Carrots

Strategic Agrichemical Review Process 2011-2014

HAL Projects - MT10029 & VG12081

AgAware Consulting Pty Ltd
Checkbox 3D Pty Ltd

February 2014

Horticulture Australia project no:
MT10029 – Managing pesticide access in horticulture.
VG12081 - Review of vegetable SARP reports.

Contact:
Noelene Davis
Checkbox 3D Pty Ltd
PO Box 187 Beecroft NSW 2119
Ph: 0424 625 267 Email: ndavis@checkbox3d.com.au

Purpose of the report:
This report was funded by Horticulture Australia and the Australian vegetable industry to investigate the pest problem, agrichemical usage and pest management alternatives for the carrot industry across Australia. The information in this report will assist the carrot industry with its agrichemical selection and usage into the future.

Funding sources:
MT10029 - This project has been funded by HAL using the vegetable industry levy and across industry funds with matched funds from the Australian Government.
VG12081 - This project has been funded by HAL using the vegetable industry levy and matched funds from the Australian Government.

Date of report:
5 February 2014

Horticulture Australia

Contents

1. Media summary

A Strategic Agrichemical Review Process (SARP) through the process of a desktop audit and industry liaison assesses the importance of the diseases, insects and weeds (plant pests) that can affect a horticultural industry; evaluates the availability and effectiveness of fungicides, insecticides and herbicides (pesticides) to control the plant pests; determines any 'gaps' in the pest control strategy and identifies suitable new or alternatives pesticides to address the 'gaps'.

Alternative pesticides should ideally be selected for benefits of:

- Integrated pest management (IPM) compatibility
- Improved scope for resistance management
- Sound biological profile
- Residue and trade acceptance domestically and for export

SARP workshops for Carrots were conducted in Victoria, New South Wales and Western Australia as part of combined vegetable meetings in 2008, 2010 and 2011. The results of the process provide the Carrot industry with pesticide options for the future that the industry can pursue for registration with the manufacturer, or minor-use permits with the Australian Pesticides and Veterinary Medicines Association (APVMA).

DISEASES

Diseases identified as high priorities:

Disease (common name)	Disease (scientific name)
Powdery mildew	*Erysiphe heraclei*
Sclerotinia rot	*Sclerotinia sclerotiorum, Sclerotinia minor*

Registrations for control of diseases in Carrot are primarily for old chemistry. Growers want additional, "safer" options and more choice to reduce risk of resistance. Non-chemical options are a consideration, with basic crop rotation a common practice to reduce disease carryover.

INSECTS

Insects identified as priorities:

Insect (common name)	Insect (scientific name)
Aphids including: Carrot aphid	*Cavariella aegopodii*
Rutherglen bug	*Nysius vinitor*
Thrips	*Thysanoptera*

As a generalisation there is a desire for different chemistry to be used for alternation and growers seek solutions that will fit with IPM programs. In the case of aphids and Rutherglen buts, weed management in an important strategy to reduce the source of pest populations.

There is some new chemistry recently registered or with potential to be registered in the coming years. Growers are mindful that this chemistry will need to be carefully managed to reduce resistance threats. It would be most helpful for management of the chemicals if use patterns could be developed in conjunction with registrants, rather than relying on grower-driven permits.

NEMATODES

Nematode identified as priorities:

Nematode (common name)	Nematode (scientific name)
Root-Knot Nematodes	*Meloidogune* spp.

The vegetable industry heavily relies on various soil fumigants for control of nematodes and other pests and disease. Problems with the prolonged use of these are now being seen, ie resistance and reduced efficacy of chemicals such as Nemacur and Metham Sodium.

Although the chemistry is old growers are concerned that there may not be adequate replacements if these are removed from the market

WEEDS

Weeds identified as high priorities:

Weed (common name)	**Weed (scientific name)**
Resistant ryegrass (predominantly Group A)	*Lolium rigidum*

Overall there is a need for newer chemistry and increased options for control of weeds in Carrot.

2. The Australian Carrot industry

The Australian carrot industry is a mature, innovative, resourceful and dynamic vegetable industry with a constant consumer demand for their product. The carrot industry is a major horticultural industry, ranking as the in terms of production and the 5th largest in terms of value of production (Ausveg website, 2014).

Carrots production is concentrated in three states, WA (31%), SA (17%), Tasmania (23%) with the remainder in Victoria, QLD and NSW (2009 figures, Ausveg website, 2014) The main carrot growing regions are (ABS 2003):

- Manjimup (WA)
- Gin Gin (WA)
- Perth Metro (WA)
- Adelaide Plains (SA)
- Riverland (SA)
- Devonport (Tas)
- Robinvale (Vic)
- Melbourne (Vic)
- Darling Downs (QLD)
- Fassifern Valley regions (QLD)
- Riverina (NSW)
- Central Coast (NSW)

The area planted to carrots in 2008/09 was 5,174 ha with 253,527 tonnes produced and an average yield of 50.9 t. These levels were down on the maximum production levels and areas planted, reached in 2001-02. Yields are below the record highs of 2007 and 2008 but overall productivity gains leading to higher yields have offset reduced plantings. (Ausveg website, 2014)

The Australian market comprises both fresh and processed (predominantly frozen) segments, with a wide number of varieties grown. The major growing period is from March to August but carrots are available throughout the year. (Ausveg website, 2014)

Although South East Asian competition is intense, Australian carrot growers are internationally competitive due to scale and productivity. Fresh produce is exported to Asia (Singapore, Malaysia, and Japan) and the Middle East, with volumes rising by 20% in 2009 to $46 million. (Ausveg website, 2014)

3. Introduction

3.1. Background

Growers of some horticultural crops suffer from a lack of legal access to crop protection products (pesticides). The problem may be that whilst a relatively small crop area is valuable in an agricultural sense, it is not of sufficient size for agchem manufacturers to justify the expense of registering a product use on that crop. Alternately, the disease, pest, or weed problem may be regional or spasmodic, making agchem companies unwilling to bear the initial high cost of registering suitable pesticides. As an added complication some horticultural crops may be grown in protected cropping or hydroponic situations. These can have a significant impact on pesticide performance and residue outcomes, further increasing product development requirements and registration costs.

