Plant Health Desktop Study

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RMCG

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VG12048 Plant Health Desk Top Study

Final Report

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Purpose of the Project

The purpose of this project was to provide a strategic investment plan for the Australian Vegetable Industry (the Plan) that is based on a review of previous RD&E, new technologies and opportunities, and on stakeholder consultation. This report provides the background research for the Plan. The Plan has been compiled as a separate document, which is attached to this report.

This project has been funded by HAL using the vegetable industry levy and matched funds from the Australian Government.

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Media Summary

Australia's vegetable industry and government have invested heavily in plant health and crop protection R&D. Therefore, a substantial volume of published R&D information has been produced for the vegetable industry. However, much of the information is not fully known or used by growers and their advisers. This project analysed this issue, and formulated a plan to improve growers' return from levy investment in this area.

The study encompassed a situation and needs analysis of plant health and crop protection in the vegetable industry. This was done via a desktop study of available information, an economic investigation and a stakeholder consultation component. The project report describes and discusses issues, future opportunities, and requirements for vegetable plant heath RD&E.

The key project output is the Plant Health and Crop Protection RD&E Investment Plan for Vegetables. It provides direction and strategies for a coordinated, cohesive approach that addresses current industry and RD&E positions with a focus on future needs through integration. Integration means that RD&E programs or projects incorporate:

- Development/dissemination of plant health knowledge under consideration of vegetable production systems
- Inclusion of aspects related to production, economics, marketing and decision making
- Integration of technical disciplines and capacity required for the delivery of effective RD&E and
- Integration of extension and evaluation throughout R&D activities and budgets.

While integration is a focus, the Plan highlights the importance of considering regional issues and the diversity of the industry in RD&E program design and delivery. It stressed the need for major focus on effective extension and capacity building.

The Plan also provides guidance on development and prioritisation of programs or projects, measurement and evaluation (M&E) needs and reporting.

The project and the implementation of the RD&E Investment Plan are highly significant for industry. Effective plant health and crop protection is of great economic importance to vegetable producers. Safe use and minimising inputs of pesticides is of great interest to producers for OH&S, economic and sustainability reasons. Safe crop protection measures are also highly important for consumers who demand pesticide free, high quality and well presented vegetables.

Technical Summary

The need for an RD&E investment plan for vegetables

Australia's vegetable industry and government, through Horticulture Australia Limited, have invested heavily into plant health and crop protection R&D over the past 15 years. A substantial volume of published information is available for vegetable producers and their advisers to assist them in protecting crops in an integrated manner. For a range of reasons, use of much of the information appeared to have been less thorough or widespread than anticipated. The reasons for this situation needed to be explored, and solutions for existing and new R&D formulated in a Plant Health and Crop Protection RD&E Investment Plan (RD&E Plan) for the Australian vegetable industry

Key components of the project – what has been researched?

The main output from the project VG12048 is the Plant Health and Crop Protection RD&E Investment Plan (RD&E Plan) for the Australian vegetable industry. It is based on a situation analysis of plant health and crop protection in the vegetable industry, which was guided by an investigative framework. The situation analysis encompassed a desktop study and a consultation component. Findings are presented in an RD&E outputs database and a project report containing discussions of issues and opportunities, and recommendations for each aspect.

The below aspects of plant health and crop protection were included in the desktop study.

1. Environmental scan of available information
    a. A review of existing RD&E (including scope, content and currency)
    b. Analysis of existing plant health and crop protection information including relevant RD&E conducted for other crops and new approaches and technologies relevant for vegetables
    c. Synthesis of previous key planning and review reports relevant to pest, weed and disease management
2. Environmental scan of relevant aspects of production systems
    a. Industry context and distinction between chronic and acute pests, weeds and diseases
    b. Pesticides and integrated crop protection (ICP)
    c. Soil health, crop nutrition, irrigation, rotation, cover or biofumigation crops, seed quality, transplant health, crop establishment, hygiene and plant breeding
3. Environmental scan of extension and adoption principles and issues
    a. Understanding the target audience, extension approaches, drivers and barriers of adoption and facilitating change
    b. Estimating the likely adoption of new technology for integrated pest management (IPM) using the ADOPT tool
    c. IPM extension and adoption in practice
    d. Designing an extension approach
4. Environmental scan on data availability and data needs to inform pest, weed and disease management decisions

5. Economics of plant health including an economic model to investigate economic impacts of weeds, pests and diseases and their control at a farm and regional level, as well as determining the economic impacts of practice change (e.g. IPM or ICP)

The following was included in the consultation component:

1. On-line survey and telephone interviews with growers and advisers
2. A workshop and personal communication via phone and email with R&D providers
3. Conversations with industry partners (vegetable growers) and the AUSVEG Vegetable Technical Advisory Group (VTAG)
4. Language other than English (LOTE) producer needs
5. Protected cropping industry needs and opportunities

The situation analysis and synthesis of findings provided the basis for the RD&E Plan.

Industry significance of the project

The project and the implementation of the RD&E Investment Plan are highly significant for industry. Effective plant health and crop protection is of great economic importance to vegetable producers; losses can be high, if pests, weeds and diseases are not controlled. Safe use and minimising inputs of pesticides is of great interest to producers for OH&S and economic reasons. Safe crop protection measures are also highly important for consumers who demand pesticide free, high quality, well presented vegetables.

Key outcomes

The key project outcome is the RD&E Investment Plan. It addresses the current industry position and potential future influences identified in the project report for VG12048. It describes a vision for RD&E as well as priorities and objectives. The vision says that activities undertaken through the plant health and crop protection RD&E investment plan should ultimately result in an:

> *Informed industry that has the necessary tools (technologies and management practices) and capacity (knowledge and skills) to manage pest, weed and disease risks from a production, economic and biosecurity perspective and meets market requirements and consumer expectations.*

The RD&E Plan provides clear direction, strategies and recommendations towards an integration of RD&E on many levels while at the same time considering special needs in future RD&E. This includes regard for such issues as acute or chronic plant health problems, or regional and specific grower group needs. The main direction is summarised as follows:

The vegetable industry requires a more coordinated and cohesive approach that focuses on integration at all levels including:

- Development / dissemination of plant health knowledge associated with management of vegetable production systems (e.g. soils, pests, diseases, water, nutrition) – **The Plant View**
- Inclusion of aspects related to production, economics, marketing and decision making – **The Grower View**
- Technical disciplines in the undertaking of R&D (e.g. pathology, soil science, entomology)
- Implementation and skills associated with the delivery of RD&E (e.g. research, and especially development and extension).

The key RD&E investment areas and levels (% of available RD&E funds) for vegetable plant health and crop protection are summarised in the table below.

Specific activities for each of the four listed program areas are included in the RD&E Plan. The Plan also provides guidance on development and prioritisation of programs or projects, measurement and evaluation (M&E) needs and reporting.

Program area (% of RD&E funds)	Sub-program	Integration/Conditions	
Vegetable Production Systems (50%)	a) Response to chronic problems Progress ICP/IPM continuum Risk management systems	Inclusion of elements from areas 2, 3, & 4 in planning and delivery	**Monitoring and Evaluation** included in planning and throughout delivery
	b) Responses to acute problems New and emerging issues Biosecurity (internal and external)		
Business implications (10%)	Production and supply chain economics	Inclusion of elements from areas 1, 3, & 4 in planning and delivery	
	Markets and consumers		
	Public benefit and environment		
Information management (20%)	a) Foundation data and information	Inclusion of elements from areas 1 & 2 in planning and delivery	
	b) Knowledge resources/products/tools		
Good decision making (20%)	Capacity building activities		
	Education and training facilitation		
	Extension programs		

Conclusions and recommendations to industry, research providers and HAL

RD&E in plant health and crop protection is important in delivering economic, environmental and social sustainability for the vegetable industry. It is also critical in contributing to food security and human nutrition and health.

Levy payers and government cannot afford a disjointed, non-collaborative or duplicative plant health and crop protection RD&E approach if it is to continue to improve productivity and sustainability. The vegetable industry's annual RD&E levy investment in the area of plant health and crop protection needs to be:

- Focused on on-farm and value chain outcomes
- Prioritised, and
- Implemented in a cost-efficient manner.

Current knowledge and new technology must be easily accessible and adoptable. The RD&E Plan provides the direction and strategies to achieve this. It is recommended to implement the RD&E Investment Plan with and for the Vegetable Industry.

1 Introduction

1.1 Why have an RD&E Investment Plan?

Australia's vegetable industry cannot afford a disjointed or duplicative plant health and crop protection RD&E approach if it is to continue to improve productivity and sustainability. The vegetable industry's annual RD&E levy investment in that area needs to be focused on on-farm and value chain outcomes, prioritised and used cost-efficiently.

RD&E programs need a collaborative approach, wisely using national research, development and extension capability within and across sectors, disciplines, organisations and regions.

RD&E in plant health and crop protection is important in delivering economic, environmental and social sustainability for the vegetable industry. It is also critical in contributing to food security and human nutrition and health because:

1. The risks of crop losses to pests, weeds and diseases, if they are not adequately controlled, is high and consequences can affect the entire value chain
2. The costs of plant health and crop protection management are high
3. Plant health and crop protection are interconnected to land, water and nutrient management, and climatic conditions
4. Public opinion about crop protection management influences retailers and their requirements in regards to growers' practices
5. Pesticides have the potential to cause environmental or health issues if not used appropriately.

The ultimate aim of RD&E must be capacity building and continuous improvement of practices in industry, associated agribusiness, advisers and all involved in RD&E.

1.2 Background

Plant health and crop protection RD&E for levy vegetables is funded by Horticulture Australia Limited. Work funded through other RDCs (e.g. GRDC, RIRDC) or government programs (e.g. Caring for our Country, Carbon Farming Initiative) is often relevant to plant health and crop protection in this industry (refer to point 3 above). Various research and/or extension providers and agribusinesses with countless interconnections carry out industry and/or government funded and 'in-house' research and extension activities about or related to plant health and crop protection. They include:

- Universities, CSIRO
- State government departments of primary industries / agriculture and environment
- Private research providers
- Industry (individual and corporate growers, supply chain members)
- Agricultural chemical and biotechnology (plant science) companies
- Agronomy services providers and independent crop consultants

- National and State Peak Industry Bodies, Professional Associations
- Natural Resource Management bodies and Catchment Management Authorities.

The level of activities includes the full range from basic to applied R&D and a variety of extension approaches. The scope covers all aspects of plant health and crop protection management including effects of water, soil and nutrition management, climatic, biosecurity and consumer research. In the main, preventative and corrective management aspects are addressed. Most RD&E projects do not include an analysis of economic effects of pests, weeds and diseases and their management.

A large amount of information on plant health and crop protection for vegetables is available in written formats from a wide range of sources and media. Information exchanges occur during scientific and industry conferences. Direct and more specific information is provided to growers during field days, workshops and one to one discussions. It may be hard for growers to evaluate the relevance and quality of information as well as risks and cost/benefits associated with its use on their farm. Information may be missing practical detail or be contradicting other knowledge sources.

1.3 Target Audience for the RD&E Investment Plan

The RD&E Plan will provide direction to HAL, AUSVEG and associated committees (IAC and Design Teams) on funding priorities for projects submitted either under industry and general calls, and/or tenders, e.g. in the case of market failure. It will help those implementing the Plan decide:

- Where to invest (e.g. key regions, issues, strategies, crops)
- How much (as proportion)
- At which level within industry
- Who is best placed to deliver RD&E based on relevant criteria.

The Plan will provide guidance to RD&E providers for the preparation of relevant funding proposals.

1.4 What can be expected?

This document provides a prioritised, *integrated Plant Health and Crop Protection Research, Development and Extension (RD&E) Investment Plan* for the levy paying vegetable industry. It provides clear vision and direction for RD&E in pest, weed and disease management that is aligned with the Australian Vegetable Industry Strategic Investment Plan (SIP) 2012–2017.

Pest, weed and disease management encompasses all combinations of direct and indirect preventative and corrective measures that reduce the risks and actual losses of marketable yield on farm, and subsequent losses throughout the value chain.

The Investment Plan considers economic principles and addresses barriers to research adoption, so that growers will benefit from their R&D investment via resilient crops, lower pesticide bills and improved marketable yields. It has a focus on exploring innovative technologies and techniques whilst building upon previous industry wide programs.

Plant health and crop protection RD&E programs for levy vegetables should be oriented towards industry needs, with a multidisciplinary approach and specific regional focus. Research, development and extension capabilities need to be used collaboratively; programs and activities should build on previous work and be less ad hoc and fragmented. Grower participation and demonstration of R&D outcomes is an important part of applied research. Efficiency and effectiveness of R&D and especially extension can be improved through linkages between sectors and organisations and the delivery of regional and local programs.

2 Approach to Developing the Investment Plan

2.1 Working Hypothesis

The working hypothesis for the project was based on our current knowledge and understanding of plant health and crop protection and its adoption by industry. The hypothesis was formulated prior to the review and consultation phase of the project and was used to obtain objective evidence and synthesise the findings.

Integrated Crop Protection (ICP) is a desirable principle for plant health and crop protection management (desirable for growers, their markets and the environment). A substantial volume of published information is available to vegetable producers and their advisers to assist them in protecting their crops in an integrated manner. The extent to which they implement ICP depends on a range of factors including but not necessarily limited to:

- *Awareness of and access to relevant information sources and advice and support*
- *Complexity of the information and technology and capacity for adoption or adaptation*
- *Personal attitude, motivation, and perceived or known risks of implementation*
- *Ease of implementation (including cost and time) and fit with current practices. Growers frequently look for the most efficient and easy to use solution, especially to present or imminent problems. In the case of plant health and crop protection, the options are often limited to the use of pesticides. ICP or IPM approaches aimed at reducing the reliance on pesticides are mostly pursued when straightforward chemical control is not available, too costly or fails*
- *Opportunity of maintaining a position in the marketplace or being rewarded for ICP (often indirectly – for example, may be continued access in the market).*

2.2 Definitions

These definitions are included to provide clarity (a common language and meaning) for the consultation and review. They provide important context for the scope and hypothesis. It is intended that they align with current terminology used by AUSVEG/HAL and will be utilised consistently in communication and reporting to HAL, AUSVEG and industry.

Table 2-1 Definitions

Plant Health	In agricultural systems, healthy plants can reach their genetic and economic potential; whereby pests, diseases or cultural factors (environmental or management impacts that reduce plants' tolerance of or resistance to pests and diseases) are not adversely affecting plant health or having an economic impact.
Crop Protection	Crop protection refers to chemical, biological, genetic and cultural management factors used to protect crops to support production of food, feed and fiber; chemicals are subject to regulatory requirements, primarily in terms of safety to humans and the environment.
Integrated Crop Protection (ICP)	Integrated Crop Protection (ICP), is an effective combination of chemical, cultural (such as farm management practices), and biological methods to keep weeds, insect pest numbers, disease pressure, and other crop production problems low enough to prevent significant economic loss. Mainly, it provides practical alternatives to conventional pest control that often relies on synthetic chemicals applied on a calendar basis.
Integrated Pest Management (IPM)	The optimisation of pest control in an economically and environmentally sound manner. It is a coordinated use of multiple techniques to maintain pest damage below the economic injury level while minimising hazards to humans, animals, plants, and the environment. IPM uses pesticides, but only after systematic monitoring of pest populations and natural control factors indicate a need. IPM prioritises the use of protectant and selective chemicals that do not harm beneficials. IPM integrates available control measures (biological, cultural and chemical) in a compatible way. *"The vegetable industry and HAL need to have a clearly communicated and accepted definition of IPM to avoid problems of different expectations and also to avoid poor results where IPM was not used correctly." J.Page, VG06086, Hal 2007*
Pests	Invertebrates (including insects, mites, slugs, snails, free living nematodes), ectoparasites, vertebrates, and other pests that affect plant health by consumption of plant tissues and weeds in a broad sense, in agriculture a pest is a competitor to cultivated plants. Insects that do not cause damage to plants but are contaminants to food and fiber products may also be considered pests.
Diseases	Organisms that cause infectious diseases including fungi, oomycetes, bacteria, viruses, viroids, virus-like organisms, phytoplasmas, protozoa, parasitic nematodes and plants; not included are pests.
Entomology (or insectology)	Is the scientific study of insects (although the term is often expanded to include other invertebrates such as spiders, scorpions, centipedes and millipedes). Insects are a critical part of the ecosystems that support life e.g. as pollinators, other beneficial insects for food production, natural pest control, and waste decomposition. But, insects also cause billions of dollars in yearly losses to crops, stored products, forests, and buildings. Insect pests affect millions of people worldwide with insect-borne diseases causing illness or even death.
Plant pathology (or phytopathology)	Is the scientific study of plant diseases. Plant pathology involves the study of pathogen identification, disease etiology, disease cycles, economic impact, plant disease epidemiology, plant disease resistance, how plant diseases affect humans and animals, pathosystem genetics, and management of plant diseases.

2.3 Overall Approach

Our approach to this project has been based on:

- A consideration of prior RD&E programs to identify opportunities and gaps
- An analysis of risks (e.g. due to market failure, lack of knowledge and skills or extension and adoption issues)
- Decision making processes by growers, their advisers, and others that affect plant health and crop protection outcomes in vegetables
- Future opportunities (e.g. new technologies and extension methods) and challenges (especially biosecurity, emerging pest and diseases, climate change)
- Production economics.

2.4 Review and Consultation Framework

A framework was developed to guide the overarching approach to the review and consultation phase of the process. The outcomes from this phase provided the required background information for the development of the Investment Plan.

The review and consultation phase has:

- Included levy vegetable crops and considered pests and diseases in the field, protected cropping and postharvest
- Considered factors that may predispose vegetables to pest and disease attack in the field or after harvest (e.g. soil health or physiological issues)
- Considered relevant RD&E publications related to current management practices and management under future production (climate change, reduction in available pesticides) and market (consumer expectations, domestic and global markets) scenarios
- Involved consultation with industry groups at various levels.

The review of information provided guidance on:

- Elements of pest and disease risk and incidence (Table 2-2)
- Vegetable plant health and crop protection information available through the AUSVEG website (Table 2-3)
- Drivers and barriers for plant health and crop protection management decisions (Table 2-4)
- Drivers and barriers for the adoption of new technologies for plant health and crop protection management decisions (Table 2-5)
- Principles and approaches to achieve capacity building and adoption of R&D outcomes (Table 2-6)
- Evaluation framework, impact assessment, and potential for using the ADOPT model to predict adoption of research outcomes and new technologies
- The capacity to deliver the required RD&E.

Elements of Pest and Disease Risk

The key elements that determine the risk and incidence of pest and disease expression in vegetable crops are described in Table 2-2. Each element also relates to economic loss potential. Fundamental questions guiding review and consultation are included for each Element.

Plant Health and Crop Protection Information

Considerable review of information sources has been undertaken by AUSVEG/HAL and this is compiled through two key information avenues (Technical Insights and R&D database) (Table 2-3). To assist in the review of material and provide consistency the categories used in these databases was utilised. They relate to the elements as described above. Other sources of information on plant health and crop protection for vegetable growers were also investigated during the review and consultation.

Drivers and Barriers for Management Decisions

Understanding the drivers, barriers and hierarchy of crop management decisions and how to use this understanding was a focus of the review and consultation phase. What do growers want and need to manage crop health and why? Is what they want the best way of going about crop health management for them, markets, consumers and the environment? Who makes decisions? How can they be influenced? How can RD&E help to facilitate good decisions? Table 2-4 highlights key drivers and barriers explored during consultation. Decisions on plant health and crop protection are usually made by vegetable growers in consultation with or based on recommendations from advisers or after talking with others in their industry.

Drivers and Barriers for Adoption of New Technologies

There are important characteristics for the adoption of an innovation, which include: relative advantage, compatibility, complexity, trialability and observability. Recent research (ABARES, 2012) identified key motivations for change in landholder practices related to financial, environmental, personal factors and availability of support. Previous research undertaken in the vegetable industry (RMCG, 2012) identified that the adoption of particular management practices and technologies will depend largely on the:

- Industry context (e.g. industry profitability and limiting resources)
- Farming context (e.g. business fundamentals – equity, structure, succession, farming systems, irrigation infrastructure)
- Personal attributes (e.g. attitude to risk, propensity for change, motivations, skills).

Key drivers and barriers for the adoption of new technologies were explored during consultation (Table 2-5).

Principles for Effective Extension Practices

Previous research of successful industry extension programs has identified principles that should be consistently used to achieve a desired change in practices (Table 2-6). The review and consultation investigated the application of these principles.

Table 2-2 Elements of pest and disease risk and incidence, and related review and consultation queries

Goal: No incursion	Elements of pest and disease risk and incidence						
Major Element	**1. Pest and pathogen type & genetics**	**2. Crop type & genetics**	**3. Production/postharvest environment**	**4. Control and management methods**	**5. Crop management and business decisions**	**6. Market access and consumer expectations**	**7. Biosecurity & emerging pests ar disease threats**
Major factors	Virulence Invasiveness Pesticide resistance	Susceptibility Tolerance Resistance	Climate (including Climate Change) Biosecurity Soil or substrate condition Water quality Storage, transport & handling conditions	Chemical (including minor use), biological & cultural control ICP & IPM Emerging technologies (e.g. tissue culture, biopesticides)	Control through integration of BMP e.g. site selection, protection from climatic influences, crop and variety selection, predictive testing of soil & plant material, soil, water and nutrition management, density, crop protection, harvest maturity & care, postharvest management	Market entry restrictions, buying decisions / preferences	Preparedness for incursions and 'new' pests and diseases Climate change and variability
Alignment with Technical Insights	(I) Crop protection (II) Chemicals and pesticides	(IV) Varietal Improvement	(III) Environment (V) Productivity (VI) Business Improvement	(I) Crop protection (II) Chemicals and pesticides (V) Productivity	(I) Crop protection (II) Chemicals and pesticides (III) Environment (IV) Varietal improvement (V) Productivity (VI) Business improvement	(III) Environment (V) Productivity (VI) Business improvement	(I) Crop protection (II) Chemicals and pesticides (III) Environment (IV) Varietal improvement (V) Productivity
Questions to answer during review and consultation	1. Do we have sufficient knowledge of pest and pathogen genetics and how it affects control options?	2. Do we have/use varieties that support plant health, ICP, IPM? Acceptable to growers / the market? If not used, why not?	3. Do we adequately understand climatic and soil impacts and the effects potential changes may have? Do we have adequate postharvest management knowledge?	4. What options are available and used? If not used, why not? What options could or should be available and used? Why?	5. Do we understand how growers make crop management decisions? How is / should this be considered in extension (capacity building and practice change management)?	6. How are plant health and crop protection decisions influenced by market access & consumers (e.g. no tolerance of pests or residues)?	7. Do we have adequ understanding of risks related to biosecurity and emerging pests a diseases? Do we hav systems in place to de with these?
	8. Do we have data on how each Element and major factor affects crop economics (or how economics affect decisions)? How do we use data we have to make better decisions on RD&E needs? Which data should we regularly collect e.g. to evaluate project and conduct cost benefit analyses in proposals and after project conclusion?						
	9. What are the drivers for plant health and crop protection decision-making? **Where do growers and their advisers get their information? Where do they get their training? How good are information and training sources?**						

Table 2-3 Vegetable plant health and crop protection information based on HAL R&D available through AUSVEG website

Goal: Information Resource	Plant Health and Crop Protection Information available through AUSVEG website					
Technical Insights	(I) Crop Protection	(II) Chemicals and pesticides	(III) Environment	(IV) Varietal improvement	(v) Productivity	(VI) Business Improvement
Technical Insights Subheadings	**Vegetable Categories:** Brassica vegetables; Greenhouse vegetables; Leafy vegetables (includes lettuce); Bunching vegetables; Cucurbit vegetables; Solanaceous vegetables; Asian vegetables; Herbs; Other Vegetables; Root and tuber vegetables **Pests and Diseases** Thrips; Aphids; Whitefly; Flies; Mites; Slugs/snails; Leafhoppers; Caterpillars; Beetles; Bugs; Nematodes; Vertebrate pests Fungal diseases; Bacterial diseases; Viral diseases **Weed Management** Weeds - an overview; Impact of weeds; Identification of weeds; Management of weeds; Preventing weeds in the greenhouse	Minor use permits	Enviroveg		Enviroveg	Gross margin tool
Factsheets	Plant Biosecurity Mega Pests - Managing Chewing and Biting Insects Mega Pests - Managing Foliar Diseases Mega Pests - Managing Sucking Pests Mega Pests - Soilborne Diseases Mega Pests - The Basics of Protecting Your Crop A Guide to Effective Weed Control in Australian Brassicas	Managing Pesticide Resistance Spray Application Basics Why Cleaning Spray Tanks Is Important?	Climate Change: Managing Variability and Carbon		Soil Health Post-Harvest Management	Business Decision Making Succession Planning Business Management: Thinking Through the Numbers Gross Margins: Using VegTool
R&D Database	**Pests, weeds and diseases**	**Chemicals and pesticides**	**Environment**	**Varieties and breeding**	**Productivity**	**Added Value** **Supply Chain** **Market Development**

Goal: Information Resource	Plant Health and Crop Protection Information available through AUSVEG website					
R&D Database Sub-headings	Pest management Plant diseases Integrated pest management Biosecurity Biodiversity Cleaning practices	Chemical residues Herbicides Insecticides Minor use permits	Climate change Environmental management	Varietal development	Crop management Fertilisers Irrigation Handling and storage Nutrition Productivity Soil health	Business development Business regulation On-farm food safety Packaging Processed vegetables Supply chain
Questions to answer during review and consultation	1. What options are available and used? What options could or should be available and used?	2. If pesticides 'do not work' what are the issues: application timing, technology etc.? Does the vegetable industry have adequate pesticides available for plant health and crop protection? Do the products support ICP / IPM (as per definition)? Are beneficial friendly resistance and gaps in control addressed (e.g.in SARP?)	3. Do we adequately understand climatic and soil impacts and the effects potential changes may have?	4. Do we have sufficient knowledge of pest and pathogen genetics and how it affects control options? Do we have / use varieties that support plant health and crop protection?	5. Do we have adequate postharvest management knowledge? Do we understand how growers make crop management decisions? How is / should this be considered in extension (capacity building and practice change management)?	6. Do we have data on ho each major factor affects crop economics (or how economics affect decisions)? How do we us data we have to make bet decisions on RD&E needs Which data should we collect regularly?
	7. Has research information been translated into 'tools' or 'information products' that are easy to access and understand, to support good decision-making by growers and their advisors? Is the information accessible / relevant to all vegetable growers? Is it understandable, useful and used? Does it cover all topics and all levy vegetable crops equally? Wher are gaps? How often and how is information used? If not, why not? Does it need improving? If yes, why, what, how?					

Table 2-4 Drivers of plant health and crop protection decisions and related review questions

Goal: Effective and efficient control	Drivers of Plant Heath and Crop Protection Decisions (for developed, available methods)					
Drivers & Barriers	Crop type, growing conditions, farming system, diseases / pests to be managed	Knowledge about management methods	Access to management methods	Cost / time demand of management method vs benefits	Complexity of management method / understanding and managing interactions between factors and /or pests and diseases	Risk (real or perception) associated with management method
Influencing factors	Options available, understanding of options (e.g. what is ICP or IPM)	Use of, access to (knowledgeable) advisers, reach by extension, access to \ use of media & information	Equipment, beneficial organisms, biocontrol agents, pesticides	Direct or indirect costs Perceived & real costs / benefits	e.g. spray program vs. ICP (monitoring, decision making, training needs) Integration of several pest issues.	Fit with other management activities, perceived or known efficacy, ease of getting it right, market demands
Questions to answer during review and consultation	What is the role of different stakeholder groups in influencing crop health management decisions? How do they do it? What influences influencers? How can they become involved in making good decisions in crop health management? What are good decisions?					
	How good is the uptake of technologies developed by R&D over the past 10 years? Was sufficient support and training provided to growers and their advisers to use available methods? What were barriers and how can they be overcome?					

Table 2-5 Drivers for the adoption of new technologies for plant health and crop protection and related questions

Goal: Maximum adoption	Drivers / Barriers for the Adoption of New Technologies for Plant Health and Crop Protection Management								
Drivers & Barriers	Awareness of and access to relevant information and support	Complexity of information/ method	Perceived or actual technical feasibility'	Ease of implement-ation of new technology	Cost/time demand of new technology	Risk (real or perception) or relative advantage	Capacity / opportunity to hear & learn about new technologies	Capacity to adapt & adopt / implement practice change	Attitudes, motivation
Influencing factors (to do with information, technology, research or presentation)	Location, networks, attitudes e.g. actively searching for information / looking for 'a better way', or passive	Easy alternative available (e.g. pesticides vs. IPM), fit with other activities/ methods, presentation of information	Attitude, technical aptitude, quality of RD&E, level of change required, presentation of information	Fit with existing systems and practices, extension method (e.g. participatory or not)	Equipment changes, time & cost or saving doing new things differently, efficacy, longer term outcomes e.g. with IPM	Fit with existing systems and practices efficacy, chance of getting it right, consumer / market needs	Time, willingness and ability to research, learn and access support	Fit of required change with other activities, magnitude of change required	Region, culture, age, experiences, advise, habit, availability of 'technique that works' (e.g. pesticides)
Questions to answer during review and consultation	What is the role of different stakeholder groups in influencing uptake of new technologies? How do they do it? What influences influencers? How can they become involved in capacity building and facilitating the adaptation and adoption of new technologies?								
	What are growers' expectations and needs from future RD&E into crop health? Who can deliver what in RD&E? What would it take to change approaches and technologies used? How are biosecurity, climate change considered? How much should they be considered?								
	It is of interest to understand whether there are differences in how growers and their advisers approach acute and imminent issues as compared to chronic or strategic, longer-term issues. Are these dealt with differently e.g. through in-house research, trial and error, funded R&D?								

Table 2-6 Principles and approaches for extension programs to achieve capacity building and adoption

Principle	Description of core principle
1. Understand and respect the target audience	Extension programs must be targeted to the appropriate audience and address their specific motivations. Understanding the audience includes an analysis of their differen needs and circumstances, the decisions they find difficult, the assistance they require and how they use information. Extension programs should focus on groups of growers (market segments) where a specific need has been identified rather than using a 'blanket' approach for the whole grower group (*one size does not fit all*).
2. Segment the target audience and identify expected outcomes	The needs of different market segments will vary enormously. For the vegetable industry smaller growers will have different requirements from the larger growers (i.e. 20% o industry) who are also likely to be responsible for the majority of production. The needs of these various segments, and the type of delivery program required to address these needs will be substantially different.
3. Understand motivations for adoption of innovation	Extension programs must primarily consider the grower respecting their individual situation, views and motivations. An in depth understanding of the many technical and socia factors which lead to a decision and the background, needs and aspirations will ensure that growers perspective can be appreciated. Growers have good reasons for no adopting a specific innovation (practice and/or technology) and this is not necessarily limited by lack of knowledge. Adoption of an innovation may occur for a range of reasons relating to the individuals motivations – including social benefits such as labour saving, prestige, comfort and opportunities for recreation (not just finance).
4. Ensure clarity of objectives and alignment with growers	Success of an extension program will be facilitated by clearly identifying the end goal or objective. Project activities should be planned that build the capacity of participants anc enable them to work towards the overarching goal. Extension programs need to ensure that their messages are consistent with the motivations of the target audience. Benefits for growers in participating need to be promoted with targeted messages for specific groups (messages that are relevant to their motivations and farming context).
5. Utilise a range of extension methods/models	Extension programs need to incorporate a mix of extension methods (i.e. linear 'top down' transfer of technology and participatory 'bottom up' approaches). Utilisation of the range of extension methods/models will cater to the needs of different groups. *'Reach – in' extension*, where the focus is on the farmer and their experiences, rather than the information provided to the farmer will be preferred where the issues are identified as complex.
6. Consider range of different learning styles	Extension programs need to be developed incorporating a suite of activities suited to different learning styles. Storytelling and story listening, case studies and grouṗ discussions are effective means to learn.
7. Appreciate complexity of decision making	An appreciation of the complexity of farm decision-making will facilitate the development of successful extension programs. The focus of programs should be on striving for bettei decisions rather than best practice – given many decisions are complex and best practice implies there is only one way to achieve a desired outcome. Extension is important ir facilitating the process for complex decision-making.
8. Focus on capacity building	As decisions become more complex, there is a need for increased people skills and human capacity. Extension programs can support better decision-making by helping tc improve producers awareness and skills in the decision making process and developing intuition to improve decision making i.e. facilitating farmers ability by increasing the growers experience, discussion of and thinking about a particular area. There is a core need to build capacity of individuals to seek the relevant information and make the correc decisions for their individual situation.
9. Utilise trusted service providers with appropriate skills	Extension practitioners need to incorporate the adult learning principles into the activities of the programs to increase participation rates and establish a supportive learninç environment. Service providers must be trusted by the grower and support, respect and really listen to the target audience.
10. Adopt a flexible and responsive approach	Extension programs need to be flexible to respond to changing needs and circumstances. This should include evaluation for the on-going adaptation and continuous improvement including changing extension models or using a combination of extension models in parallel.

2.5 Program Logic

A program logic (also known as outcome model, outcome logic, logic model, or outcome hierarchy) sets out what a project will do and how it will do it. In other words, it represents a project's theory of change.

The program logic does this by visually representing a linear sequence of steps that need to occur for a project to meet its desired outcomes. This generally consists of identifying the inputs, activities, outputs, and outcomes (from immediate to long term). An important component of program logic is the identification of assumptions that link steps.

A program logic is a useful tool in the planning phase to determine what success looks like, and in the evaluation phase to determine if the project has been successful in achieving the desired outcomes.

2.5.1 Plant Health and Crop Protection RD&E Plan for the vegetable industry

A program logic approach was used to describe what is to be achieved through a plant health and crop protection RD&E investment plan. The chosen Wisconsin Model[1] displays the sequence of actions that describe what the plan/program is and will do or how investments link to results.

The logic (Figure 2-1) highlights that ultimately we aim to ensure that we have an:

"Informed industry that has the necessary tools (technologies and management practices) and capacity (knowledge and skills) to manage pest, weed and disease risks from a production, economic and biosecurity perspective, and meets market requirements and consumer expectations"

The necessary inputs, outputs, short and medium term outcomes to achieve this are described in Figure 2-1. The key assumptions and critical external factors are also listed.

2.5.2 Focus on activities to reduce risks

There are critical areas of RD&E that we know will contribute to the overall desired outcome. These elements are described in the activities section of Figure 2-1. They influence the risk of pests, weeds or diseases and contribute to a productive and profitable business.

Figure 2-2 describes these key elements of the production system in more detail. This summary guided the overall assessment of RD&E activities undertaken, the gaps in knowledge, understanding and use of technologies, and needs for research, development or extension.

[1] Program Development and Evaluation, University of Wisconsin – Extension, http://www.uwex.edu/ces/pdande/evaluation/evallogicmodel.html

Figure 2-1 The Wisconsin Model

Required Situation:
Prioritised, integrated Plant Health and Crop Protection Research, Development and Extension (RD&E) for the vegetable industry. RD&E is building upon previous industry wide programs and focuses on investigating innovative, new production technologies and techniques. RD&E uses economic principles and addresses industry needs. Industry and government through HAL make investment decisions based on the RD&E Investment Plan.

