Know-how for Horticulture™

Organic production systems - technology transfer

Felicity Wardlaw
TAS Department of Primary Industries, Water and Environment

Project Number: VG99002

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Know-how for Horticulture™

Tasmania

DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Organic Production Systems – Technology Transfer

Horticulture Australia Project Number: VG99002

Project Leader: Felicity Wardlaw

Tasmanian Department of Primary Industries, Water and Environment

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Horticulture Australia Ltd Project VG99002

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This is the final report of the above project. It covers the conduct and results of the project in detail, and also includes media and technical summaries.

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Media Summary

A project was undertaken to investigate organic vegetable production techniques and to identify alternative methods to manage weeds, diseases and insects that may be applicable to conventional vegetable production. A number of strategies that were identified from oversees study tours were demonstrated in field trials. The experiences and information collected from these demonstrations were brought together in a manual that forms the basis of an integrated pest management manual for the Tasmanian vegetable industry. Techniques demonstrated included:

- *Cover cropping in broccoli* – A rye corn cereal cover crop significantly reduced weed growth in broccoli. No other forms of weed management were required.

- *Insect exclusion netting* - A permeable fabric was laid over a broccoli crop to exclude insect pests from the crop. The netting worked well, although further improvements in cost, application and design are needed for it to be suited to large scale production.

- *Crop monitoring* - Monitoring was demonstrated in a commercial broccoli crop and significantly improved the timing and application of insecticides. This led to a significant reduction in the number of sprays used while still achieving effective control of insect pests.

- *Finger weeding* - A finger weeder was investigated as an alternative method of mechanical weeding in row crops. A number of factors were critical in the operation of the machine, with accuracy being paramount when the crop was small. This tool is better suited for use when the crop is more established and can more readily cope with some interaction with the tool.

- *Brush weeding* - Another way demonstrated to mechanically remove weeds from row crops was the brush weeder. The brush weeder uses a series of spinning brushes to remove small weeds from between the rows of crops such as onions, peas, carrots, lettuce, beans, potatoes and brassicas. Using a brush weeder can significantly reduce the need for post-emergence herbicides, although repeated use may damage surface soil structure.

Technical Summary

Background
Herbicides, fungicides and insecticides are all used to varying degrees to control weeds, diseases and pests in commercial vegetable production. For the grower and consumer alike, strategies that reduce the use of chemicals are considered desirable and beneficial.

This project set out to examine organic vegetable production techniques to identify alternative methods that may be applicable to conventional vegetable production in the management of weeds, diseases and insects. Organic production systems were screened for strategies to deal with a number of pest problems in the vegetable industry. A number of the strategies were then demonstrated in field trials. The experiences and information collected from these demonstrations were brought together in a manual that forms the basis of an integrated pest management manual for the Tasmanian vegetable industry.

Project findings
IPM techniques identified from oversees travel were used in demonstration trials at the Forthside Research and Demonstration Station, near Devonport, Tasmania. These demonstrations were profiled at field days held on the station during the life of the project.

- *Cover cropping in broccoli* - A rye corn cereal was used as a dead mulch cover crop in broccoli. This eliminated the need for any other form of weed control. The dense biomass of the cover crop prevented competitive weed growth.

- *Insect exclusion netting* - A fine permeable fabric was placed over broccoli to exclude major brassica pests such as diamondback moth (*Plutella xylostella*), cabbage white butterfly (*Pieris rapae*) and grey cabbage aphid (*Brevicoryne brassicae*). The netting was effective in directly excluding pests. Further improvements, such as reducing cost and improving the durability and installation of the fabric are required before this technique could be adopted into large scale vegetable production.

- *Crop monitoring* - This technique was used in a commercial broccoli crop to improve timing and application of insecticides. The presence and absence method was used to monitor insect pest activity. Crop monitoring resulted in accurate timing and application of insecticides and greatly reduced the number of spray applications required.

- *Finger weeding* - Finger weeding was used briefly in an attempt to judge the critical aspects of set up required for a satisfactory weeding result. Accuracy was paramount when the crop was small and auto-guidance would be useful to allow efficient operation of the finger weeder. Speed was also found to be important, with faster speeds (4 – 5 km/h) being more effective.

- *Brush weeding* - Brush weeding for weed control was demonstrated for carrots and other row crops. The brush weeder is a series of spinning brushes used to remove small inter-row weeds in crops such as onions, peas, carrots, lettuce, beans, potatoes and brassicas. Using the brush weeder can significantly reduce the need for post-emergence herbicides and also control soil borne pests such as cutworm (*Agrotis infusa*).

Recommendations and future work

- Regular updating of the Tasmanian vegetable grower's IPM manual should continue as new and improved techniques are identified tested and demonstrated.
- Certified courses on IPM should be developed for growers and industry.
- It is essential for a team approach to be adopted for IPM to develop and grow in the Tasmanian vegetable industry.
- Further training and emphasis should be placed on extension of the research and development done in pest management. Developing effective extension programs is the key to increase the uptake IPM on farms.
- A significant amount of work needs to be done to determine the economic impact beneficial insects (parasitoids and predatory insects - spiders, ladybirds, lacewings, hover flies etc) have in the field and to determine the current status of released predatory insects.
- Ongoing R, D&E activity is needed to support improved pest management approaches and facilitate the adoption of IPM practices.
- As weed control is one of the most difficult tasks to achieve without chemicals, there is a need for a program to obtain and demonstrate new technologies and management practices for weed management in vegetable crops.
- An Area Wide Management (AWM) approach to pest management should be investigated.

