incorporating Integrated Crop Management (ICM) systems for vegetable production to control diseases and insect pests. ICM includes the principles of Integrated Pest Management (IPM) that relates specifically to the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimize the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

An ICM/IPM program needs to be developed for all the major crop-disease combinations included in this project. Traditional methods of disease management including crop hygiene, crop rotation and irrigation management remain important elements of ICM. Today a range of fungicides treatments are also available to assist in the management of crop diseases as are some disease resistant crops varieties.

Pesticide treatments vary in cost, efficacy, withholding period, re-entry period and environmental impact. It is accepted that knowledge in this area is incomplete and dynamic.

This document presents a summary of the IPM compatibility of the fungicides currently used in Australia to manage the soilborne diseases caused by **Fusarium, Pythium and Rhizoctonia** as well as their pesticide residue and environmental profiles.

For further information on ICM and IPM research initiatives in the Australian vegetable industry can be found on the Ausveg website: www.ausveg.com.au.

Sclerotinia of lettuce
(Photo courtesy of D. Wite VicDPI)

Rhizoctonia of brassicas
(Photo courtesy of D. Carey QPI&F)

Table of Contents

1. Disease background

Fusarium, Pythium and Rhizoctonia can all cause similar symptoms of infection in plants and are often associated in "complexes". Of the three fungi, Pythium is probably the most important but due to a scarcity of effective fungicides for Rhizoctonia and Fusarium, particularly of a systemic nature, these other two diseases produce challenges for control.

The following table lists the crops where the outcomes of the Strategic Agrichemical Review Process (SARP) conducted during 2007 and 2008 identified gaps in control for Fusarium, Pythium or Rhizoctonia.

Crop	Disease Gap
Beans & Snake beans	Fusarium
Beetroot	Pythium
Brassicas	Pythium
Capsicums	Fusarium
Cucurbits	Fusarium, Pythium
Endive and Chicory	Pythium
Lettuce	Pythium
Okra	Fusarium
Parsley	Pythium
Peas	Pythium
Silverbeet & Spinach	Pythium
Snow peas	Fusarium
Sweet corn	Fusarium

Fusarium

Fusarium species are very diverse and are found in all soil types around the world. The majority of Fusarium species do not cause disease. There are 3 broad groups of disease caused by Fusarium:

- vascular wilts
- root rots
- fruit infections

This report will only address vascular wilts and root rots.

Vascular Wilts

Most of the Fusarium vascular wilts belong to the species *Fusarium oxysporum*. Vascular wilt disease is typically a specific interaction and only limited special forms of the fungus are able to cause the disease on specific crop hosts.

Symptoms of root/stem rotting and/or vascular decay compromise plant growth, restrict yield and in severe cases result in plant death. Wilt symptoms may be evident initially in young leaves in warmer parts of the day and may appear to affect only one side of the plant. Leaves initially yellow but become necrotic, brown and dry as the disease progresses. Vascular tissue in the taproot, crown or lower stem of many plant species will be discoloured light to dark brown.

Vascular wilts such as Fusarium are among the most difficult to control with only a single infection of a plant by one spore able to initiate infection. The pathogen then grows, sporulate and via the vascular system of the host plant spreads internally. Hence, surface or protectant fungicides are ineffective.

Fusarium wilt of snow peas showing the infected xylem or vascular tissue of the stem (right)
(Photo courtesy of A Watson NSW DPI)

Root rots

Some Fusarium species are only weak pathogens and will invade the roots of plants if they are already weakened or damaged. A good example of this is that burrowing nematode damage to the roots cortex can allow Fusarium (as well as other diseases such as Rhizoctonia and Pythium) inside to further damage the roots.

In the field, early infection can result in damping off in some crops. Rot symptoms can occur on roots, particularly upper roots and crown. Initially these appear moist and light brown, but later they become darker brown and relatively dry. As the decay progresses or enlarges they can become sunken, the skin wrinkled and small tufts of whitish, pink or yellow mould appear.

Plants affected by Fusarium rots are beans carrots, cucurbits, onions, peas, potatoes and tomatoes.

Fusarium can survive in the soil saprophytically (survive on dead plant tissue) for extremely long periods. It can also survive as long lasting chlamuydosprores. This also makes control via crop rotation very difficult. Infections can be also spread on 'root' vegetables and seed contaminated with dust or trash.

Fusarium root rot of watermelon
(Photo courtesy of A. Watson NSW DPI)

Pythium

More commonly referred to as 'damping off', Pythium is a water loving fungus which will often become problematic in waterlogged conditions. Pythium typically is most damaging to the seed and seedling stage of vegetables immediately post planting or transplanting. In hydroponically grown crops a range of Pythium species can cause disease with some species being devastating in warmer conditions and others causing severe root rots in cooler conditions.

When seeds of susceptible plants are planted in infested soils and are attacked by the 'damping off' fungi they fail to germinate, become soft and mushy then turn brown, shrink and finally disintegrate. Later infection of established plants can cause root rot and/or lesions on the stem. If sufficiently large these lesions can cause girdling, stunting or death. In carrots, Pythium causes cavity spot and can cause forking symptoms.

In hydroponic crops, an early symptom of Pythium infection is browning off of the feeder roots, which is often followed by browning off of the entire root system and collapse of the plant. Total crop loss can occur as the disease moves quickly through the recirculating nutrient systems.

The use of good systemic fungicides eg. metalaxyl has lead to effective seed treatments in vegetable crops and can give protection for extended periods of time to ensure the successful establishment of crops. As a result most vegetable seed will come pretreated with a seed protectant fungicide for Pythium control.

Pythium sulcatum- carrot seedling healthy on left (Photo courtesy C. Donald Vic DPI)

Pythium infection which has caused girdling of older lettuce plant (Photo courtesy of R. Holding)

Rhizoctonia

Besides causing seedling 'damping off' Rhizoctonia attacks established crops. Some isolates of Rhizoctonia are able to infect a wide range of vegetable crops whereas others may have restricted host ranges. Rhizoctonia diseases often have common names which describe symptoms on particular crops. For example, for carrots - Crater rot; lettuce - Bottom rot and potato tubers - Black scurf.

The majority of Rhizoctonia rots are caused by *Rhizoctonia solani*, a fungus which has a range of sub groups called anastamosis groups (AG). It is not known how many AG groups are found within Australia. Recent research work conducted by Peracto (4) evaluated 40 soil samples from Tasmania, Queensland and Victoria and found one dominant *R. solani* (AG2.1) variant which mainly attacks vegetables. Bioassays were also conducted on these soil samples using beans and results indicated that although *R. solani* was present in most samples, actual damage was caused by other associated pathogens such as Thieloviopsis, Pythium, Fusarium and Aphanomyces. Associated work with non chemical soil amendments (saw dust, molasses and gypsum) highlighted the value of organic matter in the soil in suppressing Rhizoctonia diseases. It was suggested that methods that increase organic matter in the soil such as green manure, recycling of organic waste, etc. could be used commercially to reduce potential Rhizoctonia infection in vegetable crops (4)

Rhizoctonia infection of carrots
(Photo courtesy of R. Holding)

Rhizoctonia (wire stem) of brassicas
(Photo courtesy of C. Donald Vic DPI)

For all of the above 3 diseases it is important to reduce or totally eliminate root and plant damage during the growing and harvesting phase. This includes the control of damaging pests such as nematodes.

2(a). Current registered products for Fusarium control in vegetable crops

Compound	Chemical group	Crop	Disease
1,3-dichloropropene eg. Telone C-35	Fumigant - insecticide/fungicide	All crops	Fusarium + others
dazomet eg. Basamid	Fumigant - insecticide/fungicide	All crops	Fusarium + others
fludioxonil eg. Maxim 100FS	Group 12 Fungicide	Maize/Sweet corn (Seedling disease)	Fusarium & Penicllium
metham sodium eg Metham	Group1A Fumigant - insecticide/fungicide	All crops	Fusarium + others

2(b). Current registered products for *Pythium* control in vegetable crops

Compound	Chemical group	Crop	Disease
1,3-dichloropropene eg. Telone C-35	Fumigant - insecticide/fungicide	All	Pythium + others
dazomet eg. Basamid	Fumigant - insecticide/fungicide	All	Pythium + others
metalaxyl or metalaxyl-M eg. Ridomil Gold 25G	Group 4 Fungicide	Cucurbits, capsicums, brassicas, carrots & tomatoes	Pythium & Phytophthora
metalaxyl or metalaxyl-M eg. Apron XL	Group 4 Fungicide	Beetroot, carrots & peas (seed dressing)	Damping off
metham sodium eg. Metham	Group1A Fumigant - insecticide/fungicide	All	Pythium + others

2. (c) Current registered products for Rhizoctonia control in vegetable crops

Compound	Chemical group	Crop	Disease
1,3-dichloropropene eg. Telone C-35	Fumigant - insecticide/fungicide	All crops	Rhizoctonia + others
chlorothalonil eg. Bravo	Group M3 Fungicide	Cucurbits	Rhizoctonia (Belly rot)
dazomet eg. Basamid	Fumigant - insecticide/fungicide	All crops	Rhizoctonia + others
metham sodium eg. Metham	Group1A Fumigant - insecticide/fungicide	All crops	Rhizoctonia + others
quintozene eg. Terraclor	Group 14 Fungicide	Lettuce Beans Brassicas	Bottom rot Stem & root rot Wire stem

3. Products used under permit for Fusarium, Rhizoctonia and Pythium control in vegetable crops

*** These permits are current as at 30th September 2009.**

Fusarium

Permit No.	Description	Date Issued	Expiry Date
PER10971	Thiabendazole / Sweet Potato / Field Rots of Seed Roots caused by scurf (Monilochaetes infuscans) and root rot (Fusarium spp)	01-Nov-08	30-Sep-10

Pythium

Permit No.	Description	Date Issued	Expiry Date
PER9379	Ridomil Gold 25G (metalaxyl-M) / Parsley / Pythium & Phytophthora	26-Jun-06	30-Sep-11
PER10301	Mancozeb + Metalaxyl / Carrots and Parsnips / Pythium spp. and Phytophthora spp.	1-Apr-08	31-Mar-13
PER10735	Apron XL 350 ES & Maxim 100FS / Broccoli / Damping off & Rhizoctonia	1-Jun-09	30-Sep-11
PER11474	Metalaxyl-M / Lettuce / Damping off	1-Jul-09	30-Jun-11

Rhizoctonia

Permit No.	Description	Date Issued	Expiry Date
10588	Iprodione / Broccoli / Rhizoctonia	07-May-08	30-Apr-13

IMPORTANT NOTICE
Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au

4. Environmental profile of fungicides

The choice of fungicide should not be based on efficacy or price alone as other considerations need to be taken into account when employing an ICM/IPM based best management practice.

The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

EIQ assess each fungicide for:

- Applicator effects } Farm worker effects
- Picker effects } Farm worker effects
- Consumer effects
- Leaching
- Fish effects } Ecology effect
- Bird, bee & beneficials } Ecology effect

EIQ rates each of these factors and gives a rating that can be used to compare one pesticide with another for its environmental profile.

Further information on EIQ can be found on their web site - see reference (2).

The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems. The lower the EIQ rating the better the environmental profile.

The following table includes information for those products that could be considered for *Fusarium, Pythium* and *Rhizoctonia* control in vegetables. Some of the information can already be found on product labels (eg. chemical group, withholding period, re-entry period, etc).

Below are the explanations for terms used in the table.

1. WHP = withholding period for harvest
2. REP = re-entry period after spraying
3. EIQ = Environmental Impact Quotient. Rating system which provides a relative rating for pesticides active ingredients based on worker consumer and environmental effects. The lower the rating indicates a better environmental profile.
4. EIQ field rating = EIQ x product formulation concentration x application rate (kg or L/ha). A lower rating indicates a better environmental profile.
5. Effect on beneficials - Individual component of EIQ as field rating.
6. NIFWR – no information further work required

Active Ingredient and Product Name	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4] (per app)	Effect on Beneficials [5] (IPM fit)	Comments
1,3-dichloropropene eg. Telone C-35	Fumigant – insecticide / fungicide	N/A	48	>100	>20000	300	Total soil sterilant. No IPM fit
dazomet eg. Basamid	Fumigant – insecticide / fungicide	N/A	48	>100	>20000	300	Total soil sterilant. No IPM fit
fludioxonil eg. Maxim 100 FS	12	28 - sweet corn	N/A	26	5	0	Sweet corn as seed treatment
iprodione eg. Rovral	2	N/A	N/A	11	<1	<1	Permit - broccoli – seed treatment
metalaxyl-M eg. Ridomil Gold 25G	4	N/A	N/A	29.4	15	23	Potting mix for seedlings or field use
metham sodium eg. Metham	Group 1A Fumigant – insecticide / fungicide	N/A	48	>100	>20000	300	Total soil sterilant. No IPM fit
quintozene eg. Terraclor	14	28	N/A	35	1967	1866	Lettuce, beans & brassicas – pre-plant incorporation or early post plant
thiabendazole eg. Tecto	1	N/A	N/A	35.5	N/A	N/A	Permit - sweet potato – seed root dip

(See page 10 for explanations of terms used in this table-consult individual product labels for full details)

5. Product application rates and other information

Fungicides presently registered or used under permit

Active Ingredient and Product Name	Group	Max no. of apps per crop	Rate per ha	Concentration
1,3-dichloropropene eg. Telone C-35	Fumigant – insecticide / fungicide	1 only - soil treatment	470 kg/ha	615 g/kg
dazomet eg. Basamid	Fumigant – insecticide / fungicide	1 only - soil treatment	500 kg/ha	940 g/kg
iprodione eg. Rovral Seed Dressing	2	1 only - seed treatment	800mL/100kg seed	500g/L
M\metalaxyl-M eg. Ridomil Gold 25G	4	1 only - soil treatment	40 kg/ha	25 g/L
metham sodium eg. Metham	Group 1A Fumigant – insecticide / fungicide	1 only - soil treatment	500 L/ha	423 g/L
quintozene eg. Terraclor	14	1 only - soil treatment	150 g/100 L water	750 g/kg
thiabendazole eg. Tecto	1	1 only - seed treatment	1L/22 L water	500 g/L

IMPORTANT NOTICE
Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

6. Application

Fusarium, Rhizoctonia, Pythium

Seed dressing application

Commercial seed will very often be pre treated with a commercial seed treatment prior to packaging.