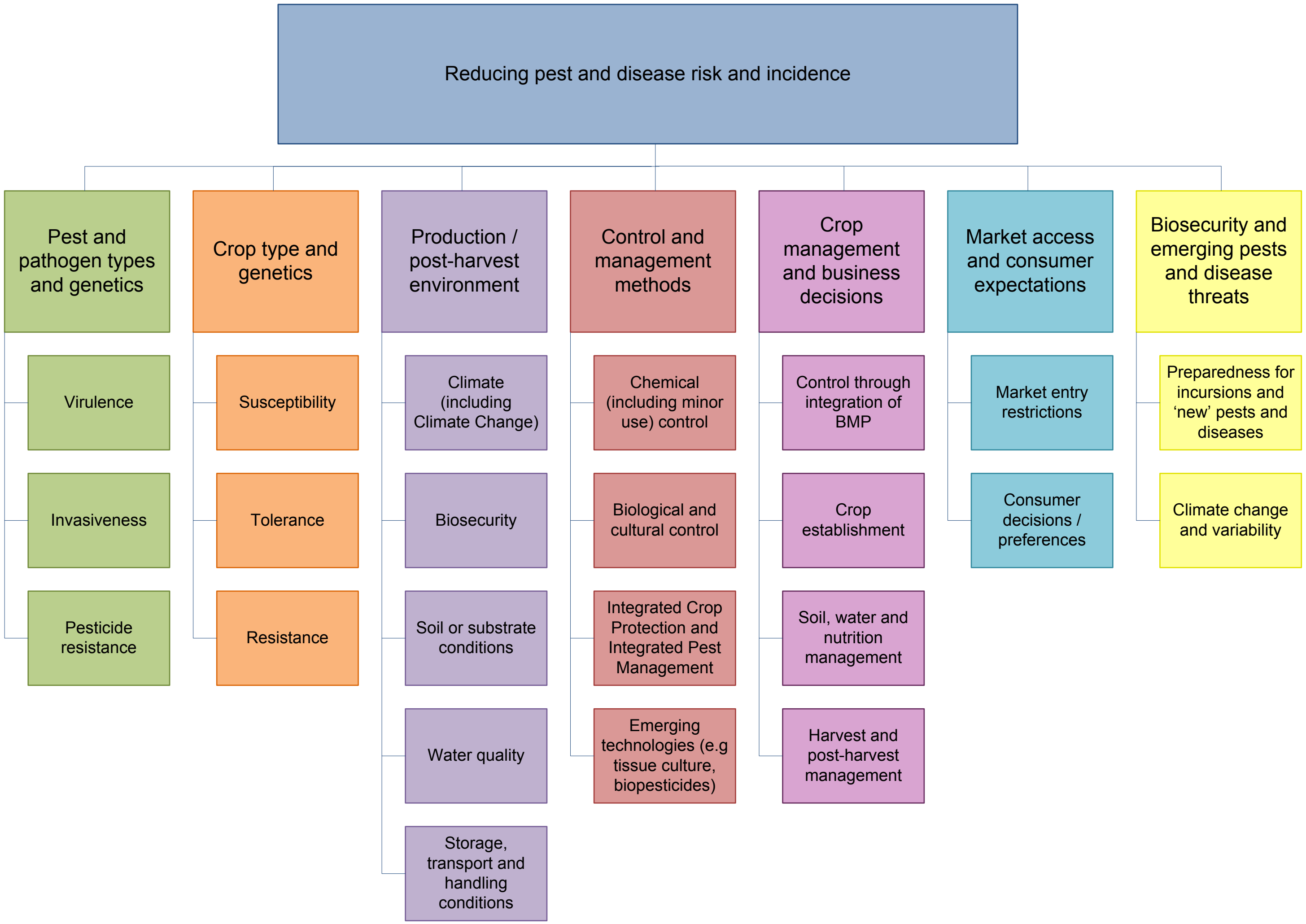
Inputs	**Outputs – Activities, Participation**		**Outcomes – Impact: Short Term**	**Medium Term**	**Long Term**
What we (industry & government) invest: People and funding to enable: ▪ Research ▪ Development ▪ Extension	**What we do:** **Have information on and address RD&E needs about:** 1. Pest and pathogen type and genetics 2. Crop type and genetics 3. Production/postharvest environment 4. Control and management methods 5. Crop management and business decisions 6. Market access and consumer expectations 7. Biosecurity and emerging pests and disease threats **To fill knowledge gaps and be prepared for the future**	**Who we involve and reach:** ▪ Growers ▪ Service providers ▪ Crop protection developers and suppliers ▪ Agribusiness ▪ Industry associations ▪ Researchers ▪ Extension staff ▪ Policy makers	**What the short term results are:** ▪ Assessment of key pest and disease risks ▪ Identification of gaps in knowledge ▪ Identification of technologies and management practices ▪ Identification of needs for information, tools and capacity to assist sound decision making	**What the medium term results are:** ▪ Understanding of key pest and disease risks and prioritisation (based on consequence and likelihood including economics) ▪ Application of technologies and management practices to reduce risks ▪ Increased capacity of all involved to implement good practices ▪ Targeted, coordinated, integrated RD&E investment decisions and programs	**What the ultimate results are:** ***An informed industry that has the necessary tools (technologies and management practices) and capacity (knowledge and skills) to manage pest, weed and disease risks from a production, economic and biosecurity, all of supply chain perspective that meets market requirements and consumer expectations***

Assumptions
- Increased research, development and extension will assist in achieving the long-term outcome
- Information (technologies and management practices) is a barrier to decision making
- Capacity (knowledge and skills) is a barrier to decision making
- Identification of risks and their prioritization will result in improved outcomes for industry

External Factors
A RD&E plan that invests in activities that will address the desired outcomes.

UW Extension **University of Wisconsin-Extension Cooperative Extension Program Development & Evaluation** © 2002
http://www.uwex.edu/ces/pdande/

Figure 2-2 Elements of importance for reducing pest and disease risk and incidence



3 Situation Analysis - Plant Heath and Crop Protection in Vegetables

The Situation Analysis provides important background for the objectives, direction and strategies in the RD&E Investment Plan for Plant Heath and Crop Protection in Vegetables.

3.1 Environmental Scan – Available Information

Existing plant health and crop protection research and development (R&D) information was reviewed to determine the current availability, accessibility and major gaps in knowledge. The review included assessment of:

- Current RD&E on plant health and crop protection funded by the vegetable industry levy (Section 3.1.1)
- Key planning and review projects funded by the vegetable industry levy (Section 3.1.4)
- Current RD&E on plant health and crop protection conducted within other commodity groups that could be applied to the vegetable industry (Section 3.1.6)
- New/enabling approaches and technologies which may be used or researched to enhance plant health and crop protection within the vegetable industry (Section 3.1.7)

A situation analysis on plant health and crop protection aspects and approaches for the vegetable industry that builds on relevant information from this section and incorporates the experience of the project team is included in section 3.2.

3.1.1 Review of existing research, development and extension (RD&E)

Scope of RD&E review

One output of the review is a database listing existing information resources by crop and pest, disease or weed issue and types of information products available.

The crops included within the review database are reflective of the major vegetable commodity groups (as outlined in the Technical Insights section of the AUSVEG website) and are aligned with the vegetable crops included in the National RD&E Framework for Horticulture. With the exception of celery (which was included as a minor crop), the representative crops reviewed here (Table 3-1) are also the highest value vegetable crops produced in Australia (Section 3.4, Table 3-20).

Table 3-1: Levy Crops reviewed within database

Vegetable Product Group	Selected representative crop	Gross value ($m) 2010-11 of selected crop
Leafy vegetables (some Asian vegetables, lettuce types, spinach, silverbeet, rocket etc.)	Lettuce	164.0
Root and tuber vegetables (carrot, parsnip, beetroot)	Carrot	130.7
Legumes (beans & peas)	Beans	129.6
Protected Cropping (solanaceous vegetables such as tomatoes, capsicums, eggplant)	Capsicum	113.5
Brassica vegetables (broccoli, cabbage, cauliflower, Brussels sprouts, kohlrabi, swedes, turnips and some Asian vegetables)	Broccoli	104.6
Other vegetables	Sweet corn	85.8
Cucurbit vegetables (pumpkin, cucumber, zucchini)	Pumpkin	71.3
Speciality leafy vegetables (celery, parsley etc.)	Celery	45.0

A number of the R&D outputs reviewed within individual crops covered vegetable production in general and/or R&D conducted on crop health issues that affect more than one crop. A 'general' category was included within the database to cover these outputs. The general category is not a comprehensive summary of all the R&D, which may pertain to vegetable production systems and should be used only as an example of the types of projects conducted. Overarching issues such as soil health, biosecurity and market access are discussed throughout the report but are not reviewed in detail within the database. Soil health has been dealt with in a previous review, which is discussed in section 3.1.4 of this report. General aspects and approaches of soil health for plant health are discussed in detail in section 3.2.5.

Identification of Crop Health and Plant Protection R&D

Crop health and plant protection R&D previously conducted within each crop was identified through review of key information sources. A summary of the reviewed resources is provided in Table 3-2. The Information available via the AUSVEG website has been used as a major source of information. This site effectively combines and provides access to current RD&E outputs for the vegetable industry.

Table 3-2: Review of previous information

Information Source	Key Documents
Key R&D review documents	▪ VG05043 - Benchmarking vegetable integrated pest management systems against other agricultural industries Or Field Vegetable IPM Stocktake ▪ VG11034 – Benchmarking Uptake of Soil Health Practices ▪ VG06092 - IPM Gap Analysis for Vegetable Pathology ▪ VG09191 - National Vegetable IPM Coordinator ▪ VG11035 - Review of Soilborne Disease Management in Australian Vegetable Production
Knowledge R&D database (AUSVEG website)	A business tool for vegetable growers and other industry participants to obtain the results of levy funded research into a wide range of technical issues and challenges facing vegetable production in Australia.
Technical Insights database (AUSVEG website)	A solid base of summary information for pests and diseases by individual crop types. It is a practical means by which industry and other participants can share in the findings of R&D for use in their business. Technical insights are available in a number of areas: ▪ IPM ▪ Chemicals and Pesticides ▪ Environment ▪ Varietal Improvement ▪ Productivity ▪ Business Improvement
InnoVeg Fact Sheets	Developed on broader groupings of pests and diseases.

Categorisation of R&D

Each R&D output was categorised according to the filters shown in Table 3-3 and based on the categorisation of information within the Technical Insights section and the Knowledge R&D Database of the AUSVEG website.

Table 3-3: Categorisation of crops within database

Filter 1	Filter 2	Filter 3
Field cropping	Diseases	Chemical control
Protected cropping	Insects	Crop management/Productivity
Post-harvest management	Weeds	Environment
Integrated Crop Management		Varietal improvement
Biosecurity		Integrated pest management
Market Access		
Business Improvement		

These filters have subsequently been used in the analysis of R&D outputs to determine the main content/focus areas of existing crop health research.

Analysis of RD&E

The analysis of information involved applying the following criteria:

- Elements of pest and disease risk and incidence, and associated decision making processes – evaluating whether information and how it is delivered provides a basis for sound, integrated decision making
- Amount, content and quality of information – is the amount, content and quality of information sufficient for sound decision making (including technical, environmental, economic & social aspects)
- Information available on economic drivers for pest and disease control decisions
- Relative awareness, accessibility, understandability and ease of use of information, and reasons for 'use' or 'non use' assessed against drivers for decision making and adoption
- Relevance of review and consultation findings to the Plant Health and Crop Protection Research, Development and Extension (RD&E) Investment Plan
- Identification of gaps in knowledge at a strategic level.

The details of each R&D output reviewed are presented in the attached excel file (see Appendix 2). The information presented below represents the summarised data for the crops reviewed and focuses on answering:

- In what content areas has the majority of existing R&D been conducted?
- How current is the R&D that has been conducted?
- What was the final communication output of the R&D conducted?
- How does existing R&D align with the Elements of pest and disease risk and incidence?

Content

The focus of existing crop health R&D for vegetables is shown in Table 3-4.

Table 3-4: Focus areas of reviewed levy funded R&D

R&D Focus Area	Proportion of R&D (%)
Field Cropping - diseases	38
Field Cropping - insects	27
Field Cropping - weeds	5
Post-harvest Management	1
Protected Cropping	6
Integrated Crop Management (pest, weed & disease)	17
Soil Health	1
Biosecurity	2
Market Access	2
Business Improvement	2

The majority of existing R&D has focused on in-field pest management, in particular the management of diseases and insects. This is likely to be a reflection of the immediacy with which most pests need to be managed, making this a high priority for producers. Other issues such as soil health, biosecurity and market access tend to be dealt with more strategically e.g. in overarching industry projects. These may have not been considered a priority for R&D projects submitted for HAL general industry project calls by researchers and Industry Advisory Committees.

Small quantities of R&D have been conducted in the following areas:

- Weed management
- Protected cropping
- Soil health
- Biosecurity
- Market access
- Business improvement
- Postharvest management.

Weed management

Existing R&D relating to in-field management focused predominately on insects and diseases, with only 5% of research pertaining directly to weed management. While weeds can incur a significant cost to producers in terms of lost yield, lack of management may be due more to factors such as lack of time and/or organisation, rather than insufficient knowledge of management techniques. One of the major threats to effective weed management is herbicide resistance, which mainly is an extension issue.

Protected Cropping

Summarised data from the review indicates that there is only a minor component of existing R&D on plant protection in a protected environment. However, this 6% only represents the information available for the crops reviewed within the database (of which, capsicum was chosen as a representative levied greenhouse crop). All R&D outputs specific to protected cropping were not reviewed as a separate focus area.

Pest and disease that impact on protected crops can also be common to field crops and a significant amount of research has been conducted on these (i.e. damping-off, *Heliothis* and aphids, leaf diseases). In a greenhouse environment, healthy seedlings and strict hygiene form the basis of effective pest management. A wide range of R&D outputs are available to assist producers in managing pest and disease within a protected environment. These include:

- **Improving greenhouse systems and production practices** (greenhouse production practices component) (Parent - VG07096), Barbara Hall South Australia Research & Development Institute (SARDI), Project Number: VG07144
- **The Keep it CLEAN guide (2009).** This is a comprehensive guide for greenhouse growers that lists and describes more than 70 management practices that can significantly reduce the costs and losses that can result from pests and diseases

- **Pests, diseases, disorders and beneficials in greenhouse vegetables (2002).** This field guide is designed to assist producers, workers, students, and consultants in correctly identifying pests, diseases, disorders, and beneficials of greenhouse vegetable crops in Australia. It is a tool for integrated pest management (IPM) and draws on the experience of a range of scientists and industry experts
- **Integrated pest management in greenhouse vegetables: information guide (2002).** This information guide is designed to meet the needs of new and existing commercial growers of greenhouse vegetable crops in Australia. It focuses on the practical aspects of IPM, and will help you to answer the most important questions about getting started with IPM and how to manage an existing program better
- **Converting to hydroponics** manual for growers, funded by HAL, available for purchase from SARDI as book or DVD.

A range of other R&D outputs specific to the management of pest and disease issues within a protected cropping environment can be found at: http://ausveg.com.au/Default.aspx?PageID=5090194&A=SearchResult&SearchID=5920808&ObjectID=5090194&ObjectType=1

Currency

The publication date of the R&D outputs was used as an estimation of the currency of information presented in the final communication products. Table 3-5 shows currency of outputs and highlights the increase in plant health R&D for vegetables since 2000. It is not clear whether the increase reflects increasing pest and disease problems or an increased awareness of these.

Table 3-5: Currency of R&D within database

Age of report	Proportion of R&D (%)
1996 - 2001	14
2002 - 2007	40
2008 - 2013	46

Of the crops reviewed, the majority of plant protection research has been conducted in the last ten years, and nearly half of all research has been conducted in the last five years.

Is currency essential?

Research into new technologies and techniques for crop health management will continue to be important. Consultation with the vegetable industry has also indicated that producers are dealing with new pests that have arrived from neighbouring countries (e.g. the Currant Lettuce Aphid) and/or existing pests moving into new crops or cropping areas that were previously not affected. In these cases, further research and extension may be required to assist producers in managing these new pests and/or the application of a new technique/technology into their production systems. Basic research in many countries continues to develop new techniques, products and equipment for improved plant health and crop protection. These new advances most likely will need applied R&D before they can be used in the vegetable industry.

However there continues to be a range of pests and diseases (in particular soilborne diseases such as Sclerotinia and Rhizoctonia, but also Pythium, water moulds and nematodes) that producers are still finding difficult to manage in their crops. For soilborne diseases in particular, the implementation of an integrated management approach that incorporates appropriate rotations, breaks or cover crops may reduce their prevalence. In these cases, on-ground support for an integrated management approach is required, rather than the introduction of new technical information about each disease generated through further research. The economic and longer-term impacts of changing management practices and rotations are however not understood e.g. pertaining to the use of cover or biofumigation crops. Further research that includes longer-term impact and economic information for growers is warranted.

Seasonal conditions will also impact on the importance of a particular crop health issue. A recent example is the increased prevalence of anthracnose in lettuce crops, which is driven by extended periods of wet weather during cool periods. While this may have become an increased management priority, after a long period of drought, it may not require further research (unless conditions have changed substantially) but review of existing information, possible re-packaging it, and an increased effort of getting the message out to producers.

Availability

The majority of R&D reviewed is available electronically either on the AUSVEG website (in the Technical Insights section or the R&D database) or on individual websites administered by state government departments of agriculture. However, consultation with the vegetable industry and others has indicated that many growers, advisers and researchers are not aware of the type and location of information available to assist them in managing crop health and how to access this information.

Communication Product

The final form of the communication product was determined for each R&D project reviewed within the database (Table 3-6).

Table 3-6: Final communication product of R&D

Communication Product	Proportion of R&D (%)
Poster	2
Presentation	1
CD/Video	1
Webpage	11
Guide	12
Factsheet	23
Research report	49
Newsletter	0.4
Book	1

The majority of final communication products for crop health projects are either a web page, user guide, fact sheet or research report. The final communication product for nearly half of the R&D reviewed is a research report (49%), which is not an effective method for communicating research results and how to implement them on farm to the vegetable industry. Within each R&D project there is a component of technology transfer, which in some cases, would have included the production of other communication products or resources. These have often not been kept together with reports and many could not be located.

A number of crop health R&D projects have also been chosen as subject material for the production of **Vegenotes**, a four-page publication included in the Vegetables Australia magazine, which discusses the outcomes of research projects. Although not specifically reviewed within the database, we found that 18 crop health R&D projects were included in the 2010 – 2012 series of Vegenotes. Further information on the 2010 – 2012 Vegenotes series is available at:
http://ausveg.com.au/intranet/technical-insights/docs/130033_VG09096%20Final%20Report%20Complete.pdf

Extension of R&D within existing plant health and crop protection information

A selection of recent R&D outputs (2011 - 2012) was chosen to investigate in greater depth the extension of R&D results into the vegetable industry. The projects reviewed included wide range in the level and quality of extension activities conducted. Projects that included some level of research and focused on the development of management techniques for crop health issues commonly included technology transfer such as:

- Grower/agronomist visits
- Presentations at grower workshops, field days, industry meetings and scientific conferences
- Publication in industry newsletters/magazines and scientific journals
- Development of user guides and fact sheets that were mailed to producers and/or posted on relevant websites
- Some manuals were developed, some of which are now for sale.

These activities do not appear to be part of a planned extension strategy but rather the project team using existing capacity/resources and opportunities as they present themselves. These projects contrast those that focus primarily on the development of capacity and skills relating to pest and disease management in the vegetable industry; they contained a much larger extension component. Recent examples include *Increasing adoption of integrated pest management by western Australian vegetable growers and development of an ongoing technical support service (2011)* and *Regional extension strategy for managing western flower thrips and tomato spotted wilt virus in the Sydney Region (2011).* These projects commonly include activities such as:

- Benchmarking surveys pre and post project
- Demonstration farms
- On-farm grower workshops/field days
- Training workshops for agronomists and consultants
- Provision of one-on-one advice and crop scouting.

Section 3.3 of this report deals with extension issues and opportunities in detail.

3.1.2 Analysis of existing plant health and crop protection information

Seven key elements of pest and disease risk and incidence have been identified and discussed in Section 2.5. The proportion of R&D aligned with these elements is provided in Table 3-7.

Table 3-7: Proportion of R&D aligned with elements of pest, weed and disease risk

	Element	Proportion of R&D (%)
1	Pest and pathogen type and genetics	19
2	Crop type and genetics	3
3	Production/postharvest environment	3
4	Control and management methods	63
5	Crop management and business decisions	8
6	Market access and consumer expectations	2
7	Biosecurity and emerging pests and disease threats	1

An analysis of previously conducted RD&E against these key elements is provided in further detail in Table 3-8.

Table 3-8: Analysis of RD&E against key elements

Element	Analysis of R&D
1. Pest and pathogen types and genetics *Do we have sufficient knowledge of pest and pathogen types and genetics and how it affects control options?*	A large proportion (19%) of the R&D identified in this review has been conducted to better understand pests that affect vegetable crops. The development of management options for vegetable crop health issues has generally been based on research which improves our understanding of various aspects of the pest and how these can be manipulated or controlled to minimise crop damage. This may include a greater understanding of: ▪ Pest life-cycle and what conditions are required for the life-cycle to be completed and/or disrupted ▪ Environmental conditions that may impact on the incidence and spread of pest ▪ Identification of the pest and what an affected crop looks like (symptoms) ▪ Risks via DNA analysis.
2. Crop type and genetics *Do we have and use varieties that support plant health management options? Are these acceptable to growers and the market? If not used, why?*	Only 3% of the R&D reviewed focused on improving the resistance of plant varieties to pests. This is not necessarily a reflection on the availability of varieties that support integrated crop management. It is generally the domain of plant breeding companies to conduct research on developing varieties that have decreased susceptibility to pests. Selection of varieties will also be based on attributes other than pest resistance such as yield, quality and consumer preferences.
3. Production/ postharvest environment ***Do we adequately understand climatic and soil impacts and the effects potential changes may have?*** ***Do we have adequate postharvest management knowledge?***	Although only 3% of the R&D reviewed could be specifically attributed to understanding climatic and soil impacts on pests, weeds or diseases, the control options developed, particularly those within an integrated management strategy, have taken these factors into consideration. The development of predictive models (such as that developed for white blister management in brassica crops) is an example of where environmental impacts have been considered in developing pest management options. Building of producer confidence in these types of tools is required to encourage adoption. A wealth of information on soil health and climate change impacts, and how this may impact on production, is available. The extension 'making it practical' and adoption of this information is where the gap exists. R&D into postharvest management appears to be a significant gap, with only 3% of the R&D reviewed focused on post-harvest issues. However, the majority of postharvest issues are a result of poor in field and harvest management that then facilitates the development of disease during storage and transit. A wealth of information exists on how to correctly manage both harvest and postharvest processes such as the best handling, temperature control and storage conditions in order to preserve shelf-life. Examples include: ▪ The VIDP Factsheet on Postharvest Management for Vegetables ▪ The Postharvest Fresh website ▪ The Freshcare Code of Practice on the VGA website.
4. Control and management methods *What options are available and used? If not used, why not? What options could or should be available and used? Why?*	The majority of R&D previously conducted in crop health (63%) has been focused on developing management options, and more recently the development of options within the framework of an integrated crop protection strategy (ICP). A substantial volume of information is available to vegetable producers to assist them in protecting their crops in an integrated manner. The extent to which they implement ICP will depend on a range of factors including: ▪ Their awareness and access to this information ▪ The complexity of the information/ease of implementation (including cost and time) and the perception of risk involved in practice change ▪ Personal attitude.
5. Crop management and business decisions *Do we understand how growers make crop*	A number of the R&D outputs reviewed present a holistic view of crop management, with a range of factors considered in the management of pests and diseases. However, the majority of projects still focus predominately on the development of control options without consideration of how this management is effectively integrated into the whole production system that deals with multiple

<table>
<tr><th>Element</th><th>Analysis of R&D</th></tr>
<tr><td>management decisions? How is/should this be considered in extension (capacity building and practice change management)?</td><td>issues and potential impacts on the costs of production and ultimately profit.

A number of resources have been developed recently that focus specifically on business improvement within the vegetable industry. These include:
InnoVeg Factsheets on business decision making, succession planning and business management http://ausveg.com.au/rnd/fact_sheets.htm
VegTool for gross margin analysis http://ausveg.com.au/intranet/technical-insights/tools/grossmargin.htm
It is probably the combination of these two aspects (financial management and pest management) that needs to be improved to assist producers in making good crop management decisions. This could be facilitated through:
Greater involvement of extension specialists and vegetable producers during the project design phase and delivery of results.
Benchmarking studies to determine current practice and costs (which can then be compared to costs following implementation of new techniques)
Inclusion of economic data to indicate the cost/benefit ratio of implementing various control options into production systems.
Examples of recent R&D outputs that combine these aspects are:
Benchmarking predictive models, nutrients and irrigation for management of downy and powdery mildews and white blister (research report)
Business case for IPM in lettuce http://ausveg.businesscatalyst.com/rnd/businesscases/BC_IPM%20in%20Lettuce-LR.pdf</td></tr>
<tr><td>6. Market access and consumer expectations

How are plant health and crop protection decisions influenced by market access and consumers (e.g. no tolerance of pests or residues)?</td><td>A minor proportion (2%) of previous crop health R&D has focused on market access and consumer expectations, largely due to this area traditionally not being considered a focus area for crop health research.

At this stage, retailers' quality assurance programs and Minimum Residue Level (MRL) regulations still largely drive crop health decisions relating to market access and consumer expectations.

There is also likely to be continuing tension between the use of 'softer' control options for environmental/sustainability reasons, the cost of using this chemistry and consumer expectations of blemish-free and 'beneficial-free' product.

The VIDP Consumers and Markets Program developed a number of resources to assist producers with understanding consumer preferences. These include:
Veginsights – a monthly report providing insight into trading dynamics and influences in the past month
Quarterly market reports - which track volumes and values at a state level by channel and commodity group, and profile buyer behaviour and household vegetable consumption patterns for a defined set of household segments
Annual vegetable industry situation and outlook - which provide explanations of what has influenced and shaped the vegetable market for the previous the 12 months and a forecast of market conditions for the next year.</td></tr>
<tr><td>7. Biosecurity and emerging pests and disease threats

Do we have adequate understanding of risks related to biosecurity and emerging pests and diseases? Do we have systems in place to deal with these?</td><td>A minor amount (1%) of previous R&D has focused on biosecurity in the vegetable industry, related to the development of a pest specific incursion management plan for pests in carrot crops. There is also a factsheet available on biosecurity within the vegetable industry available from http://ausveg.businesscatalyst.com/rnd/fact%20sheets/Biosecurity.pdf

There are also a number of general resources available for producers to assist them in managing biosecurity aspects on their properties through Department websites and Plant Health Australia, including a Biosecurity Plan for the Vegetable Industry.</td></tr>
</table>

3.1.3 Conclusions and recommendations from review of plant health information

There is a significant amount of information available to assist the vegetable industry manage crop health and plant protection issues. However an enhanced effort in effectively extending the results of research into the vegetable industry is required to increase the adoption of known and new approaches/technologies.

Adoption of known and new approaches/technologies could be improved by:

- Considering a more holistic approach to RD&E which focuses on whole farming system (including factors taken into consideration by producers when making decisions). Economic analyses of control options need to be an integral part of future R&D.
- Using existing research reports, rather than conducting new research, to determine:
  - Opportunities to build extension on/leverage existing research
  - Extent of extension and focus on adoption within original project. *Was there sufficient technology transfer? How could key messages within report be extended through other formats? How could adoption be improved? How does or can it fit with production systems?*
- Less research and more on the ground training for growers and advisers to implement control strategies through better understanding of:
  - Use of diagnostic tools, especially risk management tools such as DNA testing for soilborne diseases
  - Use of predictive models
  - Spray application technology
- Ensure that future R&D projects incorporate:
  - A greater design/development phase that considers how the key messages/outputs from the research will be extended to the vegetable industry throughout the project's life
  - An evaluation component (such as pre and post project surveys) which provide a quantitative and qualitative indication of how well project objectives have been met and allow for an adaptive management approach throughout the project's life
  - A project team or project advisory team comprising a range of skills such as:
    - *Extension specialists to develop or help with the development of a dedicated extension strategy as part of the project*
    - *Economists to enable the financial impacts of various control options to be determined*
    - *Team members who are in regular contact with vegetable producers and or agronomists, crop protection product producers, consultants as appropriate for the project*
- Involvement of private industry in RD&E loop (participatory RD&E).

3.1.4 Synthesis of key planning and review reports relevant to pest, weed and disease management

This section summarises and synthesises major planning, project delivery and review work relevant to plant health and crop protection management conducted for the levy vegetable industry with HAL funding in the past 5-7 years; this includes work on IPM, soilborne diseases and soil health.

The main reports considered in this section are:

1. VG05026 Workshop to develop research, development and extension priorities for nematode control in vegetable crops, Frank Hay, Tasmanian Institute of Agricultural Research 2006 (Nematode stocktake)
2. VG05043 Benchmarking vegetable integrated pest management systems against other agricultural industries Or Field Vegetable IPM Stocktake, Sandra McDougall 2007
3. VG06092 National Vegetable Industry IPM Pathology GAP Analysis, Horticulture Australia, Ian Porter et al. Victorian Department of Primary Industries (VICDPI), 2007
4. VG07128 Integrated Viral Disease Management in Vegetable Crops, Denis Persley Department of Agriculture, Fisheries and Forestry, QLD, 2011
5. VG09191 Vegetable IPM Coordinator, Scholefield Robinson Horticultural Services Pty Ltd, 2011
6. VG11035 Review of Soilborne Disease Management in Australian Vegetable Production, Dr Prue McMichael Scholefield Robinson Horticultural Services Pty Ltd, 2012
7. VG11034 Benchmarking Uptake of Soil Health Practices, Gordon Rogers, Applied Horticultural Research, 2012 which reviewed amongst others:
   - *VG06100 - Vegetable Plant and Soil Health (sub-tropical), Pattison, QDPI 2009*
   - *VG07125 Project 2.2 Best-practice IPM Strategies for Control of Major Soilborne Diseases of Vegetable Crops throughout Australia, Ian Porter et al., Victorian Department of Primary Industries (VICDPI), 2010*
   - *VG07008 Benchmarking Soil Health for Improved Crop Health, Quality and Yields in the Temperate Australian Vegetable Industries.*

VG05026 Nematode stocktake

The report VG05026, dated 2006, provides an overview of nematode issues and gives pertinent recommendations on improving nematode management in vegetable crops. They are:

1. Prepare extension material for use by growers and consultants to improve the way nematodes are managed in the vegetable industry
2. Demonstrate the value of rotation crops for root-knot nematode control in various vegetable-growing regions of Australia
3. Establish regionally-based, multi-disciplinary research groups to develop sustainable farming systems and soil management practices for local vegetable industries and ensure that there is adequate nematological input into each research group

4. Enhance the adoption of DNA technologies for identifying and quantifying nematodes - diagnostics
5. Increase the number of nematologists working in the vegetable industry and ensure that programs are in place to provide the industry with nematological expertise in the long term
6. Support basic research that is likely to lead to the development of the next generation of nematicides
7. Enhance Australia's biosecurity by characterising the plant-parasitic nematodes present in Australia and by developing rapid and reliable diagnostic procedures for major pests
8. Review progress on this action plan and make appropriate changes where required.

The report lists previous projects of direct relevance to vegetable nematology conducted up to 2006 (29 reports). It provides information on occurrence of Meloidogyne spp. Pratylenchus spp. on vegetables in different States of Australia (N=NSW, NT=Northern Territory, S=SA, V=VIC, T=TAS, W=WA. (Adapted from Nobbs 2003). It includes a tabulation of some exotic nematode species posing a potential biosecurity risk to vegetable crops in Australia.

While the recommendations from VG05026 are still relevant and should be considered by industry (if not already done), some review information provided in the report, being up to 10 years old, may need updating. The reason is that nematodes have been identified as one of five chronic soilborne disease issues (VG11035) and consultation identified changes in nematode populations as a future risk, especially with changing climatic conditions and increased production intensity or lack of rotation due to economic pressures in some regions (refer to section 3.2 and section 4).

VG05043 Field Vegetable IPM Stocktake

The project VG05043 (McDougall, 2007) reviewed existing IPM methods and tools that have been developed for some field vegetable crops and selected non-vegetable commodities, which have potential to be used or adapted in vegetables. McDougall has collated an extensive list of IPM projects funded by HAL and other Research and Development Corporations up to 2006, which is available from her. It was considered in our review of existing R&D information. For VG05043, growers and their advisers were consulted via surveys about their understanding of IPM information and knowledge gaps. The project report:

- Summarised a selection of the field grown vegetable IPM projects
- Listed Australian vegetable IPM tools
- Began collating management options for key pests and diseases
- Summarised pests and diseases found in 10 vegetable crops not covered by National IPM projects
- Included IPM case studies on IPM adoption in cotton, citrus, processing tomatoes, sweet corn and brassicas and surveys of growers and consultants
- Evaluated existing management options
- Proposed what is currently adoptable as IPM strategies and suggested how they may be further developed.

The report also lists impediments to IPM uptake and how to overcome these.

Most of the recommendations made on research and extension priorities in the VG05043 report remain relevant; they include:

- Collaborative, multidisciplinary work
- Continued review of existing IPM information and collating it into formats that are accessible to growers, consultants and researchers alike (e.g. an IPM information Toolbox, Apps - Australian IPM information should be collated in a central web based resource and links to other international sources should be made available)
- Active surveillance for pests and diseases
- Producing data on the economic benefits of IPM
- Advocating career paths for and as IPM consultants
- Training of growers and advisers in IPM including
    - Use of new selective and soft chemistry and biopesticides
    - Pesticide resistance management
    - Management of beneficial organisms
    - Integrated soil, crop and pest, weed and disease management.

The report lists important IPM tools that should be available to vegetable growers (comments have been added in brackets):

1. Soft chemistry & biological products (and training on their use)
2. (Practical) Crop monitoring protocols (multiple pests, weeds and diseases)
3. IPM guidelines (need to be integrated overall issues and be by crop growth stage)
4. Endemic beneficials (especially how to foster them)
5. Soil, water & nutrition management (how it links to pest, weed and disease management)
6. Post-harvest cultivation information (crop rotation)
7. Best-bet thresholds (determine economic and biological thresholds).

Training in IPM for growers and consultants was considered important but lacking. Information tools such as field guides and CDs were considered to not be driving adoption, but being tools to assist those already wanting to adopt.

Priority areas for general IPM research that would have benefit across many or most field (and greenhouse) vegetable crops were identified as follows:

1. Status of fungicide efficacy and resistance for the key diseases, a resistance strategy where loss of efficacy is suspected and permits to give access to new chemistry. A cross industry fungicide management strategy to be supported

2. Insecticide and fungicide (and herbicide) resistance management strategies should be integrated into regional or area-wide strategies where possible

3. IPM (and pesticide resistance management) requires good knowledge on the impacts of fungicide and insecticide on beneficials, including sub-lethal effects

4. Soil disease management strategies that include prediction modelling (assessing risks e.g. via DNA testing), crop rotations, cultural controls and biological options need investigation including understanding of degradation of soil pathogens

5. In-field (and lab based) disease identification test kits

6. New chemistry, bio-rational and biological control opportunities need to be explored for all pests but are urgent for sucking pests such as Silverleaf whitefly, thrips particularly Western flower thrips, Rutherglen bugs and leafhoppers

7. Monitoring and prediction guidelines and soft management options for soil pests, including nematodes, weevils, cutworm and wireworm are needed

8. Clarification of efficacy of petroleum spray oils

9. Potential of trap crops and insectary crops

10. Regional crop loss impacts are not well known or documented making assessment of relative priorities difficult to estimate (this should be done)

11. Training materials for potential and current IPM service providers, including technical support, better interaction between growers, consultants and researchers.