Introduction

Herbicides, fungicides and insecticides are all used to varying degrees to control weeds, diseases and pests in commercial vegetable production. For the grower and consumer alike, strategies that reduce the amount of chemicals used are considered desirable and beneficial. For the grower, provided pest management is effective and economical, non-chemical methods generally provide a safer work environment. For the consumer, there is significant market attraction in produce that is grown using “clean and green” methods. There is increasing market pressure on vegetable growers for either pesticide-free produce or produce grown with reduced pesticide applications. Integrated pest management is one strategy that growers can use in order to meet those market pressures. A comprehensive kit of strategies is needed to assist growers to make the transition from current production practices to reduced chemical practices in order to meet these market requirements promptly and efficiently.

Pressure is also being exerted on Australian exporters to maintain and expand market share by providing produce that can compete with other overseas producers in complying with consumer requirements. This pressure comes, in part, from the fact that many developed nations have government subsidies to assist in the period of adoption to new technologies.

While this project was directed at changes that could be made to “conventional” production systems, it set out to examine organic vegetable production techniques to identify alternative methods that may be applicable to conventional vegetable production to control weeds, diseases and insects. Organic production systems were screened for strategies to deal with a number of identified pest problems in the vegetable industry. A number of strategies were then demonstrated in field trials. The experiences and information collected from these demonstrations were brought together in a manual that forms the basis of an integrated pest management manual for the Tasmanian vegetable industry.

Methods

There were three distinct phases to the project.

Firstly, extensive searches of research and commercial information were undertaken, followed by overseas study tours. As part of this project, two separate study tours were undertaken to investigate organic and low input production techniques in vegetable production. The project staff who undertook these study tours had skills in pathology and engineering (from the perspective of mechanical weed control). Additional information relevant to the project was gained through three other study tours undertaken by other staff and funded from other sources. One was to New Zealand, as part of an RIRDC funded project (Integrated Development of Intensive Vegetable Organic Production Systems). Another was undertaken as part of a Churchill Fellowship (An Investigation into Advanced Integrated Pest Management Techniques, Systems, and Adoption in Denmark, Sweden, Finland, Holland, and the United Kingdom with Potential Application in Australian Horticulture). The third was an International Rural Youth Exchange to Sweden (Observing Integrated Pest Management (IPM) and Organic Practices in Sweden's Vegetable Industry).

Secondly, promising IPM techniques that were identified as part of the study tours and information searches were used in demonstration trials at the Forthside Research and Demonstration Station, near Devonport, Tasmania. These demonstrations were profiled at field days held on the station during the life of the project.

Thirdly, a manual for the application of IPM in vegetables was produced as an aid for growers wishing to develop and pursue an IPM pathway in their production system. The manual is not an all encompassing document on vegetable IPM in temperate regions. Rather it is a base level manual which covers the main features of an IPM program and outlines the strategies that were tried as part of this project. IPM in temperate vegetables is a complex and broad subject. The manual is structured so that additional information can be added in the future to expand its usefulness.

Some of the techniques identified and demonstrated included:

Cover cropping for weed suppression in brassicas: A rye corn cereal cover crop was used as a dead mulch to suppress weed growth in broccoli. The cover crop was selected for its ability to produce a relatively high biomass as well as its reported allelopathic affect. The crop was sown at a rate of 160 kg/ha in late spring into pre-made beds 8 weeks prior to broccoli transplanting. Two seed tubes on the drill were blocked off to leave two small rows free of the cover crop. The broccoli crop (Marathon variety) was transplanted into these rows. The cover crop was used as dead mulch, and 0.74 l/ha of glyphosate was applied to kill the rye corn. It was left for 7-10 days to die off. The cover crop was then rolled flat immediately prior to broccoli planting. The broccoli were transplanted two rows per bed into the two rows that were not planted with ryecorn.

Insect exclusion netting: A fine white mesh was placed over the crop to form a netting barrier to protect the crop from flying insect pests such as diamondback moth (DBM) cabbage white butterfly (CWB) and aphids. The mesh was placed over each plant bed immediately after broccoli transplanting. Sandbags were used to hold the netting down and only removed for weeding operations and harvest. Insect activity was closely monitored.

Brassica crop monitoring: Crop monitoring was carried out twice weekly at Forthside Research and Demonstration Station during the 2003-04 broccoli growing period. Twenty-five randomly selected plants across the cropped area were monitored using the 'presence and absence' method, which involves inspecting each plant and noting 'yes' or 'no' to any sign of pest activity. Only plants with alive and active grubs, fresh grub faeces or fresh feeding damaged were noted as 'yes' for pest presence. Diamondback moth (DBM) (*Plutella xylostella)* was the main brassica pest monitored. Predatory and parasitic insects were monitored by using yellow sticky mats and by visual noting. Ladybirds, hoverfly, lacewing and shield bugs were some of the main predatory insects that were monitored. The level of parasitic wasp activity was noted by inspection of pest cocoons. Two DBM pheromone traps were placed in the 3.5 hectare paddock to monitor DBM moth activity.

Finger weeding – although finger weeding equipment was obtained for trial and demonstration, seasonal circumstances prevented an in-depth investigation of the potential of this method of mechanical weeding in row crops. It was used briefly in a preliminary assessment of its value in removing intra-row weeds and inter-row weeds that were near to the crop row in cucurbits about 2 weeks after emergence.