Where seed treatments are to be applied on farm, eg. potato seed, very accurate methods of application are required in order to achieve correct seed loadings. Also where dusts are used, careful attention needs to be made to user safety in terms of dust control, aeration and storage.

Soil fumigants

Given their high EIQs, soil fumigants do not routinely form part of a disease management approach based on IPM principles. Soil fumigation is generally used as a remedy for very severely diseased sites or for seedbed preparation.

Effective use of soil fumigants depends on even distribution through the seed bed or soil surface, then sealing of the surface by roller or water to retain volatiles to that the biocidal activity can occur.

Soil fumigation is best handled by a licensed contractor or with specialised equipment.

Soil fumigation requires a period between treatment and crop planting so that no crop injury occurs. Careful attention has to be paid to the plant-back periods for susceptible crops, eg. lettuce and metham sodium.

Pythium of brassicas transplants (Photo courtesy of C. Donald Vic DPI)

7. Fungicide Resistance

The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Never use more than the recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action /activity group.

Never use rates higher or lower than recommended by the label.

Always use fungicides according to the label directions:

- If the fungicide is to be used preventatively, then apply prior to the onset of main disease infection period.
- If the fungicide is to be used curatively, then apply as soon as possible after the onset of main disease infection period.
- Never use fungicides after infection has fully established and is visible.

There have been reported losses of effectiveness of some fungicides in vegetable crops. In many situations it was found that poor commercial results may have been due to poor application by growers or enhanced soil breakdown of the fungicide rather than fungicide resistance/tolerance.

Occurrence of fungicide resistance is ongoing. For example, Pythium resistance to metalaxyl was recently discovered in Europe in cucumbers.

If you suspect pesticides resistance, obtain professional advice.

8. Other ICM consideration

Management Option	Recommendation
Scouting/thresholds	Monitor young crops regularly
Resistant varieties	Where available use resistant varieties (Fusarium). These varieties can also be resistant to other diseases such as Verticillium wilt.
Resistant Rootstock	Use disease resistant rootstocks and grafting is an effective ICM practice for controlling Fusarium in tomatoes, cucurbits and beans.
Crop rotation	Following major infection of crop observe susceptible crop free period of 2- 5 years (see below). Grass or cereal crops are excellent crops for this period.
Site selection Seed selection/treatment Post-harvest sanitation	Seed treatments are very successful, especially for Pythium control.
Crop Hygiene	Limit the movement of machinery and personnel from infected paddocks to non-infected properties. Also limit the spread on root vegetables and contaminated seed.
Irrigation management	For reduced Pythium infection, limit irrigation or avoid waterlogging of seedbed for young crops.
Fungicide resistance	Never use more than the recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action / activity group. Use fungicides preventatively (prior to the onset of main disease infection). Never use fungicides after infection has established. Use in this manner will increase the odds of fungicide resistance.

Crop rotation disease risk - Fusarium	
Crop	**Host crop free period**
Asparagus	Indefinitely, do not replant without fumigation
Brassica crops	Many years
Carrots	3 years
Cucurbits	3 years
Peas	4- 5 years
Potatoes	3 years
Tomato	greater than 3 years

Crop rotation disease risk - Pythium	
Crop	**Risk**
All crops	3- 4years

Crop rotation disease risk - Rhizoctonia	
Crop	**Host crop free period**
Potatoes	3 years with at least 1 grass/ cereal crop

Information on rotation risk has been provided to guide growers in their choice of rotation crops.

9. Biological control agents and chemical biofungicides

Biological control includes any organism or extract from an organism of biological origins which exhibit biofumigant, biostimulant or biofungicidal activity on fungi. At present there are no biological control products that are registered in Australia for **Fusarium, Pythium or Rhizoctonia** control, although there are some products sold under various guises that claim disease control.

Some biological control products are registered for Fusarium, Pythium or Rhizoctonia control overseas.

Many different biological control products have been trialled over many years in Australian conditions. A common observation from these trials is that the results are inconsistent from trial to trial and year to year.

It is the authors understanding that no manufacturer has presented appropriate efficacy data to APVMA to seek full registration for any biofungicide in vegetables.

10. Future directions

Additional fungicides may be registered for use or allowed by permit for Fusarium, Rhizoctonia and Pythium control in vegetables in the future.

Biological fungicides may also be evaluated for efficacy under Australian conditions and gain registration or permit if viable.

11. Summary Points

- Fusarium, Pythium and Rhizoctonia are becoming increasingly important as soil-borne diseases in vegetable crops in Australia. They often exist in disease 'complexes'.

- Fusarium, Pythium and Rhizoctonia management, it is important to reduce or totally eliminate root / plant damage during the growing and harvesting phase. This includes the control of damaging pests such as nematodes.

- Because of the nature of Fusarium, Pythium and Rhizoctonia, most fungicides (except for fumigants) are used as either seed dressings (applied to seed prior to planting) or post harvest dips (applied after harvest).

- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems

- Correct application techniques are essential for the most efficient use of seed dressings and post harvest dips.

- The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.

- Careful consideration of crop rotation is also a powerful management tool.

- At present no biological control agents are registered in Australia for *Fusarium, Pythium or Rhizoctonia* control.

12. References

1. Australian Pesticides and Veterinary Medicines Authority: www.apvma.gov.au

2. New York State Integrated Pest Management Program, Cornell University, New York, USA: www.nysipm.cornell.edu

3. CropLife Australia Ltd: www.croplifeaustralia.org.au

4. Peracto Research P/L. Dr Hoong Pung 2008. VG05090. New fungicides and strategies for sustainable management of Sclerotinia and Rhizoctonia diseases on vegetable crops in Australia. HAL Milestone Report

13. Authors Information

(1) Peter Dal Santo B Agr Sc MAIAST AAAC CPAg
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Peter has been involved with Australian agricultural since 1983. Peter's experience has included sales, marketing, research and development roles with major agchem multinational companies and Executive Officer for Crop Protection Approvals, which managed data collation and minor-use permits for the vegetable industry. Since 2003, Peter has been the Director and Principle Scientist of AgAware Consulting P/L which is a project management consultancy. AgAware manages the HAL funded project, 'MT07029 - Managing pesticide access for horticulture' to accessing minor-use permit for horticulture as well as other HAL projects. In 2009, Peter received the 'Ausveg Industry Recognition Award' for servicies to the vegetable industry.

(2) Ross Holding B Agr Sc
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

Ross has worked in the Agchem industry since 1985. First as Technical Officer/Manager Research and Development with a major multinational company (1985-1996) and then as Product Manager with an Australian agchem manufacturer(1997). Since 1998 has worked independently as a contract agricultural consultant specialising in field efficacy and residue trials in both horticulture and broadacre.

AgAware Consulting Pty Ltd

Best Practice – Powdery mildew in vegetables

Introduction

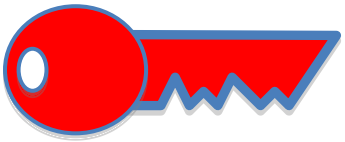
The following document incorporates information essential for economic and sustainable control of a specific disease in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VG07109.

This document is one of a series of documents intended to provide information on "best practice" control of diseases of vegetables. As a result it conforms to the strategy of Integrated Crop Management (ICM) where the "whole" crop is managed to achieve our aim of disease control. However, there is a bias in this document towards fungicide control options with other strategies blended in to the mix of disease control.

The following are the main principles of ICM used in this document for best practice:-

- To select from the available range of economically effective methods to manage plant pathogens below the threshold for disease
- To manage these methods to prolong their effectiveness as long as possible
- To use these methods to minimise adverse effects on users, environment and other crop management systems eg IPM for insect control

For each disease there is one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-



Powdery mildew of cucurbits (Photo courtesy of A.Watson NSW DPI)

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

HAL Know-how for Horticulture™ AgAware Consulting Pty Ltd Classy Solutions

Integrated Crop Management (ICM)

There is increasing attention on incorporating Integrated Crop Management (ICM) systems for vegetable production to control diseases and insect pests. ICM includes the principles of Integrated Pest Management (IPM) that relates specifically to the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimize the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

An ICM/IPM program needs to be developed for all the major crop-disease combinations included in this project. Traditional methods of disease management including crop hygiene, crop rotation and irrigation management remain important elements of ICM. Today a range of fungicides treatments are also available to assist in the management of crop diseases as are some disease resistant crops varieties.

Pesticide treatments vary in cost, efficacy, withholding period, re-entry period and environmental impact. It is accepted that knowledge in this area is incomplete and dynamic.

This document presents a summary of the IPM compatibility of the fungicides currently used in Australia to manage the foliar diseases caused by **Powdery mildew** as well as their pesticide residue and environmental profiles.

For further information on ICM and IPM research initiatives in the Australian vegetable industry can be found on the Ausveg website: www.ausveg.com.au.

Table of Contents

1. Disease background

Powdery mildew is the most serious disease of cucurbit in Australia. Powdery mildew also occur in other vegetable crops including; carrots in south east Australia; peas (including snow peas) and capsicums/peppers in Western Australia and Queensland; parsnips in southern Australia and radish swedes, turnips and tomatoes throughout Australia.

Powdery mildew of cucurbits (*Podosphaera xanthii*)

Powdery mildew of cucurbits is common in all cucurbit-growing areas of the world. Symptoms include small, white, powdery patches occurring on most plant surfaces. The infected areas eventually turn yellow on both upper and lower leaf surfaces and then brown and papery. Although Powdery mildew rarely causes death of plants, the foliar canopy may be reduced quickly causing reduced growth and production and fruit burn in mature vines.

Powdery mildew of squash (Photo courtesy of R Holding)

- Sulphur is a widely used protectant fungicide for Powdery mildew control in cucurbits.

- Resistance management needs to be taken into account when using fungicides for Powdery mildew control in cucurbits.
  - Low resistance risk fungicides include: sulphur, potassium bicarbonate and chlorothalonil
  - High resistance risk fungicides include; triazole fungicides (Group 3), Quinone outside inhibitors (QoIs) (Group 11) including azoxystrobin and trifloxystrobin.

Powdery mildew in peas (*Erysiphe pisi*)

Small spots of white/grey mycelium initially develop on the surface of leaves and pods. These spots can be rubbed off and there are no visible symptoms underneath them. Afterwards, yellow blotches develop on both upper and lower leaf surfaces and can turn purplish/brown. Small, microscopic fruiting bodies can be found in the infected tissue at this stage. Powdery mildew spreads rapidly, and can cover a large portion of the plant in a matter of days (see photo below). In cases where the disease epidemic starts early and causes severe symptoms, the crop may become stunted and seed yield / quality reduced.

Powdery mildew of peas (Photo courtesy of R Holding)

Powdery mildew in carrots (*Erysiphe heraclei*)

Powdery mildew has been found on carrot crops in the Murrumbidgee Irrigation Area of New South Wales, Virginia /South Australia and north-west Tasmania. While the organism causing the disease is commonly found in parsnip crops and other members of the Apiacea family, Powdery mildew has not previously been recorded on carrots in Australia prior to 2007.

The outbreaks have occurred on different carrot varieties and different growing conditions, providing pattern of susceptibility.

The disease affects foliage, stems and umbels (flowers). Patches of white, fluffy fungus appear on the lower leaves first, and then spread to the terminal growth. The fungus often covers entire leaves with its masses of white mycelium and powdery spores. Infected foliage becomes brittle, and may eventually turn brown, shrivel, and die.

Diseased flowers may turn brown, causing the florets to die prematurely. Severe infection can result in loss of foliage, causing lower yields and poor seed quality. Excellent fungicide coverage is required on advanced crops, to ensure adequate leaf coverage. (Section 7) See photo below.

Powdery mildew of carrots
(Photo courtesy of A.Watson NSW DPI)

Powdery mildew in capsicum (*Leveillula taurica*)

Powdery mildew of capsicums and peppers is a major problem in Queensland and West Australian crops. Symptoms are first seen as yellow blotches on older leaves, with a powdery coating on the underside. Severely infected leaves readily drop off. Powdery mildew of peppers is common in warn, dry areas.

Powdery mildew of capsicum
(Photo courtesy of K. Ferguson SARDI)

2. Current registered products for Powdery mildew control in vegetable crops

Azoxystrobin (Group 11)

Azoxystrobin (Amistar 250SC) is a member of the Quinone outside inhibitors (QoIs) activity group (Group 11) that has protectant and systemic fungicidal properties. But Amistar works best when used as a protectant for disease control.
Amistar is registered for Powdery mildew control in the 'cucurbits' group. Various restrictions are stated on the label to minimise overuse and potential resistance developing.
It is not registered for Powdery mildew control in any other vegetable crop.

Bupirimate (Group 8)

Bupirimate (Nimrod) marketed by Farmoz and Crop Care is a member of the Hydroxy-(2-amino) pyrimidine activity group (Group 8) that has systemic/curative fungicidal properties.
Nimrod is registered for Powdery mildew control in the 'melons' group, except for watermelons.
It is not registered for Powdery mildew control in any other vegetable crop.

Carbendazim (Group 1)

Carbendazim is a member of the benzimidazole chemical family (Group 1) that has protectant and systemic fungicidal properties.
There are many products containing carbendazim that are registered for Powdery mildew control in cucurbit crops. Carbendazim is not registered for Powdery mildew control in any other vegetable crop.