These recommendations should be considered in the design of integrated vegetable plant health and crop protection RD&E. A small start has been made in compiling factsheets on some economically important pests under the recent HAL InnoVeg program. The factsheet are available from the AUSVEG website.

IPM summaries for 10 selected crops were provided and should be updated in connection with SARP information and made available to industry. Summaries include information on growing areas, pests and diseases, regional importance, insecticide and fungicide registrations (would need updating), resistant varieties, current available IPM, potential IPM and suggested areas for further work. The selected crops were Beans, Beetroot, Capsicum, Carrots, Celery, Chinese Cabbage, Cucumber, Pumpkins, Sweet potato and Zucchinis.

VG06092 National Vegetable Industry IPM Pathology GAP Analysis

VG06092 used two ways of identifying IPM pathology gaps:

1. A review of vegetable pathology (disease) research conducted in the last 20 years, and
2. Surveys of pathologists and consultants / agronomists followed by workshops with both groups.

Vegetable growers, supply chain members, the Agchem industry and agribusiness were not included in the GAP analysis. The database compiling vegetable pathology research conducted in the last 20 years could not be located for this project. It was not kept with the final report.

VG06092 complemented and partially overlapped with the IPM review conducted for VG05043 at around the same time (McDougall, 2007); e.g. both projects came up with IPM strategies for the same five crops and identified similar issues. Both projects identified drivers of IPM adoption and current use and effectiveness of IPM.

The objective of the research review, surveys and workshops for VG06092 was to identify research gaps and assess them against a set of key criteria: i.e. size of problem, cost to industry, cost to implement research, chemical reduction/efficiency, ease to achieve R&D outcomes, compatibility with pest IPM programs) and develop HAL priorities. Criteria such as costs were worked through in workshops to create estimates for different areas, crops and diseases. Losses were estimated to be between $200 and $15000 per hectare depending on crop, disease and conditions. Total crop losses from priority pathogens were estimated to range between 5 to 100% depending on the region and the climatic conditions. The estimated cost in lost production from these diseases to industry was reported to be $100 million.

The following **priority research areas** were identified as the key issues to be addressed during meetings of the National Vegetable Pathology Workshops held in 2003 and 2006:

1. ***Fungicide resistance management:***
   - Development of resistance management strategies for major pathogens to maximise the longevity of existing chemistries. Strategies similar to that for the insect pest diamond back moth needed (e.g. white blister). Nurseries should be included since they may be applying several fungicide applications for a single pathogen
   - Investigate the extent of resistance for several pathogens (e.g. pathogens of cucurbits, copper resistance issue for bacterial spot of capsicum and black rot of brassicas)
   - Investigate alternative chemistries for major pathogen groups (e.g. Powdery mildews, downy mildews, white blister and Botrytis).
2. ***Seed borne diseases***
   - Undertake review/scoping study to develop a strategy to address the issue of healthy seed for the Australian vegetable industry. Identify key diseases of concern
   - Seedling project to address seedling health, nursery best practice – production of disease free seedlings
   - Develop methods of testing and managing seed borne diseases (issue for root crops, tomato, capsicum and brassicas to a lesser extent)
   - Tomato project addressing potato spindle tuber viroid and bacterial canker
   - Develop and implement Brassica model for other key commodities (beginning with lettuce and carrot). Consider setting aside dollars to fund similar commodity based road shows with associated printed materials on a regular basis, perhaps every 3 years.

3. Diagnostics

- Review predictive and diagnostic tests available worldwide, their availability, effectiveness and ease of use, determine the practicality of in-field diagnostic tests and validate for Australian conditions
- Develop diagnostic tests (e.g. for soilborne diseases of root crops)
- Develop sampling strategies for collection of soils for diagnostic testing. How to collect a sample that will give a good reflection of the disease present in the field. One sample or many? How many? etc.
- Collect field data to correlate test result with disease outcomes in a range of soils and conditions. Determine thresholds for disease (i.e. ground truth these tests).

4. Best practice

- Network pathologists, entomologists, advisers and agronomists for each major commodity group to develop 'best practice' (regional) guidelines for the commodity. Identify key recommendations for each major pest/disease issue within the commodity and test these against what is known for other pests and pathogens that affect that commodity. Are we sending conflicting recommendations? Identify best practice – this will most likely be a compromise outcome for all pest/pathogens. Prepare guidelines as summary sheets.

5. New chemistry

- Investigate new chemistry to increase the available arsenal available to combat pathogens. Ability to control some important pathogens restricted to only one or two groups. Resistance is inevitable. Liaise with the outputs from the Minor Use program conducted by Agaware and Peter Dal Santo (AH04009).

Based on above priority R&D areas, the following programs and key R&D areas were identified; 1-3 projects were put together for each program to cover below mentioned topics:

Program 1 - Chemical Use

- Review of IPM compatibility of pesticides
- Impact of pesticide withdrawals
- Reducing chemical footprint
- Resistance management of fungicides.

Program 2 - Integrated Soilborne Disease Management (Focus on Sclerotinia, Pythium and Fusarium, N.B.: nematodes not included)

- Non-chemical controls
- Seedling health
- Sampling, forecasting and detection
- Benchmark parameters for pathogen management
- Host Resistance.

Program 3 - Integrated Foliar Disease Management

- Non-chemical controls
- Seed Health
- Aerial sampling, detection and modelling
- Benchmark parameters for pathogen management (Downy, Powdery and Leaf spots)
- Host Resistance.

Program 4 - Integrated Viral Disease Management

- Technology transfer
- Alternate hosts
- Sources of epidemics
- Vector Management
- Host Resistance.

Program 5 - Communication and Extension

- Commodity based (except viruses) NOT project based
- Draw together and package information from across the entire IPM program. In particular must link with chemical use sub-program and with the other HAL IPM programs
- Each package to include:
    - Vegetable Industry Pathology Gap Analysis - Final Report VG 6092
    - National Workshops, field days and training events
    - Published material (e.g. factsheets)
    - Scout and consultant training
    - Where possible, 'best practice programs' linking pest and disease outcomes to be developed and presented for commodities
    - Role for industry development officers to coordinate (each taking on the commodity that they are responsible for within HAL industry groups).

Program 6: Novel Strategies and New Technologies

New production systems

Figure 3-1 provides an overview over the actual major HAL IPM disease R&D program conducted between 2007 and 2011 based on the GAP analysis. Extension was conducted as part of projects, including factsheets.

Project outputs from this program were reviewed as part of the section 3.1 (Available Information).

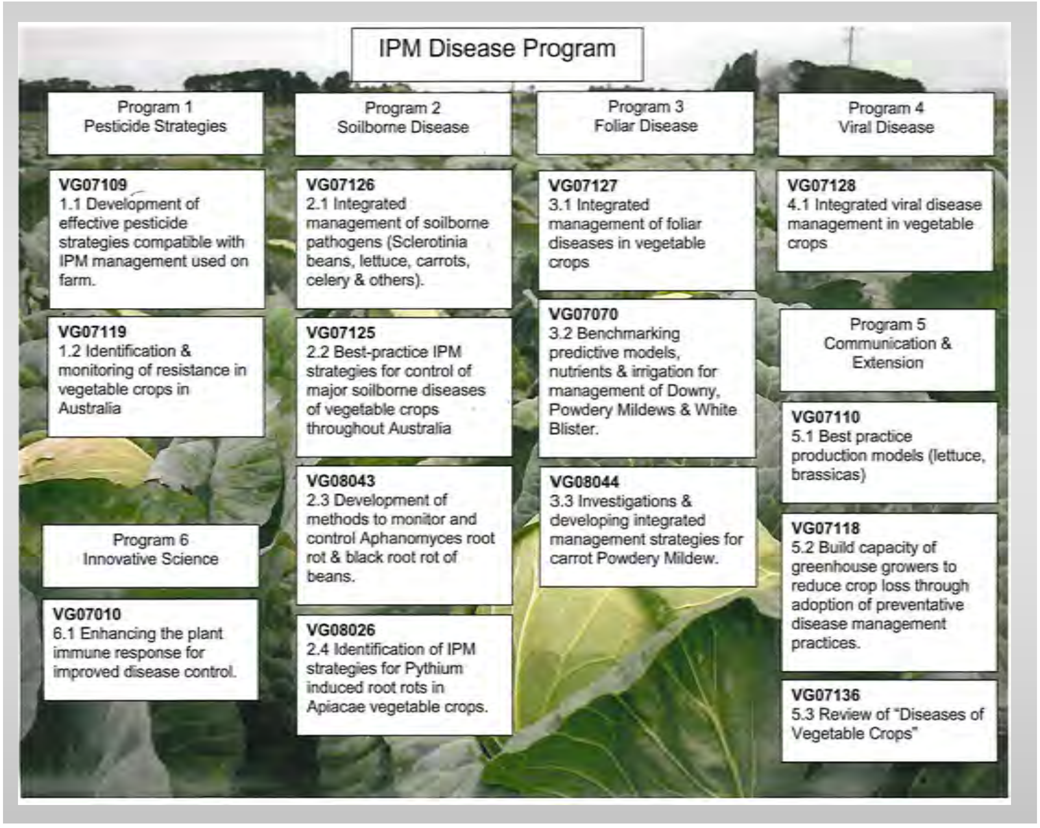


Figure 3-1: Overview over the HAL IPM disease program conducted between 2007 and 2011[2]

VG07128 Integrated Viral Disease Management in Vegetable Crops

The aim of project VG07128 was to enhance the capacity of the vegetable industry to implement integrated viral disease management and reduce the economic impact of these diseases.

Strong collaborative work by plant virologists in all States identified virus diseases as key issues in vegetable production in both field and protected cropping systems. The major economic losses were found in capsicum (Tomato spotted wilt virus, Cucumber mosaic virus, tobacco mosaic virus), all vegetable cucurbits (potyviruses and Beet pseudoyellows virus in cucumber), lettuce (big vein disease), beans (Bean common mosaic virus at Kununurra) and brassicas (Turnip mosaic virus in some areas).

Tomatoes, which are not included in the vegetable levy, have significant virus problems including Tomato yellow leaf curl virus in south Queensland and torrado virus in protected cropping in southern Australia. These viruses can infect other Solanaceous species (e.g. capsicums) that are part of the levy vegetable system. Therefore, these need to be included in area wide management plans.

Surveys over three years of processing pea, bean and brassica crops in Tasmania found relatively low levels of virus infection, suggesting that virus diseases currently have a minor impact on processing crops in the State. The survey, however, highlighted the need for

[2] Source: Soil Health in the national vegetable industry (VG07008), Porter et al., presentation AUSVEG conference 2010

continued monitoring to assist in maintaining high health and quality of processed vegetable crops in Tasmania.

Several virus diseases were identified for the first time in Australia including Tomato torrado virus and Ranunculus white mottle virus causing capsicum yellow vein disease. In addition to benchmarking surveys, experimental work provided new information on virus spread by contact, virus tolerant zucchini varieties as a means of enhancing disease management and reducing pesticide use, and the cause and impact of lettuce big vein disease.

An increased awareness of virus diseases and their management has been provided through industry seminars, personal contact at all levels of the vegetable industry and the publication of six reference notes which form the basis of a guide to the integrated management of virus diseases in vegetables. The industry seminars, some of which have involved training in virus identification and management, have been held in all mainland states and have targeted all areas where virus diseases are a production problem. The published material has been linked to the knowledge management system through the vegetable industry development program (VIDP).

The project did not include an analysis of the potential economic impact of virus diseases in levy vegetables.

The following relevant recommendations were made:

- The continued adoption of integrated viral disease management as part of crop protection programs need to be supported
- Further extension has to be undertaken on the causes, impact, epidemiology and management of lettuce big vein disease
- Area wide management of insect virus vectors must be supported, including cross industry links, to address the broad host ranges of both the vectors and viruses transmitted.

All further RD&E work should build on previous national and international R&D and include economic analyses of viral disease impacts on crops and regions and the benefits of adequate control. Virus disease control has to commence with seed and transplant health.

There is an urgent need for across industry cooperation, extension and capacity building to improve control and reduce the spread of virus diseases.

As a follow on from VG07128, Project VG10104 - Management of virus diseases in vegetables, is currently evaluating the use of integrated viral disease management systems, particularly where insect or animal vectors are involved. The goal is the prevention and/or delay of virus infection in vegetables. The project is expected to report on further RD&E needs.

VG09191 Vegetable IPM Coordinator

Following the major, mainly discipline and IPM focused, needs analyses and programs for plant health and crop protection RD&E from 2006 to 2009, the Vegetable Industry Development Program (VIDP) 2009-2012 included a 1-year National Vegetable IPM Coordinator project (Scholefield Robinson Horticultural Services Pty Ltd, VG09191). The project was initially meant to run for three years, but was capped to one year.

Longer-term aims for a 3-year vegetable IPM coordinator role were to:

1. Consolidate and coordinate IPM investment for the benefit of the Australian vegetable industry
2. Develop IPM packages and tools for the vegetable industry (using results from the latest R&D) and facilitate their uptake within industry
3. Enhance the opportunities for market access while consolidating profitability and sustainability within the vegetable industry supply chains.

The focus and outputs of the one year project, which made a start on points 1 and 2 above, is summarised below.

Benchmarking planning

A benchmarking study of IPM adoption by the vegetable industry should be conducted to identify the level of IPM use by crop, region and industry demographics; it would establish awareness, knowledge and skills as well as drivers, barriers and opportunities for the use of IPM in the industry. It would be a tool to investigate the success of previous RD&E investments in IPM and guide further RD&E programs.

Five distinct but interrelated activities were undertaken and reported within the benchmarking component.

1. Literature Review and Analysis: IPM Definition, Current Adoption and Future Benchmarking Options
2. Obtaining Benchmarking Data via Grower Surveys: Options, Guidelines and Standardised Survey Questions
3. Assessing the Current Status of IPM Adoption via a Survey of Key Informants: Guidelines, Sampling Subsets, Options and Recommended Survey Method
4. Review of the Potential for Online Business Tools to be used for Capturing Benchmarking Data
5. IPM Continuum for Australian Vegetable Crops (Draft - requires further work including development of ‘codified practices’ and a scoring system as well as exploring opportunities for EnviroVeg to benchmark IPM use through self assessments and or external audits).

A cost-benefit analysis of IPM adoption by NSW lettuce growers was conducted. It showed, similar to other studies that it can be financially beneficial for growers to adopt IPM. There are additional, non-financial benefits from adoption of IPM and these were included along with the financial benefits in a ‘business case’ for adoption of IPM in lettuce.

ICP benchmarking, if e.g. incorporated into the EnviroVeg program’s annual assessments could provide relevant data assist in fostering a positive image of the industry in regards to pesticide use.

Strategic Planning

Four high-level objectives were formulated by the IPM Coordinator to support an overall vision of “A vegetable industry effectively addressing production, market access and consumer issues related to pests, weeds and disease management”. These objectives were a result of consultations with stakeholders and a review of background documents. The vision and objectives were to underpin a Vegetable Integrated Crop Protection RD&E Plan, 2011-2015.

Still relevant objectives are:

1. Information (*on ICP as part of overall crop management*) is readily available (*to growers and their advisers through…*)
2. Market impacts (*of and on ICP*) are monitored and addressed
3. Short, medium and long-term RD&E needs are addressed through a program approach.

Strategies and actions to achieve objectives were documented. They were based on the presumption that a National Vegetable ICP / IPM Coordination program would exist in the future.

The IPM Coordinator made the important suggestion of taking a formal approach to identifying and assessing strategic threats such as:

- New pest incursions
- Current field control or market access strategies, e.g. resistance, deregistration
- Technical skill shortages
- Changes in market / consumer requirements
- Changes in regulation (environmental issues).

The envisaged strategic plan comprised nine RD&E Program Plans focusing on key pest types and other aspects of crop protection RD&E. One Program Plan for Thrips and Tospoviruses was fully developed to act as a model for development of the remaining eight program plans.

The suggested subprograms were:

1. Thrips and Tospoviruses
2. IPM Adoption
3. Invertebrate Pests (insects and mites)
4. Pathology (diseases caused by fungal, bacterial and viral pathogens)
5. Nematology
6. Soil Health
7. Greenhouse IPM
8. Weeds
9. Vertebrate Pests.

Similar to previous planning approaches for RD&E, the subprograms 'divide' some important issues that are interrelated and often occur concurrently in a crop into 'study areas' that mostly fit with disciplines and not with the practical necessities of crop protection or priority areas for the industry. Other areas have a holistic focus and could be combined into a program' e.g.:

- Soil health status and interaction with crop health
- Assisting growers to move towards ICP along the ICP continuum (compliance – GPPP – ICP).

Extension and capacity building is again treated as a separate work area in above programs, and not as an integral part of R&D projects. Economic analyses and evaluation are not mentioned in plans when they should be an important aspect of providing guidance and feedback on the relevance and impact of the work.

Integrated Information Packages for publication on the AUSVEG website

The IPM Coordinator project developed factsheets on major pests, and pest and disease management for publication on the AUSVEG website. These continue to be relevant and available. They can be updated in the future as required and / or used to develop GPPP and ICP guidance and training.

Chemical / IPM Database

Two IPM examples were created using information collated in 2009 as part of the Strategic Agrichemical Review Program (SARP) carried out by the HAL Minor Use Coordinator. The IPM team added information to the SARP Excel spreadsheets for lettuce and celery. This information is about the pests, how they are transmitted, their natural enemies, alternate hosts for the pests and non-chemical management options.

Including ICP information with the SARP information is considered a good way of compiling all relevant information for a crop into a single source for industry and identifying gaps. Doing this should be considered for the future.

VG11035 Review of Soilborne Disease Management in Australian Vegetable Production

The review of recent literature for VG11035 also confirmed that the vegetable industry levies and the Commonwealth Government funded (through HAL) a large number of projects on each of the five key soilborne pest and disease groups of Australian vegetables.

The following four pathogen groups and one pest were identified as the main causes for chronic soilborne disease issues in the vegetable industry:

1. Water moulds (> 500 species of *Oomycota* or *Oomycetes* in four groups *Phytophthora* and *Pythium* spp., downy mildews, white blister rusts)
2. *Sclerotinia* spp.
3. *Fusarium* spp.
4. *Rhizoctonia* spp.
5. Nematodes.

USA pathologists provided a similar list of soilborne pathogens of ongoing concern.

The VG11035 review recommends closing knowledge gaps as a matter of priority through targeted extension with a focus on essential risk assessment and management knowledge.

The extension focus must be on adoption-ready measures and be linked to farming systems. Adoption-ready means that information from various information sources and formats are synthesised and either transferable across farming systems or adapted to specific situations as required and practical. "Printable/hard copy summaries in the form of factsheets etc. are a preferred written output of all projects with 'ready-to-adopt' solutions to disease problems (in production systems). All documents must be dated, suitable for collation (and subsequent replacement) within a folder, and be limited to adoption ready information and tools."

Factsheets dealing with specific pest or pathogen and crop interactions have to explain how management methods link in with the overall production system e.g. soil, nutrient and irrigation management. Regional information sessions training or demonstrations may be required to increase awareness of the information and help with adoption.

"Inoculum density-disease incidence data is necessary for the management of inoculum-dependent problems (e.g. those caused by *Sclerotinia* spp. and nematodes). Technology (DNA based) to identify and quantify pathogens and nematodes in soil before planting is now available and should be utilised to guide site and crop selections. Cultivar decision support should be included (*in information for growers and advisers*), e.g. cultivar performance across soil types and under different inoculum pressures."

DNA tests are generally easy to develop but sometimes development of sampling strategies for specific pathogens e.g. *Rhizoctonia* and potentially *Sclerotinia*, can be difficult and may require specific R&D (Ophel-Keller, pers. com.).

The vegetable industries other than potatoes are yet to make good use of DNA technology and related services. Awareness of the technology and confidence in using its outputs to guide crop selection and management decisions is needed in the vegetable seed and production industries.

"Knowledge on the economics of inoculum reduction and other preventative and corrective strategies (e.g. crop rotations, cover / biofumigation crops, soil health management) across soil types is also important for risk assessments."

The VG 11035 report includes a relevant summary table about what we already know from vegetable and other R&D about soilborne pest and disease management and what extension is needed. It provides tabulated information about pathogen specific knowledge, gaps relevant to soilborne disease management and specific knowledge gaps in regards to pathogen complexes such as:

- The microbial ecology of key pathogen complexes in different soil types
- Dominant pathogen processes and sequences in colonisation and infection in multi-organism ('complexed') pathology
- Systemic chemistry with cross-pathogen genus efficacy
- Crop rotation effects on all pathogens to which host is susceptible
- Cross-pathogen genus suppressive soil characteristics.

Other knowledge and information gaps mentioned relate to:

- Quantification and characterisation of specific soil microbial communities
- Monitoring and data management – surveillance.

The VG 11035 report recommends a similar approach to RD&E as taken by the Australian Potato Research Program to develop integrated systems for soilborne pest and disease management for vegetables. The approach includes understanding of critical components in risk assessment and management decisions i.e. soilborne pathogen populations, seed quality, planting material suitability, soil type and condition, soil and crop management, and environmental factors. This suitable approach needs collaborative, multidisciplinary work / guidance, and involvement of growers and their advisers. Growers and advisers need to be part of the R&D Plan-Do-Review-Improve cycle as researchers, by nature of their work, do not have the required depth of understanding of market and economic imperatives, production systems, agronomy approaches, soil management techniques etc. and general drivers for decision making on farms, which they need to consider throughout their work.

The VG11035 report includes well-founded summary information on key soilborne pathogens, the status of available control options and suggested focus areas for future investment in integrated soilborne disease research, as well as tabulated recommendations for priority investment in extension, development and research activities. This information should be referred to for action planning that follows strategies set in this RD&E investment plan.

VG11034 Benchmarking Uptake of Soil Health Practices

HAL commissioned a review of the uptake of soil health research in the vegetable industry in 2011. The review concluded: "soil health management is generally recognised by vegetable growers as an important aspect of plant health management". VG11034 determined that adequate **general** reference information is now available on soil management for vegetable growers and advisers, and that growers are willing to change soil management practices if new approaches are shown to be effective (in improving crop health and marketable yield or reducing inputs – cost / benefit).

High adoption rates of green manure crops, composted manures and biological activators were confirmed by the HAL review. It found that most growers use conventional soil testing to get advice on fertiliser input needs. The majority of growers are however not comfortable with interpreting all aspects of a conventional soil test report themselves.

The review concluded that while general information was readily available, a lack of user **friendly** and **accurate**, (*topic, crop or site*) **specific** information is hindering (*further*) improvement in soil management. Skills deficiencies identified with growers and their advisers included (*in spite of reported high adoption rates*) soil biology and microorganisms, soilborne disease control, biofumigation and alternatives to Metham sodium as well as interpretation of soil test results, nutrition management / fertilisers and understanding of subsoils.

These reported skills deficiencies match the RD&E topics identified by Australian vegetable growers during the VG11034 review as shown in Table 3-9. This confirms that R&D needs mentioned by growers and advisers may frequently be needs for more information and capacity building; i.e. the need for knowledge and demonstration of new technologies may often be confused with the need for research. It is important to clearly identify the actual need be interpreting 'what is said, by whom and why'.

Table 3-9: R&D topics identified by vegetable growers and advisers, their relationship to recorded skills deficiencies, and plant health R&D or knowledge areas

R&D topics prioritised by growers and advisers in the review	Related skills deficiencies identified by growers and advisers in the review	Related R&D and knowledge areas
Soilborne diseases	Soilborne disease control Soil biology and microorganisms Biofumigation and alternatives to Metham sodium	Identifying pathogen presence and risks of soilborne disease expression based on pathogen type(s), and site / crop and management factors (inc. rotation & cover crops)
Biofumigation	Biofumigation and alternatives to Metham sodium Soilborne disease control Soil biology and microorganisms Nutrition management and fertilisers	Biofumigation cover crops and site specific management options (which crop for which purpose and how to manage it) Pest, weed and disease suppression in vegetable crops following biofumigation cover crops Cost / benefit of biofumigation compared to other methods
Nutrition, especially in relation to organic composts, and cation exchange (CEC) and nutrient holding capacity	Interpretation of soil test results Nutrition management and fertilisers Soil biology and microorganisms	Effect of organic amendments on nutrition management (nutrient cycling, nutrient availability and uptake, nutrient holding capacity) Site & crop specific nutrient management and how it affects plant health
Soil biology, organic supplements and microbial activators	Soil biology and microorganisms Soilborne disease control Interpretation of soil test results Nutrition management and fertilisers	How do organic supplements and microbial activators work? How do they differ? What is their effect on plant health?
Controlled traffic and no till to reduce input costs and improve soils	Understanding of subsoils Interpretation of soil test results, Nutrition management and fertilisers	Tillage approaches and equipment effects on soil condition, nutrient management and plant health
Soil health general	Soil biology and microorganisms Soilborne disease control Interpretation of soil test results, Nutrition management and fertilisers Biofumigation and alternatives to Metham sodium	Interaction of management factors Rotation and cover crops Soil conditions in the rootzone and how they affect plant health

Table 3-9 shows that, while growers and advisers have been changing soil management practices (adoption of new techniques), they would still like to better understand the relationships between certain practices and productivity. This can, in the main, be done using existing knowledge and demonstration sites (refer to section 3.2.5 on soil health). Interestingly, the need for a better understanding of the economics (short and longer term) of alternative practices was not identified during the review even though this aspect would be essential for decision-making.

All soil and plant health related knowledge areas (Table 3-9) share one overarching aspect that often is overlooked. This is the relationship between the soil health status and root growth (health, depth, distribution, and potentially symbiotic associations). Soilborne diseases and unfavourable soil biological, physical and chemical conditions lead to poor root development; then crop establishment and plant defences are compromised. Rooting depth, root length density and rhizosphere conditions are soil health indicators with a direct link to crop health. Measurement of root growth and health are often neglected in soil (health) research, probably because most root assessments are tedious and time consuming. Root health and plant health (in the short and long term) should be investigated in soil health studies.

3.1.5 Conclusions and recommendations from synthesis of key planning and review reports

RD&E planning and implementation

Previous reviews have identified issues related to the development of RD&E plans, the prioritisation of activities and their implementation[3]. This information was initially used to frame discussion with industry advisors. The following table (Table 3-10) builds on previous studies and incorporates our analysis from extensive consultation and desk-top review within this current project.

Table 3-10: Issues associated with RD&E planning and implementation and requirements for the future

Past/Current Circumstances	Future/Ideal Situation	Requirements
Integrated RD&E		
Lack of clear guidance based on a coordinated program for RD&E	Program (logic) approach provides long-term goals to enable collaborative approaches that meet industry needs	▪ Short, medium and long-term RD&E needs are addressed through a program (logic) approach
Focus on individual, not always well matched projects, with individual extension strategies	Related issues are dealt with in coordinated way. Well-planned programs based on industry needs, established priorities and capacity to deliver the desired RD&E outcomes Coordinated and effective extension and capacity building programs delivered.	▪ Adequate information base and decision making processes for planning and coordination ▪ Best practice R&D using national and international resources ▪ Effective information transfer through well resourced programs that support capacity building and adoption processes ▪ Evaluation of extension programs (technology uptake / practice adaption or change)
Lack of clear process for monitoring and addressing dynamic levy payer RD&E needs	Growers and service providers raise plant health and crop protection issues and receive feedback on status of that issue	▪ Clear systems, roles and responsibilities for monitoring and addressing RD&E needs
Difficult for Industry Advisory Committee (IAC) to establish the relative merits of projects competing for limited funds	Documented process for assessing the relative risks and benefits of project and program investments	▪ Short, medium and long-term RD&E needs are addressed based on a program (logic) approach ▪ Clear roles, responsibilities and standard decision-making processes for identifying and addressing issues exist

[3] Adapted from the Vegetable Integrated Crop Protection Research, Development & Extension (RD&E) Plan 2011-2015 developed as part of the National Vegetable IPM Coordinator Lauren Thompson, Scholefield Robinson Horticultural Services Pty Ltd Project Number: VG09191

Past/Current Circumstances	Future/Ideal Situation	Requirements
Focus on short-term, "wish-list" issues	Strategic approach based on objective assessment of importance vs urgency and risk vs benefit (economic, environmental, social)	▪ Monitoring and evaluation provides feedback to IAC to enhance decision making
Knowledge management		
Lack of good data as a basis for decision making (pest, weed and disease distribution, incidence and severity; control methods used - trends; economic impacts)	Relevant data is captured and analysed	▪ Systems of capturing data on pests, weeds and diseases e.g. via monitoring the use of pesticides and other control methods
Capacity building		
Minimal ongoing extension once project completed	Information transfer strategies will ensure ongoing availability and reappraisal of extension resources	▪ All relevant information is readily available and easy to use for growers, their advisers and others in the supply chain
Dwindling state department resources for information transfer and advice Lack of IDO's or similar extension people Agronomy providers and advisers are not adequately included in extension processes	All parties in the vegetable industry supply chain can play a role in information exchange regarding plant health and crop protection issues and information is 'packaged' according to the needs of different groups	▪ There are clear extension pathways ▪ Advisers are included in the extension process ▪ Information is targeted and easy to access and use ▪ Impacts are monitored, evaluated and arising issues are addressed
Vegetable productions systems – chronic and acute issues		
Dominance of solving on-farm, acute issues	Important immediate on-farm needs are addressed alongside longer term, strategic plant health and crop protection RD&E involving managing genetics / varieties, soil, climate, cultural and business decision impacts and market requirements	▪ All factors that influence risks and opportunities for successful, integrated management of plant health and crop protection are adequately considered in RD&E programs
Cumbersome systems and timeframes for decision making make it difficult to adequately respond to genuine emergencies	Budgeting, preparedness and program management processes enable responsiveness to emergencies	▪ There are clear systems, roles and responsibilities for addressing emergencies. ▪ Emergency response systems are part of the program (logic) approach
Most stakeholders are unclear about who is responsible for dealing with various major threats and emerging issues, related to plant health and crop protection	Robust risk and crisis management plans establish responsibilities and contribute to reducing threats to industry	▪ Information is readily available ▪ There are clear roles and responsibilities in addressing issues.

Integration of industry participants		
Minimal linkage with input suppliers (seed, chemicals, fertilisers), advisers and ex farm gate supply chain	Communication with all stakeholders in the vegetable supply chain is maintained	▪ Lines of communication with all stakeholders in the vegetable supply chain established ▪ Stakeholders receive feedback on how their inputs are used
Markets and consumers		
No monitoring of changes in consumer attitudes and demands regarding pest management	Market signals are monitored in domestic (and key overseas) markets and information is used for RD&E	▪ Market impacts are monitored and addressed ▪ Information from markets is readily available to all stakeholders

General

R&D programs and outputs for vegetable plant health and crop protection mainly followed the approach of addressing issues by discipline, pest, weed, disease and crop with some level of across discipline or crop integration. Surveys and workshop results used to design or review R&D projects were generally interpreted from the viewpoint of researchers and R&D disciplines rather than that of vegetable production systems (growers or crop perspective).

This has usually led to discipline based R&D programs or projects. Generally, it has not been taken into account that survey answers from industry may reflect important knowledge and adoption gaps, rather than actual R&D needs. Answers from researchers may reflect their area(s) of expertise and interest or that of the organisation they work for. It has to be considered that, for many organisations that are employing researchers, policy makers from within and from outside the organisation may drive broader R&D priority setting.

Communication and extension were often addressed via separate programs (refer to Table 3-10). Still, some extension activity was usually included in individual projects as explained in the previous section (3.1.1 and 3.1.2). Research outputs produced as part R&D projects usually included fact sheets, manuals, tools, articles or Vegnotes for 'Vegetables Australia' and presentations made during field days and conferences, in addition to detailed final reports. Specific tools, factsheets or manuals produced as part of HAL projects that are separate from final reports can be difficult to track down after the project has finished; they are not kept with or are electronically linked to final reports.

Final reports marked the end of a project and, in most cases, the information compiled in these reports was not distributed to industry in a different, easy to use format or integrated with other relevant crop management information, because there was no requirement and no funding to do this. The former Vegetable Industry Development Program (VIDP) included an effort to provide information from previous projects and programs to growers via different channels, especially through AUSVEG. The AUSVEG 'R&D database' and 'technical insights' are a legacy of this work. The AUSVEG web based information systems have continued to develop and could include additional, synthesised information.

R&D needs analyses or reviews should be used to guide subsequent RD&E programs or projects. A careful survey design, analysis and synthesis of information that is collected during surveys, workshops and from the examination of previous projects is required to design effective future integrated programs that produce and disseminate industry ready information. Integrating evaluation into programs and projects would eliminate the need for reviews; they would then be a part of the work. Needs analysis should include an economic impact assessment.

Needs analyses and reviews have usually been used to identify R&D projects for a certain research discipline by answering questions such as “What (more) do we need to know about soilborne diseases, soil health, certain leaf diseases, pests or weeds and their management for various crops or crop groups?’

Often various groups that influence plant health and crop protection decisions are not consulted before or during projects. These include developers or suppliers of inputs such as seed, fertilisers, equipment and pesticides, and often agronomists, consultants and other types of ‘field’ staff (e.g. processers, packers, supermarkets). The groups that are not consulted are also often not included in the dissemination of the information that comes from R&D projects. An inclusion of a wider stakeholder or expert group to advise on projects may be beneficial for getting industry ready outputs.

All of the above mentioned groups have different drivers for decision-making. While researchers have the imperative to publish in reputable scientific magazines and present at conferences to further their career, growers need to be profitable to survive. All groups that provide advice and inputs to growers on a fee for service basis have to be profitable themselves and have a vested interest in the profitability of their grower customers. These differences in drivers need to be considered when analysing what different groups do or say in regards to plant health and crop protection. Surveys should not just be used to produce data and repeat what has been said but try to understand and analyse the thinking behind it.

The questions growers usually ask about new technologies are:

- Is the new approach or product going to cost more or less?
- Do I need new equipment? What does that cost?
- Will it give me higher marketable yields, less hassle or better quality?
- Will it reduce inputs such as fertilisers or number of sprays?
- How will it affect other things I do?
- What does is do to my bottom line and time / staff commitments?
- Is it safe(r), does it affect my surroundings or my family?

These issues may not come up in surveys, due to the way they are designed and not all of these questions are answered in R&D outputs, even though they are important.

The analysis and synthesis of discipline focused needs analyses should also ask the following questions:

- What do growers and advisers need to know, and which skills, resources or technologies do they need to manage plant health and crop protection for vegetable X Y Z more efficiently, reduce crop losses and increase profitably throughout the supply chain?
- How can RD&E help all with a stake in plant health and crop protection to manage (economic, environmental) risks and make good decisions?

- Which issues can be addressed via targeted extension and capacity building programs, which need development or applied research, what are the needs for basic research?
- Do we have good data and information as a basis for crop management and RD&E decisions?
- How do we need to consider economic, environmental and social imperatives?
- What is the required scale? Is it regional, national or international?
- Who needs to be involved in RD&E programs to make them relevant and effective?

In R&D programs, extension should be an integral part of the program not a separate project. The same principle as for extension applies to evaluation; an annual evaluation of outputs against stated objectives and review of practice changes in the industry due to the work should be carried out to guide the next phase of each program or project (plan, do, review, adjust).

If levy and government funded research identifies potential new products or services, the reporting should include information about a root to market i.e. how to make them available to growers and their advisers.