Brush weeding in carrots*:* Brush weeding was demonstrated, primarily in carrots, although it proved to be a useful alternative to herbicides in other crops including broccoli, potatoes, peas, beans, onions and squash. The broad aspects that were investigated in carrots were determining:

- sowing configurations compatible with efficient brush weeding
- the number of operations required to effectively manage weeds

The following crop row configurations were evaluated :

- Four single rows evenly spaced across the bed
- Four rows with seed scattered in a 40 mm band
- Three double rows (75 mm pairs on 330 mm centres) as sown commercially for top pull harvesting of fresh market carrots.
- Triple/Double- a configuration used for standard processing carrots with outside triple rows at 50 mm and two pairs of inside double rows at 100 mm, giving a total of 10 rows across the bed.

To determine the best timing of brush weeding on carrots the following options were investigated:

- *Pre* – Brushing weeding after weeds had germinated but prior to most of the weeds emerging
- *2 TL* – Brushing weeding when most of the weeds were at the 2 true leaf stage.
- *2 TL+* - Brushing weeding about 2 weeks after 2TL when most of the weeds were at the 4 - 6 true leaf stage.

Detailed results & Discussion

Details from study tours
The two study tours undertaken as part of this project have been reported previously as part of the Horticulture Australia Limited reporting requirements for this project. A brief summary of the pertinent points is given below.

UK & Europe study tour – June, 2000 (J Dennis, Field Fresh Tasmania)
The study tour encompassed a number of commercial farms and research institutions involved with organic and low input vegetable production. Several organic production techniques were observed that could be implemented in conventional production:

- Trickle irrigation for potato production is used to reduce the incidence of target spot and Irish blight and to help control the level of both common and powdery scab.
- For crops grown from transplants, such as broccoli, the use of vetch or rye cover crops to provide a pre-transplant mulch is used to suppress weed germination for 3-4 weeks. This allows the transplants to establish without competition from weeds. Vetch and rye mulches have been found to be allelopathic. Crops can be transplanted into freshly mulched vetch and rye to provide a period of weed suppression. Seeds cannot be drilled into the mulch, as they will be suppressed along with the weed seeds.
- Brush weeding is one of a number of mechanical approaches to non-chemical weed control in row crop vegetable production.
- Finger tine weeding is used for weed control in brassica and carrot crops. The soft fingers are able to brush against the stems of plants and when used on weeds at a young stage, eliminate the need for further weed control measures. When used correctly, the finger tine weeder can remove more weeds than the brush weeder, and has the added advantage of being gentler on soil structure. The finger tine weeder is limited to removing young weeds (cotyledon stage).
- The value of building soil fertility for improving plant health and restoring biological balance should not to be overlooked for benefits in conventional production. While it may not solve all problems, it helps prevent or minimise a large number of problems that otherwise require chemical control and result in crop losses.
- Fleece or Enviromesh netting is being used for the control of insects in brassica crops. The cost of the netting is high, but the system is very effective and should be evaluated for cost-effectiveness and practicality in conventional production. A similar approach is being used to control carrot fly in organic carrots. The fine white mesh is placed over the crop to form a net like barrier that protects the crop from attack by the carrot fly. The material is held down by sand bags and only removed for weeding operations and harvest. Crops (and weeds) grow faster under the netting, presumably due to the warmer microclimate created by the cover. Although expensive, the netting can be re-used and provides an extremely effective method to control insects.
- Flame weeding is widely used as an alternative to chemicals in organic carrot and onion production, particularly as a pre-emergent operation following planting into a stale seedbed.

All of these techniques could be applied or modified for use in conventional vegetable production with the aim of reducing chemical inputs.

USA & Canada study tour – August, 2001 (J McPhee, DPIWE)
The study tour encompassed mostly commercial farms with an emphasis on non-chemical weed control techniques and the use of compost as a means of building soil health.

Cultural and mechanical approaches to weed management
The key points in relation to weed control are listed below.

- Integrated weed management must be holistic.
- A knowledge of the weed spectrum in a paddock is essential to allow crop rotation and pre-plant weed management planning.
- Good ground cover (if direct drilling), or a stale seed bed, is a good start to weed management.
- Pre-plant and pre- or post-emergence tillage or flaming can be used early in the growing season as alternatives to chemicals.
- Good plant density and uniformity of sowing and establishment are important for maximum competition during the growing season.
- Green manure crops provide organic matter and competition to weeds. Green manure crops are just as important as cash crops, since they play an important role in building soil health and reducing weeds.
- Improving soil health is an important part of weed management. There is a widely held view that the presence of particular weeds indicates an imbalance in the chemical, physical and biological health of the soil.
- Living mulches under-sown to cash crops can out compete weeds in some cropping situations, and may also allow easier and more rapid establishment of ground cover after harvest, depending on the crop. The widely used practice of growing green manure crops in the Tasmanian vegetable industry could be extended to include under-sown cover crops.
- Non-selective "blind" weeding can be used pre- and post-emergence in crops like corn, peas, beans and potatoes. The tools make no distinction between weeds and crop plants, but are cheap and quick to use. Weed kills of 60 – 70% can be achieved at high work rates, and over-sowing is required to account for crop plant losses of <3%. A ground driven rotary hoe worked at 10 - 15 km/h is one tool used for “blind” weeding. Advantages claimed for “blind” weeding include high work rates and no retardation of crop growth as often occurs with herbicides.
- Compost tea is used in some areas of mainstream agriculture for disease control, such as blight control in potatoes.
- Direct drilling deserves consideration, as there may be scope for some crops to be direct drilled to retain crop residues for better soil cover and weed suppression. This approach

would require stubble handling planting equipment, but the benefits of weed suppression, soil erosion control and reduced tillage may make such changes worthwhile. Relevant equipment may include a stalk chopper, to chop and lay stalks flat on the ground to provide mulch for weed suppression, and a transplanter suited to direct drilling.