Growers may at times be in a situation where they face severe losses from diseases, pests and weeds if they do nothing to protect their crops, or face penalties if they use a product that is not registered or available via a permit. The carrot industry is very aware of the possible consequences of the use of unregistered or non-permitted pesticides. These can include: produce with unauthorised pesticide residues; rejection at both local and export market levels; placing Australian export trading arrangements in jeopardy, and; fines and penalties.

Environmental concerns, consumer demands, and public opinion are also significant influences in the marketplace related to pest management practices. Industry/IPM Practitioners must strive to implement best management practices and tools to incorporate a pest management regime where strategies work in harmony with each other to achieve the desired effects while posing the least risks.

Pesticides have always been an important tool in the production of carrot. They control the various diseases, insects and weeds that affect the crop and can cause severe economic loss in modern high intensity growing operations. Pesticides are utilized in seedling production, pre-plant, during plant establishment, through crop development and into crop maturity to maximise crop yield, quality and customer appeal.

From a pesticide access perspective, the APVMA classifies carrot as a major crop. The crop fits within the APVMA crop group 016: Root and Tuber Vegetables.

As a consequence of the issues facing the carrot industry regarding pesticide access, Horticulture Australia Ltd and the vegetable industry undertook a review of the pesticide requirements in carrots via a Strategic Agrichemical Review Process (SARP). See Appendix 1 – the Strategic Agrichemical Review Process. The aim was to determine solutions (primarily pesticide) to current and future pest threats.

This SARP process identified diseases, insect pests and weeds of major concern to the carrot industry. Against these threats available registered or permitted pesticides, along with non-pesticide solutions, were evaluated for overall suitability in terms of IPM, resistance, residues, withholding period, efficacy, trade, human safety and environmental issues. Where tools were unavailable or unsuitable the process aimed to identify potential future solutions.

This report is not a comprehensive assessment of all pests and control methods impacting on carrot production in Australia but attempts to prioritise the major problems.

3.2. Minor use permits and registration

Carrots are classified as a major crop by the APVMA. Therefore access to minor use permits can be difficult, and will only be granted for limited uses within the crop. Possible justification for future permit applications could be based on:

- New disease, insect or weed identified as a cropping issue
- No pesticide available
- Current pesticides no longer work – resistance
- Current pesticides limiting trade
- IPM, environmental or operator issues
- Loss of pesticides due to removal from market
- New, effective pesticide registered in another crop
- Alternate pesticide has overseas registration or minor use permit

With each of these options, sound, scientific argument is required to justify any new registrations or permit applications.

Another option for the carrot industry is for manufacturers to register new pesticides uses in the crop.

3.3. Methods

The SARP was conducted in Victoria, New South Wales and Western Australia as part of combined vegetable meetings in 2008, 2010 and 2011. The meeting included leading growers, consultants, government agencies, agchem companies and agricultural reseller staff.

- Participants were given a comprehensive list of most major pests of carrots and asked to prioritise them into high, moderate and low categories.
- Participants were then asked to list the main pesticides and or other control agents used for each pest.
- Mostly pesticide trade names were used and the list provided was certainly not comprehensive but a starting point for further assessment.
- Pesticides that are under review by the Australian Pesticides and Veterinary Medicines Authority (AVPMA) were listed.
- Information was collated onto Excel spreadsheets for diseases, insects and weeds.
- The information was circulated to participants for any further comments to ensure the accuracy of the information.
- Each alternative pesticide was assessed for:
    - IPM compatibility
    - Improved scope for resistance management
    - Sound biological profile
    - Residue and trade acceptance domestically and for export

Final selections of proposed new pesticides for the carrot industry to pursue were listed.

3.4. Results and discussions

Results and discussions are presented in the body of this document.

4. Pests and diseases of carrot

4.1. Diseases of carrot

Common name	Scientific name
HIGH PRIORITY	
Powdery mildew	*Erysiphe heraclei*
Sclerotinia rot	*Sclerotinia sclerotiorum, Sclerotinia minor*
MODERATE PRIORITY	
Soft rot	*Unidentified species*
LOW PRIORITY	
Alternaria leaf spot	*Alternaria dauci*
Black rot	*Alternaria radicina*
Cavity spot	*Pythium sulcatium ,Pythium violae*
Damping off	*Pythium* spp.
Leaf spot	*Cercospora carotae*
Biosecurity risk	
Violet root rot (NZ)	*Rhizoctonia crocorum*
Rhizoctonia root rot (NZ)	*Rhizoctonia solani*
Crater rot	*Rhizoctonia carotae*
Aster yellows	*Acholeplasmataceae*
Liquorice rot	*Myconcentrospora. acerina*

4.1.1. High priority diseases

Powdery mildew (*Erysiphe heraclei*)

Powdery mildew of carrots affects the foliage, stems, and umbels.

Patches of the white felt-like fungus appear on 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 pedicels may turn brown, resulting in the florets' premature death.

- Powdery mildew is considered a high-medium priority in all states.
  - New disease, only found in pockets in NSW, SA and Tas.
  - NSW DPI research project investigated the disease - epidemiology, control, seed, soil.
  - It was seen as a potential threat to the industry, but now various control options are available.

- Fungicides **registered** for the control of Powdery mildew in carrots are:
  - Azoxystrobin + difenoconazole (AMISTAR^ TOP) – Group 11 + 3 fungicide.
    - Protective and curative fungicide.
    - Recently registered.
    - Previously azoxystrobin was available via a permit (PER10197, 10914 & 11480)
    - Only used as needed.
    - Commonly used by growers, considered very effective.
    - Growers expressed concern with resistance developing from overuse and heavy reliance.

- Fungicides listed for control of powdery mildew control in carrots via **permits** are:
  - Tebuconazole (various registered products, PER13091) – Group 3 fungicide.
    - Protective and curative fungicide.
    - Only used as needed.
    - Used in alternation with Amistar Top and copper / mancozeb (protectants).
    - Commonly used by growers, considered very effective.
    - Permit expires 31-Mar-16. No manufacturers interested in registering use.
    - Grower concern with the development of resistance resulting from overuse and reliance.

