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

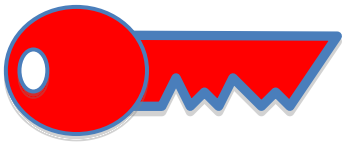
A theme that will be discussed throughout the documents is:

- 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:-



Advice given in this strategy is current as at 30 Oct 2009.
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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.

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Best Practice – Downy mildew in vegetables

Introduction

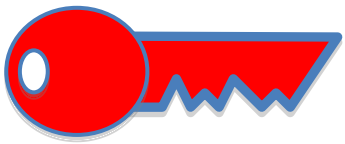
The following document incorporates information essential for economic and sustainable control of a specific disease in Australian vegetables. It has been conducted under the Horticulture Australia Ltd project: VGO07109.

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)

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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.

(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.

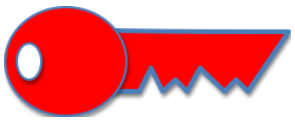
The Cornell University, New York, USA (2) have developed a system that assesses the environmental profile of many pesticides. The Environmental Impact Quotient (EIQ) system is incorporated in their New York State Integrated Pest Management Program.

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

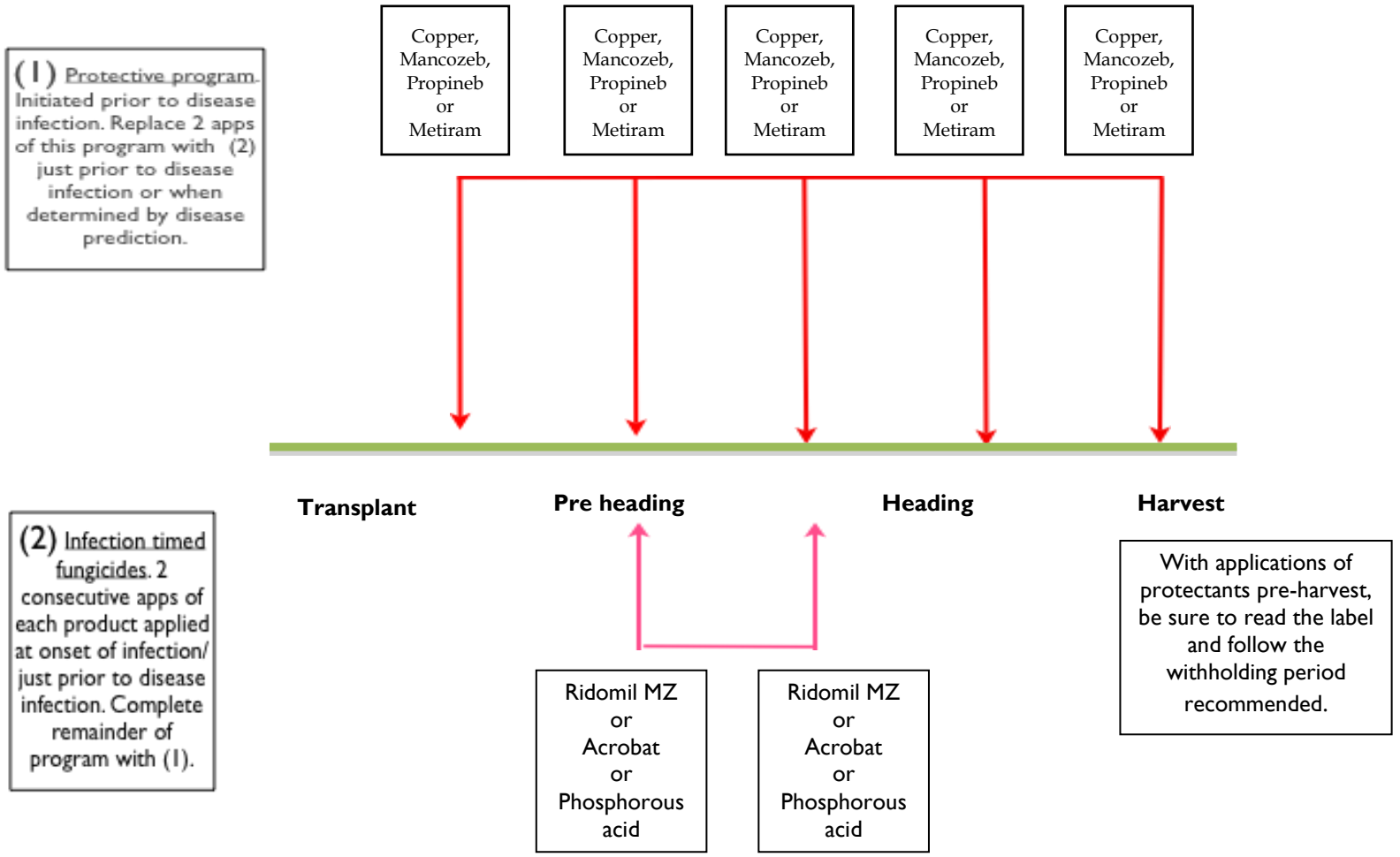
This work was performed by IPM Technologies Pty Ltd and the Department of Primary Industries (Vic). Funding by Horticulture Australia Ltd (HAL) and the Australian Vegetable Grower's Research and Development Levy (AUSVEG), Project VG06087 'Pesticide effects on beneficial insects and mites in vegetables.'

