Sweet Potatoes

Strategic Agrichemical Review Process
2011-2014

HAL Projects - MT10029 & VG12081

AgAware Consulting Pty Ltd
Checkbox 3D Pty Ltd

March 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 sweet potato industry across Australia. The information in this report will assist the 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:
14 March 2014

HAL

Horticulture Australia

Table of 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.

The sweet potato SARP was conducted in Brisbane in 2008 and in Bundaberg with the ASPG members in May 2010. The results of the process provide the sweet potato 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)
Scurf	*Monilochaetes infuscans*

As with most minor crops there is a gap in the available fungicides for treatment of diseases in sweet potato. Growers need further chemistry for alternation to keep disease under control and to reduce the risk of resistance developing. Growers would welcome greater access to chemistry available to potatoes.

NEMATODES

Nematodes identified as high priorities:

Nematode (common name)	Nematode (scientific name)
Root Knot Nematode	*Meloidogyne* spp.

Growers have several options for control of nematodes but the industry would benefit from the introduction of new chemistry.

INSECTS

Insects identified as high priorities:

Insect (common name)	Insect (scientific name)
Silverleaf whitefly	*Bemisia tabaci (all biotypes)*
Sweet potato weevil	*Cylas formicarius*
Whitefringed weevil	*Naupactus leucoloma*
Wireworms	*Elateridae*

There are limited chemical control options for all insects identified as high priorities in sweet potato. In all cases the chemistry is old and softer options are required to fit with IPM programs. If the insects identified are not controlled the crop value may be severely diminished.

WEEDS

Weeds identified as a high priority for control are:

Weed
Volunteer sweet potatoes
Broadleaf weeds

It is important to control weeds to minimise insect and disease carryover, and to allow satisfactory crop establishment in the first weeks after planting.

Most weeds can be controlled with currently available herbicides but growers would welcome inclusion of sweet potatoes in new chemical registrations.

2. The Australian sweet potato industry

The Australian sweet potato industry is an intense vegetable industry predominantly in the Bundaberg area of central Queensland. Sweet potatoes is the 13th highest ranked vegetable crop purchased during 2011. The Australian Sweet Potato Growers (ASPG) manages the interests of the industry.

Sweet potatoes are grown across northern Australian states with the main growing regions being:

- Bundaberg, Qld
- Lockyer Valley, Qld
- Atherton Tablelands, Qld
- Northern NSW
- North Adelaide Plains SA
- Carnarvon WA
- Perth metro WA
- Albany WA
- Northern Territory

Most of the production is concentrated in Qld (75%), NSW (19%), SA (4%) and WA and Vic (1%). In 2010/2011 the production of sweet potatoes was 51,567 tonnes. The majority of the produce is sold to the fresh domestic market. Approximately 240 tonnes of sweet potato were imported in 2010/11.

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 sweet potato 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 beans and peas. 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 sweet potatoes as a minor crop. The crop fits within the APVMA crop group 016 Root and Tuber Vegetables.

As a consequence of the issues facing the sweet potato industry regarding pesticide access, Horticulture Australia Ltd and the vegetable industry undertook a review of the pesticide requirements in sweet potatoes 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 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 sweet potato production in Australia but attempts to prioritise the major problems.

3.2 Minor-use permits and registration

Sweet potatoes are classified as minor by the APVMA. Therefore access to minor use permits can be relatively straight forward as long as a reasonable justification is provided. 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 industry is for manufacturers to register new pesticides uses in the crop.

3.3 Methods

The SARP was conducted in Brisbane in 2008 and in Bundaberg with the ASPG members in May 2010. The meetings included members from both the fresh and processing sweet potato industry and included members of the sweet potato association, leading growers, consultants and government agencies.

- Participants were given a comprehensive list of most major pests of sweet potatoes 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 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 beans and peas

4.1 Diseases of sweet potatoes

Common name	Scientific name
HIGH PRIORITY	
Scurf	*Monilochaetes infuscans*
MODERATE PRIORITY	
Bacterial soft rot	*Erwinia* spp.
Fusarium root rot	*Fusarium solani*
Biosecurity risk	
None listed	

4.1.1 High priority disease

Scurf (Monilochaetes infuscans)

The fungus only grows in the sweet potato skin and produces spores on the surface of the skin - dark splotches. The fungus does not penetrate below the skin, so the sweet potatoes are still edible, but because of the dark discoloration that results, diseased sweet potatoes have lower market values. Scurf is usually worse during rainy seasons.

Scurf is considered a high-moderate priority in NSW and QLD and SA, a medium-low priority in other states. This disease is spread by moisture and infection is favoured by wet weather.

- Fungicides **registered** for the control of Scurf in sweet potatoes:
  - Various fumigants, including:
  - 1,3-dichloropropene + chloropicrin (various) fumigant
    - Restricted chemical
    - Broad vegetable claim for control of soil borne diseases as pre-plant treatment.
    - Schedule 7 dangerous poison.
    - Crop rotation is preferable to fumigation.
  - Metham sodium (various) fumigant
    - Pre-plant treatment
    - Broad vegetable claim for control of soil borne pests and diseases
    - Poisonous fumes.
  - Dazomet (various) fumigant
    - Pre-plant treatment
    - Broad vegetable claim for control of soil borne pests and diseases
    - Poisonous fumes.
- Fungicides listed for Scurf control in sweet potatoes via **permit**:
  - Thiabendazole (various) (PER12047, expires Sep 2016) - Group 1 – protectant fungicide
    - Commonly used on most seed roots as a seed piece treatment.
    - Also used by some growers as a pre-storage spray for root rot (Fusarium) control.
    - Effective in high pressure situations.
    - Heavy reliance on thiabendazole by growers.