Weed management

A HAL funded ‘weed in vegetables stocktake’ or management review has not taken place in the 10 past years. Information on integrated weed management can be found on government department and AUSVEG websites. The economic impact of chronic and acute weed problems and future risks on the vegetable industry is not known. Worldwide, weeds are reported to cause greater economic losses than pests and diseases. Industry should therefore make a case for investigating weed management issues, their relationship to overall crop management and soil condition, and economic impacts to properly direct RD&E in the weeds area.

3.1.6 Relevant plant health and crop protection RD&E conducted for other crops

The following section provides a brief summary of information from crops other than vegetables and or other RDCs.

Information produced by other RDC’s

GRDC

Information produced on pest, weed and disease management by GRDC for broadacre crops covering the same species as vegetable crops, and applicable general information should be reviewed and included in extension products and events for vegetable growers. The range of available resources includes factsheets, tools, Apps, ute guides, books and training opportunities in the following relevant topic areas: Rotation and Planning, Crop Establishment, Crop Monitoring, Crop Nutrition, Crop Protection, Biosecurity, Agronomy and Farming Systems, Environment, Climate and Land Management, Business Management, Extension and Communication, Building Capacity. A few selected examples are:

- Weeds and pests ute guides and apps
- Back Pocket Guide - Nozzle Selection for Boom and Band Spraying

- Canola Diseases: The Back Pocket Guide
- Weed smart factsheets and weed identification apps
- Slug control
- Recruitment and labour management.

GRDC resources can be easily accessed from the GRDC website. Researchers should continue using relevant information on methodologies and technologies in designing their projects for vegetables.

RIRDC

RIRDC has produced relevant information for use in extension in the subject areas of: Bioenergy, “BioProducts” and Energy, Dynamic Rural Communities, Fodder Crops, Global Challenges, Investing In People, National Rural Issues, New and Developing Plant Industries, Organic Farming, and the Primary Industries Health and Safety Program.

Only one vegetable plant health specific publication could be found: Datt B., A. Apan, and R. Kelly, 2006; Early Detection of Exotic Pests and Diseases in Asian Vegetables by Imaging Spectroscopy. RIRDC Publication No 05/170 RIRDC Project No CEO-1A

Land and Water Australia

LWA has produced information on land and water management that is relevant to plant health in vegetables. Whilst LWA no longer operates, reports have been archived and most organisations have been supplied with electronic versions of LWA resources. These should be scanned and taken into account when designing projects that include land and water management aspects of plant health and crop protection.

Scientific and industry journals

Many scientific and industry journals can be reviewed for information on plant health and crop protection. Researchers routinely do this as part of their work and to keep abreast of new approaches and technologies. Some new technologies from scientific papers and other sources are compiled in the next section of this report.

3.1.7 New approaches and technologies relevant for vegetables

New approach - expanding timeframes and spatial scales

Growers, advisers and researchers tend to focus predominantly on a paddock scale and the upcoming or current growing season. Research projects are usually limited to a 3-year timeframe and trials are restricted to a relatively small number of (sub) paddocks. The relevant time and space scales for redesigning plant health crop protection R&D approaches should include that of the biological cycles of harmful and beneficial organisms, which are often much longer, although quite variable.

The need to adopt longer **timeframes** can be illustrated in the case of weeds. The effectiveness of weed control cannot be judged on results within a single season, as the resulting seed bank left in the soil and conditions will determine subsequent infestation levels. Approaches to integrated weed management need a multi-year strategy, e.g.

including varying successive planting dates by diversifying crops within a rotation. The situation is similar with soilborne pathogens and pests. In this case, the succession of host and non-host crops, soil management and inputs modify inoculum levels and the antagonistic potential of the soil microflora. Longer studies are required to get meaningful information for industry including economic information.

For other pests, weeds or disease spatial dispersion is more important than local persistence and the relevant scale extends beyond paddocks to encompass non-cultivated surroundings or even a small region (the landscape). When considering the role of landscape in pest management, the emphasis is usually placed on conservation of functional biodiversity and the role of beneficials in regulating pest populations. New results also indicate that the arrangement of vegetation in the landscape affects pest levels in crops (Valantin-Morison et al., 2007[4], Ricci et al., 2009[5]). As a specific case, the spatial distribution of resistant varieties can be used to increase their durability by slowing down virulent races (Hossard et al., 2010[6]).

Spatial scales of research approaches may need to be adjusted to provide better insights into alternative approaches to pest, weed and disease management. It also means moving away from a cause and effect approach to understanding complex systems in a regional context. Guidance for this kind of approach may be taken from ecological research.

New technologies and techniques

New technologies should be mainly considered for basic and or across industry research that may receive less than 50% funding from the vegetable industry levies, until ready for applied R&D and greater vegetable industry involvement. In the following, some new technologies are introduced briefly for consideration.

Remote sensing technology is not new but has not been extensively used for plant health management in cropping applications. This technology may be useful when expanding the spatial scales of research to vegetable production regions or subregions.

Landscape diversity and field margin management are techniques that have been trialled and are used in Europe due to the need to manage without many deregistered pesticides. The concept is that this type of management provides greater flora and fauna diversity. This is expected to reduce the incidence and severity of some chronic pests and may assist in providing greater resilience against new and emerging pests and disease. The greater the spatial spread of greater diversity, the better may be the expected effects on plant health and crop protection. Technologies like remote sensing and GIS could be used in monitoring and recording impacts of landscape diversity and field margin management. This type of work fits with the approach of large time and spatial scales.

Plant growth regulators are routinely used in broadacre and fruit crops. They are used to a lesser extend in vegetables as seed treatments, in transplant production or fruit ripening. Seaweed extracts may have growth regulator effects. Further investigation of the use of growth regulators to improve germination, root growth, and crop establishment may be

[4] Valantin-Morison M. et al., 2007; Effects of crop management and surrounding field environment on insect incidence in organic winter oilseed rape (Brassica napus L.) . Crop Protection 26 (août): 1108-1120
[5] Ricci B. et al., 2009; The influence of landscape on insect pest dynamics: a case study in southeastern France. Landscape Ecol (2009) 24:337–349
[6] Hossard L. et al. 2010. Quel déploiement spatio-temporel des variétés et des itinéraires techniques pour accrotre la durabilité des résistances variétales? Innovations Agronomiques 8, 15-33

warranted. The benefit to plant health may mainly lie in an observed effect of good initial root development and crop establishment on plant resilience.

A better understanding of microbial agents that modify the chemical environment in **allelopathic biocontrol** and their practical application is required. Allelopathic biocontrol works through the breakdown of soil organic matter and the release of antimicrobial compounds such as phenolics or by enhancing the chelation of essential nutrients for pathogens. Allelopathic biocontrol may have a part in the suppression of weeds. It may be easier to understand the breakdown products from organic matter and their effects that the multitude of microbial interactions involved in it.

Selection of **rotation or cover crops** (biofumigation) may affect the availability of allelopathic compounds that bring about biological control (disease suppression). More than one mechanism will function at the same time in any biological system. The desirable approach is to integrate biological controls with other control measures including limited chemical applications, culture practices (crop rotation, tillage, nutrition etc.) and host resistance. This approach should reduce the rate at which disease resistance can develop. An advantage should be that, in general, resistance to biological agents develops very slowly because of the complex control mechanism involving numerous biochemical systems and associated genes. Greater time scales may be required for this type of research and greater spatial scales may bring new information that has not yet been found in paddock based research.

Many knowledge gaps remain for **biocontrol systems**. They include understanding and development of various biological mechanisms e.g. microbial antagonists that produce antibiotics or lytic enzymes, that compete for nutrients with the pathogen, that directly invade and kill the pathogen as hyperparasites, that invade and transmit hypovirulence factors, or that are non-pathogenic but trigger or stimulate natural defence mechanisms in the host ('induced resistance and cross protection').

Systemic acquired resistance (SAR) is a plant immune response to pathogen attack. Research in the area is relatively new and it is worthwhile keeping up-to-date about new developments.

Population Genetics: Plant pathogens are notorious for their tendency to evolve rapidly to overcome control strategies based on resistance genes and fungicides. More knowledge of evolutionary processes may be needed to develop sustainable disease management practices based on durable genetic resistance or biological control agents.

Endophytes are fungi or bacteria that infect plants without causing symptoms. Fungi belonging to this group are ubiquitous, and plant species not associated to fungal endophytes are not known. In addition, there is a large biological diversity among endophytes, and it is not rare for some plant species to be hosts of more than one hundred different endophytic species. Different mechanisms of transmission, as well as symbiotic lifestyles occur among endophytic species. Latent pathogens seem to represent a relatively small proportion of endophytic groups. Some endophytes are generalists, being able to infect a wide range of hosts, while others are specialists, limited to one or a few hosts. Endophytes are gaining attention as a subject for research and applications in Plant Pathology. This is because in some cases plants associated to endophytes have shown increased resistance to plant pathogens, particularly fungi and nematodes. Several possible mechanisms by which endophytes may interact with pathogens have been researched. Crop rotation seems to influence endophyte / crop associations. Mycorrhiza is the best researched type of entophyte association; its commercial use in vegetable crops is still limited but may be worth investigating further in combination with soil health / root health studies.

Commercial uses of endophytes in vegetables as part of ICP approaches may be worth investigating further.

Plant cell and tissue culture have applications in plant pathology e.g. pathogen tolerance / resistance development and testing, they should be further investigated.

Nanotechnology utilises nano-sized materials, structures and functionalities. It has applications in postharvest plant health management such as:

- Controlling growth and development of microorganisms (e.g. anti-viral, anti-bacterial, and anti-fungal activities)
- A new generation of packaging films, (strength, looks), and
- Functional labels (Nanobiosensors).

Nanotechnology can also have applications for crop nutrition e.g. to take nutrients where they are needed in the plant, and can increase crop resilience against pests and diseases. Many see it as the next frontier in the management agricultural production, after genetic engineering.

'LifeScience' companies are developing **pesticides with novel mode of action and biopesticides**, suitable for use in ICP systems. It is important for the vegetable industry to keep a watching brief on developments in this area and foster their registration or permitted use in vegetable crops in Australia.

Pest, Weed and disease diagnostics is a traditional discipline that uses new technologies such as DNA testing, internet based tools or smartphone apps. Accurate, rapid diagnosis of vegetable pests, weeds and diseases is the first step in effective management. New and emerging diseases present additional diagnostic challenges and systems have to be put in place to deal with them.

Soilborne pests and diseases are hard and expensive to diagnose from soil samples using traditional methods. DNA testing allows a quick affordable analysis of a range of organisms from the same sample and an assessment of risks to crops. Many leaf diseases are difficult to diagnose in the field and require laboratory testing to make sure they are controlled correctly; again, DNA testing is a suitable tool.

Some very distinctive pests and weeds may now be identified in the field using smart phone Apps or by sending photos to somebody who can identify them.

The vegetable industry needs to be better informed about these new technologies and how to use them through extension programs.

3.1.8 Conclusions and recommendations – use of information and new technologies

Co-investments in suitable national or international frontline research programs in vegetables or related crops may be a suitable approach for the vegetable industry to access new technologies and make use of information available from elsewhere. Horticulture Australia should continue its watching brief on new technologies and relevant R&D programs.

Some technologies such as the use of growth regulators, tissue culture, endophytes and new diagnostic methods are not entirely new but may need additional or applied R&D to find improved methods or applications and or commercialisation to allow them to be used routinely in the vegetable industry.

The economics of all potential new control mechanisms needs to be included in research at the latest when it moves from basic to applied R&D.

3.2 Environmental Scan – Relevant Aspects of Production Systems

3.2.1 Industry context

The Australian vegetable industry comprises an estimated 6000 growers and spans numerous types of vegetable crops. Needs are varied across regions, crops, position within the supply chain, and scale of operation (among other factors).

In summary, the vegetable industry in Australia:

- Is diverse in terms of having multiple and widespread regional locations around Australia in various climates and affecting stakeholders from a variety of ethnic and cultural backgrounds
- Involves diverse and highly commercial supply chains of growers, packers, processors, marketers, wholesalers, agents, providores, retailers, and food service companies (with each sector encompassing an array of enterprise structures)
- Produces a wide range of products (ranging in level of processing and packaging)
- Comprises a range of industry organisational arrangements that service the vegetable growing sector.

Overall, aggregate profit margins have contracted in recent times as a result of strong increases in farm input prices (e.g. energy, labour costs due to shortages of skilled labour), negative impacts of extreme weather conditions on production and the high cost recovery after natural disasters such as the 2011 floods in Victoria and Queensland. However, this is an average industry trend and may not represent every grower or even a majority of growers given the varied profit dispersion across crops, regions, and sectors[7].

Technology and markets drive developments on farm

Technology push and market pressure up and down the value chain strongly influence growers' plant health management and crop protection choices as illustrated in Figure 3-2. The value chain is presented in a simplified manner; in reality, most produce moves through more than two steps from grower to consumer. Figure 3-2 also highlights the main 'stress points' related to plant health and crop protection for each main sector. These differ pre and post-farm gate and again for consumers.

Growers are under pressure to supply products that do not cause 'stress points' in the supply chain. Their main option for achieving this whilst maintaining profitability is using new technologies and managing risks. Focused RD&E should assist growers in the development and use of new technologies. An effective RD&E process must ensure technologies are 'farm ready' (ready for adoption or adaptation) and able to be integrated into the farming system.

Figure 3-2 also indicates that economic losses will increase if vegetables decay after having left the farm and move through the supply chain. Produce values roughly double at each step between the farmgate to the consumer. An example is shown in Figure 3-3 for vegetable production values in Tasmania. Similar relationships for fresh fruit and vegetables have been reported from many countries. Reducing losses through the supply chain is

[7] Australian vegetable industry Strategic Investment Plan 2012 - 2017

critical for farm profitability. Premium products at the farmgate are less likely to suffer losses during postharvest handling and may get better prices, depending on the buyer.

TECHNOLOGY PUSH →				
Resources, farming input & knowledge providers	**Grower**	**Packer/trader/ processor**	**Retailer**	**Consumer**
Pre farmgate		**Post farmgate**		
←				**MARKET PRESSURE**
"STRESS POINTS"				
Availability and quality of new genetics, control methods, products, technologies, knowledge	Pest, weed, disease control risks e.g. lack of control, residues, yield loss, OH&S Cost of production vs prices Return on investment	Appeal / presentation / blemish Shelf life Losses / Waste Residues Freedom from foreign matter (incl. beneficials)	Appeal / presentation / blemish Shelf life Losses / Waste Residues Freedom from foreign matter (incl. beneficials)	Appeal / presentation / blemish (colour, shape) Convenience Flavour Waste Sustainability of production'
	PRODUCT VALUE AND POTENTIAL $$ LOSS TO PESTS AND DISEASES →			

Figure 3-2: Technology push and market pressure through the value chain, stress points for supply chain partners and increase in product value

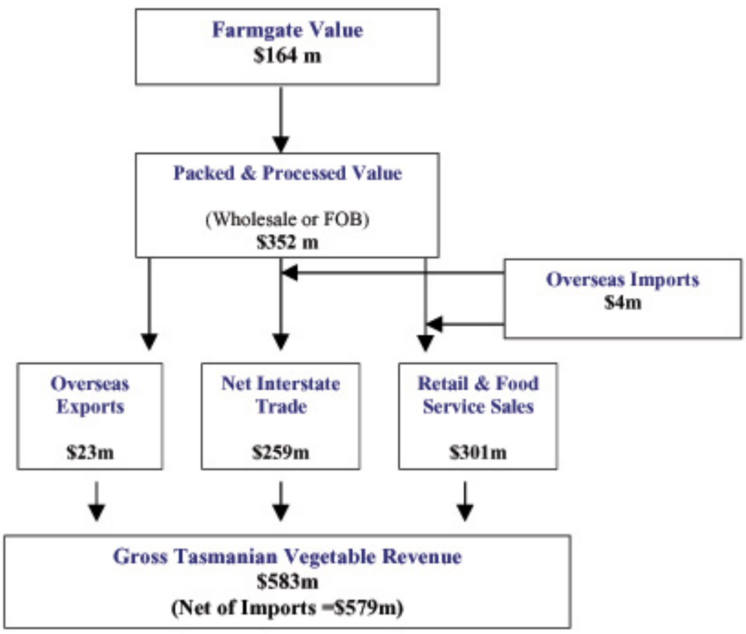


Figure 3-3: Tasmanian Vegetable Industry Score Card, DPIPWE Agricultural Policy Division

Industry priorities and aspects

The major issues of concern to the vegetable industry, as identified during recent consultation for the development of the 2012 vegetable industry Strategic Investment Plan (SIP) are[8]:

- Rising input costs (e.g. water labour, fertiliser, seeds / transplants, fuel, pesticides) impacting on profitability
- Rising concentration in the supermarket and grocery sector control and a decline in the growers' market power along the supply chain
- Ageing workforce
- Low domestic consumer demand
- Globalisation and declining terms of trade in vegetables/increasing vegetable imports
- Climate change and sustainability
- The potential for a carbon emissions trading scheme to place further pressure on profit margins.

The industry's focus on issues that directly impact on profitability emphasises that future RD&E on plant health and crop protection must include an economic analysis of the benefits of practice change. It also means that relevant data must be collected to allow for meaningful economic analyses.

The SIP strategic priorities for plant health and crop protection identified by industry reflect the main industry concerns in this area as:

- R&D on tissue culture biopesticides, IPM
- Minor use program
- R&D into low cost alternatives to replace chemical pesticides
- R&D into emerging pest and disease threats
- Biosecurity.

These priorities reflect that industry is concerned about costs and availability of alternative, traditional and new control options, as well as a lack of risk management approaches for new pests, weeds and diseases.

Industry priorities do not necessarily always mean that new, original R&D is required on a topic. It may mean that industry asks for development, extension and capacity building to better deal with the issues of concern. The actual needs associated with stated priorities are often not thoroughly investigated, with minimal consideration of the context, thinking and attitudes behind answers. The actual issues and how RD&E may be used to address them are best understood via targeted, semi-structured interviews by skilled people who can ask explorative questions, listen keenly and analyse what they have heard.

While ultimately all decisions about plant health and crop protection have economic consequences for growers, and along the supply chain, actions have many interrelated aspects or Elements; these need to be taken into account when dealing with capacity

[8] Australian vegetable industry Strategic Investment Plan 2012 - 2017

building and practice improvement (RD&E). The adoption of particular management practices and technologies will depend largely on the:

- **Industry context** (e.g. industry profitability, limiting resources, markets, regulation, policies)
- **Farming context** (e.g. business fundamentals – equity, structure, profitability, succession, farming systems, infrastructure)
- **Personal attributes** (e.g. attitude to risk, propensity for change, motivations, values, skills, expertise, cultural background).

Fundamental to facilitating change, is understanding which aspects (contexts, attributes) are relevant and considered important for the target audience.

Production systems

Different pests, weeds and diseases simultaneously affect a crop, their incidence, severity and combinations depend on many environmental, genetic and management factors, they change during crop growth. Consideration of the whole system is critical when undertaking RD&E (Figure 3-4).

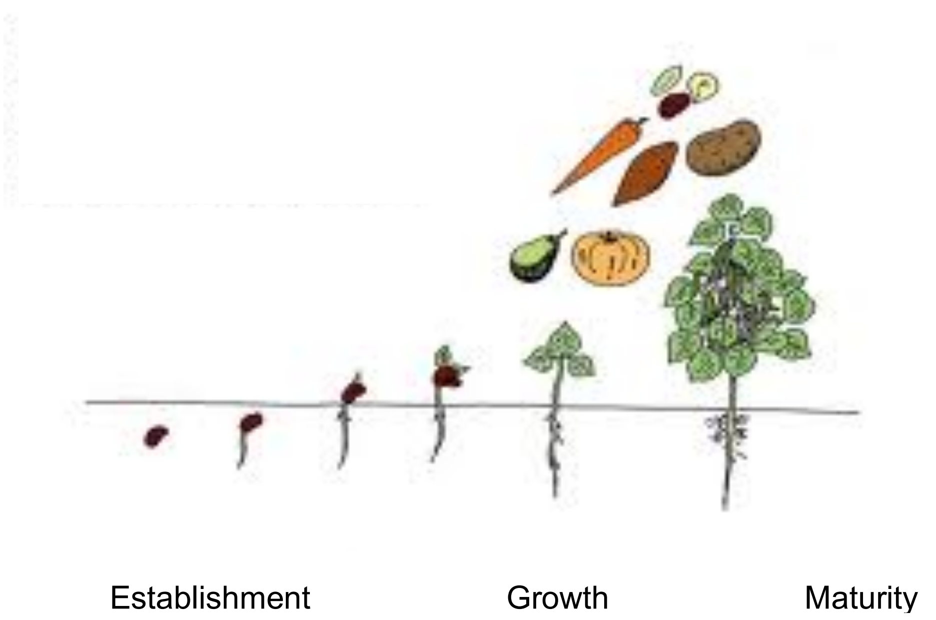


Figure 3-4: Illustration of vegetable growth stages and the complexity of decision making about pest, weed and disease control during the life of a crop

3.2.2 Chronic and acute pests, weeds and diseases

On farm issues

On farm management of pests, weeds and diseases has a number of key challenges. Management generally involves the use of a chemical product and/or ICP methods. For individual growers the primary concerns in relation to management relate to:

- Product and/or ICP method to control pest, weed or disease not being available, known to grower or adviser or suitable for the situation
- Product and/or ICP method not working (e.g. due to application timing, product resistance, pest, disease, weed pressure, lack of beneficials, climate or soil conditions helping infestation) or being used incorrectly (too often, not often enough, wrong concentration, combination timing or method).

Growers need to contend with a multitude of external requirements in relation to implementing their plant health and crop protection regime. This includes consideration of:

- OH&S requirements
- Regulation for chemical use and crop residues
- Requirements and expectations from environmental and market groups.

In addition, growers are dealing with a complex farming system with multiple issues to consider concurrently, and uncertainty about pest, weed and disease types and pressures to expect (timing, incidence, severity and combinations due to soil, climate and management factors). Often there is uncertainty as to the success of specific crop treatments.

Chronic pests, weeds and diseases

A range of **chronic** pests, weeds and diseases affect vegetable crops in varying combinations, timings and severities. These have been researched for many years and a range of control and management methods have been developed (section 3.1). Chronic issues may become acute or require a change in how they are managed due to:

- The removal of pesticides from the market and/or development of resistance
- Market demands and availability of new technologies (ICP, new genetics, equipment, surfactants) which are supported by cost pressures at the farm level
- Change in climatic seasonal conditions (i.e. prolonged wet conditions after a long period of drought may result in diseases 're-appearing' e.g. anthracnose in lettuce)
- Changes in crop management practices and varieties.

Early-warning-systems for plant pests and diseases based on climate and pest and disease monitoring (e.g. insect trapping networks, local observations), modelling and remote sensing may be useful for some chronic vegetable pests and diseases. Early-warning systems are only valuable when they provide timely forecasts that growers can easily and reliably use to inform management decisions.

Acute pests, weeds and diseases

The change of a plant health issue from chronic to **acute** may initiate a need for RD&E as:

- Previously researched management options may have been 'forgotten'

- Information about the problem is not readily available, and/or
- Solutions are not available (particularly pertinent in the case of new pests, weeds and diseases).

A recent CSIRO study developed baseline scenarios for emergency plant pests (EPP) relevant to the vegetable industry. If these scenarios become a reality, this would cost the industry and government $2.4 billion – representing 7 to 12 times the investment needed to bring a new crop protection product to the market. In the case of new and emerging pests, weeds and diseases, integrated control methods can be 'the best bet', fastest and most economical option as has been shown in the cases of the lettuce aphid incursion and the tomato/potato psyllid and zebra chip complex in New Zealand. The important point is to have good surveillance and diagnostics systems and the required expertise to be able to react quickly.

The HAL Strategic Agrochemical Review Process (SARP) considers **new or emerging (acute) pest, weed and disease** problems based on industry expertise, gaps identified by growers and advisers as well as outcomes from existing HAL projects. However, it is imperative that good decision making processes are in place for these projects on new, emerging pest, weed and disease problems. This includes rapid response times, involvement of growers and their advisers in formulation of the R&D, incorporation of functional 'forecasting and early warning systems' and linkages with other key programs (e.g. Biosecurity CRC).

Post farm gate issues

Post farm gate problems are usually **chronic** although **acute** issues may occur with new diseases or pest incursions. Infections and decay after harvest occur at any time during the supply chain and there can be an enormous variation in losses ranging from zero up to 100% depending on the issue and circumstances.

Fungi and bacteria cause most postharvest losses whilst virus diseases, nematodes, or insects common in growing crops, are not usually a major post-harvest problem. However, the damage they cause in the field (e.g. wounds, necrosis) can provide entry sites for fungi and bacteria. Physiological disorders caused in the field through poor irrigation or nutrition management can also lead to tissue breakdown and secondary infections. Insects such as fruit fly or thrips are a biosecurity problem and not liked by consumers, but they do not cause extensive postharvest damage.

Postharvest losses due to infections usually originate from field infections or infestations, and / or harvest/handling damage (mechanical damage, overripe, immature product, wrong temperature, atmosphere or humidity.

Challenges that affect the post farm gate supply chain include:

- Lack of understanding of field and postharvest issues that can lead to infestations/infections and how to control these
- Insufficient or incorrect use of postharvest treatments (dips, sprays, coatings, cooling, packaging)
- Uncertainty about the existence of field infections and product damage that can develop into rots (they often can not be seen or identified)

- Uncertainty about the outcomes (efficacy) of treatments applied during grading and packing (e.g. dips and sprays)
- Limited risk identification and treatment options once the produce is packed.

Postharvest management technologies are well-researched and effective treatment, cooling, grading and packaging technologies exist. However, they are often not used as they may not be known, and/or the economic benefits are not clear. Improving the knowledge or treatment options and information on the economics of good postharvest management would assist in reducing supply chain losses. This is a data collection and extension issue.

UC Davis (California) undertakes training in postharvest technologies. Relevant topics could be used as an example; they include:

- Postharvest biology of horticultural crops; maturity and maturity indices, measuring quality
- Harvesting systems, preparation for market, packing facilities and equipment, packaging, containers, and unitisation
- Cooling prior to shipment: methods, evaluation of efficiency
- Storage: methods, facilities, equipment, management of environmental conditions including controlled atmospheres
- Transport: systems, loading patterns, environmental control, use of modified atmospheres
- Sanitation and other procedures related to decay and insect control; food safety assurance
- Standardisation and inspection, quality evaluation and control
- Harvesting and postharvest handling systems for various commodity groups.

3.2.3 Pesticides

General issues for industry

Pesticides are standard production inputs for the control of pests, weeds and diseases in intensive vegetable production. Issues around their safe use for users, consumers and the environment have lead to increasing public scrutiny and regulation of product registration and product use. It also resulted in the development of more selective products with lower toxicity for beneficial organisms as well as ‘biologicals’ and integrated management approaches to pest, weed and disease control. Various traditional and advanced methods of genetic manipulation of the vegetable hosts or the harmful organisms have been and are being applied to reduce the reliance on pesticides and the volumes used.

Progress in spray technology, and the development of advanced adjuvants (surfactants, spreader stickers, crop oils, anti-foaming materials, buffering agents, and compatibility agents) has assisted in improving pesticide efficacy while reducing the application volumes required. The incorrect use or combination of product, spray technology and adjuvant(s) can cause crop damage, residues and reduce product efficacy by up to 50%[9]. Residues due to

[9] University of Georgia, Corporate Extension http://www.caes.uga.edu/Publications/pubDetail.cfm?pk_id=7678

incorrect product use if found, even an isolated case, can have a negative impact on the entire industry. Effective extension can help to avoid these issues.

The vegetable industry is aware of the fact that access to pesticides may decline due to deregistration and resistance development. Environmental and community concerns about the fate of obsolete and leftover products, and the management of pesticide waste, not only their use, will impact on what growers can have available.

For the vegetable industry, all this means that good pest, weed and disease management has become increasingly complex, requiring a substantial amount of knowledge, skills and experience. Some frequently asked questions are:

- How do different products and adjuvants work?
- Which products can be mixed?
- What is the appropriate spray technology?
- How does crop management affect pests, weeds, diseases and beneficial organisms?
- How do products affect the soil?
- How does the soil affect pests, weeds and diseases?
- What are the rules around pesticide use?
- How do products aimed at the same organism differ?
- How does what my neighbour does affect the health of my crops?
- How do I encourage beneficials to stay around?

Chemical users manuals exist from a range of sources including departments of agriculture to help growers, trainers, spray contractors and operators using agricultural chemicals safely and efficiently. They answer many of the above questions and cover the use of fungicides, herbicides, insecticides and other pesticides. Topics usually include some or all of the below:

- Pest, disease and weed biology
- Product formulations and labels
- Adjuvants
- Product safety, transport, storage and disposal
- Management of agricultural chemical resistance
- Spray and other application technologies and equipment
- Drift management
- Registration and regulation of agricultural chemicals incl. permits and licenses.

A range of training courses dealing with the use of pesticides exist e.g. AgSafe.

Most information products and courses do not cover integrated plant health and crop protection management by crop with relevance to production regions. Good GPPP guidelines and ultimately ICP information could fill that gap (refer to section 3.2.4 below).

Minor use permits

Many vegetable crops cover relatively small areas. Therefore, it is not economical to develop pesticides especially for them or, if they have been developed for overseas markets, it is not economical to register them in Australia.

For that reason, Horticulture Australia has commissioned a Strategic Agrochemical Review Process (SARP)[10] to facilitate determining the need for obtaining minor use permits for products the industry cannot use legally. A diagram describing the SARP process can be found in Appendix 4. The process reviews current and emerging problems, available control measures, including established integrated control methods (ICP/IPM), and issues that may affect efficiency or sustainability of a pesticide. The analysis of each pest, weed and disease problem for each vegetable crop should have the benefits of:

- Listing all control options and their advantages and disadvantages
- Improved scope for resistance management
- Sound biological profile
- Residue and trade acceptance domestically and for export.

Therefore, SARP is an important process for the industry. It could also be used to identify priority targets for GPPP and ICP development (refer to section 3.2.4 below). Selection criteria for GPPP / ICP could include: lack of available control methods now or in the future, effect of pesticides on beneficials, risk of residue development and crop value.

Statistics on pesticides

A process of collecting data on the annual amounts of pesticides placed on the market (collected annually) and the annual amounts of pesticides used on selected representative crops by state or statistical division could be useful. The Statistics would provide information on the trends of pesticides used. It would provide a reference for the types of pest, weed and disease problems occurring and changes over time, trends in management changes, potential training or control strategy development needs, and potential risks of resistance development due to overuse.

3.2.4 Integrated Crop Protection (ICP)

The crop protection continuum

In the past 20 years, the Australian vegetable industry and the federal government invested heavily into plant health and crop protection R&D projects via Horticulture Australia Limited. The underlying approach of most of these projects has been integrated pest management (IPM) or integrated crop protection (ICP). Yet, ICP/IPM appears not to be widely used in vegetables.

Losses from diseases, pests and weeds will occur if growers do not actively protect their crops. The risk and magnitude of losses is hard to predict and growers cannot afford to 'wait and see'. Vegetable growers try to balance their crop management practices according to their skills and knowledge, access to technologies and products, local production conditions

[10] AgAware Consulting Pty Ltd

and economic and market demands. Economic and market demands dictate that they have to 'play it safe' and stick to what is legally available and is known to work.

In most cases, pesticides are the chosen protective option. They are seen as the least complex method for protection with the most predictable outcome. Growers would reduce pesticide use (they are aware of the risks and it is costly), if they knew how to do this reliably and efficiently without risking crop losses and market rejections.

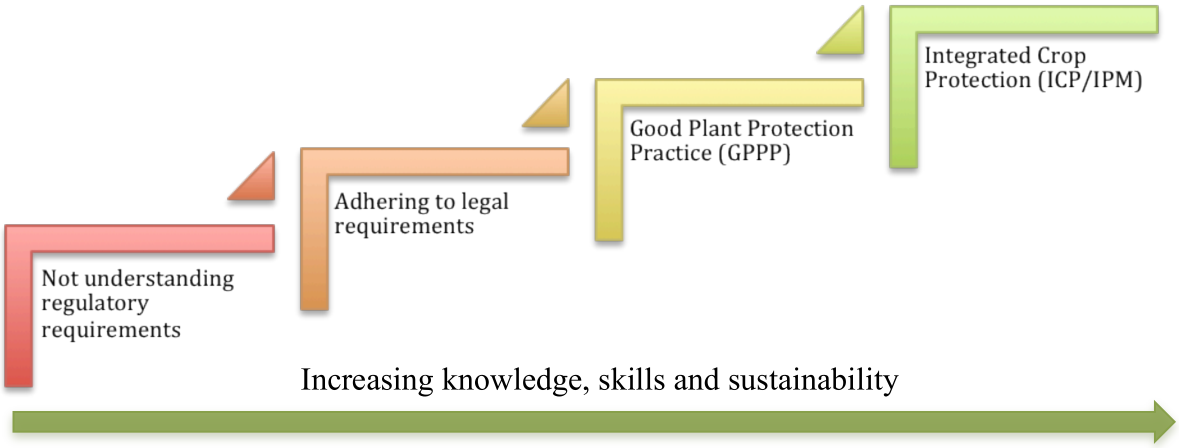


Figure 3-5: The crop protection continuum on farms

Figure 3-5 describes the crop protection continuum on vegetable farms. The grower group with a limited understanding of regulatory requirements, and how to use responsible practices, covers growers who often are new to the country, or are not 'technology savvy', and have a limited understanding of the nature of pests, weeds and diseases, and the risks associated with chemical control. This is only a small group of growers but the risks they could pose to themselves, their families, communities and the environment warrants an effort to assist them in moving along the continuum.

Given that ICP/IPM is not widely adopted (refer to HAL reports listed under 3.1.4), the majority of Australian vegetable growers would belong to the two central groups in Figure 3-5. This means that most growers use responsible practices and try to minimise the use of pesticides without compromising their crops.

For the Australian vegetable industry, exact data on the proportions of vegetables growers using different crop protection approaches by crop and region does currently not exist. It would be useful in determining the type of RD&E required to move along the continuum, if IPM/ICM is the desirable control method.

Good Plant Protection Practices (GPPP)

The EU has formulated the term and principles of good plant protection practices (GPPP) to provide a way to sensibly reduce the use of pesticides by maximising effectiveness and avoiding unnecessary use. It is a best management practice (BMP) approach and can be seen as a step towards ICP/IPM. ICP generally requires a complex decision-making system and has the objective to minimise pesticide use by replacing chemical products through other means as much as possible. GPPP looks at reducing pesticide use through better technology and understanding rather than product replacement. It is a step towards ICP.

In EU countries, GPPP involves the preparation of approved guidelines for pesticide use in different crops considering all 'most likely' pests, weeds and diseases that may affect the crop during production using the principles outlined below.

"Within the conditions and restrictions for which individual plant protection products are registered, the principles of good plant protection practice provide the basis for:

1. *the choice of active substance and formulation;*
2. *the choice of dosage (and if appropriate volume), the number of applications to be used, their timing, and the application equipment to be used and the method of application, in the context of:*
   - *crop factors (e.g. cultivar, sowing rate, timing of sowing, fertilization regime, training system, age, spacing),*
   - *climatic and edaphic factors (e.g. topography, soil type, rainfall, temperature, light).*
   - *possibilities for cultural and biological control,*
   - *cost effectiveness,*
   - *risks of resistance*
   - *safety for operators, consumers and the environment*
   - *the harmful organism spectrum to be controlled,*
   - *compatibility between products and identified side-effects*
   - *training and documentation needs*

GPPP guidelines are providing an overall, scientifically developed, practical schedule for treatment with plant protection products, timed partly by the calendar, partly by crop growth stage/phenology and partly by specific harmful organism warning systems, incorporating as appropriate other means of protection, so that effective control of the whole harmful organism spectrum (e.g. pest/disease/weed) is achieved, with the minimum amount of product usage.