- **Potential** fungicides for control of powdery mildew control in carrots:
  - Cyflufenamid (FLUTE^) – Group U6 fungicide.
    - Registered for control of powdery mildew in grapevines and cucurbits
    - First registration in 2013.
    - Agnova could be approached with regard to potential inclusion in future development programs
    - Care should be exercised with regard to broad registration and potential overuse across vegetable crops and associated resistance threats

Sclerotinia rot (*Sclerotinia sclerotiorum, Sclerotinia minor*)

Sclerotinia infection may occur at any stage of growth, and extensive root decay may occur before symptoms of wilt and collapse appear on the upper part of the plant.

Infection is always accompanied by a characteristic cottony, white mycelium that appears on the surface of the infected tissues. On or inside the white mycelium appear black, round-to-irregular-shaped structures (sclerotia), which are about 1-3mm wide. Sclerotia are survival structures of the fungus.

Sclerotinia rot is usually soft and watery.

- Sclerotinia rot is considered a high priority in all states.
    - Procymidone (no longer registered or permitted) was the only registered product for control of Sclerotinia rot in carrots. This was considered highly effective by growers.
    - Major disease problem in Qld (QLD PMS 2008).
    - Problematic across most vegetable crops in Tasmania. Current rotations probably contributing to problem. A few management options, but an integrated management strategy is needed. Micro-formulated gypsum may be a useful spray additive for Sclerotinia management (Tas).
    - Prevention: good weed control as many other plants act as hosts and good storage conditions.

- No fungicides are **registered** for the control of Sclerotinia rot in carrots.

- Fungicides listed for control of Sclerotinia rot in carrots via **permits** are:
    - Azoxystrobin (various, PER10914) – Group 11 fungicide
        - Protective and curative fungicide.
        - Generally applied soon after emergence through to root development close to completed.
        - Commonly used.
        - Considered very effective.
        - Concerns with possible resistance due to overuse and limited options.
    - Boscalid (various) - PER12050 – Group 7 protectant/curative fungicide
        - Protective and curative fungicide.
        - Generally applied soon after emergence to root development close to completed.
        - Commonly used by all growers.
        - Considered very effective but expensive.
        - Grower concern with the development of resistance in Sclerotinia resulting from overuse of boscalid and limited options.

- **Potential** fungicide for control of Sclerotinia rot:
    - Penthiopyrad (FONTELIS) Group 7 - Dupont could be approached with regard to development of this use. There are overseas registrations and an Australian label extension could be simple.

    - Cyprodinil + fludioxonil (SWITCH) - Group 9 +12 protective and systemic fungicide
        - Australian registrations for Sclerotinia and other diseases in various crops
        - IR4 project for carrot / Alternaria, Cercospora – collaboration a possibility

4.1.2. Biosecurity risk diseases

Crater rot (*Rhizoctonia carotae*)

- Initiates in the field but major damage in storage with cool temperatures favouring growth.
    - Australia currently free of the disease but it is a potential biosecurity theat. The disease has been reported from the USA, Denmark, Norway, Sweden, Russia, UK and recently from Turkey

- Symptoms become visible as white cottony mycelial growth on the carrot surface during storage.
- Cultural practices and fungicide spraying important in management. Damage during harvest, allowing soil and leaf debris to remain on roots should be avoided. Good hygiene of bins and stores is required

(DEEDI, 2012)

4.1.3 Summary

High Priority Diseases and control options.

Registrations for control of diseases in Carrot are primarily for old chemistry. Growers want additional, "safer" options and more choice to reduce risk of resistance. Non-chemical options are a consideration, with basic crop rotation a common practice to reduce disease carryover.

Disease	Control option
Powdery mildew (*Erysiphe heraclei*)	**Registered fungicides** Azoxystrobin + difenoconazole (AMISTAR^ TOP, Group 11+3), efficacious, carefully managed to keep resistance at bay **Permitted fungicides** Tebuconazole (various, registereded products, PER13091, Group 3) –alternated with Amistar Top. **Fungicide Gaps** Additional options for alternation to reduce risk of resistance **Potential fungicide solutions** Cyflufenamid (FLUTE^) – Group U6 fungicide **Non-chemical options** IPM practices
Sclerotinia rot (*Sclerotinia sclerotiorum, Sclerotinia minor)*	**Currently registered fungicides** None **Currently permitted fungicides** Azoxystrobin (various, PER10914, Group 11) - common use, resistance concerns. Boscalid (various, PER12050, Group 7) – common use, resistance concerns. **Fungicide gaps** Alternatives to minimise resistance risk **Potential fungicide solutions** Efficacy and residues data required Penthiopyrad (FONTELIS, Group 7). Dupont product with similar overseas registrations Cyprodinil + fludioxonil (SWITCH, Group 9+12) – registered for Sclerotinia in other crops, IR4 project **Non-chemical options** Crop rotation, IPM strategies

Currently available Carrot fungicides

Active ingredient	Disease name	WHP, days	Chemical group
Azoxystrobin	Black rot, Powdery mildew, Sclerotinia rot	21	Group 11
Azoxystrobin + difenoconazole	Alternaria leaf spot, Leaf spot, Powdery mildew	7	Group 3/11
Boscalid	Sclerotinia (PER12054, expires Jun 2015)		
Chlorothalonil	Alternaria leaf spot	7	Group M5
Cu as ammonium acetate	Alternaria leaf spot, Leaf spot, Septoria spot	1	Group M1
Cu as cuprous oxide	Leaf diseases/spots	1	Group M1
Cu as hydroxide	Alternaria leaf spot, Leaf diseases/spots, Leaf spot, Septoria spot	1	Group M1
Cu as oxychloride	Alternaria leaf spot, Leaf diseases/spots, Leaf spot	1	Group M1
Cu as sulfate tribasic	Alternaria leaf spot, Leaf spot, Septoria spot	1	Group M1
Difenoconazole	Alternaria leaf spot, Leaf spot	7	Group 3
Iodine	Bactericide, Fungi	NA	Sanitiser
Iprodione	Black rot (PER13656, expires Sept 2019)	NA	Group 2
Mancozeb	Alternaria leaf spot, Leaf spot	7	Group M3
Mancozeb + metalaxyl + metalaxyl-M	Damping off, *Pythium* root rot	7	Group 4/M3
Metalaxyl	Damping off, *Phytophthora* soil fungus	NFC	Group 4
Metiram	Leaf spot	7	Group M3
Phosphorous acid	Damping off (PER14184, expires Jun 2017)	1	Group 33
Tebuconazole	Powdery mildew (PER13109, expires Sept 2016)		
Thiram	Damping off	7	Group M3
Zineb	Leaf spot	7	Group M3

4.2. Nematodes of carrots

Common name	Scientific name
MODERATE PRIORITY	
Root-Knot Nematodes	*Meloidogyne* spp.
Biosecurity risk	
Carrot cyst nematodes	*Heterodera carotae*

4.2.1. Priority nematodes

Root-Knot Nematodes (*Meloidogyne* spp.)