Formulation	Trade Name	Manufacturer
500 g/kg	Bavistin FL	Crop Care
	Carbendazim 500	4Farmers
500 g/L	Boomer	Sipcam
	Carbend	Nufarm
	Carbendazim 500	Ospray, 4Farmers, Halley, Superway, Kenso Agcare
	Carbendon SC	Kendon
	Commodore 500	Conquest
	Goldazim 500SC	Campbell
	Howzat SC	Farmoz
	Rotate SC	Kendon
	Sava 500 Fungicide	Agronomics
	Spin Flo	Nufarm

Chlorothalonil (Group M5)

Chlorothalonil is a member of the chloronitriles chemical family (Group M5) that have multi-site activity. Chlorothalonil is a protectant fungicide.

There are many chlorothalonil products registered in Australia for the ***suppression*** of Powdery Mildew in the following cucurbit crops:

- Cantaloupe
- Cucumbers
- Honeydew
- Muskmelon
- Pumpkin
- Squash
- Rockmelon
- Watermelon
- Zucchini

The various chlorothalonil formulations are not registered for powdery mildew control in any other vegetable crop.

Formulation	Trade Name	Manufacturer
500 g/L	Chlorothalonil 500 SC	Bayer
	Echo 500SC	Sipcam
	Whack 500	Chemag
720 g/L	Applonil 720 Fungicide	Grow Choice
	Barrack Betterstick	CropCare
	Bravo Weather Stik	Syngenta
	Cavalry 720 SC	Farmoz
	Cheers 720	Campbell
	Chlorothalonil 720	Ospray
	Clash	Conquest
	Dacogreen 720	Campbell
	Donil Weather Stik	Kendon
	Echo 720 Fungicide	Sipcam
	Glider Fungicide	Rotam
	Unite Ultrastick	Nufarm
	Whack Fungicide	Chemag
900 g/kg	Whack 900 WG	Chemag

Copper as octanoate (M1)

Copper octanoate (Tricop Fungicide) registered by Campbell is the only 'Cu as octanoate' product registered for the 'cucurbit' group in Australia.
Copper octanoate is a member of the inorganic chemical family (Group M1) that have multi-site activity. Copper octanoate is a protectant fungicide.
It is also registered for Powdery mildew control in peas.

Fenarimol (Group 3)

Fenarimol (Rubigan) by DuPont is registered for Powdery mildew control in cucurbits in Australia.
Fenarimol is a member of the pyrimidine chemical family (Group 3) that has systemic/curative fungicidal properties.
There are no other vegetable crops listed on the label.

Oxythioquinox (Group X)

Oxythioquinox (Morestan) by Bayer is registered for Powdery mildew control in 'cucurbits' in Australia.
Oxythioquinox is a member of the quinoxaline activity group (Group X) that has protectant and systemic/curative fungicidal properties.
It is not registered for Powdery mildew control in any other vegetable crop.

Sulphur (S) present as elemental sulphur (Group M2)

There are many different formulations and variations of sulphur available on the Australian market. The all act as elemental sulphur that are protectant fungicides.
Care is sometimes required as application during warm to hot weather may cause crop damage in some crops.
Check labels of products to be used to ensure your crop is listed.

- Dusting Sulphur' by Incitec and CM is a 900 g/kg formulation registered for Powdery mildew control in pumpkins and marrow only. Powdery mildew control is not listed for any other vegetable crops.

- LiquiSulf 700SC by Ekko is a 700 g/L liquid sulphur formulation that is registered for the 'vegetable' group ***except cucumbers and rockmelon***.

- There are many examples of 800 g/kg and 800 g/L sulphur formulations registered for Powdery mildew control in the 'vegetable' group ***except for cucumbers and rockmelons.*** The other vegetable crop listed on the label is tomatoes for Powdery mildew control.

Formulation	Trade Name	Manufacturer
Sulphur as elemental sulphur - 800 g/kg	Brysulf 800WP	Swift
	Cosavet DF	RungeAgrichems
	Granusulf 800WG	Ekko
	Kumulus DF	Crop Care
	Microsul WG Elite	Melpat
	Microthiol Disperss	Cerexagri
	Scarf DF	Nipro
	SulfoStar DF	Crop Care
	Sulfur Spray	Garden King
	Sulphur 800WG	Ospray
	Sulphur 800WP	Tradewyns
	Suphur DF	Melpat
	Thiovit Jet	Syngenta
	Top Wettable Sulphur	Elders/Crop Care
	Wettable Sulfur	Searles
	Wettable Sulphur	Manutec
	Wettable Sulphur	Barmac
	Wettable Sulphur (Microfine)	CRG
Sulphur as elemental sulphur - 800 g/L	Flowable Sulphur	Stollers
	Pro-Sulpha	Ultimate Agriproducts
	Sulfur	Rutec
	Sulphur Fungicide and Miticide	Kendon
	Sulphur Fungicide and Miticide	Headland
	Suphur Spray	David Grays
Sulphur as elemental sulphur – 1000 g/kg	David Grays Powdered Sulphur'	David Grays

- Lime Sulphur Fungicide/Insecticide (polysulphide sulphur - 200 g/L) by Kendon is registered for Powdery mildew control in 'vegetables' and tomatoes.

- Lime Sulfur Solution by Miller (sulphur present as calcium polysulfide 276 g/L) are registered for Powdery mildew control in the 'vegetable' group and tomatoes.

- There are two sulphur + mancozeb (Group M2 + M3) products registered for Powdery mildew control in vegetables. 'Mancozeb Plus Garden Fungicide' by Yates is registered for Powdery mildew control in cucumbers, melons and pumpkins. 'Mancozeb Plus Fungicide' by Searle is registered for Powdery mildew control in the 'cucurbit' group

Tebuconazole (430 g/L) (Group 3)

There are many brands of tebuconazole registered for Powdery mildew control in 'peas' in Australia.
Tebuconazole is a member of the triazole chemical group (Group X) that has systemic/curative fungicidal properties.
It is not registered for Powdery mildew control in any other vegetable crop.

Tebuconazole	Blast 430	Genfarm
	Emperor	Crop Care
	Folicur 430 Sc	Bayer
	Hornet	Nufarm
	Isis 430 SC	Campbell
	Laguna 430	Sipcam
	Orius 430 SC	Farmoz
	Rebuke 430 SC	Kenso Agcare
	Stingray	Conquest
	Tebuconazole	Rygel, Chemforce, Titan
	Tebuconazole 430 SC	Agriwest, 4farmers, Ospray, United Farmers, Imtrade, Smart, Allfire

Triadimefon (125 g/L and 500 g/kg) (Group 3)

There are many brands of triadimefon registered for Powdery mildew control in cucurbits and peas in Australia.
Triadimefon is a member of the triazole chemical group (Group X) that has systemic/curative fungicidal properties.
Triadimefon is not registered for Powdery mildew control in any other vegetable crop.

Triadimefon	Bayleton 125 EC	Bayer
	Slingshot Fungicide	Sipcam
	Tee-Fon 500WP	Ronic
	Triad 125	Farmoz
	Triadimefon 125	Kenso Agcare, Allfire, Chemag, WSD, United Farmers, Conquest Genfarm, Ospray
	Triadimefon 500	Techchem, 4Farmers, Allfire, PGR, Genfarm, United Farmers, Chemag
	Turret	Nufarm

Triadimenol 250 g/L (Group 3)

There are several brands of triadimenol registered for Powdery mildew control in cucurbits in Australia. These include Bayfidan by Bayer Tridim 250EC by Campbell and Citadel by Farmoz.
Triadimenol is a member of the triazole chemical group (Group X) that has systemic/curative fungicidal properties.
Triadimenol is not registered for Powdery mildew control in any other vegetable crop.

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

3. Products available under permit for Powdery mildew control in vegetable crops

*** These permits are current as at 30th September 2009.**

Azoxystrobin (AMISTAR - Group 11)

Permit Number	Description	Date Issued	Expiry Date
PER11480	Azoxystrobin / Brassica Leafy Vegetables & Carrots / Alternaria Leaf Spot & Powdery mildew	10-Aug-09	30-Sep-11
PER10914	Azoxystrobin / Radish, leek & carrot / Powdery mildew, Downy mildew and White blister rust	9-Jun-09	31-May-14

Bupirimate (NIMROD - Group 8)

Permit Number	Description	Date Issued	Expiry Date
PER10979	Bupirimate / Cucurbits & Peppers / Powdery mildew	31-Mar-09	30-Sep-14
PER11087	Bupirimate / Eggplant / Powdery mildew	1-Oct-08	31-Dec-09

Potassium bicarbonate (ECOCARB - Group Y)

Permit Number	Description	Date Issued	Expiry Date
PER9778	Potassium bicarbonate / Greenhouse-grown brassica leafy vegetables, silverbeet, cucumbers, peppers, tomatoes, lettuce and herbs / Powdery Mildew	6-Sep-07	5-Sep-12

Tebuconazole (FOLICUR & others - Group 3)

Permit Number	Description	Date Issued	Expiry Date
PER10198	Folicur 430 SC / Carrots / Powdery Mildew	4-Sep-07	30-Sep-09

Triadimenol (BAYFIDAN & others - Group 3)

Permit Number	Description	Date Issued	Expiry Date
PER11089	Triadimenol (Bayfidan) / Eggplant / Powdery mildew	26-Sep-08	31-Dec-09
PER7632	Triadimenol / Parsnips, radish, Swede And Turnip / Powdery Mildew	8-Aug-05	31-Dec-09

Trifloxystrobin (FLINT - Group 11)

Permit Number	Description	Date Issued	Expiry Date
PER9920	Trifloxystrobin / Greenhouse capsicums (peppers) / Powdery Mildew	4-Sep-07	31-Dec-09

Various herb permits

Permit Number	Description	Date Issued	Expiry Date
PER8591	Myclobutanil / Specified leafy and woody herbs / Powdery Mildew	18-Jun-09	30-Jul-13
PER8596	Propiconazole / Specified leafy & woody herbs / Various diseases	24-Dec-08	30-Sep-11
PER8621	Quinoxyfen / Leafy and Woody herbs / Powdery Mildew	18-Jun-09	30-Jul-13
PER9283	Sulphur / Culinary herbs / Rusts, mites, mildews	26-Jul-06	31-Jul-11
PER8620	Tebuconazole / Specified leafy & woody herbs / Various diseases	24-Dec-08	30-Sep-11

IMPORTANT NOTICE
Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

4(a). Environmental profile of fungicides

The choice of fungicide should not be based on efficacy or price alone as other considerations need to be taken into account when employing an ICM/IPM based best management practice.

The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

EIQ assess each fungicide for:

- Applicator effects } Farm worker effects
- Picker effects } Farm worker effects
- Consumer effects
- Leaching
- Fish effects } Ecology effect
- Bird, bee & beneficials } Ecology effect

EIQ rates each of these factors and gives a rating that can be used to compare one pesticide with another for its environmental profile.

Further information on EIQ can be found on their web site - see reference (2).

The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems. The lower the EIQ rating the better the environmental profile.

The following table includes information for those products that could be considered for *Powdery mildew* control in vegetables. Some of the information can already be found on product labels (eg. chemical group, withholding period, re-entry period, etc).

Below are the explanations for terms used in the table.

1. WHP = withholding period for harvest
2. REP = re-entry period after spraying
3. EIQ = Environmental Impact Quotient. Rating system which provides a relative rating for pesticides active ingredients based on worker consumer and environmental effects. The lower the rating indicates a better environmental profile.
4. EIQ field rating = EIQ x product formulation concentration x application rate (kg or L/ha). A lower rating indicates a better environmental profile.
5. Effect on beneficials - Individual component of EIQ as field rating.
6. NIFWR – no information further work required

Active Ingredient and Product Name	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4] (per app)	Effect on Beneficials [5] (IPM fit)	Comments
azoxystrobin eg. Amistar 250 SC	11	1 (cucurbits) 21 (carrots)	> Spray dried	15.2	5	3	Cucurbits Powdery mildew registration only. Carrots PERMIT 11480 & 10194
bupirimate eg. Nimrod	8	1	> Spray dried	NIFWR	0.25 X 0.6	NIFWR	Melons (not rockmelons) Powdery mildew registration only. Cucurbit PERMIT 10979 Eggplant PERMIT 11087
carbendazim eg. Bavistin FL	1	0	> Spray dried	56.2	14	16	Cucurbits Powdery mildew only
chlorothalonil eg. Bravo	M5	1	> Spray dried	40.1	72	71	Cucurbit Powdery mildew suppression only
copper as octanoate eg. Tricop	M1	1	> Spray dried	33	2.08	NIFWR	Cucurbits and peas Powdery mildew only
fenarimol eg. Rubigan	3	3	> Spray dried	22.4	1	0	Cucurbits Powdery mildew only
oxythioquinox eg. Morestan	X	7	> Spray dried	44.4	4.44	5	Cucurbits Powdery mildew only
potassium bicarbonate eg. Ecocarb	Biofungicide - Y	0	> Spray dried	8	30	18.8	Greenhouse-grown brassica leafy vegetables, silverbeet, cucumbers, peppers, tomatoes, lettuce and herbs PERMIT 9778
elemental sulphur (900g/kg)	M2	0	> Spray dried	45.5	41	78	Pumpkins and marrow Powdery mildew only
elemental sulphur (700g/L)	M2	0	> Spray dried	45.5	110	210	Vegetables Powdery mildew other than cucumbers or rockmelons

Active Ingredient and Product Name	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4] (per app)	Effect on Beneficials [5] (IPM fit)	Comments
elemental sulphur (800 g/kg)	M2	0	> Spray dried	45.5	73	139	Vegetables Powdery mildew other than cucumbers or rockmelons
polysulphide sulphur (200 g/L)	M2	0	> Spray dried	45.5	91	174	Vegetables and tomatoes Powdery mildew only
calcium polysulfide (276 g/L) & calcium thiosulfate (19g/L)	M2	0	> Spray dried	45.5	121	231	Vegetables and tomatoes Powdery mildew only
sulphur + mancozeb eg. Mancozeb Plus	M2 +M3	7	> Spray dried	45.5	182	348	Cucurbits Powdery mildew only
elemental sulphur (1000 g/kg) eg. David Grays Powdered Sulfur	M2	0	> Spray dried	45.5	Dust app 200 ?	400 ?	Pumpkins and marrow Powdery mildew only
tebuconazole eg. Folicur 430 SC	3	3	> Spray dried	40.3	3	2	Carrots PERMIT 10198
triadimefon (125 g/L) eg.Turret	3	1	> Spray dried	30.7	2	2	Cucurbits and peas Powdery mildew only
triadimenol (250 g/L) eg. Bayfidan	3	1 (cucurbits) 7(P,R,S,T)	> Spray dried	NIFWR	0.25 X 0.4X EIQ	NIFWR	Cucurbits Powdery mildew only. Eggplant PERMIT 11089 Parsnips, radish, swede, turnip PERMIT 7632
trifloxystrobin eg. Flint	11	3	> Spray dried	31	4.6	4	Greenhouse Capsicums PERMIT 9920

(See page 13 for explanations of terms used in this table-consult individual product labels for full details)

4 (b). Impact of Fungicides on Beneficial Insects and Mites- Australian data

Research work funded by HAL and Vegetables R&D Levy into the effects of pesticides on beneficial insects and mites in vegetables in Australia has been ongoing for 3 years. The following table summarises results of relevant *fungicides*.