- Guidance systems are going to become important in mechanical weed control and for the wider adoption of inter-row cultivation tools which are readily available but are not widely used due to guidance and control issues.
- Improving soil organic matter and health with compost and green manure crops has been observed to reduce weed problems.
- Onions, carrots and corn can be flamed after emergence for weed control. Carrots and onions are sown a bit deeper than normal to delay emergence to allow a better weed strike before flaming.
- Any inter-row cultivation operation that hills soil around the base of the crop plants in the row helps to smother small weeds.

In addition to the points detailed above arising from the two study tours supported by this project, relevant points of interest have been extracted from other study tours supported by other funding bodies, and are detailed below.

Organic Farm Tour of New Zealand – March 2001 (Julia French, DPIWE and Sam Graham, Field Fresh Tasmania, as part of an RIRDC funded project *Integrated Development of Intensive Vegetable Organic Production Systems*.)

- Some organic growers use sheep to strip graze carrot crops soon after emergence to control weeds.
- Under-sowing of beans with grass is used for early weed-free pasture establishment after the bean crop.
- Basket weeders combined with tynes are used for inter-row weeding by some organic growers.

International Rural Youth Exchange to Sweden – June – September, 2001 (Felicity Wardlaw, DPIWE, *Observing Integrated Pest Management (IPM) and Organic Practices in Sweden's Vegetable Industry)*

- Insect exclusion netting is an efficient and effective method for insect pest management in Sweden and is used in both conventional and organic farming systems.
- Mixed cropping and cover cropping on vegetable farms was observed to be an efficient and low input method to assist with insect management. For example, onion thrips are attracted to green plants on a brown soil background. Mixed cropping would aim to increase vegetation around the crop to deter the pest from the target.
- Alleopathic cover crops, strip cropping, and mechanical weeding were observed to be effective in maintaining relatively low weed thresholds.

- Integrating herbs, clovers and legumes into pasture are techniques growers use to improve soil condition. Integration of herbs such as chikory, kummin and pimpernel all proved to be extremely beneficial especially for increasing biodiversity on the farm.
- Companion planting is important to provide biodiversity and promote beneficial and predator insects for natural insect pest control in IPM systems.
- The use and efficacy of natural sources of fertiliser (eg compost, manures), and appropriate application methods, requires investigation as alternatives to synthetic fertilisers.
- Crop monitoring is an essential component of IPM production systems.

Churchill Fellowship Tour – June – July, 2002 (Andrew Bishop, DPIWE, as part of a Churchill Fellowship *An Investigation into Advanced Integrated Pest Management Techniques, Systems, and Adoption in Denmark, Sweden, Finland, Holland, and the United Kingdom with Potential Application in Australian Horticulture*)

- Onion transplanting is widely used in Denmark to give the crop a head start on weeds in a stale seed bed.
- Plantings of host plants for beneficial insects are an essential component of IPM production systems.
- Trap cropping to attract insect pests to an area away from the main cash crop is a technique to be explored as part of an IPM strategy.
- Blight forecast systems and other disease monitoring systems have a role to play in vegetable IPM.
- Tractors equipped for take mid- and front mounted equipment are widely used in Europe and offer clear advantages for mechanical weed control in vegetable crops due to improved visibility for the operator.
- Torsion weeders are another mechanical weeding tool that is widely used in European vegetable production.
- Automated guidance systems for mechanical weeders are going to become increasingly important to assist any transition from chemical to mechanical weed control.

Although only two of these study tours were funded by this project, the information gathered on all of the overseas excursions provided useful additional direction to the objectives of this project.

Techniques demonstrated as part of the project

Cover cropping for weed suppression

Cover cropping for weed suppression in broccoli was demonstrated at Forthside Research and Demonstration Station (Figs 1a, 1b and 1c in Appendix B). Conventional weed management practices in broccoli usually require one or two passes with a light cultivator to remove inter-row weeds as well as manual weeding with a hoe to remove competing intra-row weeds.

As part of the project demonstrations, rye corn cereal was used as a dead mulch to control weed growth in broccoli planted under exclusion netting and in broccoli without exclusion netting. Weed growth in broccoli without insect exclusion netting was minimal, with very little inter- or intra-row weed competition. The two rows that were left free of cover crop in each bed allowed for some intra-row weed growth, but not enough to out compete the broccoli plants or to warrant handweeding. The dense cover crop matting completely covered the soil in the intra-row space and wheel tracks, reducing light penetration that would otherwise induce weed growth. Weed growth over the entire planting was minimal and no other form of weed management was required. Once the crop had reached full canopy closure, the broccoli plants out competed most weeds. The reported allelopathic affect that rye corn has may have worked in some way to slow down or reduce the growth of weeds.

Cover cropping under exclusion netting proved to be a challenge. The netting provided an optimal microclimate for weed growth. The weeds were able to germinate under the dense cover crop and grow prolifically and out compete the cover crop and the broccoli plants. As a result, broccoli growth was poor with poor curd formation and development. Chickweed (*stellaria media*), fumitory (*Fumaria muralis*), fat hen (*Chenopodium album*), henbit (*Lamium amplexicaule*) and shepherd's purse (*capsella bursa-pastoris*) were identified as some of the very competitive and common weeds.

It was estimated that the rye corn cover crop would cost approximately $69.75 per hectare in labour, seed, chemical and machinery operating (Table 1). However, traded off against this cost are potential total savings on herbicide applications during the growth of the broccoli crop, and a number of indirect and long term benefits such as improved soil structure, improved water management and erosion control.