- Non-chemical control options:
    - Crop rotation, planting sweet potatoes only every 2 to 4 years on light soil and 2 to 4 years on heavy soils.
    - Farm hygiene practices
    - Irrigation management.
    - Lifting for storage.

4.1.2 Disease control options

Currently available fungicides

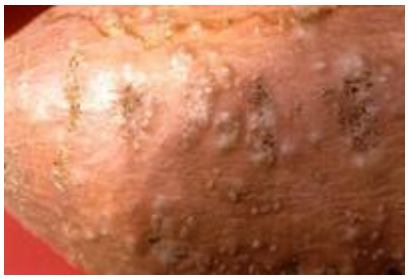
Active		Disease / Pest	WHP, days	Chemical Group
1,3-dichloropropene + chloropicrin	Fumigant	Soil Borne Diseases Incl Fusarium, Verticillium Wilts, Rhizoctonia, Pythium	NR	_
Dazomet	Fumigant	Soil borne pests and diseases	NR	_
Boscalid		Scleotinia Rot	7	7
Fenamiphos	NEMACUR	Soil Borne Plant Parasitic Nematodes	1B	84
Metham sodium		Soil borne pests and diseases	NR	_
Penthiopyrad (FONTELIS^)		Early Blight/Target Spot/Leaf Spot (Alternaria Solani)	7	1
Penthiopyrad (FONTELIS^)		Powdery Mildew	7	1
Sulphur		Bean Rust	NR	M2
Sulphur		Powdery Mildew	NR	M2
Thiabendazole	(PER12047, expires Sep 2016)	Field Rots Caused By Scurf (*Monilochaetes Infuscans*)	NR	1
Thiabendazole	(PER12047, expires Sep 2016)	Root Rot (*Fusarium* Spp.)	NR	1

4.2 Nematodes of sweet potatoes

Common name	Scientific name
Root-knot nematodes	*Meloidogyne* spp.
MODERATE and LOW PRIORITY	
None identified	

4.2.1 High priority nematodes

Root Knot Nematodes (*Meloidogyne* spp.)



Root-knot nematode (RKN) can cause roots to be malformed or cracked or to appear roughened. Aboveground symptoms are a general stunting or yellowing of the plant. These plants look like they are lacking in fertility. If this nematode attacks early in the growing season, small galls can be seen where it has attacked the root system. This pest can also enter into the enlarging roots later in the growing season.

Root-knot females can often be found in corky areas within these roots. The females are white or yellowish, often occurring in discoloured areas within the root.

- Root Knot Nematodes are considered a high priority in all growing areas.
    - The most common grown variety Beauregard has a high susceptibility to RKN.
    - Crop rotations play an important role in their management.

- Nematicides registered for the control of nematodes in sweet potatoes are:
    - Fenamiphos (NEMACUR^) Group 1B contact and systemic insecticide
        - Used in Qld once per crop.
        - Effectiveness of fenamiphos has improved with the ability of industry to rotate with Vydate L. Vydate L became permitted for use in crop during 2009/2010 production season. 2012/13 ASPG lead trials found high levels of efficacy with soil incorporation of fenamiphos prior to planting.
        - Growers want an alternative. Still need alternative due to the APVMA review recommendation that the use of fenamiphos in sweetpotato no longer be supported.
        - Product may cease production in future.
    - Various soil fumigants, including 1,3-dichloropropene + chloropicrin, dazomet and Metham sodium

      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

- Insecticides listed for nematode control in sweet potatoes via permits are:
    - Vydate (oxamyl - PER14582, expires Sep 2015) - Group 1A – contact and systemic insecticide:
        - Commonly used on many crops via trickle or drip irrigation, soon after planting.
        - Effective in high pressure situations.
        - Heavy reliance as very effective - most effective product available.
        - Use of Vydate has reduced nematode populations over past few years.

- 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.

4.3 Insects of sweet potato

Common name	Scientific name
HIGH PRIORITY	
Silverleaf whitefly	*Bemisia tabaci* (all biotypes)
Sweet potato weevil	*Cylas formicarius*
Whitefringed weevil	*Naupactus leucoloma*
Wireworms – True and False wireworm	*Elateridae & Tenebrionidae*
MODERATE PRIORITY	
Cluster caterpillar	*Spodoptera litura*
Potato moth (Leafminer)	*Phthorimaea operculella*
Spotted vegetable weevil	*Desiantha diversipes*
Two-spotted (Red spider) mite	*Tetranychus urticae*
Vegetable weevil	*Listroderes difficilis*
LOW PRIORITY	
Aphids – including Green peach aphid	*Myzus persicae*
Bean spider mite	*Tetranychus ludeni*
Crickets - including Black field & Mole	*Gryllidae, Gryllotalpidae*
Cutworms	*Agrotis* spp.
Flea beetle	*Xenidia* spp.
Hawk moth	*Agrius convuloculi*
Heliothis	*Helicoverpa* spp.
Jassids	*Cicadellidae*
Lightbrown apple moth	*Epiphyas postvittana*
Loopers	*Geometridae*
Thrips	*Thysanoptera*
Wingless grasshopper	*Phaulacridium vittatum*
Biosecurity risk	
None listed	

4.3.1. High priority insects

Silverleaf (Poinsettia) whitefly (*Bemisia tabaci* - all biotypes)

Silverleaf whitefly was first detected in Australia in 1994. Adults are approximately 1 mm long and are a narrow white wedge-shaped insect. When an infested plant is disturbed the whiteflies can be seen to flutter out and rapidly resettle.