Product	**Beneficial insect or mite and their target pest**		
Fungicide **Active ingredient**	**Brown lacewing** (Aphids)	**Transverse ladybird** (Aphid)	**Damsel Bug** (Caterpillars)
azoxystrobin (Amistar)			
sulphur eg Thiovit			

	= Harmless- less than 30% acute mortality
	= Mod harmful. 30->70% acute mortality
	= Harmful: greater than 70 %mortality

These results show the short term (or acute) effects using adults. Potential long term effects such as impact on reproduction are not shown as they were not conducted. However, it is hoped that with further funding this aspect may be evaluated.

This work was performed by IPM Technologies Pty Ltd and the Department of Primary Industries (Vic). Funding by Horticulture Australia Ltd (HAL) and the Australian Vegetable Research and Development Levy, Project VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

5. Product application rates and other information

Fungicides presently registered or used under permit

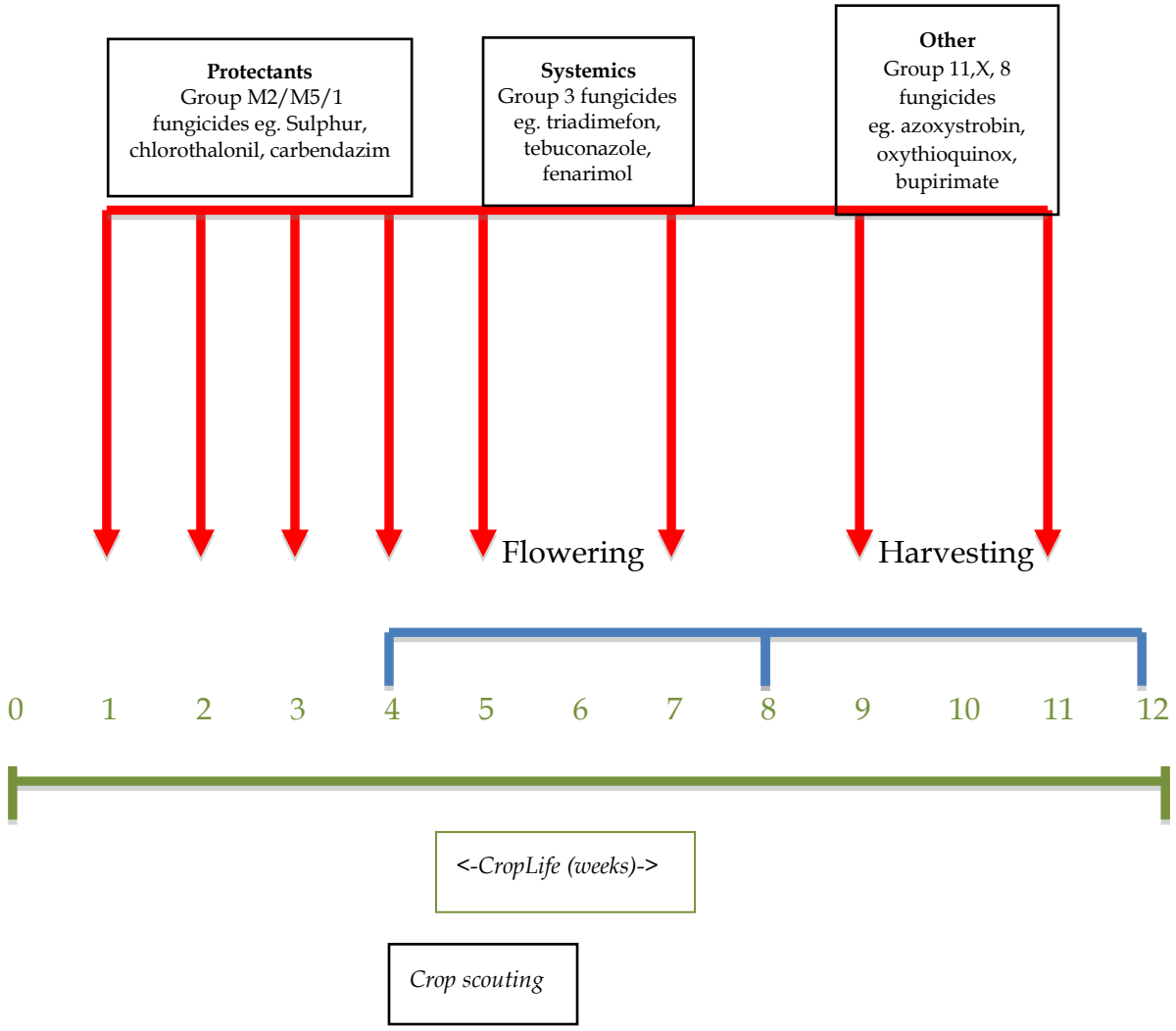
Active Ingredient and Product Name	Group	Max no. of apps per crop	Rate per ha	Spray interval (days)	Concentration
azoxystrobin eg. Amistar	11	4	800 ml- 1.2 L	7-14	250 g/L
bupirimate eg. Nimrod	8	No limit	600 ml	7	250 g/L
carbendazim eg. Bavistin FL	1	No limit	400-500 ml	7-14	500g/L
chlorthalonil eg. Bravo	M5	No limit	1.6-2.5 L	7-14	720g/L
copper as octanoate eg. Tricop	M1	No limit	3.5 L	7-10	18 g/L
fenarimol eg. Rubigan	3	No limit	200 ml	14-21	120 g/L
oxythioquinox eg. Morestan	X	No limit	250-400 g	5-10	250 g/L
potassium bicarbonate eg. Ecocarb	Biofungicide /Y	No limit	4 kg +2 L veg oil adjuvant	10-14	940 g/kg
elemental sulphur (700g/L) eg. Liquisulf 700SC	M2	No limit	2.3-3.4 L	14-21	700 g/L
elemental sulphur (800 g/kg) eg. Brysulf 800 WG or Thiovit	M2	No limit	2.0 kg	As necessary	800 g/kg WG
elemental sulphur (900g/kg) eg. Manutec Dusting Sulphur	M2	No limit	Dusting?	7-14	900 g/kg
elemental sulphur (1000 g/kg) eg David Grays Powdered Sulfur	M2	No limit	Dusting?	As necessary	1000 g/kg
polysulphide sulphur (200 g/L) eg. Lime Sulphur	M2	No limit	10 L	As necessary	200 g/L
sulphur as calcium polysulfide 276 g/L + calcium thiosulfate 19 g/L	M2	No limit	9.0 L	As necessary	295 g/L
sulphur + mancozeb eg. Yates Mancozeb Plus	M2 +M3	No limit	5.0 kg	10	800 g/Kg
tebuconazole eg. Folicur	3	3	580 ml	14-21	430 g/L
triadimefon eg. Turret	3	No limit	400 ml	5-10	125 g/L

Active Ingredient and Product Name	Group	Max no. of apps per crop	Rate per ha	Spray interval (days)	Concentration
triadimenol eg. Bayfidan	3	No limit	400 ml	5-10	250 g/L
trifloxystrobin eg. Flint	11	3	200- 300 g	No info 7-14?	500 g/kg

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

6. Disease control program (example) - Powdery mildew. Cucurbits (long crop life eg. pumpkins, melons, "longer" cucumbers)



7. Application

Powdery mildew

Successful spraying applications depend on the thorough coverage of the target with evenly distributed individual droplets. Good disease control will result if the application yields an average of the following droplets per cm^2 on the target.

- 20-50 droplets per cm^2 for systemic and translaminar fungicides
- 50-70 droplets for cm^2 for protectant type fungicides

Combine these two elements – good coverage and product deposit with the correct choice of nozzle pressure and sprayer speed. It is generally recommended that application volumes in the range 200- 500 L/ha are adequate for field grown crops sprayed with boom sprays using hydraulic nozzles. The advent of air assist /air blast equipment to boomspraying offers many advantages -

- Better coverage in dense or complete canopies where turbulence is required to achieve droplet coverage on both sides of plant leaves.
- Better management of drift

The addition of an air blast nozzles is beneficial particularly when the crop grows large enough to form a complete canopy.(6)

The addition of spray adjuvants to fungicides is important where directed by label recommendations. Spray adjuvants reduce surface tension/assist droplet formation and provide other benefits such as drift minimisation.

For other cropping situations, eg. greenhouse, the same principles can be applied with the choice of appropriate equipment - thorough coverage with evenly distributed individual droplets.

Powdery mildew can be controlled to some degree on the upper leaf surfaces by all fungicide treatments.

However, efficacy can be more variable on the lower leaf surface with protectant type fungicides. Better control of disease on lower leaf surfaces can be achieved with fungicides of systemic or translaminar activity (4).

Spraying a young vegetable crop
(Photo courtesy of R Holding)

8. Fungicide Resistance

The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Never use more than the label recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action /activity group.

Always use fungicides according to the label directions:

- If the fungicide is to be used preventatively, then apply prior to the onset of main disease infection period.
- If the fungicide is to be used curatively, then apply as soon as possible after the onset of main disease infection period.
- Never use fungicides after infection has fully established and is visible.

There have been reported losses of effectiveness of some fungicides in vegetable crops. In many situations it was found that poor commercial results may have been due to poor application by growers rather than fungicide resistance/tolerance.

CropLife Australia (3) (formerly AVCARE) implement Fungicide Resistance Management Strategies (FRMS) for various crops and diseases in Australia.

For Powdery mildew in cucurbits the following FRMS exists:-

- Group 3 (DMI, pyrimidine);
- Group 1 (Methyl Benzimidazole Carbamate); and
- Group 11 (Quinone outside Inhibitor) and other "systemic" fungicides

1. Start disease control early. DO NOT wait for powdery mildew to appear before spraying, but start as soon as practicable after crop emergence.
2. Use protectant sprays in early crop growth. Apply protectant sprays up to the fruit set stage of the crop if the disease normally occurs during this period. If this schedule is interrupted (eg. by rain) use a tank mix of protectant plus systemic before recommencing the protectant program.
3. After fruit set, use systemic fungicides in one or more of the following ways:
    a. Tank mix systemic fungicides with a protectant fungicide AND use fungicides from at least two different systemic activity groups per crop.
    b. Alternate systemic fungicides with a protectant fungicide AND use fungicides from at least two different systemic activity groups per crop.
    c. Alternate systemic fungicides from at least three different activity/chemical groups per crop

9. Other ICM consideration

Management Option	Recommendation
Scouting/thresholds	Monitor young crops regularly in an attempt to find the disease early.
Resistant varieties	No resistant varieties exist for Powdery mildew.
Crop rotation	Involves leaving land fallow, green manure crop or growing a crop which is not a host to the disease for a number of seasons between susceptible crops.
Site selection Seed selection/treatment Post-harvest sanitation	Aim to select planting sites to minimise disease inoculum carryover especially for susceptible crops. No viable seed treatment is available. No post harvest options are available.
Crop hygiene	Limit the movement of machinery and personnel from infected paddocks to non-infected properties. Powdery mildew can be easily spread, and preventative action can help limit the spread of the disease.
Fungicide resistance	Always follow the fungicide resistance warnings on product labels. Never use more than the recommended maximum number of applications per crop and where possible rotate to fungicides with a different mode of action (different chemical group). Where appropriate use fungicides preventatively (prior to the onset of main disease infection). Overuse of fungicides from only one chemical group could lead to the development of resistance. Where possible rotate chemical groups. Monitor all fungicide application for effectiveness and make future fungicide selections based on previous performance. Using fungicides in a curative manner can increase the risk of fungicide resistance.
Fertiliser practice	Manage nitrogen levels to minimise N fertilisers in order to prevent the growth of" fleshy or lush" young growth that tends to be more susceptible to POWDERY MILDEW.

10. Biological control agents and chemical biofungicides

Biological control includes any organism or extract from an organism of biological origin which exhibit biofumigant, biostimulant or biofungicidal activity on fungi. At present there are no biological control agents that are registered in Australia for **Powdery mildew** control, although there are some products sold under various guises that claim disease control.

Some biological control products are registered for **Powdery mildew** control overseas.

Many different biological control agents have been trialled over many years in Australian conditions. A common observation from these trials is that the results are inconsistent from trial to trial and year to year.

It is the authors understanding that no manufacturer has presented appropriate efficacy data to APVMA to seek full registration for any biofungicide in vegetables.

11. Future directions

Additional fungicides may be registered for use or available via permit for Powdery mildew control in vegetables in the future.