Root knot nematodes enter the roots as juveniles where they remain to feed. After feeding in carrot roots, adult females become swollen and produce an egg mass just outside the root or just beneath the root surface.

Root knot nematodes can cause substantial damage. They can stunt the plants and cause stand and yield reduction. Carrots affected by nematodes often exhibit forking of the tap root, stubbing and fasciculation (bunching) of the roots, and a predisposition to wilting. In addition, root knot nematodes induce characteristic galls on feeder roots

- Nematodes are considered a moderate problem in WA and a minor problem in other states.
  - Growers would prefer softer chemistry.
  - There are several species that affect carrots in Australia.
    - *Meloidogyne javanica* was found in carrots in WA, SA, Vic and Qld.
    - *Meloidogyne hapla* in WA, Vic and Tas.
    - *Meloidogyne fallax* in Tas (Tas. Inst. of Ag. Research 2004).

- Nematicides **registered** for the control of nematodes in carrots are:
  - Fenamiphos (NEMACUR^) - Group 1B systemic insecticide / nematicide:
    - Commonly used in WA on 50% of crops.
    - Only used in eastern states on paddocks considered at risk.
    - There have been reports in WA of this product being less effective in recent times - possibly from overuse .
    - Under review by the APVMA.
    - Growers want an alternative control measures for this pest.
  - 1,3-dichloropropene (various) - broad spectrum fumigant
    - Registered in fruit & field crops for pre-plant only.
    - Occasionally used.
    - Considered a good nematicide, much better than Metham.
  - Metham sodium (METHAM^) - broad spectrum fumigant
    - Registered in fruit & field crops for pre-plant only.
    - Commonly used.
    - Considered a weak nematicide.
    - Needs to be applied correctly to be fully effective.
    - Metham is under review by APVMA.

- No nematicides are listed for the control of nematodes in carrots via **permits**.

- Potential nematicides for the control of nematodes.
  - Fluensulfone 480EC (new Farmoz product with a novel mode of action).
    - In evaluation at the APVMA for control of nematodes in selected vegetable crops.
    - Systemic efficacy on root not nematodes. Application by soil drenching and foliar sprays.

4.2.2. Biosecurity risk nematodes

Carrot cyst nematodes (*Heterodera carotae*)

(Plant Health Australia, 2012)

- Carrot cyst nematode is considered a serious pest where it exists. It is currently restricted to parts of Europe, India and the USA (WA Dept Ag 2000). In France, this pest is reported to have caused up to 50% yield decrease.
- Can survive without host material in soil for up to 10 years.
- Symptoms include: hairy root, stunted growth and patches of irregular plant growth.

4.2.3. Summary

Nematode priorities and control options.

The vegetable industry heavily relies on various soil fumigants for control of nematodes and other pests and disease. Problems with the prolonged use of these are now being seen, ie resistance and reduced efficacy of chemicals such as Nemacur and Metham Sodium.

Although the chemistry is old growers are concerned that there may not be adequate replacements if these are removed from the market

Nematode	Control option
Root-Knot Nematodes (*Meloidogune spp.)*	**Currently registered nematicides** Fenamiphos (NEMACUR)- under review by APVMA 1,3-dichloropropene (various registered products) – occasionally used Metham sodium (METHAM) – occasionally used, under review by APVMA **Currently permitted nematicides** None **Nematicide gaps Gaps** Two of the three registered products are under review by the APVMA **Potential nematicide solutions** Fluensulfone 480EC (new Farmoz product soon to have first registration) – efficacy and residue data would be required. **Non-chemical options** Crop rotation

4.3. Insects of Carrot

Common name	Scientific name
MODERATE PRIORITY	
Aphids including: Carrot aphid	*Cavariella aegopodii*
Rutherglen bug	*Nysius vinitor*
Thrips	*Thysanoptera*
LOW PRIORITY	
Budworms	*Helicoverpa* spp.
Caterpillars	*Lepidoptera - unidentified species*
Cutworms	*Agrotis* spp.
False wireworms	*Gonocephalum* spp.
Green vegetable bug	*Nezara viridula*
Jassids	*Cicadellidae - unidentified species*
Loopers	*Geometridae - unidentified species*
White-fringed weevil	*Naupactus leucoloma*
Wireworm	*Arachnodima* spp., *Agrypnus* spp.
Biosecurity risk	
Carrot rust fly (NZ)	*Psila Rosae*

4.3.1. Priority insects

Aphids - Carrot aphid (*Cavariella aegopodii*)

The wingless summer form of the carrot aphid is pale green, and legs pale to slightly dusky. They are medium-sized aphids with elongate oval-shaped bodies that are flattened front to back.

The winged forms have a black head and thorax. The abdomen is pale green with dark areas on the sides and dark bands on the top. The antennae are black. The legs are pale in colour and black at the tips.

- Carrot aphid is primarily of concern because of its efficiency in vectoring a number of serious virus diseases. It seldom reaches numbers that trigger the need for chemical intervention. Numbers are highest in spring (WA Dept. Ag).

- Aphids are considered a medium problem in all states.
  - Vector for Carrot virus Y - growers require new aphicides to control this pest.
  - Fennel aphid (*Dysaphis foeniculus*) has been the only aphid of any pest significance in Qld (Qld DPI 1996).
  - Weed control will assist management as aphids can have a range of hosts. Having a good IPM program will also help as beneficials such as wasps and ladybird will attack aphids and reduce numbers (McMaugh 1989).

- Insecticides **registered** for the control of aphids in carrots are:
  - Dimethoate (various) – Group 1B contact and systemic insecticide
    - Restricted use.
    - Occasionally used.
    - It is reported to still be effective.
    - This treatment is disruptive to beneficial insects in an IPM situation.
    - Still able to use dimethoate in carrots per-harvest with a 14 day WHP for the control of aphids, thrips, jassids and redlegged earth mites.