Adults feed and lay their eggs on the undersides of young leaves and a female can lay up to 160 eggs during a 60 day lifespan. The eggs turn from white to brown as they get close to hatching. There is an indigenous whitefly called the Sweet potato whitefly which is identical in appearance to the Silverleaf whitefly.

Whiteflies damage sweet potatoes by sucking enormous quantities of sap and covering plants with sticky honeydew. Black sooty mould grows over the honeydew.

Beneficial insects, play a very important role in the control of whitefly. Therefore any insecticide used in sweet potato needs to be compatible with these beneficial insects.

- Silverleaf whitefly is considered a major pest in NSW, Qld and northern WA but is not regarded as a problem elsewhere.
    - Whitefly numbers can vary, but can be heavy.
    - High numbers can lead to weakened plants and defoliation.
    - Growers want IPM compatible alternatives.
    - Use of *Eretmoncerus hayati* needs to be encouraged and preserved post-release.
    - Growers commented that Silverleaf whitefly can be difficult to kill.
    - Use of broad spectrum insecticides can cause outbreaks.
    - There are insecticides available, but growers are concerned at the ability of Silverleaf whitefly to develop resistance to these insecticides.

- Insecticides **registered** for the control of Silverleaf whitefly in sweet potato are:

    - Imidacloprid (various) - Group 4A contact / systemic insecticide.
        - Commonly used on all crops.
        - Variable efficacy when applied as a foliar spray.
        - Poor IPM compatibility. Use has negative impact on beneficial insects.
        - Most growers now use imidacloprid applied through drip tape. This is more effective than foliar sprays and has less impact on IPM programs.
        - Control needed in all crops otherwise losses can be high.
        - Growers want more IPM compatible alternatives.

    - Potassium salts of fatty acids (various) contact biological insecticide
        - Greenhouse and silverleaf whitefly.
        - Occasionally used.
        - Reported as effective, but only offers short term control.
        - Minimal impact on most beneficial insects.

    - Pyrethrins+piperonyl butoxide (various) Group 3A contact insecticide
        - Good knockdown.
        - Harmful to beneficials.

    - Spirotetramat (MOVENTO^) Group 23 contact / systemic insecticide.
        - Increasingly used and is very effectibe.
        - Also controls other pests.
        - Good IPM compatibility.

- No insecticides are listed for the control of Silverleaf whitefly in sweet potato via **permits**.

- Potential insecticides for control of whitefly:

    - Chlorantraniliprole + thiamethoxam (DURIVO^) is registered for control of silverleaf whitefly in a large number of crops.

    - Cyantraniliprole (BENEVIA^) – Group 28 contact and systemic insecticide
        - Registered in cotton for control of sucking insects – silverleaf whitefly, cotton aphid (suppression only) and for chewing insects – Helicoverpa
        - Product being assessed at the APVMA. Residues studies, primarily from overseas, have been submitted for cucurbits, lettuce, peppers, tomatoes, melons, blueberries, pome and stone fruit, potatoes, beans, citrus, almonds, pecans, onion, leafy vegetables, brassica vegetables.
        - This is from the same group as Chlorantraniliprole so may have limited use for alternation.
        - The initial target Australian use pattern is not known
        - Dupont could be approached for consideration of minor crops in its development program
        - IR4 projects for various crops/thrips, beetles, leafminer, psyllids, whitefly
        - Similar comments to DURIVO with regard to resistance

- Metaflumizone (New BASF active) - Group 22B
    - Activity against Lepidoptera, Coleoptera, Hemiptera, Hymenoptera, Isoptera, and Diptera.
    - At this stage an active ingredient approval is in review at the APVMA
    - BASF could be approached for consideration of minor use crops in its development program. The Australian target use pattern is not known

- Novaluron - Group 15. Farmoz and United Phosphorous have approvals of this active. The status of development of an end use product is unknown. The active is the subject of IR4 project work. Efficacy and residue work would be required.

Sweet potato weevil (*Cylas formicarius*)

Cylas formicarius is considered the single most important pest of sweetpotato. Weevil infestation can be very high on some farms and regions. Higher infestation occurs during dry seasons.

The adult weevils feed on the tender buds, leaves, vines and storage roots while the larvae, the most destructive stage, feed and tunnel into the mature stems and storage roots. The damage is characterized by small feeding and ovipositional punctures on the surface and larval tunnels filled with frass in the tissues.

The damage leads to thickening, drying and cracking of the stems and to secondary infection by bacteria and fungi.
Infestation of the storage roots makes them unfit for human or animal consumption, even if only a small proportion of the flesh is damaged, as the damaged tissue produces terpines giving the flesh an unpleasant odour and bitter taste. Weevil damage increases during storage.

- Sweet potato weevil is considered a major pest in all regions.
    - Growers need a better understanding of the pest's impact.
    - Pheromones in use to monitor populations.
    - Considered the most serious sweet potato pest in Qld and NSW.
    - Industry has been investigating the use sweet potato varieties with a high tolerance to SPW imported from the USA.