Biological fungicides may also be evaluated for efficacy under Australian conditions and gain registration or permit if viable.

12. Summary Points

- Powdery mildew is the most serious disease of cucurbit in Australia. Powdery mildew also occur in other vegetable crops including carrots in south east Australia; peas (including snow peas) and capsicums/peppers in Western Australia and Queensland; parsnips in South Australia and radish swedes, turnips and tomatoes throughout Australia.

- Resistance management needs to be taken into account when using fungicides for Powdery mildew control in cucurbits.

- Powdery mildew has been found in carrot crops in 3 south eastern states since 2007.

- Sulphur probably forms the backbone of fungicide programs for preventative control of Powdery mildew in vegetables. Many other fungicides are also registered or can be used under permit. Fungicides from a wide range of activity groups exist and provide ample opportunity for rotation to prevent fungicide resistance.

- Other chemical fungicides and biofungicides are under review and may achieve registration or permit use in the future.

- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.

- Correct application techniques are essential for the most efficient use of fungicides.

- The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.

- Careful consideration of crop rotation is also a powerful management tool.

- At present no biofungicides of a biological nature are fully registered in Australia for Powdery mildew control but potassium bicarbonate eg. Ecocarb® does have a use permit in greenhouses for some crops.

13. References

1. Australian Pesticides and Veterinary Medicines Authority: www.apvma.gov.au
2. New York State Integrated Pest Management Program, Cornell University, New York, USA: www.nysiPowdery mildew .cornell.edu
3. CropLife Australia Ltd: www.croplifeaustralia.org.au
4. University of Arizona College of Agriculture 2001 Vegetable Report: http://ag.arizona.edu/pubs/crop/az1252/
5. NSW DPI Sept 2007 Primefacts 616. Powdery mildew – a new disease of carrots.
6. Franklin TG, O Brien RG, Banks AG.1986. Conference on Agricultural Engineering. Performance of Two methods of Boom Spray Application.

14. Authors Information

(1) Peter Dal Santo B Agr Sc MAIAST AAAC CPAg
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Peter has been involved with Australian agricultural since 1983. Peter's experience has included sales, marketing, research and development roles with major agchem multinational companies and Executive Officer for Crop Protection Approvals, which managed data collation and minor-use permits for the vegetable industry. Since 2003, Peter has been the Director and Principle Scientist of AgAware Consulting P/L which is a project management consultancy. AgAware manages the HAL funded project, 'MT07029 - Managing pesticide access for horticulture' to accessing minor-use permit for horticulture as well as other HAL projects. In 2009, Peter received the 'Ausveg Industry Recognition Award' for servicies to the vegetable industry.

(2) Ross Holding B Agr Sc
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

Ross has worked in the Agchem industry since 1985. First as Technical Officer/Manager Research and Development with a major multinational company (1985-1996) and then as Product Manager with an Australian agchem manufacturer(1997). Since 1998 has worked independently as a contract agricultural consultant specialising in field efficacy and residue trials in both horticulture and broadacre.

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

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Best Practice - Sclerotinia in green beans

Introduction

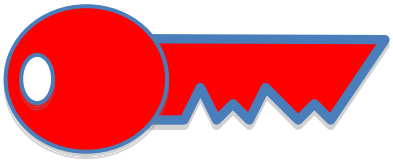
The following document incorporates information essential for economic and sustainable control of a specific disease in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VG07109.

This document is one of a series of documents intended to provide information on "best practice" control of diseases of vegetables. As a result it conforms to the strategy of Integrated Crop Management (ICM) where the "whole" crop is managed to achieve our aim of disease control. However, there is a bias in this document towards fungicide control options with other strategies blended in to the mix of disease control.

The following are the main principles of ICM used in this document for best practice:-

- To select from the available range of economically effective methods to manage plant pathogens below the threshold for disease
- To manage these methods to prolong their effectiveness as long as possible
- To use these methods to minimise adverse effects on users, environment and other crop management systems eg IPM for insect control

For each disease there is one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-



Sclerotinia in beans (Photo courtesy of D. Wite Vic DPI)

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

HAL Know-how for Horticulture™ AgAware Consulting Pty Ltd Classy Solutions

Integrated Crop Management (ICM)

There is increasing attention on incorporating Integrated Crop Management (ICM) systems for vegetable production to control diseases and insect pests. ICM includes the principles of Integrated Pest Management (IPM) that relates specifically to the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimize the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

An ICM/IPM program needs to be developed for all the major crop-disease combinations included in this project. Traditional methods of disease management including crop hygiene, crop rotation and irrigation management remain important elements of ICM. Today a range of fungicides treatments are also available to assist in the management of crop diseases as are some disease resistant crops varieties.

Pesticide treatments vary in cost, efficacy, withholding period, re-entry period and environmental impact. It is accepted that knowledge in this area is incomplete and dynamic.

This document presents a summary of the IPM compatibility of the fungicides currently used in Australia to manage soilborne diseases caused by **Sclerotinia** as well as their pesticide residue and environmental profiles.

For further information on ICM and IPM research initiatives in the Australian vegetable industry can be found on the Ausveg website: www.ausveg.com.au.

Table of Contents

1. Disease background

Long term control of Sclerotinia is difficult in beans due to a number of factors including:

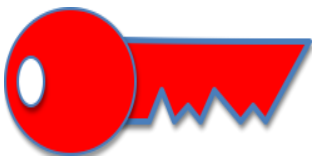
- A wide host range including bean, brassica, carrot, celery, lettuce, onion, pea, potato and tomato.
- The formation of long-lived sclerotia (up to 10 years) in the soil.
- The formation of mycelium in living or dead plants.
- With the correct conditions sclerotia produce a fruiting body or ascocarp which releases ascospores into the air.
- The aggressive nature of the infection process.
- The lack of resistant varieties.
- Reliance on fungicides for control.
- Lack of a wide range of alternate modes-of-action fungicides.
- Multiple cropping and poor rotation practices.
- Rotation with non-host crops (cereals) is difficult and at least 3 years is required.

Sclerotinia sclerotiorum is a major disease of green beans (*Phaseolus vulgaris*), but can also affect potatoes, brassicas, and lettuce. *Sclerotinia sclerotiorum* produce long lived sclerotes which can infest soil for many years. These sclerotia are large, black and somewhat irregular shaped - the size of rat faeces pellets.

Reduction of the inoculum potential is a key to the long term control of this disease. *Sclerotinia sclerotiorum* sclerotes can produce mushroom like ascocarps which release ascospores that initiate the foliar infection stage of this disease. When infection is initiated by ascospore invasion at flowering, infected seed pods suffer from a wet rot that spreads from the top of the pod to the remainder. They can then become completely rotted and disintegrate under favourable disease conditions. White fluffy mycelium and black sclerotia can usually be seen both externally and within the infected pods.

Long term control of *Sclerotinia sclerotiorum* (and in particular its aerial spore phase) is difficult in beans due to a number of factors including:

- Inability to accurately predict ascospore release
- Lack of knowledge about site factors that influence infection
- Difficulty in selecting the optimum timing for first spray application
- Spray efficacy (eg. droplet size)
- Disease inducing factors relating to minimising leaf wetness and humidity in the canopy (ie. row spacing, weed control)



Sclerotinia produces long lived sclerotes which can infest soil for many years. Reduction of the inoculum potential is a key to the long term control of this disease. The use of long rotations (green beans free), fumigants or biofungicides is essential prior to planting green beans in soils with high levels of inoculum/sclerotes. Dependence on Sclerotinia fungicides alone for disease control in high risk situations is not sustainable.

White fluffy mycelium growth of infected green beans
(Photo courtesy of John Duff Qld PI&F, Gatton Qld)

Sclerotinia crop infection on susceptible variety (right hand side of track) showing leaf and vine necrosis.
(Photo courtesy of John Duff Qld PI&F, Gatton Qld)

2. Current registered product(s) for Sclerotinia control in green beans

Fungicides (chemical)

No fungicides are currently registered for Sclerotinia use in green beans. All fungicidal control options are permit use only. (see Section D)

Fumigants

The use of fumigants is not considered ICM/IPM "friendly" as they are total biocides. However, in salvage situations or where high levels of sclerotia have been monitored or anticipated, soil fumigation may be necessary as an initial control method. All fumigants provide varying degrees of pre plant soil fumigation for bacteria, diseases (soil borne), insects, nematodes and weed seeds.

Compound	Chemical group	Crop	Disease
chloropicrin eg. Chloropicrin	Group8A Fumigant - insecticide/fungicide	All crops	Sclerotinia + others
dazomet eg. Basamid	Fumigant - insecticide/fungicide	All crops	Sclerotinia + others
metham sodium eg Metham	Group1A Fumigant - insecticide/fungicide	All crops	Sclerotinia + others

IMPORTANT NOTICE
Before any fungicides are used via the above list, the label should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

3. Current fungicides used under permit for Sclerotinia control in green beans

*** These permits are current as at 30th September 2009.**

Azoxystrobin (AMISTAR® - Group 11)

Permit Number	Description	Date Issued	Expiry Date
PER10261	Azoxystrobin: Brassica / White blister; Beans / Sclerotinia rot: Lettuce / Sclerotinia rot	3-Jan-08	1-Jan-10

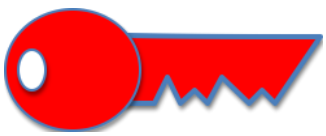
- Azoxystrobin (Amistar 250SC) is a member of the Quinone outside inhibitors (Qols) activity group (Group 11)
- Has protectant and systemic fungicidal properties. But Amistar works best when used as a protectant for disease control.
- Reduced-risk fungicide.
- Efficacy has been questioned in high pressure green bean/Sclerotinia situations in Australia.
- APVMA permit PER10261 - 1 day WHP.
- Maximum of 3 applications at 7 - 14 day intervals.
- Registered in tomatoes for Sclerotinia control.
- Registration under consideration in other crops.

Boscalid (FILAN® - Group 7)

Permit Number	Description	Date Issued	Expiry Date
PER8819	Boscalid / Brassica, Brassica Leafy Vegetables, Lettuce, Beans (green pods and immature seeds) / Sclerotinia rot	10-Oct-05	31-Jan-10

- Boscalid (Filan Fungicide) is a Group 7 oxanthiin fungicide
- Inhibits spore germination, mycelial growth and sporulation - preventative and curative.
- Reduced-risk fungicide.
- Backbone of green bean/Sclerotinia programs in Australia at present.
- Well favoured but some variability in performance under high disease pressure.
- APVMA permit PER8819 - 7 day WHP
- Maximum of 3 applications at 7 - 10 day intervals.
- Registration under consideration.

IMPORTANT NOTICE
Before any fungicides are used via the above list, the permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.



Amistar® and **Filan®** are the only fungicides available for **Sclerotinia** control in green beans. Careful use of these products is required to ensure their useable life.

4. Environmental profile of fungicides

The choice of fungicide should not be based on efficacy or price alone as other considerations need to be taken into account when employing an ICM/IPM based best management practice.

The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

EIQ assess each fungicide for:

- Applicator effects } Farm worker effects
- Picker effects } Farm worker effects
- Consumer effects
- Leaching
- Fish effects } Ecology effects
- Bird, bee & beneficials } Ecology effects

EIQ rates each of these factors and gives a rating that can be used to compare one pesticide with another for its environmental profile.

Further information on EIQ can be found on their web site - see reference (2).

The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.
The lower the EIQ rating the better the environmental profile.

The following table includes information for those products that could be considered for *Powdery mildew* control in vegetables. Some of the information can already be found on product labels (eg. chemical group, withholding period, re-entry period, etc).

Below are the explanations for terms used in the table.

1. WHP = withholding period for harvest
2. REP = re-entry period after spraying
3. EIQ = Environmental Impact Quotient. Rating system which provides a relative rating for pesticides active ingredients based on worker consumer and environmental effects. The lower the rating indicates a better environmental profile.
4. EIQ field rating = EIQ x product formulation concentration x application rate (kg or L/ha). A lower rating indicates a better environmental profile.
5. Effect on beneficials - Individual component of EIQ as field rating.
6. NIFWR – no information further work required

EIQ for registered and permitted products in beans

Product	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4] (per app)	Effect on Beneficials [5] (IPM fit)	Comments
azoxystrobin eg. Amistar	11	1 (beans)	> Spray dried	15.2	5	3	Permit - brassica, lettuce, beans
boscalid eg. Filan	7	14	after spray dried	44	22	31	Permit - brassicas, brassica leafy vegetables, lettuce, beans
chloropicrin eg. Chloropicrin	8A	N/A	Consult label	>100	>20000	300	No IPM fit
dazomet eg. Basamid	1A	N/A	48	>100	>20000	300	No IPM fit
metham sodium eg. Metham	1A	N/A	48	>100	>20000	300	No IPM fit

(See page 8 for explanations of terms used in this table)

5. Impact of fungicides on beneficial insects and mites - Australian data

Research work funded by HAL and the Vegetable R&D levy into the effects of pesticides on beneficial insects and mites in vegetables in Australia has been ongoing for 3 years. The following table summarises results of relevant *fungicides*.

These results show the short term (or acute) effects using adults. Potential long term effects such as impact on reproduction are not shown as they were not conducted. However, it is hoped that with further funding this aspect may be evaluated.