Table 1: Approximate costs/hectare associated with planting a rye corn cover crop.

Drilling of cover crop	1 hr/ha	@	$ 14.15/h	$ 14.15
Rye corn cereal	10 kg/ha	@	$ 1.30/kg	$ 13.00
Glyphosate	0.15 litre/ha	@	$ 9.00/litre	$ 1.35
Rolling	0.8 hr/ha	@	$ 4.71/hr	$ 3.75
Spraying	0.6 hr/ha	@	$ 5.48/hr	$ 3.30
Labour	2.5 hr/ha	@	$ 13.68/hr	$ 34.20
Approximate cost/ha				**$ 69.75**

Weed management in brassicas is usually not a significant problem. Using a cover crop may not directly save money, but it can eliminate the need for any form of weeding, along with the added advantages of improving a number of long term soil and crop benefits, as mentioned previously.

For crops such as onions, up to 14 applications of pre- and post-emergent herbicides are often applied, costing an average of $470/ha. A cover crop of oats may reduce this cost by eliminating a number of herbicide applications. For crops such as pumpkins, where the crop rests on bare soil, a cover crop may reduce soil-scarring damage by providing a mulch mat on which the crop rests. This can be important from an aesthetic and market viewpoint. Table 2 compares cover crop options with possible herbicide savings in a number of crops.

Table 2 Approximate cost of herbicides that could be reduced or eliminated in various crops through the use of cover crops.

Crop	Herbicides used	Rate		Cost	Total cost
Green Beans	Bentozone – 1 spray	3.0 l/ha	@	$ 36.25/l	$ 108.75
Potential herbicide costs in green beans ($/ha)					**$ 109.00**
Onions	Propachlor – 1 spray Diquat – 1 spray Paraquat - 1 spray Ethofumesate – 1 spray Linuron - 1spray Ioxynil – 1 spray	9.0 l/ha 1.5 l/ha 1.5 l/ha 2.5 l/ha 0.5 l/ha 0.5 l/ha	@ @ @ @ @ @	$ 13.16/l $ 20.75/l $ 17.40/l $ 100.00/l $ 35.00/l $ 41.00/l	$ 118.45 $ 31.10 $ 26.10 $ 250.00 $ 17.50 $ 20.50
Potential herbicide costs in onions ($/ha)					**$ 463.65**
Carrots	Linuron – 2 sprays Prometryme – 2 sprays Linuron – 2 sprays	1.5 l/ha 1.0 l/ha 2.0 l/ha	@ @ @	$ 35.50/l $ 16.70/l $ 35.50/l	$ 106.50 $ 33.40 $ 71.00
Potential herbicide costs in carrots ($/ha)					**$ 210.90**
Peas	Metribuzin – 1 spray Cyanazine – 1 spray	0.25 l/ha 2.0 l/ha	@ @	$ 70.00/l $ 6.50/l	$ 17.50 $ 53.00
Potential herbicide costs in green beans ($/ha)					**$ 70.50**
Potatoes	*Pre cultivation* Glyphosate – 1 spray Dicamba – 1 spray *Post-plant* Metribuzin – 1 spray *Pre-harvest* Diquat 200v – 1 spray Paraquat 250v – 1 spray	 3.0 l/ha 250 ml/ha 700 ml/ha 2.0 l/ha 2.0 l/ha	 @ @ @ @ @	 $ 8.50/l $ 18.10/l $ 70.00/l $ 20.75/l $ 17.40/l	 $ 25.50 $ 4.50 $ 49.00 $ 41.50 $ 34.80
Potential herbicide costs in potatoes ($/ha)					**$ 155.30**

(Figures extracted from DPIWE Hicrop2002)

Insect exclusion netting

Insect exclusion netting was demonstrated at the Forthside Research and Demonstration Station on a small broccoli planting (Fig 3, Appendix B). The netting was used to exclude brassica pests such as diamondback moth (DBM), cabbage white butterfly (CWB) and aphids.

Although effective in excluding insect pests, the durability of the fabric was only 3-5 weeks before it became ineffective. The netting proved effective in excluding the pests in the areas where the netting hadn't become damaged or torn. Areas where the netting was damaged had significant pest damage.

Monitoring and pesticide application proved to be a difficult task, as the netting needed to be lifted from the crop. This process further damaged the netting.

Weed pressure was high in the areas that were under the netting. The netting provided glasshouse like conditions where air and soil temperatures were higher than the outside conditions. Weed growth flourished in such conditions and out grew the broccoli and the netting.

In many European countries the exclusion netting is used on a large scale in broad acre vegetable production, with fabric being used re-used for 3 to 5 years. Our harsh UV conditions may well lead to the breakdown and deterioration of the netting.

It was estimated that an additional $2,512.19 per hectare would be required for installation of the insect exclusion netting (Table 4). The labour costs of installing insect netting are high and therefore it may be uneconomical in most conventional vegetable production systems. However, with improved methods of mechanical installation and better durability of the netting, it may eventually prove useful.

Table 4: Approximate costs that will be incurred if installing the netting by hand.

Material	White netting 1000m x 3.2m	$550.00	3,200m²	@	$1718.75/ha	$1718.75
Labour	Installation, removal and upkeep.	48	hours	@	$ 13.68 / hr	$ 656.64
Tractor / plant	Installation	10	hours	@	$ 13.68 / hr	$ 136.80
Approximate cost ($/ha)						**$2512.19**

For small-scale organic vegetable production, this method can be an extremely useful insect management tool, as the area planted using netting did not require any insecticides. Table 5 shows potential savings that could be made on insecticides if the insect exclusion netting was used. The figures do not include labour and machinery savings.