- Insecticides **registered** for the control of Sweet potato weevil in sweet potatoes:
    - Bifenthrin (various) Group 3A insecticide
        - Commonly used on all crops.
        - Very effective.
        - Has led to marked improvement in root quality.
        - Grower concern that overuse could lead to resistance.
        - Disruptive to beneficial insects in IPM situations

    - Carbaryl (various) Group 1A contact and systemic insecticide
        - Not reported to be used.

- Insecticides listed for Sweet potato weevil control in sweet potatoes via **permit**:
    - Chlorpyrifos (various, PER14583, expires Mar 2019) - Group 1B contact / systemic insecticide:
        - Occasionally used 0-3 x/crop.
        - Effective.
        - Also controls wireworm.
        - Poor IPM compatibility.
        - Growers want 'softer' alternative.
        - Disruptive to beneficial insects.

- Possible other insecticide to include:
    - Fipronil is reported to have activity on Sweetpotato weevil adults

Whitefringed weevil (*Naupactus leucoloma*)

The adults chew on the edges of leaves and the larvae chew holes and furrows in tubers.

The larvae are whitish grubs with brown heads and curved bodies. Immature larvae are 1 mm long and grow to 12 mm long. The larvae pupate in the soil, and the weevils push their way to the surface and feed on nearby plants.
Damage to tubers causes them to be downgraded at harvest and result in loss of early plant growth vigour.

- Whitefringed weevils are considered a major pest in all regions.

- Insecticides registered for the control of Whitefringed weevil in sweet potatoes are:
  - Fipronil (various) Group 2B contact/systemic insecticide
    - Commonly used on all crops.
    - Very effective when used as a soil surface spray and incorporated.
    - Grower concern with the development of Whitefringed weevil resistance resulting from fipronil overuse.

- No insecticides are listed for Whitefringed weevil control in sweet potatoes via permit:

Growers did not indicate through the SARP process how they control whitefringed weevil. Indications from the literature are that:

- Insecticides that manage other weevils have similar efficacy in whitefringed weevil.
- Population reduction is likely to be only temporary if used alone
- Biological control options have limited efficacy.
- Cultural control is essential alongside use of insecticides, including
  - Rotation with fallow or crops less preferred by weevils eg grass crops
  - Farm hygiene (Barnes and De Barro, 2009)

Wireworm (*Elateridae*)

Initially the wireworm larvae make a small hole in the skin of the sweet potato, then eat an enlarged cavity just under the skin. The skin over the cavity dies, leaving ragged edges on recent scars and an open cavity on healed scars.

Wireworm scars are usually randomly scattered over the root. Wireworm damage is reported to be greatest late in the season producing many fresh scars at harvest.
Secondary infection of the wounds may cause rot of some storage roots, but more often the scars heal.
The roots are still edible, but may not be marketable.

Storage root surface is damaged with round to irregular crater-like holes or shallow channels, usually less than 5 mm deep but sometimes over 1 cm. The holes are larger than those produced by sweet potato weevils,

- Wireworms are considered a major pest in all regions.
  - Feed on surface of roots, causing 'shotholes' by chewing small deep holes, leaving random damage appearance on roots.
  - Even low populations can lead to root downgrading.

- Insecticides registered for the control of wireworm in sweet potatoes are:
  - 1,3-dichloropropene + chloropicrin (various) fumigant
    - Restricted chemical – Schedule 7 dangerous poison
    - Broad vegetable claim for control of soil borne diseases as pre-plant treatment.
    - Crop rotation is preferable to fumigation.

- Bifenthrin (various) Group 3A contact / systemic insecticide
  - Commonly used by growers - once per crop.
  - Most common product for wireworm.
  - Used at high rate in furrow at planting. NOT in furrow usage. Bifentrhin is applied to soil surface and then immediately soil incorporated via rotary hoe
  - Very effective. Efficacy lasts for most of crop life.
  - Growers want alternative as concern with the development of resistance resulting from bifenthrin overuse.

- Fipronil (various) – Group 2B contact/systemic insecticide
  - Commonly used by growers - once per crop.
  - Usually applied at transplant.
  - Very effective.
  - QDPI have successfully tested 1/4 rates early post-transplant via trickle - very effective.
  - Grower concern with the development of resistance resulting from fipronil overuse.

- Insecticides listed for wireworm control in sweet potatoes via permits are;
  - Chlorpyrifos (various, PER114583, expires Mar 2019) - Group 1B contact / systemic insecticide:
    - Used at high rates soil incorporated prior to planting
    - Crop protection duration found to be not as long as bifenthrin.
    - Also controls sweet potato weevil.
    - Poor IPM compatibility.

  - Phorate (various, PER13902, expires Mar 2018) - Group 1B contact / systemic insecticide:
    - Occasionally used by some growers – maximum of one application per crop.
    - Once commonly used, but now found to be ineffective.
    - Use has decreased dramatically - now use bifenthrin instead.

4.3.2 Summary

High Priority Insects and control options

There are limited chemical control options for all insects identified as high priorities in sweet potato. In all cases the chemistry is old and softer options are required to fit with IPM programs. If the insects identified are not controlled the crop value may be severely diminished.