While Good Plant Protection Practice, permits the use of reduced rates of application and use of products in tank mixes in certain specified circumstances, it does not permit use of plant protection products for purposes for which the product was not registered, unless an extension of the field of application of an registered product has been granted (e.g. minor use permit)."

The concept of GPPP is not officially defined for Australia. However, many agronomist and growers (unofficially) apply similar BMP principles to crop protection. Developing GPPP guidelines from existing research outputs for major vegetable crops in Australia could be a useful step towards reducing the complexity of decision making and ultimately increasing the adoption of ICP/ICM. The process would pull current knowledge together into a user-friendly format and utilise information collated by the SARP.

Integrated Crop Protection (ICP), Integrated Pest Management (IPM)

Pressure from consumers and markets as well as regulators to use integrated, sustainable production methods above GPPP may continue, if it is true that Australia follows European and US trends. The European Union (EU Parliament and EU Council) has adopted a directive in 2009 (DIRECTIVE 2009/128/EC) that all EU countries will convert to the use of Integrated Pest Management in agricultural production by 2014. That means alternative methods of crop protection should be used preferentially, with only need-based pesticide application. Currently work is taking place on many levels to develop guidelines for how the objectives of this directive can be achieved.

The US EPA actively supports the use of IPM through information campaigns and PestWise grants to fund projects that are exploring innovative practices, technologies and regulatory solutions to promote the adoption of Integrated Pest Management (IPM) within the industry.

OECD is developing strategies for adoption and implementation of IPM in agriculture "to contribute to the sustainable use of pesticides and to pesticide risk reduction", especially in developing countries.

Some market demands for 'chemical-free' foods, and consumers' growing awareness of health and environmental issues means that calls for alternatives to broader spectrum chemical pesticides and an overall reduction of pesticide use will continue; it will influence policy makers, regulators and retailers. The industry is already facing increasing regulation of the use of pesticides, deregistration and pesticide resistance issues. On top of this, producers of pesticides are facing increasing development costs and will not develop products for small markets i.e. most vegetable crops or register some products they have developed for vegetables in Australia.

The above arguments highlight that the Australian vegetable industry has made the right move when supporting IPM research over the past two decades. It now is time to help industry to move along the 'crop protection continuum'. Guidance for the Australian vegetable industry could be taken from the abovementioned overseas approaches.

This 'move' involves using the information that has been produced here and elsewhere to help growers to the next step i.e. from 'adhering to legal requirements' to GPPP, from GPPP to ICM/IPM. In this it has to be acknowledged that not all growers are ready to adopt ICM/IPM in the near future, but they can move towards this aim. (Whether an aim is close or far away, it does not change the direction; it is important to be clear about the direction. In this it has to be acknowledged that not all will start from the same point of the continuum, and not all will reach the ultimate aim.)

What needs to be done? Industry-ready information has to be made available through **appropriate channels** and in the **right formats**, information that is not **ready for adoption** has to be adapted or completed, **required data** that allows good decision making has to be compiled, **gaps have to be filled** and **impediments to 'making GPPP and ICP/IPM work for growers' removed**.

ICP/IPM deals with complex systems with many feedback loops. It requires good understanding, forecasting and monitoring of all production and environmental factors, how they interact, and how they influence the likelihood and severity of infestations and crop damage. A good knowledge of the pest, weed or disease lifecycles, the mode of action of pesticides in regards to protection of beneficials, effects on different life cycle stages and economical / biological thresholds are required. Not only knowledge, information and good forecasting and monitoring of complex systems are required, experience of all involved is vital. This includes growers, their advisers and RD&E providers. Effective extension and support are vital to fostering the implementing ICP.

Vegetable crops are affected by multiple pests, weeds and diseases. It is an IPM rule that treatment should not be decided on the incidence or symptoms of a pest, weed or disease, but based on an economic threshold that links incidence and severity of 'attack' of a specific organism to potential yield loss. In practice, a given crop is never subjected to a single issue, and yield loss (or damage) will result from the combined effects of multiple damages or setbacks occurring at different stages of development. It should be possible to combine a (simple) plant physiology model with knowledge of the damage caused by types or groups of pests, weeds and diseases to model yield losses as a function of "damage profiles". This has e.g. been done for wheat in a model called ENDURE (Willocquet et al., 2008[11]).

Damage profiles could be linked with "production situations", to capture environmental factors and crop management approaches that growers use under given conditions. This could e.g. reflect regional production situations and predominant damage profiles. Regional or national damage profiles as appropriate should be created for the most economically damaging pest, weed, disease issues and combinations, initially for the most valuable crops, considering the current control options (availability, costs, impacts etc.)[12] and the likelihood for success and demand or use by industry.

The benefit of shifting from the usual single pest, weed or disease species point-of-view to a "multi-pest" and crop stage approach is that, provided there is sufficient field data to underpin the model, it makes it possible to better anticipate risks and consequences in terms of marketable yield loss and then to decide on pest management priorities.

In summary, ICP/IPM is dependent on a sophisticated understanding of and experience with the ecology, structure and dynamics of regional or even site-specific "agro-ecosystems", and having relevant data. It is possible to compile general principles and generate models. However, a clearly laid out, recipe-like instruction package with one-fits-all IPM control measures is not a realistic concept. The solution lies in creating risk based "problem-solving" and "decision-support" systems for integrated management of pest, weed and disease problems in vegetables. These should be developed in a participatory fashion with input from growers, advisers and pesticide producers. Good training opportunities, information and decision-making support will reduce the complexity, uncertainty and perceived risk of using ICP/IPM methods.

While GPPP guidelines could be prepared reasonably easily and in a short timeframe, and the adoption of existing straight forward pest / crop specific IPM methods could be better supported, implementing ICP on a greater scale will take longer, and needs to be a well planned and supported process. An initial focus should be on integrating key ICP principles:

1. Measures for prevention and/or suppression of harmful organisms
    - Rotation
    - Cultural methods
    - Resistant and tolerant varieties
    - Balanced nutrition, irrigation, drainage
    - Hygiene

[11] Willocquet L. et al., 2008; WHEATPEST: a simulation model of yield losses caused by multiple injuries for wheat in Europe. Proceedings, ENDURE International Conference 2008, Diversifying crop protection, La Grande-Motte, France
[12] from SARP and IPM research information

- Support and protection of beneficials

2. Target-specificity and minimisation of side effects of pesticides (people, beneficials / biodiversity and environment)
3. Reduction of pesticide use to necessary levels without producing resistance
4. Use of anti pesticide resistance strategies if multiple applications are economically required
5. Non-chemical (biological, physical and other non-pesticide methods) to be preferred
6. Available tools for monitoring of pests, weeds and diseases as are used; this include observations, disease forecasting systems and advice from qualified advisers
7. Available, scientifically sound threshold values (economic, biological) are used as a basis for decision-making on pest, weed and disease control; these should ideally be consider regional, climate and crop specific factors
8. Records, monitoring, documentation of product use and pest, weed and disease levels to be able to check success of intervention and control methods.

A start could be made by developing and then building on GPPP guidance to provide some basic, general rules that can be refined over time and, in priority areas replaced by more complex models as described above. The following general guidance could be provided:

- Selection criteria for seeds and propagation materials (certification, disease tolerance or resistance, protection applied)
- General criteria for the correct choice and use of plant protection products (preference for certain categories, definition of selectivity, resistance management)
- Criteria for defining thresholds, monitoring and assessment of pests, weeds and diseases, record keeping (networks, scouting, trapping, data sharing and analysis).

In some cases, more specific regional, crop and or site specific guidance could be made available that considers the availability of choices. This information is currently available from a range of sources. Much of it is, for example, already compiled in the current EnviroVeg manual, which could be reviewed with a view of supporting GPPP and ICM. It could include sections with regional relevance as required.

They may include: specific pest, weed or disease thresholds, pest identification, defining susceptible crop life stages and aggressive pest life stages, monitoring criteria, trapping guidance, seeding or planting criteria (density, spacing, timing, soil conditions), general cropping practices and possible influence on pest, weed or disease development (e.g. soil health management tillage, crop nutrition, irrigation, crop residue management), possible alternatives to chemical treatments (biological control, antagonists, physical devices), plant protection product selection and their application rate, technology and timing (selectivity, resistance prevention, mixing).

How could the adoption of existing IPM methods be improved?

The Field Vegetable IPM Stocktake (VG05043 McDougall, 2007), "Benchmarking vegetable integrated pest management systems against other agricultural industries" provides the following reasons for the slow uptake of IPM:

- Current control practices are usually adequate (apart from 'crisis situations[13])
- Market requirements for blemish/insect free produce
- Lack of active surveillance or data collation and analysis on regional pest and disease issues to guide growers and advisers
- Very few experienced IPM consultants exist around Australia
- Lack of consistent networking and cooperation between and amongst researchers, specialist IPM consultants, advisers and growers and the agrichemical industry
- Diversity of industry (crops, size of companies, cultural background, training level)
- Lack of grower and adviser participation in ICP / IPM research and training
- Lack of practical training opportunities
- IPM information sources are vast and dispersed; they are of variable quality
- Availability and or knowledge of how to best use 'soft, selective chemicals' and biopesticides is limited
- Availability of beneficials and or knowledge on how to make use of beneficials is limited
- Lack of integrated soil management strategies including monitoring and prediction of soilborne disease risks and factors that enhance disease suppression
- Lack of coordination and cooperation amongst organisations with a stake in sustainable production (e.g. peak industry bodies, government departments, CMAs, Universities, agribusiness etc.)
- Perceived risks, complexity and uncertainty of success and no proven economic advantage for growers
- Advisers being more risk adverse than growers (indemnity)
- Regulation does not require moving towards ICM / IPM like e.g. in Europe.

One of the barriers that may not be applicable anymore is a lack of sufficient pressure to adopt IPM (market, economics or economic data, loss of other control methods). The pressure and will to reduce pesticide use has increased and there is concern about loosing chemical control methods through deregistration, resistance and a lack of new registrations and developments.

Compared to the relatively high number of impediments, drivers for IPM adoption are:

- Reduce cost of pesticide applications (number of applications)
- Improve pest control
- Reduce dependence on pesticides
- Pesticide failure (mainly due to resistance)

[13] Chemical resistance and/or new major pest/disease, loss of chemical options

- Pesticide loss (deregistration or withdrawal, lack of registrations)
- Public image
- Chemical residues restricting market access
- Pressures from new and chronic pests, weeds and diseases (crises, acute issues)
- Reliability of production
- Environmental issues becoming more of a concern.

Most of the barriers can be removed and drivers can be reinforced to assist IPM and ICP adoption. Further development and adoption of ICP/IPM may be hampered by limited funding resources, job tenure and the increasing age of experts within government departments and universities causing an ever-reducing base of relevant R&D and especially extension and teaching expertise. Shortages may appear especially in the fields of nematology, bacteriology virology and entomology[14] and potentially weed science.

For the development of integrated management options, the limitation of R&D projects to three years could be a serious impediment. Longer programs that deal with complex issues need an embedded ongoing extension and evaluation obligation and report regularly to an advisory group that can make changes to the program direction, focus and staffing, if required.

The economics of all new technologies or approaches need to be part of research programs.

3.2.5 Soil health and pests, weeds and diseases

What is soil health?

"Soil health is the condition of the soil in a defined space and at a defined scale relative to a described benchmark. The definition of soil health may vary between users of the term as alternative users may place differing priorities upon the multiple functions of a soil. Therefore, the term soil health can only be understood within the context of the user of the term, and their aspirations of a soil, as well as by the boundary definition of the soil at issue." (from Wikipedia).

From the agriculture perspective and for the context of this report, soil health is understood as:

"Soil health is the capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests, form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive repercussions for soil water and nutrient holding capacity, and ultimately improve crop production" [15]. To that definition, an ecosystem perspective can be added: "A healthy soil does act as a filter for water and does not pollute the environment (e.g. via erosion or leaching); it contributes to mitigating climate change through retaining or accumulating carbon." The soil health status is the actual condition of the soil (in a defined space and at a defined scale) relative to a target conditions (described benchmark).

[14] Howie B.,2013; Plant Pathology and Entomology Capability Study. Prepared by CQual agritelligence for APPS

[15] FAO. 2008. An international technical workshop Investing in sustainable crop intensification: The case for improving soil health, FAO, Rome: 22-24 July 2008. Integrated Crop Management, 6(2008). Rome.

A major challenge for soil health management in agriculture is to sustain the 'living system' and its services while optimising production. It is proposed that soil health maintenance is dependent on the upkeep of the following major functions:

- Carbon and nutrient cycles
- Soil structure and water holding/drainage capacity
- Decontaminating and filtering harmful substances
- Regulation of pests, weeds and diseases.

Appropriate quantities of organic carbon, adequate level, size and spatial distribution of soil porosity and suitable chemical soil properties are principal requirements of a healthy soil for crop production. While general statement can be made about what constitutes soil health, the soil health status has to be determined against a described benchmark.

Soil health and plant health

The premise is that 'healthy soils' lead to healthy crops. Numerous research papers have reported how specific pathogens, and to a lesser extent pests or weeds, are suppressed or stimulated by certain measurable soil conditions. Different physical, chemical and biological soil condition indicators have been used in the various research projects.

The complex interrelationship between 'soil health' and multiple pathogens, pests and weeds that may impact on a crop simultaneously at different growth stages has been investigated to a much lesser extent. To enable meaningful systems research for vegetable crops, it would be important to have agreed indicators and methods to determine a 'soil health status' and relate that to a plant health status and or marketable yield and economics.

Benchmarking 'soil health status'.

Most soil health research investigated the impact of soil management and/or inputs on chemical, physical and biological soil conditions using a range of relevant indicators and methods. Usually this has been done without specifying what the desirable, target soil conditions should be either in general terms or for the specific crop and site. Benchmarking to determine the 'soil health status' has been done between paddocks or trial treatments (comparisons) but rarely against an agreed target soil condition.

Figure 3-6 illustrates how the soil health status can be determined via measured soil condition indicators compared to target soil condition indicators.

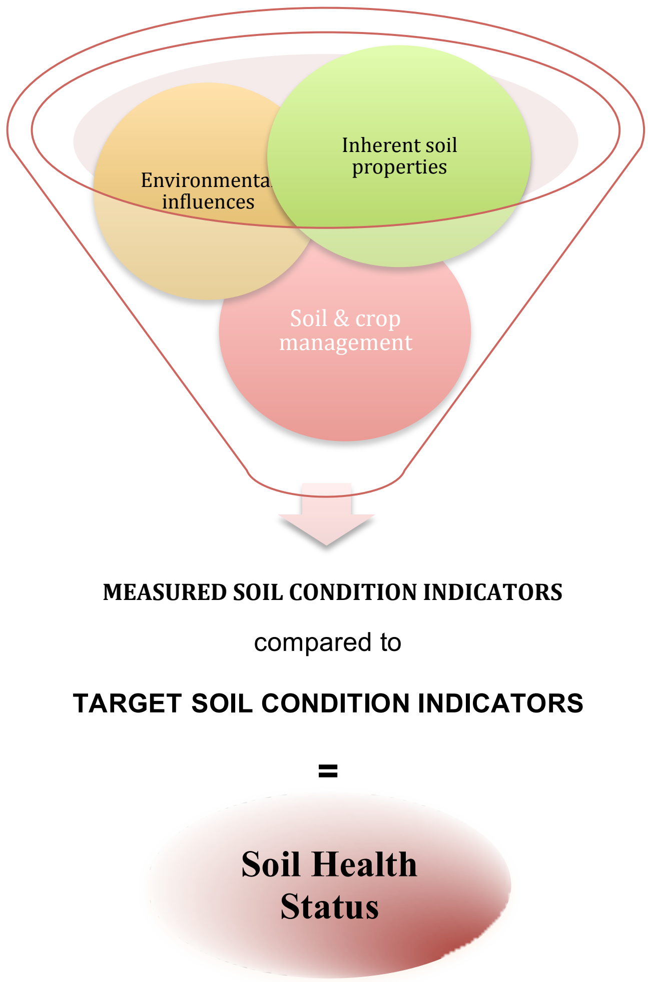


Figure 3-6: Determining soil health status.

Target soil condition indicators may need to be determined for specific soil types and climate combinations. Cornell University[16]has developed such an approach that is practical and used as a basis for growers' decision-making. Some of the Cornell methods have been used in Australian research (e.g.VG07008), and a commercial service for the Cornell Water Stable Aggregate (WSA) test is available in Australia. However, target soil condition benchmarks to determine soil health status have not been formulated.

Still, scorecards with targets and information for useful in field assessments have been developed including:

1. "The Soil Health Assessment Users Guide and In-field Test Kit" developed under the HSSF program[17] by Sustainable Resources Queensland University of Technology Brisbane, in 2007, or
2. Good Soils Project and the Northern Rivers Soil BMP Guide Vegetables: Best Management Practices for Soil Health in 2008 by NSW DPI and growers.

[16] http://soilhealth.cals.cornell.edu/extension/manual/1basics.pdf
[17] The Land and Water Australia Healthy Soils for Sustainable Farms (HSSF) Program operated from 2005 to 2008, its prime purpose was to get 'more farmers moving to practices that maintain and restore soils; which, in turn, would contribute to healthy catchments and sustainable agricultural enterprises'.

Soil health issues affecting Australian vegetable growers

The overarching soil health issues growers are facing in varying order of importance, depending on their crop(s), soil type and conditions, climate, and management are listed in Table 3-11 together with their unwanted effects and known management options. Management options are added to show that, even though a benchmarking system for 'soil health status' in vegetables does not exist, general management principles that can be used by growers are known and have been published in many good practice guides.

Table 3-11: Soil health issues for vegetable growers

Main soil health issue:	Negative effect on:	Known management options
Soil structure decline / compaction	Root growth and health, soil water holding capacity, crop nutrient uptake capacity	Conservative tillage, no fallow, maintain or increase organic carbon and rooting depth, cover crops
Decline of organic carbon	Structure, microbiology, nutrient and water holding capacity	
Nutrient imbalances or deficiencies	Crop resilience, vigour and soil chemistry and microbiology	Maintain or increase organic carbon, cover crops, site specific nutrient input based on monitoring
Decline, imbalance or low activity/viability of soil microbial populations	Disease and pest suppression, weed survival and nutrient cycling	Maintain or increase organic carbon, cover crops, crop / cover crop diversity, rotation
Erosion	Loss of top soil and with it organic carbon and nutrients Disease suppression and nutrient cycling	Conservative tillage, no fallow, maintain or increase organic carbon, cover crops
Salinity or sodicity	Loss in vigour and resilience, nutrient imbalances and toxicity	Conservative tillage, no fallow, maintain or increase organic carbon, cover crops, increase Calcium, Potassium and Phosphorus nutrition standard landscape and crop specific salinity and sodicity management

Soil health and related crop health issues of a concern to growers are often due to an increase in production intensity to deal with economic pressures or grasp market opportunities, which may lead to:

- Excessive and/or imbalanced fertiliser use
- Increase of tillage operations per year
- Tillage conducted in wet soil conditions
- Increase in monoculture or close rotations of the same crop
- Perceived high cost or risk of changing soil and nutrition management or using breaks and cover crops
- Lack of monitoring of relevant soil condition trends
- Need or desire for instant results from treatments or products

- Need or desire to look at short-term i.e. annual returns from practice change rather than 3-5 year periods.

A further issue is the confusion with the use of available soil health information and technologies amongst growers and advisors about:

- Indicators to monitor easily and record on-farm, and what these indicators mean in regards to soil health, crop health and productivity i.e. relevant benchmarks
- Practical, site and crop specific management recommendations that follow on from monitoring results i.e. which information, products, fertilisers, cover crops and or techniques to choose, how to make a decision about what works where and how to combine different pieces of information or technology for good outcomes
- How to assess the profitably (cost / benefit) of soil health driven management changes
- How to maintain soil health at a certain site under existing economic pressures
- The connection between soil health, soilborne diseases and other pest, weed and disease issues; these strongly related topics have often been dealt with separately by different disciplines (e.g. soil scientists, pathologists, nematologists, soil microbiologists) which makes them appear to be separate issues that need separate management approaches.

A plethora of 'soil experts' and product sales agents provide confusing or contradictory information and opinions about what to do and why.

Many growers and advisers believe soil health is mainly determined by the soil's microbial population, and that a better understanding of soil microbiology, e.g. knowing about the presence and level of certain organisms, will lead to a management practice or product that 'fixes' soil health. Interactions with soil chemical properties (nutrient availability, balance & uptake), and especially its physical status (compaction, water holding capacity & drainage) as major drivers of overall soil condition are still often neglected. On the other hand, soil physical or chemical studies usually omit links to soil microbiology.

The compartmentalising of R&D in the soil health/plant health area is partly a result of the high level of specialisation required of scientists. This should be overcome by a multidisciplinary program approach.

Soil health research and extension must provide tangible outputs for growers

A considerable amount of information is available on soil health monitoring technologies. Many are based on, or include soil microbial monitoring, but also monitoring of soil chemistry and assessment methods or kits for soil physical indicators. These tests, assessment guides or kits usually measure a relevant set of soil health indicators. However, benchmarks and interpretations of results to provide recommendations for site-specific actions with measurable outcomes are hard to come by. Often recommendations are based on one-size-fits all formulas or rely on products that 'fix everything'.

The challenge for individuals is currently to evaluate an overwhelming volume of information from many sources (including opinions) and translate it into successful site and crop specific management strategies.

What is needed is:

- An understanding that soil health management is crop and site specific but can be based on basic principles
- Practical soil health status benchmarks based on available information
- An understanding that one-size-fits all solutions will not materialise
- Hard data on win/win effective soil health management (economics)
- Hard data on the cost effectiveness of monitoring, recording, reviewing and using data rather than 'believes' to make informed decisions
- Training for growers and advisers away from the 'classroom' (paddock walks, site and machinery demonstrations, studies of industries, states and countries other than their own)
- Multidisciplinary RD&E with results demonstrated on farm
- Engagement of organisations and people who advise farmers (resellers of product, machinery, irrigation equipment, monitoring equipment) to provide a link between research and applications on-farm.

Recommended or agreed straightforward, affordable methods for on-farm and available laboratory services for soil health status are required to enable comparisons and analyse trends. This would include indicators for adequate air/water balance = porosity (physical indicator), micro and macro-organism activity (biological indicator) and fertility/nutrient availability (chemical indicator) as well as rooting depths.

Straightforward methods and practical benchmarks would be a first step in creating a national vegetable soil health database. Annual EnviroVeg self-assessments may provide a vehicle for data collection. CSIRO National Soil Archive and the National Soil Database (NatSoil /wiki.csiro.au/display/SoilModelling/ACLEP+Soils+Data+Exchange) and examples of systems used in other countries should be explored to avoid duplication and collect relevant data. Guiding questions for the design of a database would be:

1. What should a soil health database with vegetable specific information do for the industry? Why is it important?
2. What benchmarking data needs to be included to make it relevant?
3. Who will host the database and keep it up to date? Who will pay for that?

Targeted, practical extension programs that integrate current knowledge for regional and site specific management can address many above-mentioned issues of concerns and confusion associated with soil health management. The main R&D focus needs to be on:

1. Practical benchmarks for 'soil condition target(s)' – development based on known data
2. Relating soil health to plant health (pest, weed and disease incidence and severity) in a vegetable production system
3. Risk identification and management
4. Economic benefits of practice change – economic analysis and 'reality check' of research outputs that recommend practice change.

Extension programs should refer to existing information such as "The Healthy Soils for Sustainable Vegetable Farms Ute Guide" developed under the Land and Water Australia

Healthy Soils for Sustainable Farms (HSSF) Program[18] for AUSVEG. It currently is being reviewed for re-publishing to support the EnviroVeg program.

A commercially available monitoring and advisory system similar to that developed by Cornell University, based on many years of soil health research, could be introduced for major Australian vegetable growing regions. The overarching Cornell recommendations are to reduce tillage, improve rooting depth, use cover crops and maintaining or improving organic carbon. VG07008, a soil health benchmarking study in the vegetable industry referred to and recommended the Cornell program. However, a service for vegetable growers could not result from it in the available time.

One major issue in Australia, compared to the USA would be, that soil health testing is subsidised there, and this would not be the case here. A soil health test like the Cornell one would be expensive here; the cost benefit would have to be established.

The development of such a service may be of interest to other industries and a cross industry program may be a solution to carry development costs and reduce costs of testing. It may also be possible to streamline the testing program to make it more affordable.

Connecting soil and plant health in research, development and extension

For all soil health information and training programs, it is important to not handle soil health in isolation and ensure linkages to plant health and crop protection, management inputs and profitability.

Figure 3-7 illustrates connections between soil and plant health, and interrelationships with management and environmental factors that need to be considered in integrated research and extension programs.

[18] The Land and Water Australia Healthy Soils for Sustainable Farms (HSSF) Program operated from 2005 to 2008, its prime purpose was to get 'more farmers moving to practices that maintain and restore soils; which, in turn, would contribute to healthy catchments and sustainable agricultural enterprises'.

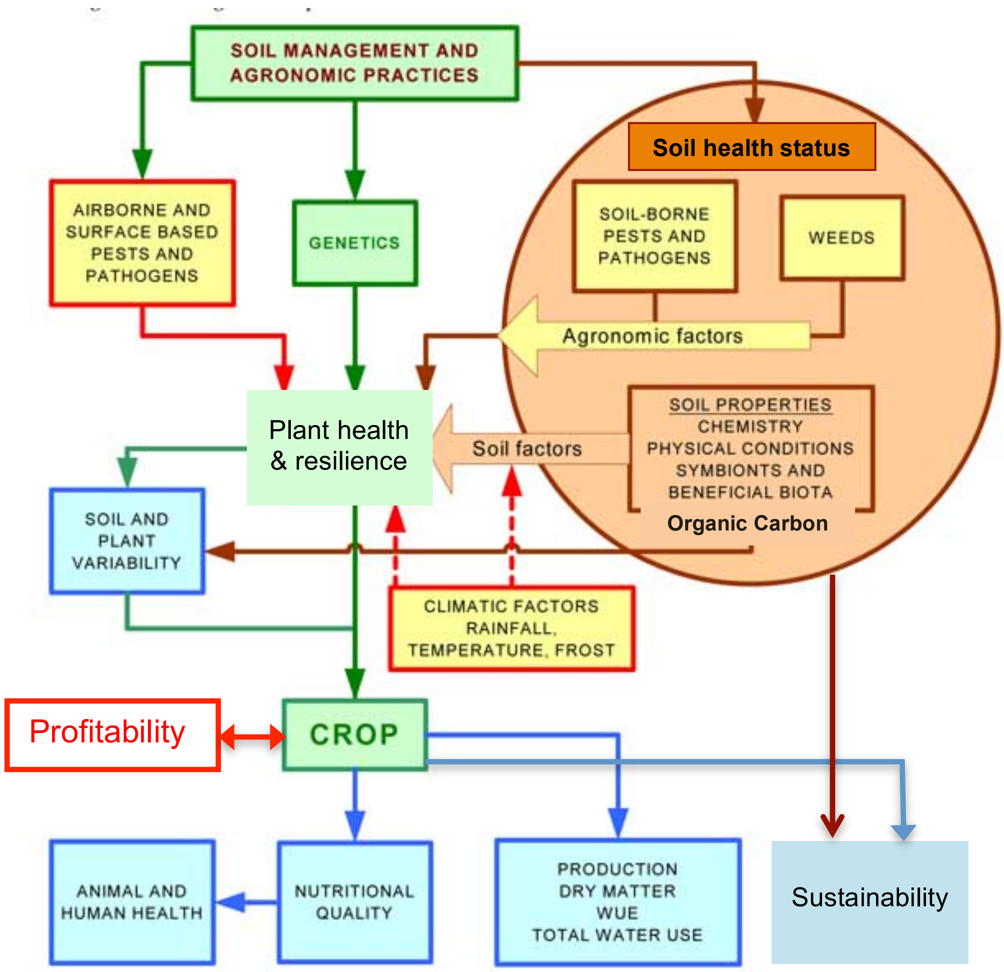


Figure 3-7: Connections between soil and plant health, and interrelationships with management and environmental factors[19]

Soil condition and especially soilborne diseases are so closely linked, that RD&E in these areas cannot be separated. Weed and soil pest ecology, as well as general soil/plant health relationships also need to be researched in an integrated manner to establish useable plant health management approaches. It is especially important for applied research to look at systems from a grower's viewpoint or the crops' perspective rather than taking a discipline-by-discipline approach. Using 'soil health status' as a central point for plant health research can be a workable concept as shown in Figure 3-7.

Multidisciplinary teams or advice to researchers may cover, but not be limited to, the following expertise:

- Soil physics and chemistry
- Crop nutrition and water relations
- Soil microbiology (including rhizosphere interactions)
- Plant pathogen, pest and weed ecology

[19] Adapted from: Soil health in agro-ecosystems, Victorian resources online http://vro.dpi.vic.gov.au/

- Economics (for cost benefit analyses)
- Extension and capacity building.

Any work that includes field trials should have clearly articulated criteria for trial design and choosing trial sites. Sites must be representative for the crop, region and issue to be investigated. Collaboration with growers and their advisers in choosing and managing trial sites is strongly recommended.

The area of soil health and pest, weed and disease RD&E relates to the elements of pest and disease risk from the project framework (section 2.4) as shown in Table 3-12. The table includes a summary of known management options based on previous R&D and literature. This table also describes future RD&E needs (new information from research), and the need to review and or re-issue known information in a user-friendly format. In the table, ‘Soil health management’ includes tillage, rotation, biofumigation or cover crops, soil amendments, and pesticide, nutrition and water management.

Table 3-12: Relationship between elements of pest, disease and weed risk, soil health management options and RD&E needs

#	Element of pest, weed and disease risk	Relationship to soil health	Management options	RD&E needs
1	Pest and pathogen type and genetics and how it affects control options	Soil conditions influence soilborne pathogens' survival and virulence	Maintain organic matter from diverse sources, crop rotation, cover crops maintain soil physical and chemical balance	Identification of soil born pests and diseases pre-planting (DNA?) and infestation risk analysis. Response of soils pests, weeds and diseases to stresses Disease suppressive soils – regional research and demonstration trials
2	Crop type and genetics (resistance or tolerance to unfavourable conditions)	Plant resistance to soilborne pathogens or nematodes	Selection of resistant or tolerant varieties, preferably based on known pest and disease risks	As above plus linking in with breeders (vegetables and biofumigation / cover crops)
3	Understanding of the production environment	Climate and soil type / conditions determine soil health targets (e.g. how much organic carbon can be accumulated, total invertebrate and microbial activity)	Selection of cover crops, soil tillage and crop management to fit climatic and soil condition / soil type	As above plus effective extension about relationships between production environment, soil health targets and management Establish targets through literature review inc. work done in other crops and elsewhere
4	Availability and use of control and management methods / options	Use of site specific soil health management methods affects pest, weed and disease pressure	As above	As above plus Effective extension about site specific soil health management methods and effects on pest, weed and disease pressure
5	Crop management and business decisions and motives	Pressure to grow more / intensify soil use due to low prices drives damaging soil management methods	Using an economies approach to decision making based on cost benefit of management methods over a crop rotation	Establishing cost benefit of different soil health management methods over a crop

3.2.6 Rotation including cover or biofumigation crops

Rotation

Crop rotation is generally considered an effective tool for managing pests, weeds and diseases, especially if fumigation is not used. There are no specific recommendations for rotation of vegetable crops and/or grazing enterprises; these usually depend on economic drivers and grower preferences. A common approach on vegetable farms is to rotate crops by plant families and/or alternate vegetable crops with cover crops particularly if grazing is not part of the business i.e. pasture breaks are not included.

The Pesticide Action Network Europe (PAN Europe)[20] published the following research based benefits of rotating crops.

1. Crop rotation helps to create soil biodiversity, which assists in pest, weed and disease suppression and reducing the need for pesticides

2. Crop rotation helps good soil structure, high organic matter and water holding, especially in combination with conservation tillage, resulting in higher yield potential

3. Crop rotation, especially performed with nitrogen-fixing rotation crops, can reduce the input of nitrogen fertilisers and pollution by nitrogen

4. Crop rotation, especially combined with conservation tillage, can lead to higher soil-carbon content and so contribute to mitigating climate change[21].

Most vegetable producers do not have the option of using 4-5 year rotations between crops of the same plant family. Cover crops and biofumigation crops are the main alternatives.

Cover crops (green manures)

Cover crops can include a wide range of species or species mixes that are grown to enhance soil conditions and biodiversity including that of beneficials. In most cases, they are not harvested. They can however be used as fodder, grazing or forage crops or seed to work well in systems with multiple crop enterprises and livestock. In Europe, cover crops are used to produce feedstock for energy production (biogas, fuel). Dual use cover crops may have reduced biological benefits compared to single use cover crops, but they may have economic advantages.

Most Departments of Agriculture or Primary Industries offer information on the use and general benefits of cover of biofumigation crops in their region. Economic benefits are less often reported even though claims have been made that cover crops can increase profits in their first year, and that their soil-improving effects accumulate to provide long-term management and financial benefits. Benefits such as reducing pollution, erosion and pest, weed and disease pressure can sometimes be difficult to quantify. Identifying and quantifying these benefits must be done to enable sound, long-term decisions for vegetable farms.

[20] "Pesticide Action Network Europe (PAN Europe) brings together consumer, public health, and environmental organisations, trades unions, women's groups and farmer associations from across 19 European countries. PAN Europe is part of the global network PAN working to minimise the negative pesticide effects and replace harmful pesticides with ecologically sound alternatives."

[21] L.M. Vleeshouwers et al. 2002; Carbon emission and sequestration by agricultural land use: a model study for Europe Global Change Biology 8:519-530.

The main economic and environmental aspects of cover crops that should be evaluated and (economically) quantified on-farm and as part of research projects research are listed below:

- Effect on organic carbon by adding organic material
- Effect on fertiliser costs (e.g. by contributing nitrogen cycling, scavenging and mining soil nutrients, preventing nutrient losses through leaching from the rootzone)
- Effect on suppression of pests, weeds and diseases
- Effect on the need for and costs of pesticides
- Effect on marketable yields and vegetable quality (use quality indicators demanded by the market)
- Effect on the soil health status (esp. compaction, cloddiness)
- Effect on energy use for tillage
- Effect on soil erosion (nutrient and organic matter losses, water quality)
- Effect on increasing water infiltration, conserving soil moisture, decreasing run-off
- Effect on biodiversity below and above ground esp. beneficial organisms (e.g. insects, nematodes, microbes).

These benefits will vary by location and season, but at least two or three may occur with any cover crop. Some benefits can be measured in the short term, other benefits will appear over a longer timeframe. Cumulative benefits may occur with increasing the diversity of cover crops grown, the frequency of use between vegetable crops and the length of time that cover crops are growing. Proving these cumulative benefits may need longer than a three year RD&E cycle. Vegetable growers should be able to identify economic benefits on their farm, if the appropriate records on the above benefits are kept and analysed.