- Potassium salts of fatty acids (various) – contact biological insecticide.
  - Not used
- Fenamiphos (various) – Group 1B contact and systemic insecticide.
  - Not used for this pest.
- Maldison (various) – Group 1B contact and systemic insecticide
  - Occasionally used for the control of aphids, Green vegetable bugs, jassids, leaf hoppers, Rutherglen bugs and thrips.
  - It is considered to be very effective
  - This treatment is disruptive to beneficial insects in an IPM situation.
- Phorate (various) - Group 1B contact and systemic insecticide
  - Occasionally used in problem situations.
  - Only used when multiple pests are present and difficult to control.

- No insecticides are listed for control of aphids in carrots via **permits**.

- **Potentia**l insecticides for control of aphids in carrots.
  - Flonicamid (new ISK/FMC product)– Group 9C
    - First registration application in assessment at APVMA. Likely first registration on cucurbits.
    - Aphicide.
    - IR4 projects on carrots – collaboration is a possibility.
    - Overseas registrations on aphids / brassica vegetables, root vegetables, tuberous and corm vegetables, cucurbit vegetables, hops, leafy vegetables, fruiting vegetables, pome fruit and stone fruit.
  - Pymetrozine (various) – Group 9B insecticide
    - Currently registered in other vegetable crops for control of aphids.
  - Spirotetramat (MOVENTO) – Group 23 contact and systemic insecticide
    - Broad spectrum insecticide registered in other crops for control of thrips,
    - IPM compatible.
  - Sulfoxaflor (TRANSFORM^) – Group 4C insecticide
    - Aphid regestrations in many crops.
    - May have adverse effects on parasitic wasps in IPM situations.
  - Permits are in place for control aphids in a number of other vegetable crops for the following chemicals. These may be possibilities for carrot permit applications if growers need further means of aphid management:
    - Petroleum (MRL not required)
    - Imidacloprid (no MRL)

Rutherglen bug (*Nysius vinitor*)

Adult bugs are 3 - 4 mm long and narrow bodied. They are greyish brown with darker markings and have prominent black eyes. The wings are folded flat when the bug is at rest. Immature bugs are dark red and more swollen in shape than are adults.

Rutherglen bugs are sap suckers and damage to susceptible plants is similar to that caused by aphids.

- The Rutherglen bug is considered a moderate problem in all states.
  - Rarely causes significant crop damage.
  - Contamination is a major issue for supermarket rejections when there is zero tolerance to live insects.
  - Local management will have little impact in seasons when there are major influxes of bugs from outside the cropping region in spring. As RGB also feed on weeds, managing

weeds in and around paddocks prior to sowing can reduce the likelihood of bugs moving from dying weeds onto emerging seedlings.
    - Have increased as a pest problem with the reduced use of broad spectrum insecticides.
    - RGB generally succumb to fungal attack as humidity rises after Christmas and become much less of an issue.
    - Growers currently rely on incidental control from insecticides being used to control other pests
    - Chemistry with an IPM fit is required

- Insecticides **registered** for the control of Rutherglen bugs in carrots:
    - Maldison (various) – Group 1B contact and systemic insecticide
        - Occasionally used for the control of aphids, Green vegetable bugs, jassids, leaf hoppers, Rutherglen bugs and thrips.
        - Only a problem in SE states.
        - This treatment is highly disruptive to beneficial insects in an IPM situation.
        - It is considered to be very effective

- There are no insecticides listed for control of Rutherglen bugs in carrots via **permits**.

Thrips (*Thysanoptera* spp.)

The common thrips are Greenhouse thrips (*Heliothrips haemorrhoidalis),* Plague thrips *(Thrips imaginis*) and Western flower thrips *(Frankliniella occidentalis)*. Thrips are 0.5mm – 10 mm long and range in colour from white to yellow to black. Thrips generally have wings that are fringed but this can only be seen with magnification. Thrips attack the flowers, fruit and foliage of a variety of plants.

Thrips found in carrots are very small, 1-2 mm long and they are a sucking pest which damages the surface of plant tissue such as leaves.

- Thrips are considered a moderate problem in all states.
    - Need more effective and soft options.
    - Tas report that populations resistant to diazinon and SPs exist in some areas.
    - Thrips have few insect enemies however populations can decrease due to weather, i.e. heavy rain or hot dry conditions.

- Insecticides **registered** for the control of thrips in carrots are:
    - Dimethoate (various) – Group 1B contact and systemic insecticide.
        - Occasionally used for the control of a range of pests.
        - It is reported to still be effective.
        - This treatment is disruptive to beneficial insects in an IPM situation.
        - Still able to use dimethoate in carrots per-harvest with a 14 day WHP for the control of aphids, thrips, jassids and Redlegged earth mites.
    - Potassium salts of fatty acids (various) – contact biological insecticide.
        - Not used
    - Fenamiphos (various) – Group 1B contact and systemic insecticide.
        - Not used for this pest.
    - Maldison (various) – Group 1B contact and systemic insecticide.
        - Occasionally used for the control of aphids, Green vegetable bugs, jassids, leaf hoppers, Rutherglen bugs and thrips.
        - It is considered to be very effective
        - This treatment is disruptive to beneficial insects in an IPM situation.
    - Phorate (various) - Group 1B contact and systemic insecticide
        - Occasionally used in problem paddocks.
        - Only used when multiple pests are present and difficult to control.

- No insecticides are listed for control of thrips in carrots via **permits**.

- **Potential** insecticides for control of thrips in carrots follow. Residue data would be required
  - Spirotetramat (MOVENTO) – Group 23 contact and systemic insecticide
    - Broad spectrum insecticide registered in other crops for control of thrips,
    - IPM compatible.
  - Sulfoxaflor (TRANSFORM^) – Group 4C insecticide
    - Thrips registrations in a number of other vegetables.
    - May have adverse effects on parasitic wasps in IPM situations.
  - Thiamethoxam + chlorantraniliprole (DURIVO) - Group 4A + 28 contact and systemic insecticide
    - Registered in other vegetables as a seedling drench or soil drench for aphids, lepidoptera, whitefly and thrips.
    - Effective but moderately harmful to some beneficial insects.