Insect	Control option
Silverleaf (Poinsettia) whitefly (*Bemisia tabaci* - all biotypes)	**Currently registered insecticides** - Imidacloprid (various) - Group 4A contact / systemic insecticide. - Potassium salts of fatty acids (various) – contact biological insecticide - Pyrethrins+piperonyl butoxide (various) – Group 3A contact insecticide - Spirotetramat (MOVENTO^) - Group 23 contact / systemic insecticide. **Currently permitted insecticides** None **Insecticide Gaps** Alternates with good IPM fit. **Potential insecticide solutions** - Chlorantraniliprole + thiamethoxam (DURIVO^) - Cyantraniliprole (BENEVIA^) – Group 28 contact and systemic insecticide - Metaflumizone (New BASF active) - Group 22B **Non-chemical options** Best management practice includes the use of IPM compatible insecticides in combination with beneficials.

Insect	Control option
Weevils	**Currently registered insecticides** - Bifenthrin (various) Group 3A insecticide. - Carbaryl (various) Group 1A contact and systemic insecticide. - Fipronil (various) Group 2B contact/systemic insecticide. **Currently permitted insecticides** - Chlorpyrifos (various, PER14583, expires Mar 2019) - Group 1B contact / systemic. **Insecticide Gaps** Soft chemistry to protect beneficials. **Potential insecticide solutions** A range of actives have in-crop weevil approvals for other crops and also have MRLs established. These include imidacloprid and maldison **Non-chemical options** - Use of tolerant sweet potato varieties - IPM, including population monitoring
Wireworm (*Elateridae*)	**Currently registered insecticides** - 1,3-dichloropropene + chloropicrin (various) fumigant - Bifenthrin (various) Group 3A contact / systemic insecticide - Fipronil (various) – Group 2B contact/systemic insecticide **Currently permitted insecticides** - Chlorpyrifos (various, PER14583, expires Mar 2019) - Group 1B contact / systemic. - Phorate (various, PER13902, expires Mar 2018) - Group 1B contact / systemic insecticide: **Insecticide Gaps** Soft chemistry to protect beneficials. **Potential insecticide solutions** None identified **Non-chemical options** - IPM strategies

Currently available insecticides

Insect	Active		WHP, days	Chemical Group
Ants	Pyrethrins+Piperonyl Butoxide		1	3A
Aphids	Dimethoate		7	1B
	Phorate	(PER13902, expires Mar 2018)	91	1B
	Pirimicarb	PER13032-PIRIMOR	2	1A
	Potassium Salts of Fatty Acids		NR	-
	Pyrethrins+Piperonyl Butoxide		1	3A
Aphid - Green Peach	Sulfoxaflor (TRANSFORM^)		1	4C

Insect	Active	WHP, days	Chemical Group
Armyworm	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
Cabbage Moth	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
	Trichlorfon	2	1B
Cabbage White Butterfly	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
	Flubendiamide (BELT^)	1	28
	Trichlorfon	2	1B
Caterpillars	Pyrethrins+Piperonyl Butoxide	1	3A
Cluster Caterpillar	Flubendiamide (BELT^)	1	28
	Methomyl (PER13395, expires Sep 2014)	3	1A
Crickets	Chlorpyrifos	NR	1B
	Fipronil	NA	2C
Cucumber Moth	Methomyl (PER13395, expires Sep 2014)	3	1A
Cutworm	Chlorpyrifos	NR	1B
Diamondback Moth	Flubendiamide (BELT^)	1	28
Grasshopper - Wingless	Chlorpyrifos	NS	1B
	Dimethoate	7	1B
Green Vegetable Bug	Trichlorfon	2	1B
Helicoverpa	Flubendiamide (BELT^)	1	28
	Methomyl (PER13395, expires Sep 2014)	3	1A
	Spinosad	3	5A
Helicoverpa Armigera (Corn Earworm / Cotton Bollworm)	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
Helicoverpa Punctigera (Native Budworm)	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
Jassids	Dimethoate	7	1B
	Phorate (PER13902, expires Mar 2018)	91	1B
Leafhoppers	Pyrethrins+Piperonyl Butoxide	1	3A
Leafminer – Potato Moth	Flubendiamide (BELT^)	1	28
	Spinetoram (SUCCESS NEO^)	3	5
Lightbrown Apple Moth	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
Lightbrown Apple Moth	Spinetoram (SUCCESS NEO^)	3	5
Loopers	*Bacillus thuringiensis subsp. kurstaki*	NR	11C
	Spinetoram (SUCCESS NEO^)	3	5
Mealybug	Potassium Salts of Fatty Acids	NR	-
Mites	Dimethoate	7	1B
Mite - Two-Spotted, Organophosphate Susceptible	Phorate (PER13902, expires Mar 2018)	91	1B
Mite - Two Spotted Mite (Red Spider Mite)	Propargite	7	12C
	Sulphur	NR	_
	Potassium Salts of Fatty Acids	NR	-