Table 5: Potential insecticide savings that could be made when using insect exclusion netting. The figures do not include savings on machinery or labour costs.

Crop	Insecticide	Rate		Cost	Total cost
Broccoli	Permethrin – 5 sprays Primicarb – 5 sprays	0.1 l/ha 0.5 kg/ha	@ @	$160.00 /litre $ 56.00 /kg	$ 80.00 $140.00
Potential pesticide savings in broccoli ($/ha)					**$220.00**
Onions	Dimethoate – 3 sprays	0.6 l/ha	@	$ 9.75 /litre	$ 17.55
Potential pesticide savings in onions ($/ha)					**$ 17.55**
Carrots	Chlorpyrifos – 2 sprays Dimethoate – 1 spray	0.7 l/ha 0.8 l/ha	@ @	$ 19.90 /litre $ 9.74 /litre	$ 27.85 $ 7.80
Potential pesticides saving in carrots ($/ha)					**$ 35.65**
Green Beans	Chlorpyrifos – 1 spray	1.0 l/ha	@	$ 19.90 /litre	$ 19.90
Potential pesticide saving in green beans ($/ha)					**$ 19.90**

(Figures extracted from DPIWE Hicrop2002)

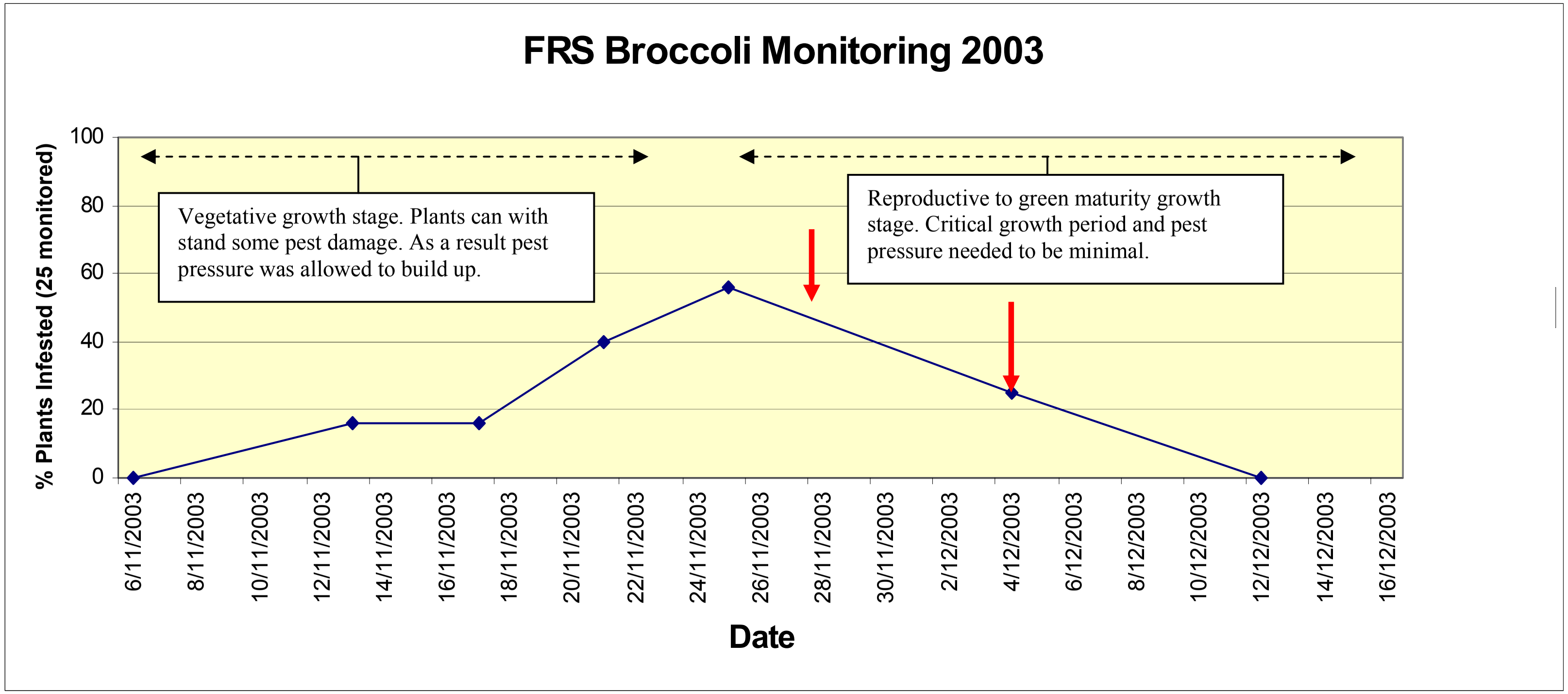
Broccoli crop monitoring

Results from each monitoring session of the broccoli were documented, graphed, interpreted and issued to the farm manager (Graph 1). The results indicated DBM pest activity as a percentage of the crop infested. The growth stage of the crop and the level of infestation determined when and what control needed to be implemented. The red arrows on the graph indicate when chemical control was required. Chemical selection was important in order to preserve the beneficials. Entrust® (refer to Appendix A for information sheet) was selected for its organic certification, and its ability to control most pests while having minimal effect on the beneficial population.

The first application was applied at a 60% level of DBM infestation when the crop was nearing curd formation. This is a critical growth stage and the pest level needed to be close to 0% infestation. Prior to this time the plant can withstand some pest damage. Once the crop commences curd formation, the grubs that were feeding on the outer part of the plant tend to move in and shelter and feed in the curd, making it difficult to achieve insecticide contact with the pest.