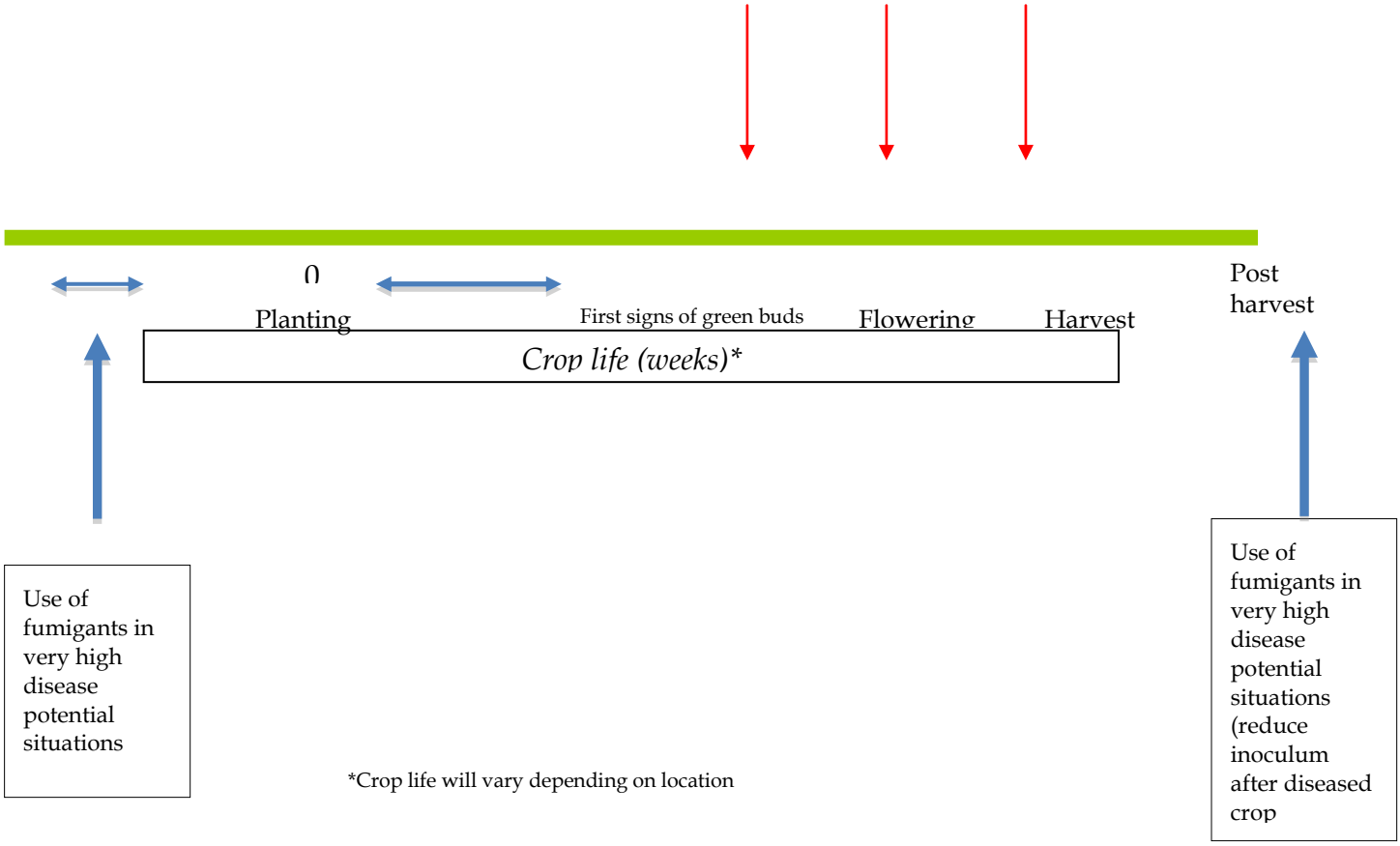
Product	**Beneficial insect or mite and their target pest**				
Fungicide **Active ingredient**	**Brown lacewing** (Aphids)	**Transverse ladybird** (Aphid)	**Common spotted ladybird** (Aphid)	**Damsel Bug** (Caterpillars)	**Trichogramma wasp parasitoid** (Caterpillars)
Azoxystrobin (Amistar)					
Boscalid (Filan)					

	= Harmless- less than 30% acute mortality
	= Mod harmful. 30->70% acute mortality
	= Harmful: greater than 70 %mortality

This work was performed by IPM Technologies Pty Ltd and the Department of Primary Industries (Vic). Funding by Horticulture Australia Ltd (HAL) and the Australian Vegetable Research and Development Levy, Project VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

6. Disease control programs for *Sclerotinia sclerotiorum* in beans

Disease risk	1st app**	2nd app	3rd app	EIQ **
High	Filan	Filan	Filan	66
Medium /Low		Filan	Filan	44



*Crop life will vary depending on location

7. Product application rates and other information

Fungicides presently used under permit

Product Name (active)	Concentration	Group	Application Rate (per ha)	Max no. of apps per crop	Spray interval (days)	Withholding Period (days)
AMISTAR (azoxystrobin)	250 g/L	11	500-600 mL/ha or 50-60 mL/100L	3	7-14	1
FILAN (boscalid)	500 g/kg	7	800-1000 g/ha	3	7-10	7

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

8. Application of fungicides

Sclerotinia sclerotiorum

Choose appropriate application indices (spray intervals, droplet size, volume etc) and technique to ensure adequate coverage to prevent ascospore infection. These are sometimes outlined in fungicide label directions. Use of adjuvants with fungicides may also be required.

Follow label directions for application intervals, droplet size, volume, etc.

Spray nozzle types and spray water volume have little or no influence on disease control. An increase in the spray water volume; for example from 250 to 700 L/ha does not cause a significant improvement in the level of disease control. (4)

In areas that are prone to Sclerotinia diseases, the timing of the first spray application is likely to be the most important factor in determining the level of disease control. The first application, applied at 10% plants with open flowers, can give much better disease control than those applied at 90% plants with open flowers. (4)

See Section10 regarding strategies to minimise fungicide resistance.

Spraying of crops.
(Photo courtesy of R. Holding)

9. Fungicide Resistance

The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Never use more than the label recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action /activity group. However, in green beans it is acknowledged that alternative fungicides to Amistar and Filan are not yet available and so rotation is limited.

Always use fungicides according to the label directions:

- If the fungicide is to be used preventatively, then apply prior to the onset of main disease infection period.
- If the fungicide is to be used curatively, then apply as soon as possible after the onset of main disease infection period.
- Never use fungicides after infection has fully established and is visible.

Crop Life Australia (5) (formerly AVCARE) implement Fungicide Resistance Management Strategies for various crops and diseases in Australia. To date, no FRMS has been formulated for *Sclerotinia* diseases in Australia.

There have been reported losses of effectiveness of some fungicides in vegetable crops. In many situations it was found that poor commercial results may have been due to poor application by growers or poor application timing rather than fungicide resistance/tolerance.

Fungicide testing from other crops has shown that some strains of *Sclerotinia* are resistant to some fungicides from different activity groups. If using fungicides monitor the results to check for effectiveness and if results are not as expected contact your local DPI, agchem manufacturer or retailer to investigate further.

HAL Project VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', (Barbara Hall, SARDI and Leanne Forsyth, NSWDPI) is investigating fungicide resistance by testing diseased samples collected in the field.

From initial testing in VG07119 of 45 samples of *Sclerotinia sclerotiorum* received from Vic, SA, WA, NSW, Qld and Tas, 2 from NSW and 2 from Victoria were resistant to benzimidazoles (carbendazim, thiabendazole), 6 others showed reduced sensitivity and 5 were resistance to dicarboximides (iprodione, procymidone).
Further testing is underway.

Sending diseased plant samples in for testing for chemical resistance

If you suspect that the applications of pesticides that you are applying to your crop are failing to suppress disease, the pathogen present on your farm may have chemical resistance. Currently a resistance testing project funded by HAL and Vegetable R&D levy being undertaken across Australia, assessing **Sclerotinia**, Botrytis, White blister, Downy mildew and bacterial pathogens for resistance to pesticides. If you are encountering spray failure you should have the pathogens tested to ensure you aren't wasting money applying chemicals which may not work as well as they normally do.

To have the pathogens present on your farm tested for resistance:

- Collect plants or parts of the plant showing the disease. It is important that the diseased plant isn't dead.
- Wrap the diseased plant tissue in slightly moist paper, and then wrap further in dry paper, then in a plastic bag. It is important not to wrap the diseased plant directly in plastic as it can cause the plant to "cook".
- It is important to collect the plant/plant parts on the day that you are going to send the sample in, and samples should not be sent on a Thurs/Friday.
- Samples should be sent preferably early in week eg. Monday or Tuesday to allow transit to their destinations prior to the weekend.
- Send the plant sample either by courier or by overnight post.
- Include with the sample information stating what plant cultivar is being used, what pesticides have been applied and any additional information e.g. more severe than in a regular season.

For Botrytis and **Sclerotinia** resistance testing samples should be sent to:

Barbara Hall
SARDI (South Australia Research & Development Institute)
Plant Research Centre
GPO Box 397, Adelaide, SA 5001
Ph: (08) 8303 9562
Email: hall.barbara@saugov.sa.gov.au`

Prior to sending please advise the above researchers by email or phone that samples are in transit

10. Other ICM considerations

Management Option	Recommendation
Scouting/thresholds	Record the occurrence and severity of Sclerotinia. No thresholds have been developed. Use history to make your decisions on paddock selection and spray timing.
Resistant varieties	No resistant varieties are available.
Crop rotation	Minimum of three year rotation with non-hosts such as grains is needed, if practical. Avoid double cropping with beans. Brassica crops could be considered as they are less likely compared with other crops to be Sclerotinia susceptible. Green manure crops as also a viable alternative. See Crop Disease Risk in table below.
Site selection Seed selection/treatment Post-harvest sanitation	Aim to select planting sites to minimise disease inoculum carryover especially for susceptible crops like green beans. No viable seed treatment available. Some post harvest options available.
Fungicide resistance	Overuse of fungicides from only one chemical group could lead to the development of resistance. Where possible rotate chemical groups. Monitor all fungicide application for effectiveness and make future fungicide selections based on previous performance.

Crop rotation disease risk - Sclerotinia	
Crop	**Risk**
Lettuce	High
Potatoes	High
Carrots	High
Celery	High
Peas	High/medium
Tomatoes	High/medium
Turf	Medium
Clovers	Medium
Brassicas eg. Broccoli	Medium/Low
Cereal crops	Low
Sweet corn	Low

Information on rotation risk has been provided to guide growers in their choice of rotation crops.

Avoid situations where highly susceptible crops eg. green beans or lettuce follow long periods of semi susceptible crops eg. potatoes.

11. Biological control agents and chemical biofungicides

Biofungicides and Biofumigant crops

Biological control includes any organism or extract from an organism of biological origins which exhibit biofumigant, biostimulant or biofungicidal activity on fungi. At present there are no biological control products that are registered in Australia for *Sclerotinia* spp. control, although there are some products sold under various guises that claim disease control.

Some biological control products are registered for *Sclerotinia* spp. control overseas.

Many different biological control agents and biofumigant crops have been trialled over many years in Australian conditions. A common observation from these trials is that the results are inconsistent from trial to trial and year to year.

It is the authors understanding that no manufacturer has presented appropriate efficacy data to APVMA to seek full registration for any biological control agents in vegetables.

12. Future directions

Additional fungicides may be registered for use or allowed by permit for Sclerotinia control in green beans in the future.

Biological fungicides may also be evaluated for efficacy under Australian conditions and gain registration or permit if viable

13. Summary Points

- *Sclerotinia* produces long lived sclerotes which can infest soil for many years. Reduction of the inoculum potential is a key to the long term control.
- Amistar and Filan are the only fungicides available and can be used under permit.
- The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.
- Other chemical fungicides and biofungicides are under review and may achieve registration or permit use in future.
- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.
- Correct application techniques are essential for the most efficient use of fungicides.
- The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.
- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.
- Careful consideration of crop rotation is also a powerful management tool.
- At present no biofungicides are registered in Australia for *Sclerotinia spp*. control, although there are some products sold under various guises that claim disease control.

14. References

1. Australian Pesticides and Veterinary Medicines Authority: www.apvma.gov.au

2. New York State Integrated Pest Management Program, Cornell University, New York, USA: www.nysipm.cornell.edu

3. Verbal communication . Ian Porter DPI Vic Knoxfield. Sept 2008.

4. Effects of application methods on the efficacy of chemical control of *Sclerotinia* disease on beans. H. Pung, R. O'Brien and S. Cross. Serve-Ag Research, PO Box 690, Devonport, 7310, Tasmania, Queensland Department of Primary Industries, Meiers Road, Indooroopilly, 4068, Queensland

5. CropLife Australia Ltd: www.croplifeaustralia.org.au

6. Diseases of vegetable crops. D. Persley DPI Qld 1994

15. Authors Information

(1) Peter Dal Santo B Agr Sc MAIAST AAAC CPAg
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Peter has been involved with Australian agricultural since 1983. Peter's experience has included sales, marketing, research and development roles with major agchem multinational companies and Executive Officer for Crop Protection Approvals, which managed data collation and minor-use permits for the vegetable industry. Since 2003, Peter has been the Director and Principle Scientist of AgAware Consulting P/L which is a project management consultancy. AgAware manages the HAL funded project, 'MT07029 - Managing pesticide access for horticulture' to accessing minor-use permit for horticulture as well as other HAL projects. In 2009, Peter received the 'Ausveg Industry Recognition Award' for servicies to the vegetable industry.

(2) Ross Holding B Agr Sc
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

Ross has worked in the Agchem industry since 1985. First as Technical Officer/Manager Research and Development with a major multinational company (1985-1996) and then as Product Manager with an Australian agchem manufacturer(1997). Since 1998 has worked independently as a contract agricultural consultant specialising in field efficacy and residue trials in both horticulture and broadacre.

Best Practice - Sclerotinia in lettuce

Introduction

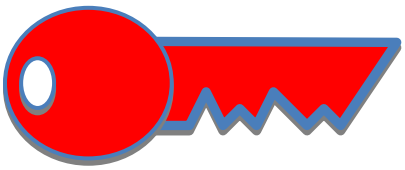
The following document incorporates information essential for economic and sustainable control of a specific disease in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VG07109.

This document is one of a series of documents intended to provide information on "best practice" control of diseases of vegetables. As a result it conforms to the strategy of Integrated Crop Management (ICM) where the "whole" crop is managed to achieve our aim of disease control. However, there is a bias in this document towards fungicide control options with other strategies blended in to the mix of disease control.