4.3.2. Biosecurity risk insects

Carrot rust fly (*Psila Rosae*)

- Carrot rust fly is considered a potential threat to Australian carrots. It is widespread in Europe, Canada, USA and NZ and has the potential to kill many seedlings, damage due to larval mine, secondary rots and uneven root development.
- Farm protection – regular checks for new pests and unusual symptoms

(Plant Health Australia, 2011, 2012)

4.3.3. Summary

High priority insects and control options
As a generalisation there is a desire for different chemistry to be used for alternation and growers seek solutions that will fit with IPM programs. In the case of aphids and Rutherglen buts, weed management in an important strategy to reduce the source of pest populations.

There is some new chemistry recently registered or with potential to be registered in the coming years. Growers are mindful that this chemistry will need to be carefully managed to reduce resistance threats. It would be most helpful for management of the chemicals if use patterns could be developed in conjunction with registrants, rather than relying on grower-driven permits.

Insect	Control option
Aphids – carrot aphid (*Cavariella aegopodii*)	**Registered fungicides** Dimethoate (various registered products) – effective but not IPM compatible Potassium salts (various) - not used Fenamiphos (various) – not used for this pest Maldison (various) - effective but not IPM compatible Phorate (various) - Group 1B – only used when multiple pests present and difficult to control **Permitted fungicides** None **Insecticide Gaps** No aphid-specific chemistry for Carrot "Soft" solutions **Potential insecticide solutions** Efficacy and residue work required: Flonicamid (new ISK/FMC product, Group 9C) – Aphicide, IR4 projects. Pymetrozine (various, Group 9B) – IPM compatible, registered in other crops for aphids. Spirotetramat (MOVENTO, Group 23) – broad spectrum, IPM compatible. Sulfoxaflor (TRANSFORM^) – Group 4C – aphid registrations in many crops **Non-chemical options** Best management includes the use of IPM practices

Insect	Control option
Rutherglen bug (*Nysius vinitor)*	**Currently registered insecticides** Maldison (various, Group 1B) – Efficacious but IPM disruptive. **Currently permitted insecticides** None **Insecticides Gaps** Registrations and permits required, although chemistry registered to control other insects will incidentally control Rutherglen bug. **Potential insecticides solutions** None specifically requested by growers. **Non-chemical options** Weed control around crops – this pest feeds on weeds then moves to the crop as weeds die. Management of the Retail / supermarket zero tolerance of live insects.
Thrips (*Thysanoptera* spp.)	**Currently registered fungicides** Dimethoate (various) - effective but not IPM compatible Potassium salts (various) - not used Fenamiphos (various) - not used for this pest Maldison (various) - effective but not IPM compatible Phorate (various) - Group 1B – only used when multiple pests present and difficult to control **Currently permitted fungicides** None **Insecticide Gaps** Soft alternatives, more alternatives **Potential insecticide solutions** Spirotetramat (MOVENTO, Group 23) broad spectrum, IPM compatible. Sulfoxaflor (TRANSFORM^) – Group 4C – thrips registrations in many crops Thiamethoxam + chlorantraniliprole (DURIVO, Group 4A+28, efficacious but moderately harmful to some beneficial insects **Non-chemical options** None identified – this should be investigated in future SARPS

Currently available carrot insecticides

Active ingredient	Insect name	WHP	Chemical group
Alpha-cypermethrin	Helicoverpa, Potato moth (Leafminer), Rutherglen bug	-	3/11C
Bacillus thuringensis	Helicoverpa, Potato moth (Leafminer), Rutherglen bug	-	3/11C
Bifenthrin	Helicoverpa, Potato moth (Leafminer), Rutherglen bug	-	3/11C
Carbaryl	Australian plague locust	SL	1A/1B
Chlorpyrifos	Australian plague locust, Black field cricket, Cutworms, Earwigs, False wireworms, Field crickets, Lightbrown apple moth, Mole crickets, Seed harvesting ants, Spotted vegetable weevil, Vegetable weevil, Wingless grasshopper	SL	1A/1B
Diazinon	Australian plague locust, Caterpillars, Cutworms	SL	1A/1B
Dimethoate	Aphids, Bugs, Green vegetable bug, Jassids, Leafhoppers, Leafminer flies, Mites, Redlegged earth mite, Thrips, Wingless grasshopper	14	1B
Fenamiphos	Aphids, Insects – sucking, Thrips	84	1B
Maldison	28-spotted potato ladybird, Aphids, Australian plague locust, Green vegetable bug, Jassids, Leafhoppers, Redlegged earth mite, Rutherglen bug, Thrips	3	1B
Phorate	Aphids, Carrot aphid, Jassids, Thrips	70	1B
Spinetoram	Aphids, Loopers, Redlegged earth mite	3	5

4.4. Weeds of carrot

4.4.1. High priority weeds

- Weeds identified as a high priority for control are:

Common name	Scientific name
HIGH PRIORITY	
Resistant ryegrass (predominantly Group A)	*Lolium rigidum*

- Herbicides **registered** and used in carrots:
  - Chlorthal-dimethyl (various) – Group D pre-emergent residual herbicide.
    - Rarely used and only for problem paddocks - specific weeds.
    - No MRL at Codex.
  - Fluazifop-P as butyl (various) – Group A grass selective post-emergent herbicide.
    - Occasionally used.
    - Considered very effective.
  - Linuron (various) - Group C general knockdown & residual herbicide
    - Commonly used pre and post-emergence.
    - Commonly used for in-crop self-sow potato control.
    - Linuron withholding period under review by is APVMA - currently to 10 weeks.
  - Pendimethalin (various) - Group D residual herbicide.
    - Occasionally used.
    - Growers comment that does not control all weeds that occur.
  - Prometryn (various) - Group C general knockdown & residual herbicide.
    - Commonly used both pre and post-emergence.
    - Considered very effective.
  - Quizalofop-P-ethyl (various) - Group A grass selective post-emergent herbicide.
    - Occasionally used.
    - Used more than Fusilade - controls cereal cover crop.
    - Considered very effective.
  - Sethoxydim (various) - Group A grass selective post-emergent herbicide.
    - Not used.
  - Trifluralin (various) - Group D residual herbicide.
    - Commonly used.
    - Pre tank mix with linuron. Very effective.
  - Glyphosate (various) – Group M pre-plant general knockdown herbicide.
    - Commonly used.
    - Works well as a pre-crop spray.
  - Paraquat + diquat (various) - Group L pre-plant general knockdown herbicide.
    - Occasionally used.
    - Works well as a pre-crop spray
- The herbicides listed for control of weeds in carrots via **permits** are:
  - Clethodim (various, PER13788) – Group A grass selective post-emergent herbicide.
    - Occasionally used.
    - Used for fop resistant ryegrass and Winter grass control.
    - Considered effective. Some issues with resistant ryegrass.
    - Used as a spot spray for couch control.
    - Permit expires Mar 2018.