The second application of Entrust ® was applied 8 days after the first application. Although pest pressure had dropped, there were still some live grubs feeding in or around the curd. Following this application, pest pressure dropped to zero percent. There was a significant number of beneficials in the crop, which seemed to be working to manage pest level. As a result, no more insecticide applications were required for the rest of the crop growth stages.

Graph 1: Diamondback moth (*Plutela xylostella)* monitoring in broccoli that was carried out at Forthside Research and Demonstration Station, near Devonport, Tasmania.



Finger weeder
As mentioned previously, seasonal constraints prevented extensive use of the finger weeder. It was, however, used briefly in an effort to judge the critical aspects of set up in order to achieve a satisfactory weeding result. It became clear during this exercise that a number of factors were critical in the operation of the machine. Accuracy is paramount when the crop is small. If the crop row is not straight, or there is no guidance system, the finger weeder can readily remove a large number of crop plants. This is the primary reason that finger weeders are mostly used when the crop is larger and can more readily cope with some interaction with the tool. Speed is also important, with faster speeds (4 – 5 km/h) being more effective. It is possible to achieve intra-row weeding with the finger wheels set close to the edge of the crop row, provided the crop plant is large enough to cope with the action of the finger weeder. This means that the main weeding action is in and close to the row, requiring additional tools to be mounted on the same machine to deal with the inter-row weeds.

Brush weeding
Brush weeding was demonstrated for mechanical weed removal in carrots. The weeder was also demonstrated in other row crops including onions, peas, broccoli, squash and beans. The brush weeder consists of a series of brushes mounted on a horizontal axle that spans the bed width. The axle is PTO driven so that the spinning brushes remove small weeds from between the rows of crops. (Refer to Appendix B for photographs of the brush weeder.) Using the brush weeder significantly reduced the need for post-emergence herbicides.

The number of times the carrots needed to be brushed depended on weed density and the rate of crop canopy growth. Up to three weeding operations were used in the demonstration. The optimum time seems to be about the 2 - 4 true leaf stage. Delaying brushing to this stage of weed growth meant only one brushing was required for most of the row configurations used. For mid-spring sowing, it could be expected that 1 or 2 operations may be necessary depending on weed species and the conditions affecting successive weed strikes. For later sown carrots, only one brushing is required as the carrots grow and become more competitive more quickly.

It proved possible to satisfactorily brush weed all configurations used, and brushing 10 rows across a bed (triple/double configuration) was surprisingly no more difficult than to do four single rows. There was little difference in machine setup time between the various configurations. At the first brushing, a 15 mm wide brush segment could be set between 75 mm paired rows (3Ds) and 30 mm width of brush between 100 mm pairs (T/D). No brush could be set between the triples at 50 mm (T/D), meaning there was no inter-row weed control between the close spaced twin rows. Close brushing of this nature could only be done at very slow speeds.

The rate of brushing was essentially dependent on the size of the carrots and the closeness of the guards and brushes to the row. Speeds achieved ranged from 0.8 - 2 km/h (7.6 - 3.0 hours/ha). Higher speeds may be possible with more experience, but without guidance systems, speeds would be limited to about 4 km/h at wide row clearances.

Brushing when the carrots were only at the cotyledon to one true leaf stage required slower speeds to allow accurate tracking of the rows and to avoid smothering the small seedlings. Higher travel speeds were possible when the carrots were larger and wider guards were used. In these circumstances, tracking was easier and smothering became less important. Widening the guards was the main factor in allowing higher speeds.

Soil conditions at the time of weeding had a large influence on the success of the operation. Soil that was too wet allowed the weeds to re-strike, and also clogged the brushes. Soil that was too dry can be easily eroded by the wind. Also, weeds were often more difficult to remove from dry soil. Slightly moist to dry soil tended to suit the brush weeder best.

Using the brush weeder also eliminated some of the soil borne pests, such as cutworm. It is thought that the brushes pulverise the grub, which sits on or just below the soil surface during the day.

An economic assessment of brush weeding indicates it would cost approximately $155 per hectare for a single brush weeding operation (Table 3). This cost includes labour for two people (one to drive the tractor, the other to operate the weeder) and the tractor running costs. The initial capital cost of the brush weeder would be around $15,000.

Table 3 Estimated brushweeding costs per operation**

Labour	2 people	3.5 hr/ha	@	$ 13.68/hr	$ 95.75
Tractor / Plant		3.5 hr/ha	@	$ 6.55/hr	$ 22.95
Approximate running costs ($/ha) *					**$ 118.70**

**2- 4 runs maybe required.
* Does not include the cost of purchasing the brushweeder.

Table 2, shown previously in relation to the cover cropping demonstration, identifies possible savings that could be made by using a brush weeder instead of, or in conjunction with, herbicide applications. Further savings could be made by using more technologically advanced brush weeeders with guidance systems, or front mounted brush weeders, the purpose being to remove the need for the second person to steer the weeder.

IPM Manual

As a result of this project, a manual has been produced as an aid for growers wishing to develop and pursue an IPM pathway in their production system. The manual is not an all encompassing document on vegetable IPM in temperate regions. Rather it is a base level manual which covers the main features of an IPM program and outlines the strategies that were tried as part of this project.

The manual is made up of five sections:

- The first section is a basic overview and introduction to the principles and components that make up an IPM system and how it fits into a whole farm plan. It broadly defines and discusses the biological, cultural, mechanical and chemical tools in an IPM system, how to monitor crops and the processes and steps involved in getting started with IPM. Pesticide resistance management and spray calibration and application are also covered.