Potential disadvantages of cover crops

No cash income: While cover crops may require some management inputs, they do not provide a cash return unless used for grazing, seed, and/or energy production. Benefits could be compared against the income that a cash crop would generate. However, a cash crop would not provide any of the above listed benefits, would need much higher inputs and may have a negative effect on the soil health status. Ideally, economic comparisons should be made for a crop rotation of at least three years.

Timing: If cover crops are incorporated into the soil too late, when the plants are tougher, drier and relatively low in nitrogen, soil nitrogen levels may drop briefly as the soil microbes use available soil nitrogen to decompose the cover crop. The vegetable fertiliser program needs to be adjusted accordingly.

Short window of opportunity: Some cover crops may not fit into the crop rotation easily because they take too long to develop and also too long for their residues to decompose sufficiently to allow planting of the next vegetable crop. However, a wide range of cover crop options exist and suitable solutions can be found.

Biofumigation crops

Biofumigation crops are brassica cover crops with an added function of soil fumigation via isothiocyanates (ITCs) and other volatile glucosinolate (GSL) derived compounds. The general cover crop benefits described above also apply to biofumigation crops.

The added benefits of ITCs and GSL derived compounds on soilborne disease suppression has been shown in many studies by producers' of cover crop seed and researchers. Major biofumigation programs were conducted in Australia mainly between 2000 and 2008. The third International Biofumigation Symposium held in Canberra in July 2008 marked a slow down of research in this area in Australia. From about 2000 to 2008, Australian scientists were at the forefront of this area of research. They ran projects on tropical vegetable production systems in north Queensland and the Philippines, supported by the Australian Centre for International Agricultural Research (ACIAR), and on temperate southern Australian vegetable production, supported by Horticulture Australia Limited (HAL). A great amount of knowledge has been accumulated during that time.

The commercial use of biofumigation crops is increasing rapidly in Europe and North America. In 2009/10, an estimated 14,500 tonnes of biofumigant seed varieties were sown in Western Europe (source: Peracto Pty Ltd). The main drivers for this development are deregistration and ban of pesticides used for soil fumigation. Several breeding companies now run programs to increase levels of ITCs and GSL derived compounds and improve agronomics of relevant brassica cover crops.

Cover and biofumigation crops are considered useful as part of IPM strategies. The development of new and extension of known cover and biofumigation crop applications, and study of economic benefits, including using on-farm demonstrations should be one priority for the vegetable industry.

Research here should use and link in with international work including that conducted by relevant seed companies to avoid repetition. It should be part of a soil health / plant health program.

3.2.7 Transplant health, seed quality and crop establishment

A common sense, basic rule that often is neglected is to begin production with healthy, vigorous seed and transplants. Introduction of diseased material as primary inoculum will result in poor establishment, reduced yields, poorer quality products, and added costs for chemical control and low profits and can lead to loss of markets. For example, disease cause by *Alternaria radicina* was identified as a 'new' seedling establishment disease in South Australia in 1994, and further work on its management was conducted by industry funded HAL projects between 1998 and 2003 (VG00014 - Managing Alternaria blight in carrots). A crop survey found that up to 7% of seedlings and 88% of mature plants on some properties were infected by *A. radicina*[22].

Disease incursions like this can occur, if the need for proven quality seed or transplants are neglected, and planting material are sourced from uncertain sources (often because they

[22] Coles, R.B. and T.J. Wicks, 2001; The incidence of Alternaria radicina on carrot seeds, seedlings and roots in South Australia. http://www.sardi.sa.gov.au/__data/assets/pdf_file/0007/46807/alt_carrot.pdf

appear cheaper). The result is that acute or chronic disease problems in vegetable crops may be introduced, which are expensive to control.

Programs aimed at integrated management need to reinforce basic rules for seed crops and transplants. They should not be grown/sourced within a vegetable growing region or from near ornamental crops that can carry vegetable diseases. The potential for spread of vegetable and ornamental plant diseases has been documented with tomato spotted wilt virus and its vector, western flower thrips. Another example is powdery mildew (two different species) spread to tomato and cucurbits from ornamental plant sources. Correct seed treatment is essential, especially for beans, sweet corn, beetroot, carrots and peas. Good materials and technologies are available.

If transplants are used, the nursery is responsible for using healthy good-sized seed and keeping plants healthy until they are ready to use. Transplants that are ' past their use-by' will be prone to pests and diseases, and poor establishment and growth.

Good crop establishment is crucial. Slow growing plants (roots and tops) easily suffer from pest and disease attack. Once a disease gets started in a field because of poor quality transplants or seeds, or poor establishment due to other stresses, crop damage or yield loss will result no matter how many 'rescue treatments' are applied.

RD&E, especially extension, with a focus on seed and transplant quality and early crop establishment could assist in giving due attention to this important aspect of crop protection and plant health management.

3.2.8 Plant breeding

A new concept for plant breeding?

The genetic features of available varieties are strong constraints in redesigning cropping systems. For instance, new species useful for diversifying crop rotations have not yet received enough attention from breeders. In major crops, high yield and quality have been the main targets, with lesser attention to resistance to pests and diseases; pesticides are meant to control these. When this is no longer the case, e.g. due to loss of products, the requirements of varieties may be different. Varieties that can sustain some level of pest or disease incidence without being significantly affected in terms of yield or quality are desirable for the development of more resilient systems. The concept of designing new growing systems e.g. with a focus on integrated soil and plant health management, including biofumigation, reduced tillage, fostering of beneficials and a change in inputs may require the varieties that would suit them.

Resistant varieties

Many crop protectant producers have become involved in breeding and seed production, realising that plant 'resistance' to pest and disease is one of the most effective control methods. Involvement in breeding and seed production provides an opportunity to deliver an 'integrated package' of genetics and pesticides.

Independent breeders also focus on pest and disease 'resistance' apart from selecting for desirable yield and quality traits to maintain or gain market share.

Using inherent plant 'resistance' is one of the most effective pest and disease control tools. The vegetable industry should be actively liaising with breeders and seed producers to ensure 'resistance' to priority pests and diseases are included in selections. Lobbying retailers may be required so they preferentially market resistant varieties.

Basic resistance concepts that are important to differentiate are included in the table below.

Table 3-13: Explanation of 'Resistance' types

'Resistance' type	Explanation
Immunity	A specific pest or pathogen does not attack or infect a plant variety
High Resistance	The ability of a plant variety to highly restrict the activities of a specific pathogen or insect pest and/or to restrict the symptoms and signs of a disease, when compared to susceptible varieties. Varieties with high resistance may exhibit some symptoms when pressure from a specified pathogen or pest is severe. New and/or atypical strains of the specific pathogen or pest may overcome the resistance.
Intermediate Resistance	The ability of a plant variety to restrict the growth and development of the specified pest or pathogen, but it may exhibit a greater range of symptoms compared to resistant varieties. Intermediate resistant plant varieties will still show less severe symptoms or damage than susceptible plant varieties when grown under similar environmental conditions and/or pest or pathogen pressure.
Susceptibility	The inability of a plant variety to restrict the growth and development of a specified pest or pathogen.
Tolerance	The ability of a plant variety to endure abiotic stress without serious consequences for growth, appearance and yield i.e. tolerance to disorders caused by of diseases or pest attack.

Transgenic crops

Genetic transformation for the introduction of foreign genes to enhance resistance to insect pests and fungal diseases has been accomplished for at least 19 vegetable crop species belonging to eight botanical families. Although some reports of genetically engineered vegetable crop species are limited to expression of selectable marker genes, there are many reports, that have demonstrated the expression of genes which encode potentially useful agronomic and horticultural traits. These include enhanced resistance to insect pests through the expression of *Bacillus thuringensis* crystalline endotoxins and trypsin inhibitors. Enhanced resistance to fungal pathogens has been achieved through the expression of antifungal proteins and various other antimicrobial compounds, while virus resistance has been achieved through coat-protein mediated expression. Transgenic vegetable crops with enhanced resistance to pests and diseases should be carefully considered as a part of an integrated pest management program in the future. [23]

3.2.9 Crop nutrition and pests, weeds and diseases

This section summarises how different nutrients affect different types of plant diseases (fungal, bacterial, viral, and soilborne) and pests. The summary is provided because

[23] Punja Z.K. 2001; Transgenic vegetable Crops for Managing Insect Pests and Fungal and Viral Diseases. Biotechnology, Vol. VIII

questions about nutrition and pathogens and pests were raised during consultation. The information presented here is based on three main review publications on the topic[24].

Details of nutrient: pathogen or pest interactions are still not well enough understood. Overall, plants with well balanced nutrient levels and no deficiencies appear to withstand pest and disease pressure better than plants that are nutritionally stressed.

Interaction with diseases is better documented than interaction with pests. Plant nutrients may affect susceptibility through metabolic changes, creating favourable conditions for disease development or pest attack. When a pathogen or pest infests a plant, it alters the plant's physiology, particularly mineral nutrient uptake, assimilation, translocation, and utilization. Pathogens may immobilise nutrients in the soil or in infected tissues. They may also interfere with translocation or utilisation of nutrients, inducing nutrient deficiencies or toxicities.

Other pathogens or pests may themselves utilise nutrients or their metabolites, reducing availability to the plant and increasing the plant's susceptibility. Soilborne pathogens commonly infect plant roots, reducing the plant's ability to take up water and nutrients. The resulting deficiencies may lead to secondary infections by other pathogens. Plant diseases can also infect the plant's vascular system and impair nutrient or water translocation. Such infections can cause root starvation, wilting, and plant decline or death, even though the pathogen itself may not be very destructive.

Mineral nutrition can affect two primary resistance mechanisms:

1. The formation of mechanical barriers, primarily through the development of thicker cell walls
2. The synthesis of natural defence compounds, such as phytoalexins, antioxidants, and flavonoids.

Fungal and bacterial diseases

Thin, weak cell walls leak nutrients from within the cell to the apoplast (the space between plant cells). This can create a fertile environment that stimulates the germination of fungal spores on leaf and root surfaces. Mineral nutrient levels directly influence the amount of leakage as well as the composition of what is leaked.

Integrity and strength of cell walls and cell-to-cell connections

Potassium (K) and Calcium (Ca) play key roles in forming an effective barrier to infections. K is essential for the synthesis of proteins, starch, and cellulose in plants. Cellulose is a primary component of cell walls, and K deficiency causes cell walls to become leaky, resulting in high sugar (starch precursor) and amino acid (protein building blocks) concentrations in the leaf apoplast.

[24] Dordas C., 2008; Role of nutrients in controlling plant diseases in sustainable agriculture. A review, Aristotle University of Thessaloniki, Faculty of Agriculture, Laboratory of Agronomy, University Campus, Agron. Sustain. Dev. 28, 33-46,
Datnoff L.E., W. H. Elmer and D. M. Huber, 2007; Mineral Nutrition and Plant Disease, Amer Phytopathological Society, ISBN: 0890543461, 278 pages
Spann T.M. and A.W. Schumann, 2010; Horticultural Sciences Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida EDIS Web Site at http://edis.ifas.ufl.edu.

Ca compounds play an essential role in the formation of healthy, stable cell walls. Adequate Ca inhibits the formation of enzymes produced by fungi and bacteria, which dissolve the middle lamella, allowing penetration and infection. Tissue that is low in Ca develops physiological disorders that cause rotting during storage.

A frequent symptom of B deficiency is the development of "corky" tissue along leaf veins and stems because of the irregular (misshapen) cell growth that occurs when B is deficient. These irregular cells are more loosely bound than normal cells, producing wounds like entry points for fungi and bacteria.

Most fungi invade the leaf surface by releasing enzymes, which dissolve the middle lamella that bonds adjacent cells. The activity of these enzymes is strongly inhibited by Ca, which further explains the close correlation between the Ca content of tissues and their resistance to fungal diseases.

Nutrition also affects the formation of mechanical barriers in plant tissue. As leaves age, the accumulation of silicon (Si) in the cell walls helps form a protective physical barrier to fungal penetration. Excessively high nitrogen (N) levels lower the Si content and increase susceptibility to fungal diseases.

Defence mechanisms

As stated above, plant tissues contain and produce a variety of defence compounds, which prevent fungal attacks. Boron (B) plays a key role in the synthesis of these compounds. Borate-complexing compounds trigger the enhanced formation of a number of plant defence chemicals at the site of infection. The level of these substances and their fungistatic effect decreases when the N supply is too high.

Calcium (Ca) and boron (B) deficiencies cause a build up of sugars and amino acids in both leaf and stem tissues (in the apoplast), which lowers disease resistance.

Other micronutrients play a role in disease resistance too. Copper (Cu) is a plant nutrient that is widely used as a fungicide. The amount required as a fungicide is much higher than the nutritional requirement. The action of Cu as a fungicide relies on direct application to the plant surface and the infecting fungi. From a nutritional perspective, Cu deficiency leads to impaired defence compound production, accumulation of soluble carbohydrates, and reduced lignification (wood development), which all contribute to lower disease resistance.

Nitrogen (N) is a key component of amino acids; therefore, an excessive supply of N can bring about higher amounts of amino acids and other N-containing compounds in plant tissues. These mineral imbalances lower resistance to fungal diseases by creating a more favourable environment for them. Adequate N levels increase plant resistance to most diseases; however, excessive N can have the opposite effect. As a rule, pests and diseases that live on dying tissue or that release toxins in order to damage or kill the host plants thrive in low N situations. However, some bacteria actually increase under high N conditions. These bacteria usually depend on food sources from living tissue.

Molybdenum (Mo) deficiency can lower disease resistance by impeding the production of nitrate reductase, an enzyme that contains two molecules of Mo, and it is required to convert nitrates to proteins which are required for all plant functions.

Virus diseases

Nutritional factors that favour the growth of host plants also favour virus multiplication. This particularly applies to N and phosphorus (P). However, despite the rapid multiplication of the virus, visible symptoms of the infection do not necessarily correspond to an increase in mineral nutrient supply to the host plant. In fact, symptoms of virus infections sometimes disappear when N supplies are large, even though the entire plant is infected. Visible symptoms are dependent upon the competition for N between the virus and the host cells. This competition varies with different diseases and can be influenced by environmental factors, such as temperature.

Soilborne diseases

A micronutrient-deficient plant usually has depressed defence capabilities against soilborne diseases. Soil-applied manganese (Mn) can inhibit the growth of certain fungi.

The use of ammonium-based fertilisers can increase the incidence of some diseases (e.g. Fusarium and Phytophthora root rots), whereas nitrate-based fertilizers generally have the opposite effect. The different N forms affect soil pH. Ammonium fertilisers generally decrease soil pH over time, particularly in soils with low buffering capacity, and nitrate fertilisers tend to either slightly increase soil pH or have no effect. However, some studies have found that the effects these two N fertiliser forms have on soilborne diseases are independent of soil pH.

Pests

In contrast to fungal and bacterial pathogens, visual factors such as leaf colour are important factors in pest susceptibility. Nutritional deficiencies discolour leaf surfaces and increase susceptibility to pests. Many insects tend to settle on yellow reflecting surfaces.

Three primary pest defences of plants are:

1. Physical surface properties: colour, surface properties, and hairs
2. Mechanical barriers: tough fibres, silicon crystals, and lignification
3. Chemical/biochemical: content of attractants, toxins, and repellents.

Mineral nutrition affects all three defence systems. Generally, young or rapidly growing plants are more likely to suffer attack by pests than older, slower-growing plants. Therefore, there is often a correlation between N applications (stimulation of growth) and pest attack. Boron deficiency reduces the resistance to pest attack in the same ways it reduces resistance to fungal infections. It is used in the synthesis of flavanoids and phenolic compounds, which are a part of the plant's biochemical defence system.

General

Relationships between plant K and diseases or pest infestations are the most frequently reported. The generalisation has been made in review literature that adequate K uptake usually results in an increased resistance to diseases and pests; K deficiencies lower this resistance.

3.2.10 Irrigation and pests, weeds and diseases

Soil water and irrigation management can have an influence on pest and disease incidence and severity directly through providing sufficient moisture for pathogens to survive, develop and spread, and indirectly by influencing plant physiology and thus vigour and defence mechanisms. Recent research on the control of White Blister in broccoli highlights the importance of irrigation management to control diseases[25].

Important factors for soil water and irrigation management are:

- Water quality – water may contain pathogens and affect nutrient uptake
- Timing of irrigation or rain – interaction of plant wetness with other conditions conducive for infection
- Application rate and frequency – length of time plant and soil are wet and plants are stressed by wet or dry conditions.

3.2.11 Hygiene

Farm hygiene

Farm hygiene is the protection of the farming environment by preventing the introduction and/or spread of pests and diseases that may adversely affect production. Keeping farmland and equipment clean and preventing unnecessary access to production areas by other vehicles, machinery or people will help prevent the introduction of new pests to your farm. Also, keep machinery and equipment clean when moving between paddocks.

The introduction of a new pest onto your property can be a costly experience for you. Prevention of pest entry, or restriction of pest movement between fields can save you much time and effort in the longer term.

Risk management information exists for vegetable growers, contractors and visitors; state departments of agriculture usually publish it with biosecurity information.

Working with a management system like Freshcare or EnviroVeg will also assist in farm hygiene management.

Supply chain hygiene

Hygiene through the supply chain is supported by quality assurance (QA) systems for food safety. Large retailers request suppliers to implement food safety systems. The large wholesale markets and smaller vegetable retailers do not have the same QA requirements. Hygiene in the supply chain is closely linked to good postharvest management. Information on postharvest management for vegetables usually covers this aspect.

[25] Minchinton E. and V. Galea, 2011; Benchmarking predictive model, nutrients and irrigation for downy and powdery mildew and white blister. Final report VG07070, Horticulture Australia Limited

3.2.12 Conclusions and Recommendations – relevant aspects for production systems

Research usually investigates cause and effect of a limited number of factors and, sometimes for good reason, ignores the complexity of production systems. This means however that research outputs usually deal with each pest, weed or disease risk and management approach separately. General best practice management and specific background information on all relevant environmental and crop management topics covered in this section of the report is also available from many sources.

Growers and advisers are required to make the connections and choices between the multiple management recommendations for pest, weed and disease problems that may affect a crop simultaneously. They need to decide which risk(s) to prioritise and which pest, weed and disease problems or management actions may cause the greatest decline in yield potential. They must to make a call on which crop protection options and other inputs would be compatible with each other, how a change to one part of their system may affect other parts, and what would fit best with their overall management approach and philosophy. Above all, they need to decide which choices would be the most profitable. The driver usually is the highest marketable yield in the short term and less often the most resilient system for sustained yields in the longer term. Apart from the economic imperative, people and environmental issues need to be taken into account. All this involves a high level of uncertainty and complexity in decision-making. Therefore, well-known and proven solutions will be chosen over unknown and complicated ones.

A systems approach and integration are required in research and information delivered to growers and their advisers i.e. growers and their advisers need to get information on how to deal with a range of pest, weed and disease problems that may affect their crop simultaneously at certain crop stages. Understanding inherent risks posed e.g. by the soil health status and climate, and problems to expect during early crop establishment stages should be given priority.

3.3 Environmental Scan – Extension and adoption

3.3.1 Introduction – what is extension?

Extension is understood as capacity building and facilitation of practice change. Extension has been an important component of ensuring that R&D is utilised. In the past, extension has been an addition to traditional research programs. However, there has been significant change in how extension is undertaken over the past couple of decades and also the relevance of broader industry participants than the once "extension officer".

3.3.2 Facilitating change

There has been extensive social research into understanding why farmers do or do not change or adopt certain practices and technologies (e.g. Black, 2000[26], Cary et al. 2002[27]).

Adoption has been defined as '*the result of making full use of an innovation as the best course of action available'* (Rogers 1983[28]). In agriculture, the term adoption has been used to define the uptake of agricultural practices and innovations and is targeted at the farmer or grower.

The adoption of particular management practices and technologies will depend largely on the:

- **Industry context** (e.g. industry profitability and limiting resources)
- **Farming context** (e.g. business fundamentals – equity, structure, succession, farming systems, irrigation infrastructure).
- **Personal attributes** (e.g. attitude to risk, propensity for change, motivations, values, skills, expertise).

Fundamental to facilitating change is understanding which aspects (contexts, attributes) are relevant and considered important for the target audience.

3.3.3 Understanding the target audience

Farming groups

It is important to recognise that there is significant social diversity among farmers, multiple methods to facilitate change and good reasons for non-adoption (Vanclay, 2004[29]).

Extension programs therefore must consider the needs and circumstances of individuals and their different learning styles. The farming community is not homogeneous and extension programs need to be tailored to these different priorities, understandings, values, ways of working and problems (Vanclay, 2004[29]).

Market segmentation is one method that has been used to describe groups of growers with similar needs and circumstances in relation to their farming context (Kaine et al., 2005[30]).

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[26] Black A (2000) Extension theory and practice: a review. Australian Journal of Experimental Agriculture 40, 493-502.
[27] Cary J, Webb T, Barr N (2002) 'Understanding landholders capacity to change to sustainable practices. Insights about practice adoption and social capacity for change.' (Bureau of Rural Sciences: Canberra).
[28] Rogers E M (1983) Diffusion of Innovations. Rev edn. Macmillian., New York NY.
[29] Vanclay F (2004) Social principles for agricultural extension to assist in the promotion of natural resource management. Australian Journal of Experimental Agriculture 44, 213-222. doi:10.1071/EA02139.

Extension activities and messages can then be tailored to the individual groups (Boland et al., 2006[31]). This type of approach has been used to describe different farming styles for specific industries and regions.

3.3.4 Drivers and barriers of adoption

Considerable research has been undertaken to understand the drivers and barriers to the voluntary adoption of farming practices and technologies. Frequently, a key premise of extension programs is that farmers actually want to change. For adoption to occur there must be a certain level of dissatisfaction with the current situation and the proposed or desired alternative must be seen to improve this. Understanding what is causing the dissatisfaction can be the key to success of an extension program. It is important to note that extension activities will only reach those landholders who are in a position to be receptive at the time the activities are delivered (Pannell et al, 2011[32]).

Barriers to adoption can be motivational, technical, financial or biophysical (Erol, 2007[33]):

- **Motivational** e.g. lack of direction from government, the wrong extension model, lack of confidence, lack of support and cultural resistance to change
- **Technical** e.g. limited knowledge, advice and information, lack of clearly written materials, or lack of access to adequately skilled and trusted NRM advisers
- **Financial** e.g. lack of money and incentive grants, the perception that costs outweigh benefits, lack of equipment and time
- **Biophysical** e.g. variable seasons, poor productivity (because of salinity, acidity, and lack of trace elements), poor off-farm drainage and lack of suitable productive land. These barriers are very region-specific and vary according to production system.

The process of adoption and decision-making

One of the main theories of adoption is the innovation decision process developed by Rogers who uses a complex process model of change, where an individual passes through the following steps (**Figure 3-8**):

I. Knowledge of an innovation

II. Forming an attitude about the innovation

III. Decision of adoption or rejection

IV. Implementation

V. Confirmation of the decision.

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[30] Kaine G, Bewsell D, Boland AM, Linehan C (2005) Using market research to understand the adoption of irrigation management strategies in the stone and pome fruit industry. Australian Journal of Experimental Agriculture 45, 1181-1187.

[31] Boland AM, Bewsell D, Kaine G (2006) Adoption of sustainable irrigation management practices by stone and pome fruit growers in the Goulburn/Murray Valleys, Australia. Irrigation Science 24, 137-145.

[32] Pannell, D.J., Roberts, A.M., Park, G., Alexander, J., Curatolo, A. and Marsh, S. (2011) Integrated assessment of public investment in land-use change to protect environmental assets in Australia, Land Use Policy 29: 377-387.

[33] Erol, C. (2007) Increasing landholder adoption of improved surface water management practices. Literature review of relevant Australian studies. Department of Agriculture and Food, Government of Western Australia.

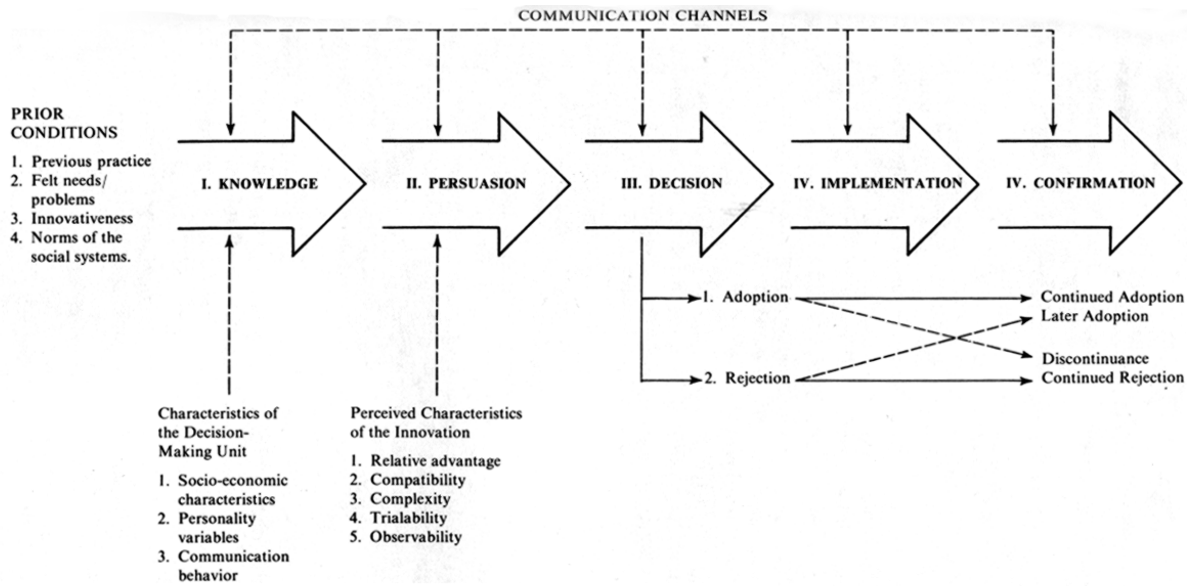


Figure 3-8: Model of stages in the innovation-decision process (Rogers 1983)

Complex decisions

Making decisions about change can be an extremely daunting and complex task. As the rate of change increases, the ability to sift through information and adapt to the business situation becomes a valuable skill. Decisions are never made based on isolated pieces of information – rather they consider the whole farming system incorporating personal, financial, technical and environmental aspects.

It is critical to recognise that many farm decisions are complex where there are many difficult answers rather than simple (one right answer) or complicated (one difficult answer) (Snowden, 2003[34]).

Supporting decisions about change involves understanding several important characteristics of the innovation including: relative advantage, compatibility, complexity, trialability and observability. Change can be considered if the practice and/or technology has a clear relative advantage and is trialable.

- **Relative advantage:** perceived superiority to the idea or practice that it supersedes and identification of a reason for change. This encompasses a wide range of factors including: the expected profitability over different time scales and in comparison with existing practices; the innovation's expected effect on and compatibility with the farm and the family's lifestyle, beliefs, values and self-image; environmental credibility; complexity and effect on the riskiness of production; and the adjustment costs in making the change (Pannell et al., 2006[35]).

- **Trialability:** how easy is it to test and learn about prior to adoption. This is determined by two main factors: the risk and cost of trialing the innovation, including partial adoption; and the ability to attribute results of the trial to the innovation.

[34] Snowden DJ (2003) Managing for serendipity or why we should lay off 'best practice' in Knowledge Management. ARK Knowledge management Vol 6 Issue 8 2003.
[35] Pannell DJ, Marshall GR, Barr N, Curtis A, Vanclay F, Wilkinson R (2006) Understanding and promoting adoption of conservation practices by rural landholders. Australian Journal of Experimental Agriculture 46, 1407-1424.

Farmers' reasons for non-adoption or partial adoption are legitimate, and relate either to their farming context or personal attributes (Vanclay, 2004[36]). Research has shown that growers often have sound, logical reasons for not adopting an innovation and lack of awareness, limited information or inadequate knowledge are not necessarily barriers.

Botha and Coutts (2011[37]) reviewed decision-making theory and project evaluations to better understand the decision-making processes. They suggested that a major driver is the ability of the decision maker to 'play' with the innovation, so that a decision can be made with confidence – that is, confidence that it will work for them – including how it fits with the farming system and their personal context. The stages in the adoption process are shown in **Figure 3-9** below.

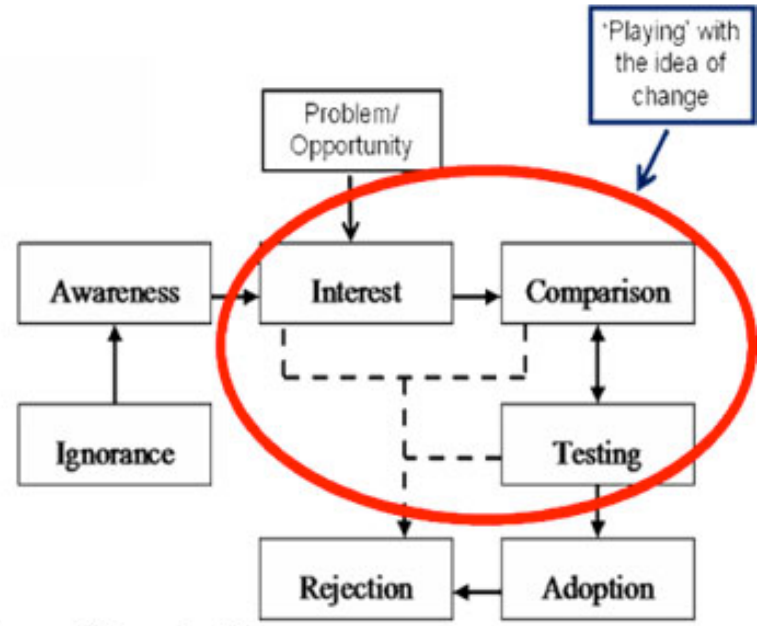


Figure 3-9: Stages of the adoption process (Botha, 2004 adapted by Botha and Coutts, 2011)

3.3.5 Extension approaches

Traditionally the emphasis of agricultural extension has been based on transfer of technology i.e. linear 'top down' transfer of technology. Scientists typically developed agricultural technologies and knowledge and the task of extension agencies was to promote adoption of these technologies by farmers (Black, 2000[38]). More recent extension has focused on engagement of individuals and approaches that assist them in making decisions.

Coutts et al. (2005[39]) reviewed extension models involved in the building of capacity in agriculture. These models operated across industries and communities, with each playing key and complementary roles within a capacity building framework. Current extension

[36] Vanclay F (2004) Social principles for agricultural extension to assist in the promotion of natural resource management. Australian Journal of Experimental Agriculture 44, 213-222. doi:10.1071/EA02139.
[37] Botha, C., and Coutts, J. (2011) Moving change to the top of the agenda – learning from the on-ground decision makers. South African Journal of Agricultural Extension, V39, 1-16.
[38] Black A (2000) Extension theory and practice: a review. Australian Journal of Experimental Agriculture 40, 493-502.
[39] Coutts JA, Roberts K, Frost F, Coutts A (2005) The role of extension in building capacity – what works and why. A review of extension in Australia in 2001-2003 and its implications for developing capacity into the future. Cooperative Venture for Capacity Building.

projects utilise a range of extension models as a suite of complementary capacity building avenues.

Table 3-14: Types of extension models

Extension Model	Description	Contribution to Capacity Building
1. Group Facilitation/ Empowerment	This model focuses on increasing the capacity of participants in planning and decision-making and in seeking their own education and training needs based on their situation. They will often resource a facilitator to define their own goals and learning needs and realise these.	Platform for ongoing learning
2. Programmed Learning	This model delivers specifically designed training programs or workshops or both to targeted groups of landholders or community members to increase understanding or skills in defined areas. These can be delivered in a variety of models and learning approaches.	Specific topics and learning events
3. Technology Development	This model works with individuals and groups to develop specific technologies, management practices or decision support systems which will be available to the rest of the industry or community. It often involves local trials, demonstrations, field days and on-site visits.	Development or integration of new approaches
4. Information Access	This model provides a range of information that individuals and groups can access at a time that suits them. It can be based in a library, information center, on a website, or other centralised location.	Ongoing access to support information
5. Individual Consultant/Mentor	This model provides individualised one-on-one support. It may be a technical expert visiting and providing advice, diagnosis, and recommendations. It may be an ongoing facilitating mentor relationship which provides a sounding board for decision-makers.	Individual iterative support to make decisions about changes

The integration of elements of the five extension models is described by the Capacity Building Ladder, which can be used in the successful development of human capacity (**Figure 3-10**).

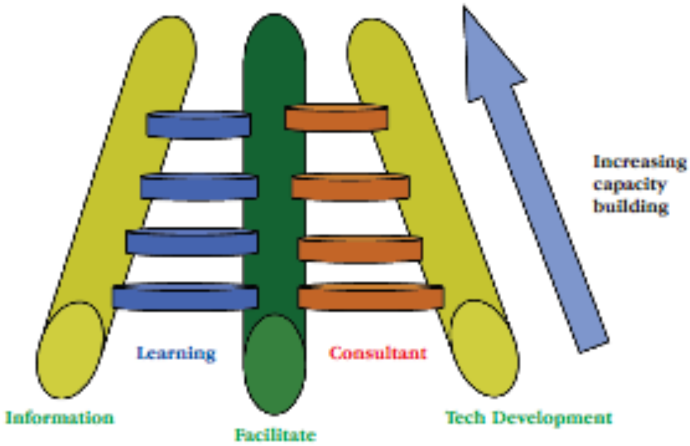


Figure 3-10: Extension models – Capacity Building Ladder (Coutts et al., 2005)

3.3.6 Estimating the likely adoption of new technology

The ADOPT (Adoption and Diffusion Outcome Prediction Tool) model, developed by the Future Farm Industries CRC, is being tested as an approach to estimate the extent and rate of adoption of new technologies (Kuehne et al, no date[40]). The model includes a series of questions based on four quadrants.

Table 3-15: Four main components of the ADOPT model

Population-specific influences on the ability to learn about the innovation The ability of the target population to learn about the innovation – this is about learning the benefits or relative advantage. Constraints will slow the time to peak adoption, they do not affect peak adoption level. Factors include: ▪ Group involvement ▪ Advisory support ▪ Existing skills and knowledge and ▪ Awareness of the technology in their district	**Relative advantage for the population** Is the advantage gained from adopting the innovation, sufficient to motivate the target population to adopt? Factors include: ▪ Enterprise scale ▪ Family succession/management horizon ▪ Profit orientation ▪ Environmental orientation ▪ Risk orientation ▪ Short-term constraints
Learnability characteristics of the innovation This is about the innovation and not the target population. Some innovations are easy to learn while others are more difficult. Factors include: ▪ Trialability ▪ Innovation complexity ▪ Observability	**Relative advantage of the innovation** The relative advantage of the innovation (not the perception of the target population). Factors include: ▪ Relative upfront cost of the innovation ▪ Reversibility ▪ Profit benefit ▪ Time for profit benefit ▪ Risk effect ▪ Environmental costs and benefits ▪ Time to environmental benefit ▪ Ease and convenience

[40] Kuehne, G., Llewellyn, R., Pannell, D., Wilkinson, R., Dolling, P., Ewing, M. (no date) ADOPT: a tool for predicting adoption of agricultural innovations. Future Farm Industries CRC. http://www.futurefarmonline.com.au/research/agribusiness-education/adoptability-planning-tool.htm

This model incorporates the theory associated with relative advantage and trialability. The model is still being tested, and could be used to indicate the expected level of adoption, time to reach peak adoption and also highlights where efforts could be focused to increase adoption and adoption rates.