The following are the main principles of ICM used in this document for best practice:-

- To select from the available range of economically effective methods to manage plant pathogens below the threshold for disease
- To manage these methods to prolong their effectiveness as long as possible
- To use these methods to minimise adverse effects on users, environment and other crop management systems eg IPM for insect control

For each disease there is one or more key components which are integral for the management of the specific diseases - these will be called the "KEYS" and highlighted by:-



Sclerotinia in beans
(Photo courtesy of D. Wite Vic DPI)

Advice given in this strategy is current as at 30 Oct 2009.
Prepared and funded by:-

HAL Know-how for Horticulture™
AgAware Consulting Pty Ltd
Classy Solutions

Integrated Crop Management (ICM)

There is increasing attention on incorporating Integrated Crop Management (ICM) systems for vegetable production to control diseases and insect pests. ICM includes the principles of Integrated Pest Management (IPM) that relates specifically to the use of beneficial organisms for the control of various diseases, insect pests and weeds. This has been driven by the desire to manage pesticide use to:-

- minimize the impact of pesticide resistance developing
- satisfy the consumers' desire for minimum residue food
- reduce environmental impact
- limit possible restrictions in trade (domestic and export)

An ICM/IPM program needs to be developed for all the major crop-disease combinations included in this project. Traditional methods of disease management including crop hygiene, crop rotation and irrigation management remain important elements of ICM. Today a range of fungicides treatments are also available to assist in the management of crop diseases as are some disease resistant crops varieties.

Pesticide treatments vary in cost, efficacy, withholding period, re-entry period and environmental impact. It is accepted that knowledge in this area is incomplete and dynamic.

This document presents a summary of the IPM compatibility of the fungicides currently used in Australia to manage soilborne diseases caused by **Sclerotinia** as well as their pesticide residue and environmental profiles.

For further information on ICM and IPM research initiatives in the Australian vegetable industry can be found on the Ausveg website: www.ausveg.com.au.

Table of Contents

1. Disease background

Long term control of Sclerotinia is difficult in lettuce due to a number of factors including:

- A wide host range including bean, brassica, carrot, celery, lettuce, onion, pea, potato and tomato.
- The formation of long-lived sclerotia (up to 10 years) in the soil.
- The formation of mycelium in living or dead plants.
- With the correct conditions sclerotia produce a fruiting body or ascocarp which releases ascospores into the air.
- The aggressive nature of the infection process.
- The lack of resistant varieties.
- Reliance on fungicides for control.
- Lack of a wide range of alternate modes-of-action fungicides.
- Multiple cropping and poor rotation practices.
- Rotation with non-host crops (cereals) is difficult and at least 3 years is required.
- Control is required in lettuce from just after transplanting up to harvest. This is particularly important for follow-up crops as they can also be highly susceptible, eg. beans following lettuce in SE Qld.

Two species of *Sclerotinia* are important pathogens in Australia on lettuce crops:

1. ***Sclerotinia minor***
   Affects mainly lettuce and is more problematic in southern cooler districts.
   Sclerotinia minor attacks the outer leaves of lettuce that are in contact with the soil in addition to root hairs and plant crowns.
   Wilting of these leaves is the initial symptom.
   The infection moves inwardly until the entire plant wilts (Lettuce drop).
   Look for soft watery decay, white mycelium and black sclerotia the size of mustard seeds.
   Early prevention of infection by *Sclerotinia minor* at the base of the young lettuce plant is critical and depends on correct application techniques.

2. ***Sclerotinia sclerotiorum***
   Affects mainly beans, but also potatoes, brassicas and lettuce and is more common in northern warmer districts. In South Australia *Sclerotinia sclerotiorum* is more common than *Sclerotinia minor*).
   Sclerotinia sclerotiorum can also produce Lettuce drop symptoms and aerial phase can infect upper leaves and cause a head rot.
   Large black sclerotia, the size and shape of rat faece pellets, are probably *Sclerotinia sclerotiorum*.
   The aerial infection phase of *Sclerotinia sclerotiorum* is difficult to control because of additional factors such as:
   - Inability to accurately predict ascospore release.
   - Lack of knowledge about site factors that influence infection.
   - Difficulty in selecting the optimum timing for the first spray.
   - Spray efficacy (eg. droplet size).
   - Canopy leaf wetness and humidity (managed via row spacing/direction etc)

Sclerotinia produces long lived sclerotes which can infest soil for many years. Reduction of the inoculum potential is a key to the long term control of this disease. The use of long rotations (lettuce free), fumigants or biofungicides is essential prior to planting lettuce in soils with high levels of inoculum/sclerotes.
Dependence on Sclerotinia fungicides alone for disease control in high risk situations is not sustainable.

Photos showing characteristic ascocarps (left) and black sclerotes / white fluffy mycelium of *Sclerotinia sclerotiorum* (right). (Photo courtesy of D. Wite Vic DPI)

Lettuce drop of mature iceberg lettuce
(Photo courtesy of D. Wite Vic DPI)

2. Current registered product(s) for Sclerotinia control in lettuce

Fungicides (chemical)

Iprodione (various formulations and trade names)

- Group 2 dicarboximide fungicide with preventative and curative activity, but only works on contact. For Sclerotinia, need to use a seedling drench and foliar spray.
- Controls Sclerotinia Lettuce drop (*Sclerotinia minor)* and Sclerotinia rots *(S. sclerotiorum*).
- 7 day WHP.
- Can be used on all types of lettuce.
- According to growers/consultant reports, efficacy varies from state to state. Poor efficacy in some states eg Qld (7).
- Only registered fungicide for *Sclerotinia minor* and *Sclerotinia sclerotiorum*.
- Toxic to fish and bees.

Tebuconazole (430 g/L)

- Group 3 triazole (demethylation inhibitor) with systemic curative and protectant activity.
- Only registered for control of *Sclerotinia sclerotiorum* in lettuce.
- Campbell's 'Isis®', Farmoz 'Orius®' and Genfarm 'Blast®' registered in lettuce.
- Can be used on all types of lettuce (field grown only).
- Apply only during early stages of plant development - 35 day WHP.

Fumigants

The use of fumigants is not considered ICM/IPM "friendly" as they are total biocides. However, in salvage situations or where high levels of sclerotia have been monitored or anticipated, soil fumigation may be necessary as an initial control method. All fumigants provide varying degrees of pre plant soil fumigation for bacteria, diseases (soil borne), insects, nematodes and weed seeds.

Compound	Chemical group	Crop	Disease
chloropicrin eg. Chloropicrin	Group8A Fumigant - insecticide/fungicide	All crops	Sclerotinia + others
dazomet eg. Basamid	Fumigant - insecticide/fungicide	All crops	Sclerotinia + others
metham sodium eg. Metham	Group1A Fumigant - insecticide/fungicide	All crops	Sclerotinia + others

WARNING: Lettuce is extremely sensitive to fumigant residues and adequate plant back periods are required to prevent phytotoxicity.

IMPORTANT NOTICE
Before any fungicides are used via the above list, the label should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

3. Current fungicides used under permit for Sclerotinia control in lettuce

*** These permits are current as at 30th October 2009.**

Azoxystrobin (AMISTAR® - Group 11)

Permit Number	Description	Date Issued	Expiry Date
PER10261	Azoxystrobin: Brassica / White blister; Beans / Sclerotinia rot: Lettuce / Sclerotinia rot	3-Jan-08	1-Jan-10

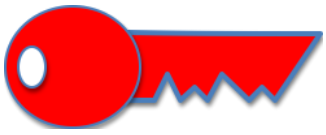
- Azoxystrobin (Amistar 250SC) is a member of the Quinone outside inhibitors (QoIs) activity group (Group 11)
- Has protectant and systemic fungicidal properties. But Amistar works best when used as a protectant for disease control.
- Reduced-risk fungicide.
- Efficacy has been questioned in high pressure lettuce/Sclerotinia situations in Australia.
- APVMA permit PER10261 - 1 day WHP.
- Maximum of 3 applications at 7 - 14 day intervals.
- Registered in tomatoes for Sclerotinia control.
- Registration under consideration.

Boscalid (FILAN® - Group 7)

Permit Number	Description	Date Issued	Expiry Date
PER8819	Boscalid / Brassica, Brassica Leafy Vegetables, Lettuce, Beans (green pods and immature seeds) / Sclerotinia rot	10-Oct-05	31-Jan-10

- Boscalid (Filan Fungicide) is a Group 7 oxanthiin fungicide
- Inhibits spore germination, mycelial growth and sporulation - preventative and curative.
- Reduced-risk fungicide.
- Backbone of green lettuce/Sclerotinia programs in Australia at present.
- Well favoured but some variability in performance under high disease pressure in some regions.
- APVMA permit PER8819 - 14 day WHP
- Permit to control Sclerotinia rot (*Sclerotinia minor & S. sclerotiorum*) on all types of lettuce.
- Maximum of 2 applications at 7 day intervals.
- Registration under consideration.

IMPORTANT NOTICE
Before any fungicides are used via the above list, the permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.



Iprodione, tebuconazole, Amistar® and **Filan®** are the only fungicides available for **Sclerotinia** control in lettuce. Careful use of these products is required to ensure their useable life.

4. Environmental profile of fungicides

The choice of fungicide should not be based on efficacy or price alone as other considerations need to be taken into account when employing an ICM/IPM based best management practice.

The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

EIQ assess each fungicide for:

- Applicator effects } Farm worker effects
- Picker effects } Farm worker effects
- Consumer effects
- Leaching
- Fish effects } Ecology effects
- Bird, bee & beneficials } Ecology effects

EIQ rates each of these factors and gives a rating that can be used to compare one pesticide with another for its environmental profile.

Further information on EIQ can be found on their web site - see reference (2).

The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.
The lower the EIQ rating the better the environmental profile.

The following table includes information for those products that could be considered for *Powdery mildew* control in vegetables. Some of the information can already be found on product labels (eg. chemical group, withholding period, re-entry period, etc).

Below are the explanations for terms used in the table.

1. WHP = withholding period for harvest
2. REP = re-entry period after spraying
3. EIQ = Environmental Impact Quotient. Rating system which provides a relative rating for pesticides active ingredients based on worker consumer and environmental effects. The lower the rating indicates a better environmental profile.
4. EIQ field rating = EIQ x product formulation concentration x application rate (kg or L/ha). A lower rating indicates a better environmental profile.
5. Effect on beneficials - Individual component of EIQ.
6. NIFWR = no information further work required

EIQ for registered and permitted products in lettuce

Product	Chemical Group	WHP[1] (days)	REP [2] (hours)	EIQ [3]	EIQ Field rating [4] (per app)	Effect on Beneficials [5] (IPM fit)	Comments
azoxystrobin eg. Amistar	11	1 (beans)	> Spray dried	15.2	5	3	Permit - brassica, lettuce, beans.
boscalid eg. Filan	7	14	after spray dried	44	22	31	Permit - brassicas, brassica leafy vegetables, lettuce, beans.
iprodione eg. Rovral	2	7	after spray dried	11	5	3	Only product registered for Lettuce drop (*Sclerotinia minor)* and Sclerotinia rots *(S. sclerotiorum*).
tebuconazole eg. Folicur	3	35	after spray dried	40	6	4	Some products registered. Permit only for other products.
chloropicrin eg. Chloropicrin	8A	N/A	Consult label	>100	>20000	300	No IPM fit
dazomet eg. Basamid	1A	N/A	48	>100	>20000	300	No IPM fit
metham sodium eg. Metham	1A	N/A	48	>100	>20000	300	No IPM fit

(See page 8 for explanations of terms used in this table)

5. Impact of fungicides on beneficial insects and mites - Australian data

Research work funded by HAL and the Vegetable R&D levy into the effects of pesticides on beneficial insects and mites in vegetables in Australia has been ongoing for 3 years. The following table summarises results of relevant *fungicides*.

These results show the short term (or acute) effects using adults. Potential long term effects such as impact on reproduction are not shown as they were not conducted. However, it is hoped that with further funding this aspect may be evaluated.