Insect	Active		WHP, days	Chemical Group
Nematodes	1,3-dichloropropene + chloropicrin		NR	8B
	Oxamyl	(PER14582, expires Sept 2015, NSW, Qld only)	NR	1A
Rutherglen Bug	Trichlorfon		2	1B
Soil borne pests and diseases	Dazomet	Fumigant	NR	_
	Metham sodium		NR	_
Symphylans (Garden Centipedes)	1,3-dichloropropene + chloropicrin		NR	8B
Thrips	Dimethoate		7	1B
	Methyl Bromide	(PER11092, PER10145, expires Oct 2014, not persons generally)	3	8A
	Phorate	(PER13902, expires Mar 2018)	91	1B
	Potassium Salts of Fatty Acids		NR	-
	Pyrethrins+Piperonyl Butoxide		1	3A
Weevil - White Fringed	Fipronil		0(H), *(G)	2C
Weevil - Sweet Potato	Bifenthrin		1	3A
	Carbaryl		3	1A
	Chlorpyrifos	(PER14583, expires Mar 2019) (Qld, NSW, WA, NT)	14	1B
Weevil - Vegetable	Carbaryl		3	1B
	Chlorpyrifos		NR	1B
Whiteflies	Pyrethrins+Piperonyl Butoxide		1	3A
	Potassium Salts of Fatty Acids		NR	-
Whitefly – Greenhouse	Botanical Oil		NR	-
Whitefly - Silverleaf	Imidacloprid		NA	4A
	Spirotetramat (MOVENTO^)		7	23
Wireworms	1,3-dichloropropene + chloropicrin		NR	8B
	Bifenthrin		1	3A
	Chlorpyrifos	(PER14583, expires Mar 2019) (Qld, NSW, WA, NT)	14	1B
	Fipronil		0(H), *(G)	2C
Wireworm - Organophosphate Susceptible	Phorate	(PER13902, expires Mar 2018)	91	1B

*Do not graze or cut for stockfood
NR= Not required
H=Harvest
G=Grazing

4.3 Weeds of sweet potatoes

- Registered and permitted herbicides used in sweet potatoes:
  - Chlorthal-dimethyl (various) Group D general knockdown and residual herbicide
    - Not reported to be used
  - Diquat (various) – Group L general knockdown pre-plant and desiccation herbicide
    - Occasionally used by growers.
    - Used pre-planting.
    - Effective in controlling a wide range of weeds.
  - Fluazifop-P as butyl (various) (PER13394, expires Sep 2015) Group A grass selective post-emergent herbicide
    - Commonly used by most growers.
    - Used for post-em grass control.
    - Very effective.
  - Glyphosate (various) Group M pre-plant general knockdown herbicide
    - Used pre-planting.
    - Effective in knockdown of a wide range of weeds, although they re-grow soon after.
  - S- Metolachlor (various) Group K pre-plant residual herbicide
    - Not used.
    - Paraquat + diquat (various) Group L pre-plant general knockdown herbicide
    - Used pre-planting.
    - Effective in controlling a wide range of weeds.
  - Sethoxydim (various) Group A grass selective post-emergent herbicide
    - Occasionally used.
    - Used for post-em grass control - very effective.
- Weeds identified as a high priority for control:
  - Volunteer sweet potato
    - Major problem in crop rotations as carries over nematodes, wireworm and weevil.
    - Glyphosate +/- 2,4-D used in rotational crops - effective in controlling current weeds, but roots reshoot soon after.
  - Broad leaf weed control
    - Major problem during crop establishment, within the first 21 days after planting

5. References

Information

- Australasian Biological Control website.
- Australian Horticultural Statistics Handbook, 2003.
- Australian Pesticide and Veterinary Medicines Authority website.
- Ausveg 'Commodity spotlight – sweet potatoes' (2011) website.
- Barnes T, De Barro J. Improving pest management in the Australian Lucerne Industry. RIRDC Publication 09/172. 2009
- Biobest website.
- CSIRO Handbook of Australian Insect names (1993) Ian Naumann
- IPM Technologies (Paul Horne) Milestone report. Project: Pesticide effects on beneficial insects and mites in vegetables.
- Infopest, Department of Primary Industries and Fisheries, Queensland Government, July 2012.
- McMaugh J. What garden pest or disease is that? 1989.
- New South Wales Department of Primary Industries website.
- Pest management strategy documents for Queensland's fruit and vegetable industries, Queensland Fruit and Vegetable growers, 2008.
- Queensland Department of Primary Industries.Managing insects and mites in horticultural crops, 1996.
- Qld Department of Primary Industries. Diseases of Vegetable Crops, 1994.
- The IR-4 Project website.
- University of California, Agriculture and Natural Resources website.
- UC Pest Management Guidelines website.
- USA Foreign Ag Service website.

Images:

- Google images
- Infopest, Department of Primary Industries and Fisheries, Queensland Government, July 2012.

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)
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

Australian states and territories: NSW (New South Wales), NT (Northern Territory), Qld (Queensland), SA (South Australia), Tas (Tasmania), Vic (Victoria), WA (Western Australia)