3.3.7 Application of the ADOPT tool for Integrated Pest Management (IPM)

The impact of extension is changes in practices, knowledge, thinking and decision making processes based on lessons learned during the extension process.

Adoption refers to the use of R&D outcomes and outputs (technologies) by producers and their advisers. R&D outcomes may be adapted during the adoption process to fit individual farming conditions.

IPM, as an approach for managing crop health issues, was tested using ADOPT to provide an estimate of the likely level and time to adoption.

The model provided the following predicted adoption levels:

Predicted years to peak adoption	24.5
Predicted peak level of adoption	31%
Year innovation first adopted or expected to be adopted	N/A
Year innovation adoption level measured	N/A
Adoption level in that year	N/A
Predicted adoption level in 5 years from start	5.5%
Predicted adoption level in 10 years from start	19.7%

The above predictions are based on the following information entered into the Adoptability and Diffusion Outcome Prediction Tool.

Table 3-16: Relative Advantage for the Population

ADOPT Question	Response
Profit orientation: *What proportion of the target population has maximising profit as a strong motivation?*	**A majority have maximising profit as a strong motivation** Commercial vegetable producers need to be profitable in order to maintain a sustainable business operation.
Environmental orientation: *What proportion of the target population has protecting the natural environment as a strong motivation?*	**About half have protection of the environment as a strong motivation** ABARE statistics for 07/08 show that across Australia 45% of vegetable farms were involved or planning to be involved in an environmental management program.
Risk orientation: *What proportion of the target population has risk minimisation as a strong motivation?*	**About half have risk minimisation as a strong motivation** Within the vegetable industry there would be a very wide range of 'appetite for risk'. Older, more traditional producers with small landholdings are likely to highly risk adverse while younger and/or corporate style business are likely to be far more comfortable with risk.
Enterprise scale: *On what proportion of the target farms is there a major enterprise that could benefit from the innovation?*	**A majority of the target farms have a major enterprise that could benefit from the innovation** The majority of commercial vegetable producers would have vegetable production as the major enterprise on their properties. Other enterprises on site are likely to be minor and not the major source of income.
Management horizon: *What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?*	**A majority have a long-term management horizon** Across Australia, 72% of vegetable businesses expect to be engaged in the same line of business in 5 years time.
Short term constraints: *What proportion of the target population is under conditions of severe short-term financial constraints?*	**A minority currently have a severe short-term financial constraint** In 2010/11, 17% of vegetable growers failed to produce a positive cash income.

Is the advantage gained from adopting the innovation, sufficient to motivate the target population to adopt?

For many vegetable producers it may be difficult to determine the immediate benefit from implementing an IPM approach if profitability is the primary motive (although increasing insecticide resistance may change this). Appealing to alternative benefits such as environment and reduced time spraying may influence the message delivered for specific audiences. The complexity of the treatment systems may also impact on those that are risk adverse and reluctant to change. Short-term financial constraints will impede the ability of producers to use 'soft' insecticides which are more expensive than traditional chemistries.

Table 3-17: Learnability Characteristics of the Innovation

ADOPT Question	Response
Trialable: *How easily can the innovation be trialled on a limited basis before a decision is made to adopt it on a larger scale?*	**Difficult to trial** IPM needs to be implemented across the whole farm to really work.
Innovation complexity: *Does the complexity of the innovation allow the effects of its use to be easily evaluated?*	**Difficult to evaluate** The results of IPM usually take a while to evaluate and are multi-faceted. IPM is also a more complex approach than simply spraying to control a pest.
Observability: *To what extent would the innovation be observable to other farmers when it is used in a district?*	**Difficult to observe** Reduced damage to crops through improved IPM would be observable but it would be difficult for the casual observer to know how this was achieved.

This is about the innovation and not the target population. Some innovations are easy to learn while others are more difficult.

IPM as an approach to managing pests and disease is difficult to trial on a limited basis and to be truly successful needs to be implemented across the whole cropping area. The use of IPM would also be difficult for other vegetable producers to observe, unless they were specifically aware that IPM was the chosen method of pest control. Conducting field days or demonstrations on a local property where IPM has been implemented would overcome this barrier to adoption and is an effective tool in creating greater awareness and uptake.

Table 3-18: Learnability of Population

ADOPT Question	Response
Advisory support: *What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?*	**About half use an advisor** The type of advisor used is likely to vary significantly from the use of a qualified IPM consultant through to a sales agronomist.
Group involvement: *What proportion of the target population participate in farmer-based groups that discuss farming?*	**A minority are involved with a group that discusses farming** Vegetable producers often regard themselves as competitors rather than collaborators and therefore find it difficult to share information within a group setting.
Relevant existing skills & knowledge: *What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?*	**A majority will need new skills and knowledge** Successful implementation of IPM will require that producers have the ability to successfully identify pests and diseases and also beneficials.
Innovation awareness: *What proportion of the target population would be aware of the use or trialling of the innovation in their district?*	**A majority are aware that it has been used or trialled in their district** IPM has been in use for a number of years and there has been substantial R&D conducted on this practice.

The ability of the target population to learn about the innovation – this is about learning the benefits or relative advantage. Constraints will slow the time to peak adoption, they do not affect peak adoption level.

This area highlights the difficulty in dealing with a highly diverse and fragmented population. It will require different methods to target specific segments of the industry. It also means that there needs to be a general focus on awareness and capacity building to enable producers to be able to identify pest species, beneficials and when to spray. The use of advisor to support producers in implementing an IPM approach will be crucial to its success.

Table 3-19: Relative Advantage of the Innovation

ADOPT Question	Response
Relative upfront cost of innovation: *What is the size of the up-front cost of the investment relative to the potential annual benefit?*	**Minor initial investment** Initial investment is largely in relation to changing practices rather than investing in infrastructure. Although financial up-front costs are minor, the implementation of an IPM approach will require a substantial up-front investment of time and knowledge.
Reversibility of innovation: *To what extent is the adoption of the innovation able to be reversed?*	**Easily reversed** If the IPM approach is not working it is easy for the producer to resort back to a chemical-only approach.
Profit benefit in years that it is used: *To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?*	**Small profit advantage in years that it is used** Lettuce business case shows an increase in profit by $1,113 in year that it is used. However this increase in profit will be highly dependent on seasonal conditions, disease pressure and how successfully the IPM approach is implemented.
Future profit benefit: *How long after the innovation is first adopted would it take for effects on future profitability to be realised?*	**Small profit advantage in the future** Flow on benefits may be decreased risk of insecticide resistance and enhanced build-up of beneficials.
Time until any future profit benefits are likely to be realised: *To what extent would the use of the innovation have environmental benefits or costs?*	**Immediately** Small increase in profit achieved in same year of introduction (depending on success of implementation).
Environmental costs & benefits: *To what extent would the use of the innovation have environmental benefits or costs?*	**Moderate environmental advantage** Successful implementation of IPM will reduce amount of chemical sprayed into the local environment.
Time to environmental benefit: *How long after the innovation is first adopted would it take for the expected environmental benefits to be realised?*	**Immediately** Environmental benefits such as increased number of beneficial insects, reduced chemical released into air, soil and water should be realised immediately.
Risk exposure: *To what extent would the use of the innovation affect the exposure of the farm business to risk?*	**Increase risk** There is an increased risk of crop damage becoming severe if the pest population increases rapidly due to not crop scouting at the right time or seasonal conditions worsening.
Ease and convenience: *To what extent would the use of the innovation affect the ease and convenience of the management of the farm?*	**Decrease ease and convenience** IPM requires more intensive management (time) by vegetable producer. However the producer will also need to spend less time spraying.

The relative advantage of the innovation (not the perception of the target population).

The relative advantage of the innovation to the producer will depend on their primary drivers (of which profitability is likely to be the most dominant). The complexity of the approach and potential for increased risk are likely to be impediments to the uptake of this approach, however providing producers with confidence in the approach (through support of an advisor) will assist in increasing adoption.

The 31% adoption rate predicted by the ADOPT model over a period of 25 years is quite different to a recent case study of the Victorian strawberry industry where a 100% adoption rate was achieved within 4 years[41]. At the time of the case study, the Victorian strawberry industry was facing a crisis in the form of insecticide resistant insects and mites. This provided a significant incentive to producers to implement other forms of crop health management. However practitioners in the field of IPM implementation believe that the use of a farmer participatory approach is a successful means of delivering IPM training and research and will improve adoption even in the absence of a crisis.

3.3.8 IPM extension in practice

Integrated Pest Management around the world is typically characterised by low rates of adoption and very long periods before there is significant uptake of IPM strategies. This is despite significant government support for IPM in many countries. It seems that slow rates of adoption of IPM are accepted even if that is not what is desired. However, this does not need to be the standard, and this paper describes recent work with several industries that show that this certainly does not need to be the norm. This paper outlines how IPM adoption can be rapid and offers examples (case studies) from three different agricultural industries (both horticulture and broad-acre) in two countries. A full version of the paper is available in Appendix 5.

Despite the perceived advantages of IPM there are also disadvantages and studies worldwide have often shown poor rates of adoption. Even in horticulture where the theory of IPM is well developed, achieving widespread adoption on farms remains a challenge (Page and Horne 2007[42]). This paper describes how IPM strategies in both horticultural and broad-acre crops in Australia and New Zealand were developed and implemented using principles that have previously been established in extension theory.

The paper describes three case studies concerning IPM. In all three cases there was a reliance on chemical (pesticide) applications to deliver the required level of control of invertebrate pests prior to the projects conducted in each sector. The description of the separate projects can be found in individual publications in addition to this report. These are:

Case Study 1: Victorian Strawberry Production. (Victoria, Australia) (Horne and Page 2011[43])

Case Study 2: Arable Crops, Victoria, Australia. (Horne, Page & Nicholson 2008[44])

Case Study 3: Arable Crops, Canterbury, New Zealand. (Horrocks *et al*. 2010[45]).

[41] How to achieve (rapid) adoption of IPM. Paul Horne and Jessica Page (IPM Technologies Pty Ltd)
[42] Page, J. and Horne, P.A. (2007). Final Report to Horticulture Australia Limited. Project VG06086: Scoping Study on IPM Potential and Requirements. Available online at http://www.horticulture.com.au
[43] Horne, P and Page, J. (2011). HAL Project BS08011. Develop an effective IPM strategy to deal with pests in the Victorian Strawberry industry. Report to Horticulture Australia Limited
[44] Horne, P., Page, J. and Nicholson, C, (2008). When will IPM strategies be adopted? An Example of development and implementation of IPM strategies in cropping systems. Australian Journal of Experimental Agriculture **48**: 1601 -1607.
[45] Horrocks, A., Davidson, M.M. Teulon, D.A.J. and Horne, P.A. August (2010). Demonstrating an integrated pest management strategy in autumn-sown wheat to arable farmers. New Zealand

In all three cases, the two principal entomologists of IPM Technologies Pty Ltd, (the authors of this paper) used the same approach to work with growers to implement change. It is this approach that is described here that is the key to adoption in our view and is the focus of this paper.

These case studies all involved the same approach – collaboration between farmer and IPM advisor, involving an on-farm trial of the approach to be tested. The farmer needed real-time advice on what actions to be taken in regards to pesticide application and this was provided. That is, whenever a pesticide application was being considered, the farmer could consult with the IPM advisor and ask advice on what would be the likely consequences in terms of pest control and so hopefully choose the best option. In the examples given, this was the situation weekly.

A successful implementation of any IPM strategy will require the provision of support for the farmer. In most cases manuals and fact sheets (the usual means of delivering information by government agencies) alone cannot provide the support needed and it must come from direct contact with experts. The contact must also be timely, in that the farmers asking a question about control of pests will need an answer in a suitable time frame to deal with the pest problem (i.e. same day). The key decision-making can be summed up as follows:

1. Do I need to spray today or not? If so, with what?

2. If I do not spray, what are the likely consequences?

Note, the decision-making does not include –3. How much will this cost?

The alternative (conventional) insecticide approach provided peace of mind that all necessary actions to control pests had been taken and so it is up to the IPM experts, as much as possible, to provide the same level of reassurance. That is, the farmer needs to feel confident that pests are under control as a result of his actions, based on the advice received.

Adoption or non-adoption of IPM by farmers

For an IPM strategy to be effective it must deal with all pests in the crops and ideally would be as easy to implement as a pesticide – based strategy. One likely factor for the poor rates of adoption in some cases is that researchers have concentrated on a single pest and have not dealt with all pests in a crop. Also, when the current pesticide based strategies work, then there is an absence of a crisis to demand an alternative approach. When pesticide-based strategies work and when information given to farmers is complex, and is given without contact with an IPM expert to help with implementation, then it is easier for a farmer to use an established, proven and simple pest control method that relies totally on pesticide application.

Successful examples of adoption of IPM have usually involved several key elements – collaboration between farmers and advisors, local demonstrations and availability of expertise. The adoption of IPM described in this paper has been achieved through a combination of available knowledge, rapid testing of IPM approaches at a farm scale and the application of proven extension principles. The use of such a farmer participatory approach is recognised as an important tool in extension generally and is known to be a successful means of delivering IPM training and research. Critical in the successful adoption of IPM was the willingness of growers to be involved in commercial scale trials following their acceptance of the IPM principles outlined in workshops and courses. An essential part of this adoption has been the close one-on-one relationship developed with experts in the paddock. It enabled uncertainty over observations to be resolved and allowed tactics to be discussed. The effective answering of questions by experts in the paddock, and the access to experts to give an immediate response at any time has underpinned the adoption at the whole farm scale.

Poor adoption rates have also been attributed to:

- Too few entomologists as advisors
- Focus on research rather than implementation
- Too complex
- No local advisor
- Not enough information
- Chemical based control still works.

To improve the rate of adoption of IPM it is necessary to deal with each of these issues, but we can add a couple of further comments. Firstly, if chemical based-control is familiar and it is effective, then there is little incentive to make any change of practice. The chemical industry has, for many years, ensured that the simple chemical-based strategy is viable. This approach is now changing and sectors of the chemical industry are now actively supporting a broader approach to pest management – IPM.

The following factors have been identified as critical in successfully achieving an increased uptake of an IPM approach:

- On-going, timely and site-specific support by a qualified advisor (entomologist)
- Integration of selective pesticides with biological control agents (not total elimination of chemical options)
- Training of reseller agronomists (to ensure that they support the approach and provide appropriate advice)
- Local demonstration / on-farm trial of the approach
- Management of all pests in the crops (not just a single species).

3.3.9 Designing an extension approach

Industry stratification extension approach

In order to develop an extension approach which meets the needs of all of the vegetable industry, there needs to be recognition that there is no ‘average’ vegetable producer and that there is significant variation in the age, cultural background education and training level, as well as operation size, production system, business structure and business priorities. Location, vegetable types and supply chain arrangements contribute to the diversity. All of these factors will impact on how vegetable growers seek, understand and utilise information that relates to their business.

In order to tailor the content and delivery of plant health and crop protection information, it is suggested that producers within the vegetable industry could be grouped loosely into three categories based on the size of operation, attitude towards innovation and change (progressiveness) and capacity to adopt new technologies. These are:

Progressive vegetable producers: These producers manage large businesses that contribute significantly to Australia's overall vegetable production (around 12% of vegetable farms contribute 58% to overall vegetable production[46]). They are most likely to:

- Seek specialist advice to help manage various aspects of the business, including the use of agronomist and or IPM consultants for managing crop health or employ a specialist in the business to look after agronomy including crop health management
- Be proficient at searching for information using on-line resources and travel (or getting somebody to do this for them), and using / adapting this suitable information in the business
- Be open to new ideas and people and see the benefit in direct conversation with researchers and others developing new technologies, as well as providing direction to these people
- Conduct trials and develop new production methods for their business to improve efficiencies, profitability and their position in the market
- Be able to take some risks and deal with complexity and uncertainties when implementing change.

Advancing vegetable producers: These producers manage medium sized businesses and are seeking to expand the size and value of their operation (move towards the top 20% of the industry). They are most likely to:

- Be especially motivated to improve the efficiency and profitability of their businesses by using new technologies, varieties, supply chain arrangements etc.
- Want to hear about research results relevant to their business and how it could be used without having to spend a lot of time searching for it or reading lengthy reports
- Appreciate assistance in filtering and interpreting relevant information due to the vast amount of material available and time constrains
- Not employ specialists to look after agronomy and crop health management or conduct trials
- Prefer to hear about new technologies and concepts from trusted people
- See the benefit in organised study tours, case studies and demonstration trials which show how new approaches and technologies can be successfully implemented
- Feel uneasy about taking risks and dealing with complexity and uncertainties, and will therefore implement change when new technologies are proven to be 'safe'.

Stable vegetable producers: These producers manage smaller sized businesses which may struggle to provide a positive return in every year of production (36% of vegetable farms have an estimated value of operations less than $50,000 and they contribute around 2% of

[46] Thompson & Zhang (2012) Australian vegetable growing farms. An economic survey 2010-11 and 2011-12. ABARES research report 12.11

the value of vegetable operations[47]). These producers (which also include LOTE producers) are most likely to:

- Have reasons, other than profitability, for remaining in the vegetable industry
- Not widely search for new technologies or information in written formats
- Require support to ensure they meet environmental and food safety requirements
- Prefer one-on-one support by trusted individuals (potentially from advisors who speak their main language, if it is not English)
- Be risk adverse and try to avoid complexity and uncertainty.

Some of the characteristics of these three categories have been summarised in Figure 3-11 below. This summary has been developed from data provided by the recent ABARES surveys for 2010-11 and 2011-12, which assessed the performance of growers as measured by rate of return on capital, and on our knowledge of the vegetable industry.

An approach to deliver crop health information to the vegetable industry has been outlined in

[47] Thompson & Zhang (2012) Australian vegetable growing farms. An economic survey 2010-11 and 2011-12. ABARES research report 12.11

Figure 3-12 below. The diagram suggests the most appropriate type of service providers, method of delivery and type of information required in order to best meet the needs and priorities of each category in the industry. The yellow boxes within the diagram indicate content areas, extension methods and service providers that could be used across the industry. This approach has been developed based on information from recent industry consultation and review of industry development needs such as the *Review of Skills and Training in the Vegetable Industry* conducted by Macquarie Franklin in 2012.

Obviously, this approach will require further refinement based on the location of the vegetable producers, resources available and specific information requirements. However, as an initial step it provides a view as to how existing crop health information and delivery resources could be best utilised to facilitate uptake and adoption of new technology and crop health approaches.

New tools for extension

There are many tools available to assist in extension programs. A significant innovation in the past 5 years has been the explosion of Apps for smart phones. Australian farmers have been the first to embrace many of these Apps in the management of their businesses. An analysis of smart phone Apps that could be used within the vegetable industry to assist in the management of crop health issues is provided in Appendix 6.

This includes Apps for:

- Production
- Tank mixing and spray application
- Weather
- Pest and diseases.

	Stable Vegetable Producers (50% of Industry)	**Advancing Vegetable Producers (30% of Industry)**	**Progressive Vegetable Producers (20% of Industry)**
Information sources	Increased attendance at workshops Reliance on small circle of informants	Increased attendance at field days and workshops	Increased attendance at conferences and advice from a consultant
Main selling outlets	State capital wholesale Local market	State capital wholesale Direct to processor Retailers via packers	State capital wholesale Interstate and export Retailers
Perceived impediments to future business viability (top three)	Increased farm input costs Increased marketing costs Low prices due to imports	Increased farm input costs Low prices due to imports Low prices for other reasons	Increased farm input costs Increased marketing costs Low prices due to imports
Business size	Increasing size of property, production area of vegetable crops, number of employees and area engagement of specialised staff (i.e. IPM consultant) →		
Supply chain management	Increasing level of supply chain management including obtaining feedback from markets, level and sophistication of packing and distribution →		
Financial management	Increasing average farm cash income (profitability), preparation of budgets, risk analysis, decisions driven by economic considerations →		
Production efficiency	Increasing average yields →		
Implementation of IPM approach	Increasing proportion have a pest and disease monitoring program in place →		
Environmental management	Increasing proportion have participated in or are considering an environmental management program (i.e. EnviroVeg) →		
Chemical management	Increasing proportion test produce for chemical residues →		
Quality assurance	Increasing proportion have food safety program in place →		

Figure 3-11: Characteristics of three producer categories within the vegetable industry

	Stable Vegetable Producers (50% of Industry)	**Advancing Vegetable Producers (30% of Industry)**	**Progressive Vegetable Producers (20% of Industry)**
Subject Areas	• Chemical usage requirements • Soil health and IPM principles 101 • Quality assurance	• Support to implement IPM approach • Support to implement new spray technologies • Support to use disease forecasting tools • Risk management and soil health	• Access to latest R&D outputs on crop health • Information on new technology/approaches • Improving business efficiency through better crop health management
	• Demonstrating links between soil health, plant health and crop management • Demonstrating link between crop health management and productivity/profitability		
Targeted Extension Methods and Products	• One-on-one support (LOTE growers) • Informal training sessions (i.e. field days, workshops) • Instructive, brief factsheets	• Study tours • Re-packaging of existing crop health R&D outputs • Use of case studies and grower groups • EnviroVeg	• Digital technologies (i.e. Webinars, smart phone apps, social media) • Master Classes/Think Tanks (direct discussion between researchers, service providers and producers) • Progressive Producers 'Club'
	• Regionally targeted, participatory style training (site specific and relevant) • Investment in digital technologies • All sectors to have access to all products/events		
Service Providers	• LOTE extension officers • AgChem Industry Reps • Chemcert Courses in their language	• Vocational Education Training providers • State growers associations (i.e. VIC VGA) • National grower association (AUSVEG)	• Agricultural advisors/consultants • State R&D agencies (i.e. DPI) • Sales agronomists
	• Agricultural advisors/consultants • Private Registered Training Organisations (RTOs) • State R&D Departments		

Figure 3-12: Extension approach based on stratification of the vegetable industry

3.4 Environmental Scan – Data to inform management decisions

Good decisions are based on good data, their analysis and synthesis. The following data sets could improve the decision making process for RD&E investment and plant health. Data that would also be useful for decisions on RD&E investments into crop protection management includes but is not limited to:

- Economic data such as collected by ABS by region for all levy vegetable crops
- Regional / state crop data on production costs, areas planted & harvested, tonnage harvested and sold as well as prices / values for fresh and processing crops
- Data on the occurrence, severity and distribution of major pests, weeds and diseases
- Data on crop losses throughout the supply chain and reasons for these
- Information on the use of different pests, weeds and disease management approaches for different vegetables (conventional, GPPP, ICP)
- Information and data on local production conditions and methods and key crop management issues that relate to plant health and crop protection
- Data on the economic importance of crop protection (e.g. impact on farm profitability, value chain profitability).

Some data could be collected via the annual EnviroVeg self-assessment. Not all vegetable growers are members, but Membership now covers about 50% of the current vegetable production area and member numbers are increasing. Most of the larger producers are already members so that a substantial area and value is covered.

It is difficult and expensive to collect reliable data. However, the vegetable industry may want to invest into a system that facilitates the collection of confidential data that will allow growers to make more informed decisions for their business, and provide well founded information for RD&E investment and evaluation.

The following sections talk about the data and information that currently is available.

3.4.1 Vegetable production data

ABARES vegetable statistic is compiled annually based on Australian Bureau of Statistics (ABS) data on agricultural commodities. New ABARES vegetable data is expected to be available in mid 2013. Horticulture Australia (HAL) also compiles a horticulture statistics handbook that includes vegetable data. The key information sources for HAL is the Australian Bureau of Statistics and horticulture peak industry bodies (PIBs) where available. It covers number of businesses, production area, value, tonnages (by state), exports (by state and markets), imports, per capita consumption and market data as available.

The routinely collected datasets have limited value for decision making about plant health and crop protection. ABS and ABARE data covers the major crops with higher production values only. The data projects information provided by industry during the census process. Table 3-20 shows data for major levy vegetable crops sorted by value for 2010-11. The accuracy of ABS data is sometimes questioned by industry. Still, in the absence of better information provided by growers and the supply chain, the data has been used for this project, especially the economic analysis tool.

Table 3-20: Production data for higher value vegetable crops (Source: ABS[48])

Levy crops sorted by value		Aust.	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
Lettuce	**Gross Value $m**	164.0	16.4	56.1	64.3	10.1	13.7	3.2	0.2	0
	Area (ha)	9,071	1,018	4,000	2,390	299	891	470	4	0
	Production (kg)	144,636,602	15,800,448	49,434,647	54,351,176	7,139,169	14,960,950	2,767,919	182,294	0
	Yield (t/ha)	15,945	15,526	12,359	22,743	23,885	16,794	5,885	48,773	0
Carrots	**Gross Value $m**	130.7	1.3	25.7	13.5	25.6	44.0	20.5	0.0	0
	Area (ha)	4,636	160	1,179	671	614	1,301	712	0	0
	Production (kg)	224,571	3,979	48,054	24,758	28,925	64,896	53,958	0	0
	Yield (t/ha)	48	25	41	37	47	50	76	0	0
Beans - Total	**Gross Value $m**	129.6	1.3	24.6	94.3	0.3	6.5	2.4	0.1	0
	Area (ha)	6,504	113	895	4,199	10	467	812	9	0
	Production (kg)	32,886,181	268,879	4,418,427	22,707,139	55,360	1,119,819	4,257,669	58,886	0
	Yield (t/ha)	5,056	2,387	4,939	5,407	5,824	2,400	5,242	6,597	0
Capsicums (no chillies)	**Gross Value $m**	113.5	3.8	4.5	83.0	10.4	9.6	2.3	0.0	0
	Area (ha)	2,372	165	108	1,768	175	150	5	1	0
	Production (kg)	50,862,241	1,659,895	1,646,771	39,556,029	3,814,734	3,351,861	831,274	1,677	0
	Yield (t/ha)	21,442	10,049	15,298	22,377	21,768	22,291	153,056	3,197	0
Broccoli	**Gross Value $m**	104.6	5.2	48.7	28.8	2.6	16.7	2.6	0.0	0
	Area (ha)	7,090	342	3,370	1,920	236	846	375	0	0
	Production (kg)	49,112,085	2,233,569	22,778,689	12,808,523	1,288,796	6,366,059	3,636,449	0	0
	Yield (t/ha)	6,927	6,527	6,758	6,670	5,464	7,524	9,698	0	0

[48] 71210DO001_201011 Agricultural Commodities, Australia, 2010-11, released 29/06/2012

Levy crops sorted by value		Aust.	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT
Sweet corn	**Gross Value $m**	85.8	9.1	14.0	35.8	0.3	26.7	0.0	0.0	0
	Area (ha)	6,744	1,456	692	3,739	25	831	2	0	0
	Production (kg)	70,808	25,675	9,026	25,822	189	10,096	0	0	0
	Yield (t/ha)	10	18	13	7	8	12	0	0	0
Pumpkin	**Gross Value $m**	71.3	25.3	1.9	25.8	2.6	12.6	0.8	2.2	0.0
	Area (ha)	6,986	2,127	270	3,233	217	924	69	145	0
	Production (kg)	102,934	36,322	2,990	41,183	4,301	13,453	1,176	3,509	0
	Yield (t/ha)	15	17	11	13	20	15	17	24	0
Cauliflower	**Gross Value $m**	42.9	7.3	12.9	11.5	3.8	5.3	2.1	0.0	0.0
	Area (ha)	3,118	477	1,011	841	174	399	216	1	
	Production (kg)	66,932	11,245	20,018	17,771	5,857	8,426	3,606	10	
	Yield (t/ha)	21	24	20	21	34	21	17	20	
Green peas - Total	**Gross Value $m**	9.7	0.5	1.9	1.3	0.0	0.1	5.9	0.0	0.0
	Area (ha)	32,153	4,112	7,585	3,308	9,292	1,901	5,954	0	0
	Production (kg)	1,128,208	110,783	236,717	87,665	356,468	84,822	251,752	0	0
	Yield (t/ha)	35	27	31	27	38	45	42	0	0
Other vegetables	**Gross Value $m**	644.6	93.8	165.1	280.7	47.7			4.8	0.4
	Area (ha)	17,875	2,366	5,109	7,869	769			168	10

3.4.2 Distribution, incidence and severity of pests, weeds and diseases

Australia has limited regional surveillance data about the distribution, incidence and severity of pests, weeds and diseases for levy vegetable crops.

Therefore, previous R&D needs analyses (Gap analysis) relied on surveys and workshops with researchers, growers and advisers. This is the best possible process in the absence of general or specific objective surveillance. It relies on getting responses from a representative cross section of industry and that pest, weed or disease issues are identified correctly.

Vegetable growers are increasingly adopting smart phone technology; this could have the potential to assist with collecting data, e.g. if the data collection is linked to a service for growers that relates to the type of data collected.

In some countries, annual crop growers increasingly have access to sophisticated APP tools for accessing specific information, and recording and receiving data associated with their specific sites. "In the United States for example, the Integrated Farming SystemsSM Platform (Monsanto) utilises sophisticated software and hardware to capture annual data from growers on seed genetics x on-farm practices x environment, in yield management zones that are differentiated by planting and nutrient systems. Similarly, FieldScriptsSM (Monsanto) advises corn growers of the optimal row spacing, hybrid and seeding rate for their specific management zone (Monsanto)."[49]

Environmental changes affecting e.g. climate, or water in different production regions will have an effect on the distribution, incidence and severity of pests, weeds and diseases without monitoring systems, these effects will only be recognised when major problems occur. The same could be said for internal biosecurity; without adequate surveillance, pest, weed or disease incursions may be recognised too late to contain them.

Given that government agencies are pulling back from data collection, alternative systems have to be installed to collect useful data as a basis for decision-making.

3.4.3 Availability and use of control options for pests, weeds and diseases

Strategic Agrichemical Review Process (SARP)

The Strategic Agrichemical Review Process (SARP) collects valuable information on the availability of pesticides by crop and pests, weeds or diseases and additional information on chemical group, withholding period, frequency of use, current product suitability and industry comments. The process is a way of consolidating information on changes to pesticide registrations and permits, making it available to industry, and identifying gaps in control options that need addressing. The original intention is to fill gaps in available control options, including IPM, via minor use permits for suitable pesticides, however, the process could also be used to identify areas for GPPP and ICP development.

For this the SARP could be built upon to include information about pesticide effects on beneficial organisms and pesticide use patterns that avoid pesticide resistance, while at the same time protecting beneficials. Further information relevant to ICM could be included;

[49] McMichael, P. 2012; Review of Soilborne Disease Management in Australian Vegetable Production, Horticulture Australia VG11035

examples on this were produced for lettuce and celery by the Vegetable IPM Coordinator project (VG09191, 2011). The information collected for the SARP could potentially be analysed spatially to understand the distribution of pest, disease and weed problems and how these are dealt with. This could help targeting extension programs and directing regional R&D.

Annual pesticide use data

While the SARP process collects subjective information on the frequency of use of certain products, a process of collecting data on the annual amounts of pesticides placed on the market and used (e.g. by type or active ingredient) on selected representative crops by state or statistical division would be useful. The data could provide a reference for the types of pest, weed and disease problems occurring in different regions and changes over time, trends in management changes, potential training or control strategy development needs, and potential risks of resistance development due to overuse.

In Europe, this information is collected using "A common methodology for the collection of pesticide usage statistics within agriculture and horticulture"[50]. It is further analysed and used in connection with other data to provide agro-environmental indicators (European Commision, EuroStat [51]).

3.4.4 Production and supply chain economics – impact of pests, weeds and diseases

Reliable information on the impacts of pests, weeds and diseases on production economics and profitability for different vegetable crops throughout the supply chain could not be found for this project. This type of data would be important for understanding where and how the greatest value losses occur, and to prioritise RD&E activities to address the major problems and provide the greatest gain.

HAL recently commissioned work to identify and prioritise current on and off farm business costs and then develop a process to address the key issues. The program will categorise the costs that impact on levy payer profitability and measure the magnitude of that impact on the profitability of Australian growers. Impacts of crop losses due to pests, weeds and diseases and costs of their control, and associated supply chain costs may be part of the information provided by the project. If not, this area may be identified as costs that require further detailed investigation via the national research and development program.

3.4.5 Data about markets and consumer demands

Conflicting consumer expectations about pesticide use and lack of blemishes and any sign of beneficial organisms on vegetables affect how growers can control pests and diseases. To generate greater market acceptance of ICP there is a need to understand attitudes and barriers that exist in the marketplace, and to develop strategies to overcome identified barriers. HAL has recently commissioned work to collect relevant information about market attitudes towards IPM and sustainable vegetable production practices. The market information can guide RD&E into ICP methods that are acceptable for growers and consumers.

[50] http://ec.europa.eu/eurostat/ramon/statmanuals/files/KS-RA-08-010-EN.pdf or EU Bookshop (http://bookshop.europa.eu)
[51] http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Agri-environmental_indicator_-_consumption_of_pesticides

4 Situation Analysis – Industry Outlook

The vegetable industry was consulted to determine the:

- Current crop health issues impacting on vegetable production in Australia
- Where future R&D should be focused to assist vegetable producers in protecting their crops
- How this support should be provided.

Consultation occurred using a range of methods including workshops, phone interviews and an on-line survey. A summary of the responses to the consultation is presented in Appendix 3 and the key findings and themes are discussed below.

4.1 Approach

4.1.1 Consultation Targets

Consultation occurred with the following groups and focused on insights and understanding of issues rather than collating a large number of data sets.

- Growers
- AUSVEG
- Horticulture Australia portfolio and industry service managers
- Advisers and agronomists
- Producers and resellers of crop protection products
- Industry sectors that have specific needs (such as LOTE vegetable producers and protected cropping)
- Others in the vegetable supply chain.

4.1.2 On-line Survey

The desktop review guided the development of an on-line survey for consultation with growers and industry advisors. The survey was hosted on the AUSVEG website and an invitation to respond included in the AUSVEG newsletter which is sent out to vegetable producers and industry service providers on a weekly basis. The survey was designed to assess:

- What vegetable producers and service providers considered to be the major crop health issues
- How this impacted on production
- What further support they required to manage these issues.

A copy of the questionnaire and a summary of the responses are provided in Appendix 3.

4.1.3 Telephone interviews

Phone interviews were conducted with six agronomists from across Australia (2 x VIC, 2 x SA, 1 x NSW, 1 x QLD). Interviews ranged from 45 to 60 minutes in length and while questions were similar to those used for the on-line survey, direct conversation during the interview provided the opportunity to explore issues in greater depth.

A summary of the responses provided to the interviews is provided in Appendix 3.

4.1.4 Workshops

A workshop was held in conjunction with the Annual Diagnosticians Workshop, in February 2013, to discuss how the research community can support the Australian vegetable industry to effectively manage pest and disease over the next 10 years. Attendees represented state R&D departments, Universities and private industry. Attendees were provided with a pre-workshop survey which requested their views on:

- The emerging/future plant health risks for the vegetable industry
- The emerging/future opportunities in crop protection
- Where and how should future investment occur?

Those invitees who were unable to attend the workshop were encouraged to submit a response to the pre-workshop survey.

4.2 Key Outcomes/Findings

4.2.1 Industry Partners

The following industry partners were approved by the IAC:

1. Allison Clark, General Manager Customer Relationships at Houston's Lettuce Farm, Tasmania
2. Jim Trandos, Trandos Farms, Western Australia, production focus is corn and beans.