- Glyphosate (various, PER13305) – Group M pre-plant general knockdown herbicide.
  - Occasionally used with shielded sprayers between rows.
  - Works well.
  - Considered effective.
  - Permit expires 30-Jun-15.

- Prometryn (various, PER12383, Group C – supplemental permit for Qld only

- Potential herbicides for control of weeds in carrots:
  - Growers did not identify gaps in weed control programs. Nevertheless it would be helpful for carrots to be considered as new chemistry is developed, in particular as many of the current products are subject to resistance threats.

5. References and information

- Australasian Biological Control website.
- Australian Bureau of Statistics, Agricultural Commodities website.
- Australian Horticultural Statistics Handbook.
- Australian Pesticide and Veterinary Medicines Authority website.
- Ausveg 'Domestic Vegetable Industry Snapshot' (2009) website.
- Ausveg 'Fresh Vegetable Exports' (2011) website.
- Biobest website.
- Codex MRL database website.
- Cornell University website.
- DEEDI, 2012 http://www.appsnet.org/publications/potm/pdf/Mar12.pdf, accessed 14 Feb 2014
- Diseases of Vegetable Crops. Department of Primary Industries Queensland, 1994.
- Infopest, Department of Primary Industries and Fisheries, Queensland Government, July 2012.
- IPM Technologies final report. Project: Pesticide effects on beneficial insects and mites in vegetables.
- IR-4 Project website.
- Managing Insects and Mites in horticultural crops, QLD DPI, 1994.
- McMaugh, 'What garden pest or disease is that?' published 1989.
- New South Wales Department of Primary Industries websites.
- Pest management strategy documents for Queensland's fruit and vegetable industries, Queensland Fruit and Vegetable growers, 2003 & 2008.
- Plant Health Australia. Threats to Australia's plant production. http://www.planthealthaustralia.com.au/wp-content/uploads/2013/06/2012-Status-Report-Chapter-2.pdf, accessed February 14, 2014.
- Plant Health Australia, 2011: Carrot rust fly Fact sheet. http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Carrot-rust-fly-FS.pdf, accessed 14 Feb 2014
- USA Foreign Ag Service website.
- Vegetable Spotlight – Carrots. Ausveg website, http://ausveg.businesscatalyst.com/statistics/Carrot%20Commodity%20Report%20June%202010.pdf, accessed 10/2/2014
- Vegetable IPM Coordinator draft report 2011. Sandra McDougall NSW DPI.
- Western Australia Department of Agriculture (2000) 'Carrot cyst nematode'.
- Western Australia Department of Agriculture website.

Images:
- Google images

Acronyms

APVMA ……..	Australian Pesticides and Veterinary Medicines Authority
DPI ……..	Department of Primary Industries
HAL ……..	Horticulture Australia Ltd
IPM ……..	Integrated pest management
IR-4 ……..	Interregional Research Program 4 (USA, minor use)
MRL ……..	Maximum residue limit (mg/kg or ppm)
Plant pests …	Diseases, insects, nematodes, viruses, weeds, etc
Pesticides ….	Plant protection products (fungicide, insecticide, herbicide, nematicides, etc).
SARP …….	Strategic Agrichemical Review Process
WHP ……..	Withholding period

Acknowledgement

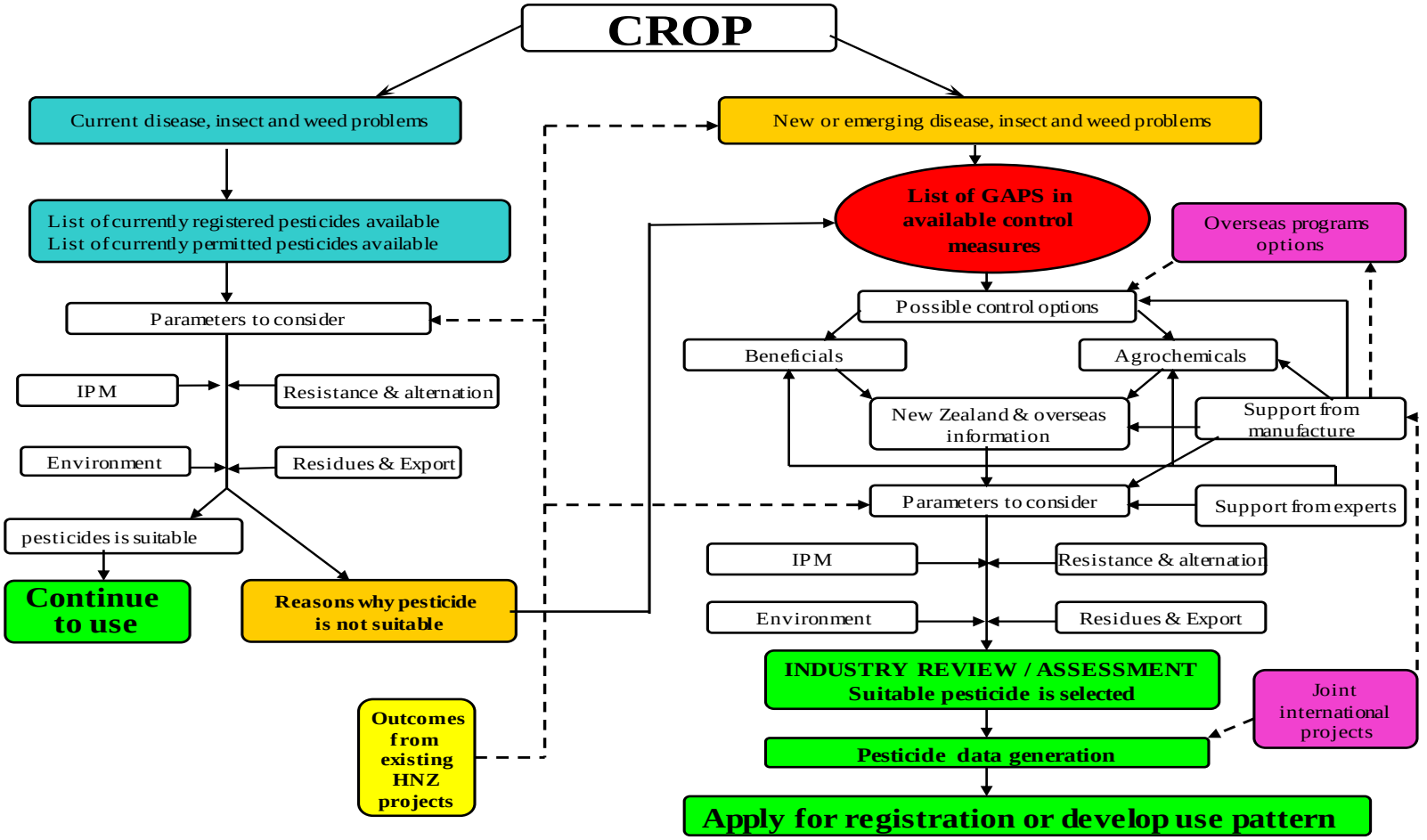
APVMA: All staff especially Alan Norden
Government agencies: Each state DPI as excellent sources of information
Industry development officers and associates