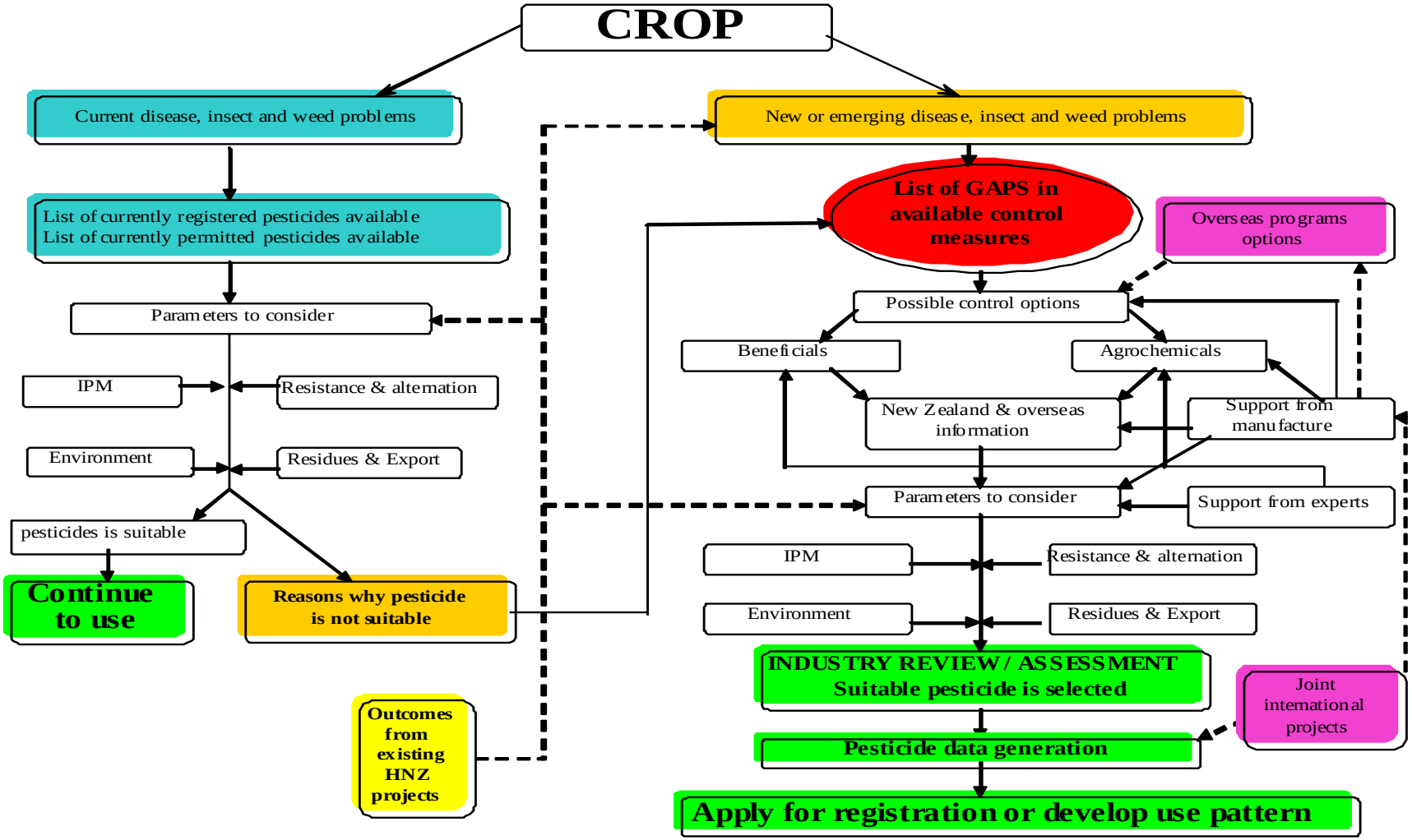
Acknowledgement

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 sweet potato.

Active		Disease / Pest	WHP, days	Chemical Group
1,3-dichloropropene + chloropicrin		Soil Borne Diseases Incl Fusarium, Verticillium Wilts, Rhizoctonia, Pythium	NR	–
Boscalid		Scleotinia Rot	7	7
Fenamiphos	NEMACUR	Soil Borne Plant Parasitic Nematodes	1B	8B
Oxamyl	PER13465 - VYDATE	Nematodes (Meloidogyne Sp.)	NR	1A
Penthiopyrad (FONTELIS^)		Early Blight/Target Spot/Leaf Spot (Alternaria Solani)	7	1
Penthiopyrad (FONTELIS^)		Powdery Mildew	7	1
Sulphur		Bean Rust	NR	M2
Sulphur		Powdery Mildew	NR	M2
Thiabendazole	(PER12047, expires Sep 2016)	Field Rots Caused By Scurf (*Monilochaetes Infuscans*)	NR	1
Thiabendazole	(PER12047, expires Sep 2016)	Root Rot (*Fusarium* Spp.)	NR	1

NR= Not required

Appendix 3 – currently available insecticides in sweet potato.