Product	**Beneficial insect or mite and their target pest**				
Fungicide **Active ingredient**	**Brown lacewing** (Aphids)	**Transverse ladybird** (Aphid)	**Common spotted ladybird** (Aphid)	**Damsel Bug** (Caterpillars)	**Trichogramma wasp parasitoid** (Caterpillars)
azoxystrobin (Amistar)					
boscalid (Filan)					

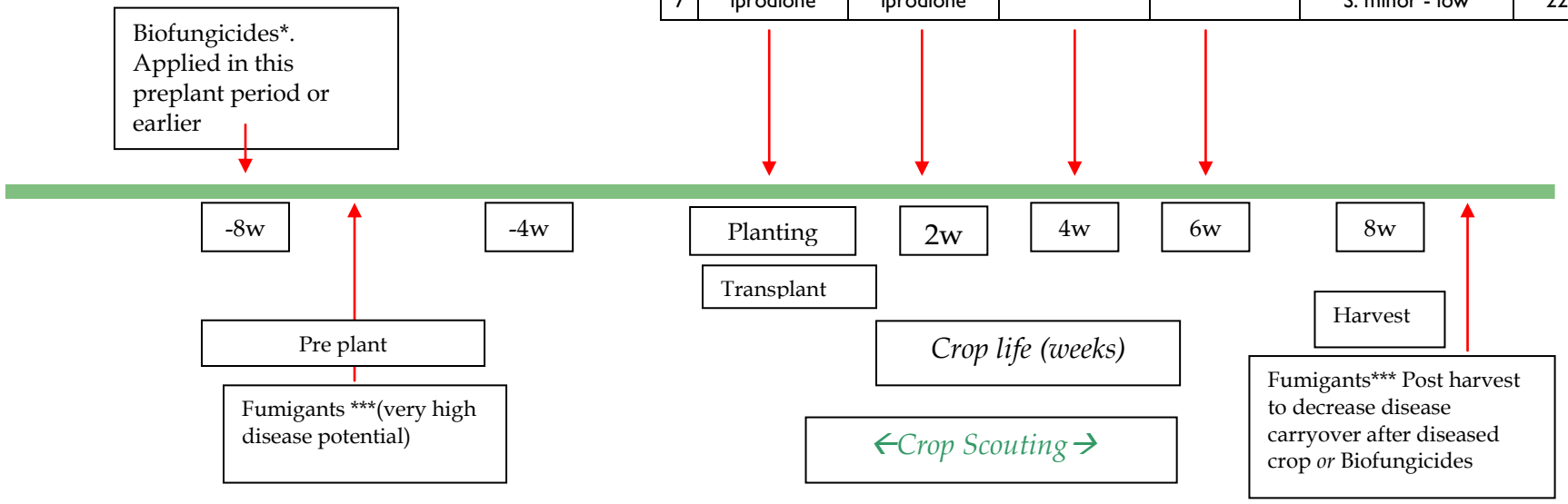
	= Harmless- less than 30% acute mortality
	= Mod harmful. 30->70% acute mortality
	= Harmful: greater than 70 %mortality

This work was performed by IPM Technologies Pty Ltd and the Department of Primary Industries (Vic). Funding by Horticulture Australia Ltd (HAL) and the Australian Vegetable Research and Development Levy, Project VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

6. Disease control programs example incorporating ICM options

Examples of possible fungicide programs

	1st application	2nd application	3rd application	4th application	Disease potential	EIQ**
1	Filan	Filan	iprodione	iprodione	S. sclerotiorum - high	66
2	tebuconazole	tebuconazole	iprodione	iprodione	S. sclerotiorum - high	34
3	iprodione	iprodione	iprodione	iprodione	S. sclerotiorum - high/medium	44
4			iprodione	iprodione	S. sclerotiorum - medium/low	22
5	Filan	Filan			S. minor - high/medium	44
6	tebuconazole	tebuconazole			S. minor - high/medium	12
7	iprodione	iprodione			S. minor - low	22



* compatible with foliar program
** EIQ rating for program
*** not compatible with Biofungicide

7. Product application rates and other information

Fungicides presently registered or used under permit

Product Name (active)	Concentration	Group	Application Rate (per ha)	Max no. of apps per crop	Spray interval (days)	Withholding Period (days)
AMISTAR (azoxystrobin)	250 g/L	11	500-600 mL/ha or 50-60 mL/100L	3	7-14	14
FILAN (boscalid)	500 g/kg	7	800-1000 g/ha	2	14	14
ROVRAL (& others) (iprodione)	500 g/L	2	1.0 L/ha	4	10	7
ISIS (& others) (tebuconazole)	430 g/L	3	350 mL/ha	2	10	35

IMPORTANT NOTICE

Before any fungicides are used via the above list, the label or permit should be thoroughly read to determine if the use and situation is appropriate to your needs. The latest information of current permits is available on the APVMA website: www.apvma.gov.au.

8. Application of fungicides

Sclerotinia minor

Ensure early fungicide applications

1. Apply as a seedling drench soon after transplanting or seed emergence.
2. If conditions favour Sclerotinia development or disease pressure is expected to be moderate/high, apply another application 2 weeks after transplant/emergence.
3. Use a high volume system (minimum of 1000 L/ha) or alternatively as a directed drench to base of transplants.

It is essential that the early fungicide applications for *Sclerotinia minor* are used at high water volume which enables the fungicide to be effectively "washed/distributed" into the root zone and base of plant

Sclerotinia sclerotiorum

Choose appropriate application indices (spray intervals, droplet size, volume etc) and technique to ensure adequate coverage to prevent ascospore infection. These are sometimes outlined in fungicide label directions. Use of adjuvants with fungicides may also be required.

Follow label directions for application intervals, droplet size, volume, etc.

In areas that are prone to Sclerotinia, the timing of the first application is likely to be the most important factor in determining the level of disease control.

See 10 regarding strategies to minimise fungicide resistance.

Spraying of crops.
(Photo courtesy of R. Holding)

Fumigant application

Fumigants should only be considered in very high disease risk situations when all other control measures have been considered first. Fumigants are not compatible with IPM systems.

Careful attention is required prior to and after fumigant application eg. Metham sodium. Significant seedbed preparation and time is needed prior to application and appropriate safe withholding periods need to be observed after application.

As an example the following are directions taken from a Metham sodium label:-

Soil should be carefully prepared in advance according to the directions for use.
Cultivate the area thoroughly and break up clods.
Loosen soil deeply one week in advance of application.
Soil should be kept moist until application, and if soil has not crusted in the meantime, re-cultivate lightly.
Soil temperature should be in the range 10-32°C to depth of 8cm.
Where fumes become unpleasant spray with water to seal fumes in.
Planting may take place 14-21 days after application if soil is light-medium texture and not excessively wet or cold.
A minimum interval of 30 days is necessary where soil texture is heavy, high in organic matter, wet or soil temperature is less than 15°C.
A 60 day interval is required if application rate is greater than 1100L/ha.
Sow an indicator crop to test that no toxic METHAM remains in the soil, approximately 7 days before main crop.
Lettuce or radish is suitable for this purpose because of their rapid germination process. Check for root damage which will indicate whether or not soil is still toxic.

Consult respective product labels for full application details.

9. Fungicide Resistance

The appropriate use of fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.

Never use more than the recommended maximum number of applications per crop and where possible rotate to a fungicide with a different mode of action /activity group. Also, never use rates less than recommended by the label.

Always use fungicides according to the label directions:

- If the fungicide is to be used preventatively, then apply prior to the onset of main disease infection period.
- If the fungicide is to be used curatively, then apply as soon as possible after the onset of main disease infection period.
- Never use fungicides after infection has fully established and is visible.

Crop Life Australia (5) (formerly AVCARE) implement Fungicide Resistance Management Strategies for various crops and diseases in Australia. To date, no FRMS has been formulated for *Sclerotinia* diseases in Australia.

There have been reported losses of effectiveness of some fungicides in vegetable crops. In many situations it was found that poor commercial results may have been due to poor application by growers or poor application timing rather than fungicide resistance/tolerance.

Fungicide testing from other crops has shown that some strains of *Sclerotinia* are resistant to some fungicides from different activity groups. If using fungicides monitor the results to check for effectiveness and if results are not as expected contact your local DPI, agchem manufacturer or retailer to investigate further.

HAL Project VG07119 – Identification and monitoring of resistance in vegetable crops in Australia', (Barbara Hall, SARDI and Leanne Forsyth, NSWDPI) is investigating fungicide resistance by testing diseased samples collected in the field.

From initial testing in VG07119 it was found that:

- **of the 45 samples of *Sclerotinia sclerotiorum* received from Vic, SA, WA, NSW, Qld and Tas, 2 from NSW and 2 from Victoria were resistant to benzimidazoles (carbendazim, thiabendazole), 6 others showed reduced sensitivity and 5 were resistance to dicarboximides (iprodione, procymidone).**
- **of the 21 samples of *Sclerotinia minor* from lettuce tested, that 13 were resistant to benzimidazoles (carbendazim, thiabendazole) and 3 of these were also resistant to dicarboximides (iprodione, procymidone).**

Further testing is underway.

Sending diseased plant samples in for testing for chemical resistance

If you suspect that the applications of pesticides that you are applying to your crop are failing to suppress disease, the pathogen present on your farm may have chemical resistance. Currently a resistance testing project funded by HAL and Vegetable R&D levy being undertaken across Australia, assessing **Sclerotinia**, Botrytis, White blister, Downy mildew and bacterial pathogens for resistance to pesticides. If you are encountering spray failure you should have the pathogens tested to ensure you aren't wasting money applying chemicals which may not work as well as they normally do.

To have the pathogens present on your farm tested for resistance:

- Collect plants or parts of the plant showing the disease. It is important that the diseased plant isn't dead.
- Wrap the diseased plant tissue in slightly moist paper, and then wrap further in dry paper, then in a plastic bag. It is important not to wrap the diseased plant directly in plastic as it can cause the plant to "cook".
- It is important to collect the plant/plant parts on the day that you are going to send the sample in, and samples should not be sent on a Thurs/Friday.
- Samples should be sent preferably early in week eg. Monday or Tuesday to allow transit to their destinations prior to the weekend.
- Send the plant sample either by courier or by overnight post.
- Include with the sample information stating what plant cultivar is being used, what pesticides have been applied and any additional information e.g. more severe than in a regular season.

For Botrytis and **Sclerotinia** resistance testing samples should be sent to:

Barbara Hall
SARDI (South Australia Research & Development Institute)
Plant Research Centre
GPO Box 397, Adelaide, SA 5001
Ph: (08) 8303 9562
Email: hall.barbara@saugov.sa.gov.au`

Prior to sending please advise the above researchers by email or phone that samples are in transit

10. Other ICM consideration

Management Option	Recommendation
Scouting/thresholds	Record the occurrence and severity of Sclerotinia. No thresholds have been developed. Use history to make your decisions on paddock selection and spray timing.
Resistant varieties	No resistant varieties are available.
Crop rotation	Minimum of three year rotation with non-hosts such as grains is needed, if practical. Avoid double cropping with lettuce. Brassica crops could be considered as they are less likely compared with other crops to be Sclerotinia susceptible. Green manure crops as also a viable alternative. See Crop Disease Risk in table below.
Site selection Seed selection/treatment Post-harvest sanitation	Aim to select planting sites to minimise disease inoculum carryover especially for susceptible crops like green beans. No viable seed treatment available. Some post harvest options available.
Fungicide resistance	Overuse of fungicides from only one chemical group could lead to the development of resistance. Where possible rotate chemical groups. Monitor all fungicide application for effectiveness and make future fungicide selections based on previous performance.

Crop rotation disease risk - Sclerotinia	
Crop	**Risk**
Beans	High
Potatoes	High
Onion	High
Carrots	High
Celery	High
Peas	High/medium
Tomatoes	High/medium
Turf	Medium
Clovers	Medium
Brassicas eg. Broccoli	Medium/Low
Cereal crops	Low
Sweet corn	Low

Information on rotation risk has been provided to guide growers in their choice of rotation crops. Avoid situations where highly susceptible crops eg. lettuce or green beans follow long periods of semi susceptible crops eg. potatoes.

11. Biological control agents and chemical biofungicides

Biofungicides and Biofumigant crops

Biological control includes any organism or extract from an organism of biological origins which exhibit biofumigant, biostimulant or biofungicidal activity on fungi. At present there are no biological control products that are registered in Australia for *Sclerotinia* spp. control, although there are some products sold under various guises that claim disease control.

Some biological control products are registered for *Sclerotinia* spp. control overseas.

Many different biological control agents and biofumigant crops have been trialled over many years in Australian conditions. A common observation from these trials is that the results are inconsistent from trial to trial and year to year.

It is the authors understanding that no manufacturer has presented appropriate efficacy data to APVMA to seek full registration for any biological control agents in vegetables.

12. Future directions

Additional fungicides may be registered for use or allowed by permit for Sclerotinia control in lettuce in the future.

Biological fungicides may also be evaluated for efficacy under Australian conditions and gain registration or permit if viable

13. Summary Points

- *Sclerotinia* produces long lived sclerotes which can infest soil for many years. Reduction of the inoculum potential is a key to the long term control.
- Iprodione and tebuconazole are the only currently registered fungicide for Sclerotinia control in lettuce. Amistar and Filan can be used under permit.
- The appropriate use of chemical fungicides will prolong their useable life and reduce the potential for fungicide resistance to occur.
- Other chemical fungicides and biofungicides are under review and may achieve registration or permit use in future.
- The EIQ system can be used as a guide by growers wishing to minimise effects on beneficial insects, workers, consumers, the environment and other crop management systems.
- Correct application techniques are essential for the most efficient use of chemical fungicides.
- Integrated Crop Management (ICM) - the effective control of disease requires the use of all management options. This includes site selection, crop varieties, crop timing, biological options, monitoring and rouging. Only when all these options have been employed should fungicide be considered to: control / prevent / decrease / delay disease infection.
- Careful consideration of crop rotation is also a powerful management tool.
- At present no biofungicides are registered in Australia for *Sclerotinia spp*. control, although there are some products sold under various guises that claim disease control.

14. References

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15. Authors Information

(1) Peter Dal Santo B Agr Sc MAIAST AAAC CPAg
AgAware Consulting Pty Ltd
21 Rosella Avenue
Strathfieldsaye VICTORIA 3551
Email: pds@agaware.com.au
Web: www. agaware.com.au
Ph: 03 5439 5916 Fax: 03 5439 3391 Mob: 0407 393 397

Peter has been involved with Australian agricultural since 1983. Peter's experience has included sales, marketing, research and development roles with major agchem multinational companies and Executive Officer for Crop Protection Approvals, which managed data collation and minor-use permits for the vegetable industry. Since 2003, Peter has been the Director and Principle Scientist of AgAware Consulting P/L which is a project management consultancy. AgAware manages the HAL funded project, 'MT07029 - Managing pesticide access for horticulture' to accessing minor-use permit for horticulture as well as other HAL projects. In 2009, Peter received the 'Ausveg Industry Recognition Award' for servicies to the vegetable industry.

(2) Ross Holding B Agr Sc
Classy Solutions
RSD B 812
Cardigan Vic 3352
Email- classysolutions@a1.com.au
Web- www.classysolutions.com.au
Mob: 0438 443978 Fax 03 5344 8313

Ross has worked in the Agchem industry since 1985. First as Technical Officer/Manager Research and Development with a major multinational company (1985-1996) and then as Product Manager with an Australian agchem manufacturer(1997). Since 1998 has worked independently as a contract agricultural consultant specialising in field efficacy and residue trials in both horticulture and broadacre.