- The second section, titled ‘IPM in practice’, provides information on all the techniques that were demonstrated through the life of the project including cover cropping, insect exclusion netting, crop monitoring, finger weeding and brush weeding. There is also some information on future advances to improve pest management, such as the use of guidance systems for better weed control.
- The next three sections detail the major diseases, insects and weed pests of the major vegetable crops grown in Tasmania. A comprehensive list of the biological, cultural, mechanical and chemical options is provided to give options to integrate a selection of management options rather than relying solely on chemical control.

Technology transfer

Field days and workshops

- *December 1999-2003*. The techniques described in this report were demonstrated in the field and were displayed at the annual Forthside Research and Demonstration Station field day. Approximately 100-150 growers and industry representatives attend the field day each year, which displays all research and development activities carried out on the station.
- *'IPM Road Tour 2003':* Findings from recent travel tours as well as updates of current project work was compiled and delivered to growers, industry and DPIWE staff at three locations - Burnie, Launceston and Hobart.
- Several brassica pest management workshops and training session were held across the State. The workshops combined the developments and findings from the HAL funded project 'Advancing the Integrated Management of Diamondback Moth (DBM) in Crucifer Vegetables'(VG00055) and this project 'Organic Production Systems – Technology Transfer'.

Publications

Several articles were published in Tas-Regions, a quarterly magazine produced by the Department of Primary Industries Water and Environment and distributed to all primary producers in the State.

- Tas-Regions August 2000. *Integrated Pest management News – Slugs and snail control.* Andrew Bishop (DPIWE)
- Tas-Regions March 2001. *Integrated Pest Management: Using the toolbox part 1.* Andrew Bishop (DPIWE)
- Tas-Regions June 2001. *Integrated Pest Management (IPM) – what a good strategy needs part 2*. Andrew Bishop (DPIWE).
- Tas-Regions December 2001. *Brushing the weeds away*. Roger Orr (DPIWE)
- Tas-Regions June 2002. *Keeping weeds under cover*. Felicity Wardlaw (DPIWE).
- Tas-Regions September 2002. *The good bugs that eat the bad bugs*. Felicity Wardlaw (DPIWE)
- Tas-Regions December 2002. *Crop Scouting – minimising risk, reducing pesticides*. Felicity Wardlaw (DPIWE).
- Tas-Regions March 2003. *Brassica growers inundated by moths*. Felicity Wardlaw (DPIWE).
- Tas-Regions June 2003. *IPM in Europe: Pest forecasting and warning systems*. Andrew Bishop (DPIWE).
- Tas-Regions June 2003. *Herbicide coverage*. Felicity Wardlaw(DPIWE).
- Tas-Regions September 2003. *Vegetable IPM in Europe: Hosting natural enemies and repelling pests*. Andrew Bishop (DPIWE).
- Tas-Regions September 2003. *Keeping on the straight and narrow*. John McPhee (DPIWE).
- Tas-Regions December 2003. *IPM for Tasmanian vegetable growers*. Felicity Wardlaw (DPIWE).

Grower Manual
As mentioned previously, a manual has been produced as a result of this project as an aid for growers wishing to develop and pursue an IPM program in their production system. The manual is to be launched to growers and industry at the annual Forthside Research and Demonstration Station field day in December 2004.

Recommendations

The recommendations arising from this project relate to aspects of potential future work and the opportunities in integrated pest management in the Tasmanian vegetable industry.

- Regular updating of the Tasmanian vegetable grower's IPM manual should continue as new and improved techniques are identified tested and demonstrated.
- Certified courses on IPM should be developed for growers and industry.
- It is essential for a team approach to be adopted for IPM to develop and grow in the Tasmanian vegetable industry.
- Further training and emphasis should be placed on extension of the research and development done in pest management. Developing effective extension programs is the key to increase the uptake IPM on farms.
- A significant amount of work needs to be done to determine the economic impact beneficial insects (parasitoids and predatory insects - spiders, ladybirds, lacewings, hover flies etc) have in the field and to determine the current status of released predatory insects.
- Ongoing R, D&E activity is needed to support improved pest management approaches and facilitate the adoption of IPM practices.
- As weed control is one of the most difficult tasks to achieve without chemicals, there is a need for a program to and demonstrate new technologies and management practices for weed management in vegetable crops.
- An Area Wide Management (AWM) approach to pest management should be investigated.

Bibliography

- **Hicrop 2002:** http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/EGIL-5426LR?open

Appendix A: Entrust® Information sheet

Refer to hard copy of report for Entrust® information sheet

Appendix B: Photographs of field demonstrations

Cover cropping for weed suppression in broccoli.

Fig 1(a): Rye corn cover crop in broccoli. The blue arrows indicate the gaps left for the broccoli transplants. The cover crop was left to grow to 80 cm - 1 m in height before being sprayed off.

Fig 1(b): Transplanting the broccoli into the cover crop. Prior to broccoli transplanting the cover crop was rolled flat once it had desiccated.

Fig 1(c): Broccoli in the rye corn cover crop.

Brushweeding for mechanical weed removal in row crops.

Fig 2(a): The large brushes removing inter-row weeds in a lettuce crop.

Fig 2(b): Right hand side has been brushweeded. The left hand side was left untouched.

Fig 2(c): Brushweeding carrots.

Insect exclusion netting

Fig 3(a): Insect exclusion netting covering broccoli plants.

Appendix C: Articles written on the activities of the project

Refer to hard copy of the report for copies of articles written during the project.