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

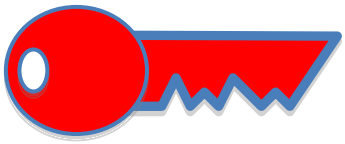
A theme that will be discussed throughout the documents is:

- 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.
Prepared and funded 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.

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

AgAware Consulting Pty Ltd

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)

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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.

<u>Vascular Wilts</u>

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.

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Prepared and funded by:-

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