Thanks go to the many industry people who contributed information and collaborated on the review of this report.

^Trademark

6. Appendices

DIAGRAM 1: The Strategic Agrichemical Review Process



Appendix 2 – currently available fungicides in carrot.

Disease name	Active ingredient	WHP, days	Chemical group
Alternaria leaf spot	azoxystrobin + difenoconazole	7	3/11
	chlorothalonil	7	M5
	copper as ammonium acetate	1	M1
	copper as hydroxide	1	M1
	copper as oxychloride	1	M1
	copper as sulfate tribasic	1	M1
	difenoconazole	7	3
	mancozeb	7	M3
Bactericide	iodine	NA	,Sanitiser
Black rot	azoxystrobin	21	11
Black rot	Iprodione (PER13656, expires Sept 2019)	NA	2
Damping off	mancozeb + metalaxyl / metalaxyl-m	7	4/M3
	metalaxyl	NFC	4
	phosphorous acid (PER14184, expires Jun 2017)	1	33
	thiram	7	M3
Fungi	iodine	NA	Sanitiser
Leaf diseases/spots	azoxystrobin + difenoconazole	7	3/11
	copper as cuprous oxide	1	M1
	copper as hydroxide	1	M1
	copper as oxychloride	1	M1
	copper as ammonium acetate	1	M1
	copper as sulfate tribasic	1	M1
	difenoconazole	7	3
	mancozeb	7	M3
	metiram	7	M3
	zineb	7	M3
Phytophthora soil fungus	metalaxyl	0	4
Powdery mildew	azoxystrobin	21	11
	azoxystrobin + difenoconazole	7	3/11
	tebuconazole (PER13109, expires Sept 2016)		
Pythium root rot	mancozeb + metalaxyl / metalaxyl-m	7	4/M3
Sclerotinia rot	azoxystrobin	21	11
	boscalid (PER12054, expires Jun 2015)		
Septoria spot	copper as ammonium acetate	1	M1
	copper as hydroxide	1	M1
	copper as sulfate tribasic	1	M1

Appendix 3 – currently available insecticides in carrot.

Insect name	Active ingredient	WHP	Chemical group
28-spotted potato ladybird	maldison	3	1B
Aphids	dimethoate	14	1B
	fenamiphos	84	1B
	maldison	3	1B
	phorate	70	1B
	spinetoram	3	5
Australian plague locust	Carbaryl, chlorpyrifos, diazinon, maldison	SL	1A/1B
Black field cricket	chlorpyrifos	-	1B
Bugs	dimethoate	14	1B
Carrot aphid	phorate	70	1B
Caterpillars	diazinon	14	1B
Cutworms	chlorpyrifos	-	1B
	diazinon	14	1B
Earwigs	chlorpyrifos	-	1B
False wireworms	chlorpyrifos	-	1B
Field crickets	chlorpyrifos	-	1B
Green vegetable bug	dimethoate	14	1B
	maldison	3	1B
Helicoverpa	alpha-cypermethrin	-	3
	bifenthrin	-	11C
	Btk	-	-
Insects - Sucking	fenamiphos	84	1B
Jassids	dimethoate	14	1B
	maldison	3	1B
	phorate	70	1B
Leafhoppers	dimethoate	14	1B
	maldison	3	1B
Leafminer flies	dimethoate	14	1B
Lightbrown apple moth	chlorpyrifos	-	1B
Loopers	spinetoram	3	5
Mites	dimethoate	14	1B
Mole crickets	chlorpyrifos	-	1B
Potato moth (Leafminer)	alpha-cypermethrin	-	3
	bifenthrin	-	11C
	Btk	-	-
Redlegged earth mite	dimethoate	14	1B
	maldison	3	1B
	spinetoram	3	5
Rutherglen bug	alpha-cypermethrin	-	3
	bifenthrin	-	11C
	Btk	-	-
	maldison	3	1B
Seed harvesting ants	chlorpyrifos	-	1B
Spotted vegetable weevil	chlorpyrifos	0	1B
Thrips	dimethoate	14	1B
	fenamiphos	84	1B
	maldison	3	1B
	phorate	70	1B
Vegetable weevil	chlorpyrifos	-	1B
Wingless grasshopper	chlorpyrifos	-	1B
	dimethoate	14	1B

Appendix 4 – currently available herbicides in carrot.

As carrots are considered a Major crop group and have a considerable number of registrations, full detail is not given of all registered active and pest combinations. This information is available on the APVMA website.

Active ingredient	**Chemical group**
2,2, -DPA	J
chlorthal-dimethyl	D
clethodim	A
diquat + paraquat	L
fluazifop	A
glyphosate	M
linuron	C
pendimethalin	D
prometryn	C
quizalofop	A
sethoxydim	A
trifluralin	D