Active		Insect	WHP, days	Chemical Group
1,3-dichloropropene + chloropicrin		Plant Parasitic Nematodes	NR	8B
1,3-dichloropropene + chloropicrin		Symphylans (Garden Centipedes)	NR	8B
1,3-dichloropropene + chloropicrin		Wireworms	NR	8B
Bacillus thuringiensis subsp. kurstaki		Armyworm	NR	11C
Bacillus thuringiensis subsp. kurstaki		Cabbage Moth	NR	11C
Bacillus thuringiensis subsp. kurstaki		Cabbage White Butterfly	NR	11C
Bacillus thuringiensis subsp. kurstaki		*Helicoverpa Armigera* (Corn Earworm / Cotton Bollworm)	NR	11C
Bacillus thuringiensis subsp. kurstaki		*Helicoverpa Punctigera* (Native Budworm)	NR	11C
Bacillus thuringiensis subsp. kurstaki		Lightbrown Apple Moth	NR	11C
Bacillus thuringiensis subsp. kurstaki		Loopers	NR	11C
Bifenthrin		Weevil - Sweet Potato	1	3A
Bifenthrin		Wireworm	1	3A
Botanical Oil		Whitefly – Greenhouse	NR	-
Carbaryl		Weevil - Sweet Potato	3	1A
Carbaryl		Weevil - Vegetable	3	1B
Chlorpyrifos		Cricket – Field, Mole	NR	1B
Chlorpyrifos		Crickets - Including Black Field Cricket, Mole Crickets	NS	1B
Chlorpyrifos		Cutworm	NR	1B
Chlorpyrifos		Grasshopper - Wingless	NS	1B
Chlorpyrifos	(PER14583, expires Mar 2019) (Qld, NSW, WA, NT)	Sweet Potato Weevil	14	1B
Chlorpyrifos		Weevil - Spotted Vegetable	0	1B
Chlorpyrifos		Weevil - Sweet Potato	0	1B
Chlorpyrifos		Weevil - Vegetable	NS	1B
Chlorpyrifos		Weevil - Vegetable	NR	1B
Chlorpyrifos	(PER14583, expires Mar 2019) (Qld, NSW, WA, NT)	Wireworm	14	1B
Dazomet	Fumigant	Soil borne pests and diseases	NR	_
Dimethoate		Aphids	7	1B
Dimethoate		Grasshopper - Wingless	7	1B
Dimethoate		Jassids	7	1B
Dimethoate		Mites	7	1B
Dimethoate		Thrips	7	1B
Fipronil		Cricket - Mole	NA	2C
Fipronil		White Fringed Weevil	0(H),	2C

Active		Insect	WHP, days	Chemical Group
			*(G)	
Fipronil		Wireworm	0(H), *(G)	2C
Flubendiamide (BELT^)		Cabbage White Butterfly	1	28
Flubendiamide (BELT^)		Cluster Caterpillar	1	28
Flubendiamide (BELT^)		Diamondback Moth	1	28
Flubendiamide (BELT^)		Helicoverpa	1	28
Flubendiamide (BELT^)		Potato Moth	1	28
Imidacloprid		Whitefly - Silverleaf	NA	4A
Metham sodium		Soil borne pests and diseases	NR	_
Methomyl	(PER13395, expires Sep 2014)	Cluster Caterpillar	3	1A
Methomyl	(PER13395, expires Sep 2014)	Cucumber Moth	3	1A
Methomyl	(PER13395, expires Sep 2014)	Helicoverpa	3	1A
Methyl Bromide	(PER10145, expires Oct 2014, not persons generally)	Thrips	3	8A
Methyl Bromide	(PER11092, expires Oct 2014, not persons generally)	Thrips	3	8A
Oxamyl	(PER14582, expires Sept 2015, NSW, Qld only)	Nematodes	NR	1A
Phorate	(PER13902, expires Mar 2018)	Aphids	91	1B
Phorate	(PER13902, expires Mar 2018)	Jassids	91	1B
Phorate	(PER13902, expires Mar 2018)	Mite - Two-Spotted, Organophosphate Susceptible	91	1B
Phorate	(PER13902, expires Mar 2018)	Thrips	91	1B
Phorate	(PER13902, expires Mar 2018)	Wireworm - Organophosphate Susceptible	91	1B
Pirimicarb	PER13032- PIRIMOR	Aphids	2	1A
Potassium Salts of Fatty Acids		Aphids	NR	-
Potassium Salts of Fatty Acids		Mealybug	NR	-
Potassium Salts of Fatty Acids		Thrips	NR	-
Potassium Salts of Fatty Acids		Two Spotted Mite / Spider Mite	NR	-
Potassium Salts of Fatty Acids		Whitefly	NR	-
Propargite		Two Spotted Mite (Red Spider Mite)	7	12C
Pyrethrins+Piperonyl Butoxide		Ants	1	3A
Pyrethrins+Piperonyl Butoxide		Aphids	1	3A
Pyrethrins+Piperonyl Butoxide		Caterpillars	1	3A
Pyrethrins+Piperonyl Butoxide		Leafhoppers	1	3A
Pyrethrins+Piperonyl Butoxide		Thrips	1	3A

Active	Insect	WHP, days	Chemical Group
Pyrethrins+Piperonyl Butoxide	Whiteflies	1	3A
Spinetoram (SUCCESS NEO^)	Leafminer – Potato Moth	3	5
Spinetoram (SUCCESS NEO^)	Lightbrown Apple Moth	3	5
Spinetoram (SUCCESS NEO^)	Loopers	3	5
Spinosad	Helicoverpa	3	5A
Spirotetramat (MOVENTO^)	Whitefly - Silverleaf	7	23
Sulfoxaflor (TRANSFORM^)	Green Peach Aphid	1	4C
Sulphur	Two Spotted Mite (Red Spider Mite)	NR	_
Trichlorfon	Cabbage Moth	2	1B
Trichlorfon	Cabbage White Butterfly	2	1B
Trichlorfon	Green Vegetable Bug	2	1B
Trichlorfon	Rutherglen Bug	2	1B

*Do not graze or cut for stockfood
NR= Not required
H=Harvest
G=Grazing

Appendix 4 – currently available herbicides in sweet potato

Active	Chemical Group
Chlorthal-dimethyl	D
Diquat	L
Fluazifop-P	A
Glyphosate	M
Paraquat+diquat	L
Sethoxydim	A
S-Metolachlor	K