5. Product application rates and other information

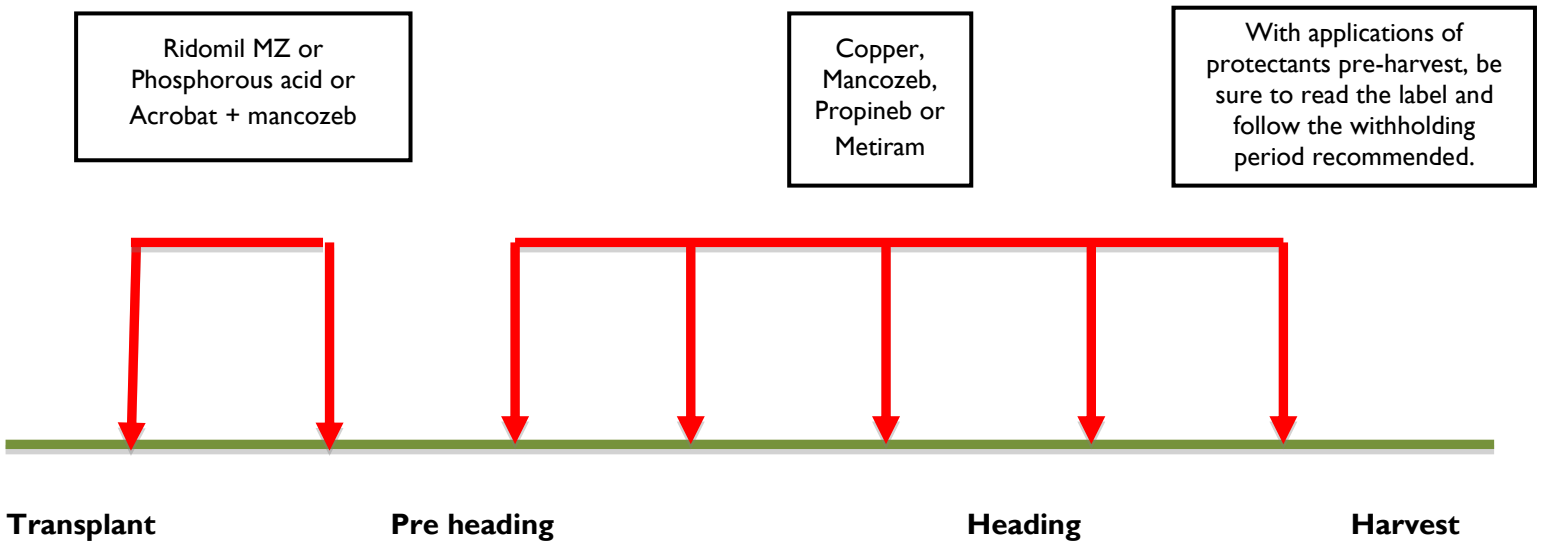
Fungicides presently registered or used under permit.

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

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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/

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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.

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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.

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