Both industry partners significantly contributed to the consultation and general approach taken for developing the investment plan because of their experience in and dedication to the industry. Both had some positive experiences with IPM programs and or rotation including biofumigation. They would support further RD&E to allow vegetable producers to use integrated methods aimed at reducing the reliance on pesticides alone. One reason for this is their experience with major retailers who ask for 'sustainable production methods'. "Retailers representatives ('agronomists') are taking notice of RD&E publications in 'Vegetables Australia' and VegNotes. They ask whether we are using these new methods."

The major points they raised are listed below:

Actions

- Get relevant R&D information out to industry in a usable format including how new technologies could be included into regional production systems
- Access relevant information produced for other product groups, by other RDC's and in other countries
- Have a more streamlined way of commissioning R&D and getting the information out to industry as it is produced "reporting is far too slow", "we do not have time to read lengthy reports, two pages with photos rather than graphs would be great"

- Acute issues (crises) should be dealt with ASAP, not via the usual slow funding cycles – systems and responsibilities need to be in place for this
- Ensure that growers understand the positive effect the RD&E program has on their progress and profitability
- Provide guidance on how to test R&D results on-farm and adapt them to individual situations (potentially via regional demonstration farms)
- More R&D trials should be on representative farms
- Researchers should link in with well frequented industry events to get information out e.g. field days organised by seed companies
- Use seed companies and other agribusinesses as a source of information.

RD&E topics

Industry partners suggested that levy RD&E should focus on some overarching topics that affect all growers and take a risk-based approach (understand, measure and prioritise risks, avoid and mitigate risks). Topics included:

- Climate variability (heat, rain) and climate change risks and how to deal with them
- Risks of soil health status decline and management options
- Understanding fertiliser and 'alternative product' impacts on crop health (are some fertilisers better than others?)
- Biosecurity vigilance
- Natural pest, weed and disease control mechanisms, ICP
- Understanding the connection between soil health, plant health, nutritional value and human health (to better use it in the promotion of vegetables)
- Food safety in general and after extreme weather events especially floods
- Standardising soil amendments so they are not too variable.

Issues and potential solutions

Larger operators conduct and pay for their own applied R&D, market research and employ agronomy staff for three main reasons:

- Relevance to the operation (sites, markets, technologies)
- Competitiveness (market share, improving marketable yield and profitability, IP protection)
- Poor return from many external services.

The companies still pay levy contributions and often feel that the return on levy RD&E investment is not as good as what they are getting from their own R&D. The suggestion was made that companies who exceed a certain levy threshold could use a percentage of their levy funds on their in-house R&D programs. The rationale was that other growers eventually use new technologies and techniques developed by industry leaders. Therefore, supporting industry leaders' R&D programs, guided by a set of rules on eligibility and IP protection, should be beneficial to the entire industry.

4.2.2 AUSVEG Vegetable Technical Advisory Group (VTAG)

A workshop was conducted with the VTAG at the AUSVEG offices. The workshop considered the issues facing the vegetable industry in relation to plant health and crop protection and considered the work undertaken by the project to date. The VTAG were able to provide guidance on direction and specific recommendations for the project team.

Some of the key messages from the VTAG are provided in Table 4-1. Consideration of these key messages were incorporated into the development of the investment plan.

Table 4-1: Key messages from VTAG

Overview of Key Issues	Actions
▪ Why isn't information being used ▪ How is it currently used and how could it be used more effectively ▪ There is stratification/layering of industry needs which needs to be considered ▪ Need to have specific messages to target particular groups (language, size etc) ▪ Discussion around chronic and acute problems and different ways of responding to these	▪ Review stratification approach ▪ Ensure that information and messages targeted to different groups – 'horses for courses' ▪ Consider balance and provide direction on RD&E portfolio to address chronic/acute problems – strategic versus applied research (long-term versus reactive) and the timeframes expected ▪ May want to use case studies for some issues (eg IPM adoption) as RD&E model
Review of Materials	**Actions**
▪ Good information and approach ▪ Discussion around alternative approach focusing on key pests/diseases/weeds ▪ Consolidate which crops to be assessed ▪ Useful resource for advisors ▪ May need to delve deeper into research reports to determine extension and impacts ▪ Confirm use of IPM – broad definition	▪ Agree on final list of crops / crop groups for review – consider smaller crops (commodity groups) ▪ Be careful with terminology throughout report ▪ Consider information outside industry (e.g. ryegrass resistance)
Consultation	**Actions**
▪ Layering of target audience and associated messages ▪ Focus on consultation with advisors is an effective approach ▪ Need to link into NESB	▪ Continue consultation with growers that cover a range of industry levels ▪ Continue to focus on advisors as a conduit to growers ▪ Obtain feedback from the LOTE Community of Practice
Economic analysis	**Actions**
▪ Approach will be difficult ▪ Need to develop model and test sensitivity and impact of management – high variability ▪ Impact on a particular crop ▪ Potential to group some crops ▪ Moderate impact on significant crop versus catastrophic impact on minor crop	▪ Develop model and undertake sensitivity analysis including management differences ▪ Highlight assumptions
Extension and capacity building	**Actions**
▪ Mentoring for advisors ▪ Making sure agronomists have the appropriate tools and training ▪ Need to consider consumer acceptance and education ▪ Post-harvest integration of IPM ▪ Extension integrated part of research	▪ Recommend that RD&E plan ensures that extension is an integrated part of research with a relevant reference group, grower representation and possibly a regional focus ▪ Ensure that there is a focus on education/training and capacity building for advisors ▪ Need to ensure that the timing of extension on appropriate ▪ Potential for regional updates e.g. spray application

Program Logic – Hot Topics	**Actions**
Pest and pathogen types and genetics (virulence, invasiveness, pesticide resistance)	▪ Need to understand pest and pathogen epidemiology better ▪ Biological and economic thresholds ▪ Principles for minimising resistance – awareness of practices for industry ▪ Managing the issue and reducing the risk ▪ Diagnostics tools to assist grower
Crop type and genetics (susceptibility, tolerance, resistance)	▪ IP for individual companies ▪ Variety selection usually based on other attributes – individual grower choice and usually focused on consumer preference
Production/post-harvest environment (climate, biosecurity, soil, water quality, storage, transport)	▪ Growers are able to adapt to weather conditions – need good forecasting information and there has been modelling of pest/disease incidence under different climate conditions ▪ Need to increase industry awareness re biosecurity (project to address this) ▪ Body of work on physical and chemical soil conditions – not lacking ▪ May need to consider a more holistic approach for RD&E focused on the farming system and consider economic pressures (e.g. increased rotations)
Control and management methods (chemical, biological and cultural, ICP/IPM, emerging technologies)	▪ Importance of improving knowledge associated with spray application ▪ Traditional area of RD&E
Crop management and business decisions (control through integration of BMP)	▪ Integration program looks at best practice for individual – no one-size fits all ▪ Farming systems research – PIPS (Productivity, Irrigation, Pests and Soils) (apple and pear) ▪ Focus on healthy plants and decrease predisposition to pests and disease ▪ Is there sufficient information on nutrition/irrigation impacts on diseases – e.g. use of nutrient analysis and avoiding waterlogging, soil health ▪ Complex to meet needs of industry – possible to use regional implementation groups ▪ Need to ensure there is good understanding of harvest and post-harvest impacts
Market access and consumer expectation (market entry and consumer decisions)	▪ Ensuring that industry has equipment and knowledge for decontamination – technology for wash lines to remove pests ▪ Consumer expectations – can impact on adoption of certain practices ▪ Significance of secondary standards implemented by markets ▪ Need for growers to understand specification and requirements of markets ▪ Providing necessary tools for growers to understand consumer preferences ▪ Awareness and education of consumers – *moves into marketing*
Biosecurity and emerging pests and disease threats (preparedness and climate change)	▪ Addressed via biosecurity project

4.2.3 Vegetable Producers

Issues

Vegetable producers felt that effective crop health management was a major priority, since loss of control could result in major economic damage to their crops. A wide range of weeds, pests and diseases were cited as issues on both their property, and within the district generally, and were usually common to a range of different vegetable crops.

While nearly half of the respondents felt that the majority of their crop health issues required immediate action due to the rapid multiplication rate of pests, a longer term solution/strategy was also considered important to reduce dependence on chemical options.

Opportunities

Opportunities to assist vegetable producers in the management of crop health issues were cited as:

- Biosecurity to prevent the entry of new pests
- Increased range of chemical products through registration of products that are currently available in the USA and EU but not in Australia
- Development of further non-chemical control options including the development of biological predators.

Extension Approach

Nearly half of the vegetable producers who responded felt that national R&D programs conducted in the past had only been of minor use to their business, and that while many of them conducted their own on-farm R&D, they did so only because they felt there was no better alternative.

4.2.4 Agronomists

Issues

There was a range of crop/pest specific issues nominated as being an on-going problem for the vegetable industry by service providers. The majority of these crop specific issues are not new to the industry but appear to be a problem, which continues to impact on production due to lack of appropriate management. A number of reasons were cited for this, mostly related to the difficulty in implementing IPM. These included:

- Lack of 'whole of industry approach' to implementing IPM – this is a major reason why soilborne diseases continue to be an issue. Chemical options are a short term solution and there is no 'silver bullet'
- Intensification of production systems resulting in insufficient time and space to allow for appropriate crop rotations/fallow periods
- Small profit margins reducing available funds to investment in the implementation of IPM.

Other issues included:

- Lack of chemical control options particularly in minor crops (the cost to chemical companies to register products for horticultural crops is cost prohibitive due to the lower numbers compared with other industries such as broadacre)
- Contaminants (both weed and pest) within leafy vegetable crops
- Emerging pests (either new pests from other countries or existing pests moving into new districts (due to changes in seasonal weather patterns) or moving into new crops, which they previously didn't infect.

Effective management of crop health issues was felt to be an area of major importance to the vegetable industry that required on-going R&D support. Estimates of the costs associated with crop health management within the industry were relatively low (10-30%) however the real cost was felt when crop management failed, an increasing risk with greater intensification of cropping systems.

Opportunities

Opportunities to assist the vegetable industry in managing these issues included:

- Emphasis on an 'area-wide' management approach
- Focusing on better monitoring and diagnostic services (through the introduction of predictive models, forecasting, smart phone technology)
- Educating consumers on beneficial insects, their role in the environment and the benefits of seeing these insects in raw and processed vegetables
- Further education on the use of biological controls, soil health and effective crop management (including improving producer awareness of susceptible host crop ranges, appropriate crop rotations and benefit of site preparation prior to planting)
- Supporting LOTE producers to ensure appropriate use of chemical products.

Extension Approach

Service providers within the vegetable industry felt that the outcomes of R&D programs could be more effectively extended to vegetable producers by:

- Ensuring research programs include an extension component which involves/informs all sectors of the industry (this includes service providers such as agronomists, consultants and AgChem reps who have frequent and regular contact with vegetable producers)
- Funding grower groups so that they can provide information on research priorities and assist in driving the adoption of research outcomes
- Embracing new technology (such as social media, internet, smart phones) to assist with the dissemination of research results and ensuring that on-line resources remain up-dated and relevant
- Including information on the economic impact of various crop health management options so that producers are aware of how implementation will affect profit margins within their business.

4.2.5 Plant health researchers

Issues

Issues nominated by researchers as new and future issues for the vegetable industry included:

- New genotypes of existing pathogens (i.e. viruses) and ensuring skills and expertise for identification
- Loss of research and extension capacity
- Loss of effective chemical control (fungicides/insecticides/herbicides) through either regulatory control/loss of product and/or evolution of resistance to the product through development of new biotypes of various common pests (multiple crops/multiple pests)
- Biosecurity – dealing with new pests such as Honey bees and Varroa mites; Tomato-Potato Psyllid; new virus diseases moving into north-west Australia on insect vectors arriving from Timor and Java
- Conflicting market demands including desire for blemish free vegetables versus 'softer' control and change in MRLs
- Climate change impacts on pest complexes and changes in outbreak patterns
- Sucking pests and viruses (e.g. thrips, whitefly, Rutherglen bug, tospoviruses, ZYMV, CMV, TSWV).

Opportunities

Opportunities for crop health RD&E nominated by researchers included:

- Development of naturally derived products for control of pest and disease including biofumigants such as use of green manure crops that produce volatile compounds and anaerobic soil disinfestation and naturally derived insecticides
- Pheromone and feeding attractant technology (better delivery systems combined with increased crop sizes could make mating disruption a potentially cost-effective alternative to insecticides for control of some key pests)
- Use of bacteriophages to control bacterial plant pathogens
- Increased use of products that enhance the plant's natural defences
- Increased development of resistance to pests and diseases through genetically modified crops
- Application of new nanotechnology to existing chemical products for increased efficacy
- Alternative control methods such as soil sterilisation using steam and rotations/fallow periods. Note that the introduction of R&D/practices implemented in other countries should consider differences in operating costs (e.g. lack of subsidies) when determining applicability for Australian production systems
- Further development of predictive models to help manage the unknown at an industry and grower level

- Better utilisation of biological control including national coordination of biological control R&D (opportunity to link with other RDCs) and national assistance to up-scale production of biological control products/beneficials
- Understanding the economic and biological thresholds for pests and diseases
- Surveillance of resistance in pest and disease and active promotion of resistance management plans
- Microwave technology for weed control
- Automated insect monitoring and trapping technology
- GPS guided spraying system for accurately targeting weed and pest infestations.

Priorities

The researchers provided suggestion for how industry may consider future investment including:

- Ensuring a two-way conversation between growers and researchers to determine the priorities for future investment
- Developing a program of work which:
  - Is cross crop/commodity (big picture not crop specific)
  - Considers spill-over benefits (leverage of available funds and cross collaboration)
  - Has long term timeframes
  - Is driven by HAL e.g. using coordinated programs similar to the approach the potato industry has taken
  - Focuses on better communication of outcomes to growers (projects should comprise at least 30 – 40% of the budget for extension, with extension specialists part of the system)
  - Provides funds for R&D program / project development
  - Allows for flexibility in extension/research models for projects
  - Includes better engagement of private industry (i.e. agricultural chemical companies which have people on the ground and can assist in the screening of new products and contact with growers)
- Generating base-line data on what pests and diseases exists in new cropping areas
- Developing improved Integrated Virus Disease Management approaches for both field and protected cropping (including increased knowledge of virus-vector interactions)
- Establishing area wide management of fruit fly and other quarantine pests to improve domestic and export market access
- Managing climate change related pest issues
- Developing readiness for key biosecurity threats
- Building on previous R&D.

4.2.6 Crop protection and biotechnology companies

The development of pesticides had to adjust over the past two decades to meet demands for more selective products with less environmental and health impacts from their production and use. Pesticide producers saw opportunities in involvement in biotechnology and conventional breeding techniques to develop improved varieties that are less affected by certain pest and diseases or are tolerant to some pesticides.

Tolerant varieties and careful use of pesticides are part of ICP, still IPM research for the vegetable industry seemed to have had less input from companies who are producing some useful ICP tools than might have been expected. Representatives from crop protection and biotechnology companies, willing to contribute, were therefore interviewed.

Approach

Most crop protection companies in Australia are members of CropLife Australia, the peak body of the plant science industry. Members were approached via email to ask whether they were able to discuss their view of future RD&E needs in the vegetable industry.

The following crop protection and biotechnology (plant science) companies were approached for comment:

- AgNova Technologies Pty Ltd
- BASF Australia Ltd
- DuPont (Australia) Ltd
- Nufarm Australia Ltd
- Sumitomo Chemical Australia Pty Ltd
- Syngenta Crop Protection Pty Ltd
- Bayer CropScience Pty Ltd
- Dow AgroSciences Australia Ltd
- Monsanto Australia Lt`d
- South Pacific Seed
- Terranova Seeds
- Faibanks Seeds (Syngenta distributor)
- Seminis (Monsanto seed).

The guiding questions used in interviews with company representatives were:

- In your opinion, what are future pest, weed and disease issues for the vegetable industry?
- What are the new opportunities for protecting crops?
- What should be HAL's priorities for future investment in plant health RD&E, paid by levy funds?
- Should industry funded research involve your business, if yes, how?

Thirty percent of companies were able to contribute to the consultation.

Priorities for development

The following priorities were mentioned for product development to meet future pest, weed and disease issues for the vegetable industry:

- Generally looking for narrow spectrum, safer products (safe to beneficials, bees, animals, people and environment)
- Nematicide for carrots, sweet potato and potatoes. Existing products are S7's and will not be available longer term. As far as is known, nothing is registered in these root vegetables to replace the S7 products
- Sclerotinia control product for beans and lettuce and in general for vegetable crops. There are only a few Sclerotinia products registered and one procymidone is an S7
- White blister control products for brassicas
- Aphid control products for red headed aphid in Ravensdown QLD, which is not even controlled by newer chemistry.

Powdery mildew control product for tomatoes was also mentioned. Current products do not adequately control the species of powdery mildew on tomatoes. This may also become an issue in levy crops belonging to the same plant family as tomatoes (solanaceae).

Issues

The below risks or gaps were identified in regards to pest, weed and disease management. They do not just relate to product availability but also to how the industry is seen to approach crop protection and pesticide resistance management.

- Resistance management was identified a major issue; the risks associated with loosing products due to pesticide resistance and how to prevent this needs to be better understood by researchers, and communicated to vegetable growers and their advisers; priorities would be aphids and mites
- The need for all of area wide management of pests, weeds and diseases rather than a paddock by paddock approach
- Removal of endosulfan (organochlorine insecticides and acaricides), dimethoate (organophosphate insecticide) and fenthion (organothiophosphate insecticide, avicide, and acaricide) without having a coordinated approach to controlling target pests without them
- Greater public and regulatory scrutiny of products – e.g. bee toxicity of products will become a greater focus
- “Poorly informed people (on all levels) can turn insect management into a problem in the future” – there is a need for better communication, networking and education “we all need to know what each other (researchers, advisers, crop protection industry) are doing”
- Virus identification in crops and control - Western Flower Thrips and Whitefly control
- Understanding risks of soilborne diseases and integrated management – using products on a needs basis, not as an ‘insurance’ when not warranted to extend their ‘lifespan’

- Extension and capacity building – get out information that is available on products, integrated methods and application technology to make sure products are used as intended to extend their 'lifespan'
- Regional differences in pest, weed and disease issues that affect a crop over its lifetime need integrated regional management approaches
- Poor collection of base data on pest, disease and weed issues "current data is useless", "data collection is poorly done, if at all".

Opportunities

Priority crops and pests, weeds or diseases for product development should be selected as candidates for ICP development. The fact that pesticide developers have identified that current control is not sufficient or is expected to have gaps in the future is a clear indication of a need for better solutions. These gaps should be checked against gaps identified via the SARP.

Previous consultations to identify gaps in vegetable crop protection RD&E appear to have mostly neglected discussions with crop protection companies even though they have a good understanding of issues because it is important for their business.

All interviewees from the crop protection industry stressed that they would like to be more involved in RD&E for the vegetable industry. Market pressures in regards to food safety and environmental sustainability, and the fact that newer products are more selective and need to be carefully managed to expand their 'lifespan' are major drivers for the interest in developing integrated crop protection approaches. Many crop protection and biotechnology companies have field staff that could be consulted or involved in applied R&D projects aimed at ICP development. Some examples for the success of this approach exist (Paul Horne, IPM Technologies, Ian McLeod, Peracto, pers. com.). Several university and department researchers have worked with crop protection and biotechnology companies during their research. Especially private RD&E services providers have built valuable relationships with these companies. They have a good understanding of the range of new products, how these work, and how they could be included in an ICP approach, based on efficacy and residue work for product registration.

Peak industry bodies like AUSVEG and CropLife Australia could liaise regarding managing issues connected to pesticides in vegetables. This could include a coordinated, risk-based approach to prioritising and dealing with issues related to deregistration and resistance management that acknowledges regional differences in crop protection issues. Liaison about how to best generate good based data for decision-making on several industry levels and for multiple users may be of value.

Some further opportunities may include:

- Smart phone Apps could be used to assist with resistance management
- Regional integrated management approaches e.g. in GPPP or ICP guidelines
- Central coordination of plant health and crop protection information, communication, networking, identification and management of issues – SARP could be a starting point.

4.2.7 Asian vegetable industry/LOTE producers

LOTE producers provide an example of the ‘stable vegetable producer’ from industry stratification approach. They also provide an example of where industry support/extension is not justified by economic reasons but by community/environmental concerns and for this reason have been consulted separately.

Background

The Australian Asian vegetable industry is a growing horticulture sector whose products have become increasingly acceptable to Australian consumers. Based on Australian Bureau of Statistics figures (ABS, 2009) the value of the Australian Asian vegetable industry has grown to $204 million, and contributes approximately 6% to the value of the Australian vegetable industry[52].

Production of Asian vegetables occurs across Australia, with Queensland, NSW and Victoria the largest producing states by both value and volume. Asian vegetable crops are grown mainly by producers who come from non-english speaking backgrounds who are variously referred to as NESB (Non-English Speaking Backgrounds), CALD (Culturally and Linguistically Diverse) or LOTE (Language Other Than English) producers. LOTE producers can also come from non-Asian background, including Italian, Greek and Lebanese, and manage conventional or “western” vegetable crops.

Issues

A number of concerns have been identified which have the potential to affect not only the growth of the Asian vegetable industry but the reputation and sustainability of the Australian vegetable industry in general. These include:

- **Sustainability production practices** – Industry support and research has been effective in shifting many first generation emigrant growers in the vegetable industry from their traditional to modern commercial practice. However the constant inflow or turn-over of first generation growers means that the issue of production practices is an ever-present one and it is likely that there will always be varying levels of knowledge and skill associated with the management of chemicals, pests and diseases, nutrients and quality assurance in particular.
- **Biosecurity** – past biosecurity programs have not effectively engaged LOTE growers and their role in managing biosecurity for the vegetable industry does not appear to be well understood.
- **Peri-Urban pressure** – Asian vegetable production is one of the many ‘intensive’ horticultural practices involved in the peri-urban landscape and it is important that as an industry they understand the urban planning process and the potential for land use conflict.

As part of this project, service providers who liaise regularly with LOTE producers were consulted on the specific crop health issues facing this sector of the industry. The major challenges were identified as:

[52] Taking Stock of the Australian Asian Vegetables Industry (2011) Barry Lee. RIRDC Publication No. 10/211

- Slow implementation of IPM due to the cost of 'soft' insecticides, lack of time to monitor and poor knowledge of pest and disease biology
- Poor disease and weed management due to inadequate hygiene practices (both in-field and protected cropping), lack of crop rotation and inter-property contamination
- Increasing pesticide resistance due to over-use of products
- Poor Occupation Health & Safety (OH&S).

Three groups of growers are recognized within the Asian vegetable industry, these are traditional practice market gardeners, commercial scale producers and hydroponic growers. A number of LOTE producers have made the transition to commercial production and require constant innovation and productivity improvements to deliver product competitively to markets. However a large proportion of the industry is still made up of market gardeners occupying smallholdings that may have limited capital and difficulty with English.

The major problem in providing information and resources to assist LOTE growers in managing crop health issues, and other issues of general concern to the industry, is the language barrier and, to a lesser extent, cultural barriers. Traditional methods in their home countries often include the unregulated use of chemicals and poor OH&S. Language difficulties include oral communication as well as reading and writing. Despite LOTE growers being industrious and resourceful, communication difficulties may lead to isolation and reduced competitiveness. This limits the opportunities of many growers to learn, understand and progress.

The language barrier is considerably increased when technical information is required by growers to implement basic farm practices, such as reading chemical labels or complying with OH&S guidelines in the preparation and application of chemicals. Language difficulties on such issues can cause hardship for growers and lead to practices that are harmful to themselves, others and to the environment. Moreover, lack of mutual understanding of cultural differences often leads to mistrust between LOTE growers and English speaking extension staff, agents and service providers, along with fellow English speaking farmers and other sectors of the industry[53].

Extension strategies to improve the capacity of LOTE growers to manage these issues need to apply an understanding of the particular characteristics of this sector, their production drivers and be targeted at overcoming communication barriers. Communication channels utilized by other sectors of the vegetable industry to identify and learn about practices/approaches for managing crop health issues are not likely to be effective for LOTE producers. Consultation with LOTE service providers has indicated that:

- LOTE growers rarely see the value in training and/or don't think they are doing anything wrong
- Engagement of bilingual extension officers in the past has been on a short-term funding basis and therefore had little impact
- Agribusinesses are unlikely to dedicate a large amount of resources to meeting the needs of this sector due to the small market size

[53] Impact of a Bilingual Extension Officer. Working with farmers from Non-English Speaking Backgrounds (NESB) (2007) Dang & Malcolm. RIRDC Publication No 07/131

- In most cases, LOTE growers do not contemplate environmental or long term sustainability or OH&S in their decision making process, even if these issues are regulated.

Recommendations

There have been numerous reviews conducted over the last 8 years examining the characteristics, issues and opportunities relating to LOTE growers and the Asian vegetable industry. Recommendations from these reports to improve the capacity of these growers have been implemented to a degree and include:

- The use of bilingual extension officers, with a background in agriculture, to:
  - Conduct frequent farm visits to develop close working relationships with individual growers
  - Build networks within LOTE communities and the wider industry to facilitate sharing of best practice information/practices
- Translation of relevant technical material into languages spoken by the larger LOTE groups
- Development of a training guide for service providers working with LOTE producers
- Education that focuses on developing growers practical problem solving and decision making skills
- Delivery of programs to address specific industry issues (e.g. on farm sanitisation and hygiene, water use and quality and spray application).

Based on our consultation we believe that further effort is required to ensure continued, effective engagement of these growers. The expenditure of vegetable levy funds on developing the capacity of LOTE growers may not be justified for economic reasons alone. However some of the issues, especially those around pesticide use, could impact negatively on the reputation and sustainability of the whole Australian vegetable industry. Pesticide residues, development of pesticide resistance and lack of biosecurity awareness and vigilance are areas of concern for all vegetable growers and should be addressed.

Recommended actions by service providers working with LOTE producers include:

- Development of regionally based participatory trials, working in partnership with agribusiness and others, to find solutions for pest and disease issues of relevance to the local Asian vegetable industry and other LOTE communities
- Supporting LOTE producers to understand and utilise more advanced spray application technology (including ChemCert training, understanding how different chemical groups work and how to avoid resistance)
- Improving LOTE producers knowledge of pest, weed and disease biology so they are able to identify and monitor pest species
- Improving LOTE producers knowledge of farm hygiene and quarantine practices
- In-field demonstrations and support from sales reps and commercial agronomists
- Development of best practice pest and disease management information for ‘minor’ crops in LOTE languages.

4.2.8 Protected cropping industry

Background

The current strategic plan for the vegetable industry does not include strategies to further protected cropping sector. This high technology sector has opportunities for producing a range of vegetables and herbs profitably with overall lower inputs of resources, including pesticides and ICP use.

The below outlook for the protected cropping industry was compiled using published information and an interview with Graeme Smith (Graeme Smith Consulting).

The vegetable sector of the protected cropping industry was worth $113.5m in 2010-11. This is the 4th highest value after leafy vegetables, root and tuber vegetables and legumes (Table 3-1). While the industry is valuable and expanding (G. Smith, pers. com.), RD&E for this industry sector appears to be less intensive than that for field produced vegetable crops. The situation has been analysed in previous sections of this document. Reasons for this situation may lie in the lack of interest by researchers in this industry (it is not part of standard education and training), and or the lack of lobbying done for or by the sector.

A recent study of the industry[54] concluded that the common theme running though the protected cropping industry still was a lack of training and skills development options for all levels of participants. This followed a 2005 review of the industry performed by the Australian Hydroponic and Glasshouse Association (AHGA) that explored market failures and constraints to industry development with the main industry representatives in all Australian states. It identified around 19 issues that urgently required attention, with the number one common issue identified as a lack of skills training opportunities. An attempt to address these were made via VG05095 Pathways to Production - A Skilling Initiative of the Australian Protected Cropping Industry, reported on in 2008 by AHGA.

The project has delivered a total of 63 base units and competencies covering certificate's II – VI aligned with the Australian Qualifying Framework (AQF) to facilitate national recognition that would create a new discipline within 'Production Horticulture' to be known as 'Controlled Environment Horticulture' (CEH). Further training units were identified and an additional output from this project was the strong potential for development of a 'National Training Centre for Controlled Environment Horticulture', based on a Dutch model that delivers both theoretical and practical training in a purpose-built glasshouse facility. A preliminary business case for this facility was developed in 2011 by Protected Cropping Australia.

While there are many compelling reasons to foster protected cropping (resource use efficiency, IPM opportunity, productivity) and the need for skills and technology input is high, the business case has not yet been realised.

Still, recent project work was conducted through HAL to foster opportunities in protected cropping for vegetable growers. One was a study tour to Europe (VG09068), another project was led by SARDI.[55] The main drivers for this project included disease issues; they were stated as follows:

[54] Bundock T., 2010; Commercial Protected Cropping Production Methodologies and Systems Applicable to VegetableGrowers in Southern Victoria. International Specialised Skills Institute Inc. ISS Institute

[55] Improving greenhouse systems and production practices, HAL projects VG07096, VG07144, VG08064

"In soil-based production systems poor soil health, soilborne diseases, soil salinity and increasing pressures on production are severely restricting productivity for many growers. In addition, vegetable growing regions are progressively being forced to the margins of arable land or onto non-arable land due to urban sprawl. However many growers are reluctant to move into hydroponics due to set up costs, high technological input, and the lack of expertise available."

The main output from the projects were a manual for conversion to simple hydroponics and best practice management, and a DVD illustrating issues outlined in the manual based on known information and lessons learned from demonstration sites. A database of interested vegetable growers was compiled during the course of the project.

Two further relevant HAL project dealt with water recycling (VG0973) and pesticide neutralisation in wastewater from protected cropping (VG09121).

A hygiene protocol for greenhouse production is in development (G. Smith pers. com.)

Issues

Major concerns relating to pest and disease management in protected cropping are:

- Chemical users training focuses on field vegetables, this can lead to growers using wrong equipment and high pesticide rates in greenhouses, potentially leading to residues and resistance
- Hygiene, pest and disease control and QA in nursery stock, esp. virus management in nursery stock
- Lack of overall training and the nature of hydroponics mean that nutritional and physiological disorders occur relatively frequently; this can lead to pest and disease issues and frequent use of pesticides
- Management of virus and vectors: whitefly, thrips, aphids
- IPM adoption and availability of beneficials for release e.g. Europe has at least double the amount of species
- Identifying and managing biosecurity risk (the industry has no biosecurity plan e.g. in tomatoes – not a levy vegetable crop but related to capsicums, eggplants and potatoes
    - Potato spindle tuber viroid (PSTVd; as an exotic pest it is covered by biosecurity procedures and information is available, but awareness may be low[56]
    - Pepino (*Solanum muricatum*) mosaic virus (PepMV) which has been identified as an emerging quarantine risk[57]; it is a huge problem in Europe, but awareness may be low
    - *Tuta absoluta* a species of moth in family Gelechiidae known by the common names tomato leafminer and South American tomato moth.

[56] e.g. http://www.dpi.nsw.gov.au/biosecurity/plant/pstvd-tomatoes, www.eppo.int/QUARANTINE/virus/PSTVd/PSTVD0_ds.pdf)

[57] DAFF Biosecurity has amended the import conditions for tomato seed from all countries. The changes are to address the emerging risks of Potato spindle tuber viroid (PSTVd) and Pepino mosaic virus (PepMV). The decision to amend the current import conditions follows several recent incursions of PSTVd in Australia. DAFF Biosecurity undertook to review the conditions (see ICON alert PQA0731 and PQA 0740) after PSTVd was detected in a greenhouse tomato crop in Queensland in April 2011.

Conclusions

Generally, the protected cropping industry appears to have less RD&E support to deal with pest and disease issues and general crop management than the field production industry, in spite of its technical, environmental and economic benefits, and apparent growth potential in Australia. This will have a range of reasons which need to be addressed elsewhere.

It would be in the interest of the vegetable industry to embrace protected cropping and especially its plant health and crop protection aspects. Virus and insect pests affecting vegetable crops can also be or become issues in field crops. Overuse of pesticides in these crops can lead to resistance issues affecting other crops or residue detection, which can affect confidence in the safety of Australian vegetables in general.

4.3 Conclusion and Recommendations – Industry Outlook

4.3.1 Issues

The results of consultation has shown that there is a major 'will' to better manage crop health issues within the vegetable industry. This is demonstrated by the high priority producers and service providers place on effective management of plant health and crop protection, and the expressed desire to see better long term strategies implemented.

Despite this 'will' there remains a wide range of 'chronic' pests, weeds and diseases which are impacting on production, with the introduction of new pests a potential threat due to changing seasonal conditions and reduction of capacity within departments (plant health research and biosecurity). Continuing difficulty in managing pests, weeds and diseases, which have been present and researched for many years indicates that it is not a lack of information, which is the issue but the effective dissemination and practical implementation of this information.

An analysis was undertaken of the pests, diseases and weeds that were cited by industry as currently being an issue during the consultation phase. The R&D that had been undertaken in relation to these was then assessed via a search of the AUSVEG knowledge management database. The results provided (Table 4-2) highlight the immense amount of information that is currently available for the vegetable industry.

Table 4-2: Pests, diseases and weeds cited as an issue during consultation and available R&D products available through AUSVEG knowledge management database

Pest	Reason for being a concern	Available R&D
Mites (broad mite, russet mite, two-spotted mite)	Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.	17
Diamondback moth		12
Heliothis	Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.	11
Soldier beetles	Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.	0
Vegetable weevil	Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.	0
Fruit fly		12
Caterpillars		3
Vertebrates (such as rabbits and ducks)		1
Silverleaf Whitefly	Poor understanding of/skills for implementing true IPM. Small profit margins reduce investment in pest management.	10
Thrips (western flower thrip)	Lack of control options due to pesticide resistance.	68
Aphids (currant lettuce aphid and green peach aphid)	Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.	11
Slugs and snails	IPM options are required for control of slugs and snails.	5

Disease	Reason for being a concern	Available R&D
Soilborne diseases (including sclerotinia and rhizoctonia)	Intensification of production systems.	19 (sclerotinia) and 13 (rhizoctonia)
Powdery mildew		16
Bacterial leaf spot	Introduced through planting material and/or endemic to susceptible crops and favourable conditions.	1
Anthracnose	Introduced through planting material and/or endemic to susceptible crops and favourable conditions.	3
Downy mildew		21
Leaf blight (stemphylium)		1
Late blight		5
Damping-off (including fusarium and phytophthora)		14 (fusarium) and 4 (phytophthora)
White blister	Limited control options. Extremes of rainfall and temperature resulting in appearance of diseases such as white blister in areas where not previously found (Qld).	14
Viruses	Emerging new vectors for virus-like organisms pose a threat in sub-tropical crops such as capsicums and tomatoes.	63 (includes R&D conducted on Thrips)

Weed	Reason for being a concern	Available R&D
Nightshade		1
Pigweed		1
Grasses		0
Wild radish		2
Fat hen		0
Amaranthus		2
Shepherd's purse		0
Double gee		0
Charlock/wild mustard	Currently registered herbicides do not provide control.	0
Thistle	Currently registered herbicides do not provide control.	1

Weed	Reason for being a concern	Available R&D
Fumitory	Currently registered herbicides do not provide control.	0
Cape weed	Currently registered herbicides do not provide control.	0
Nut grass		0
Chickweed		0
Stinging Nettle	Contaminant in leafy vegetable crops – significant food safety issue for supermarkets.	1
Groundsel	Weeds in general are difficult to control due to limited chemistry and labour costs to hand weed.	0
Weed management		45

Integrated Pest Management (IPM) was commonly cited as one of the break-through approaches in crop health over the last ten years (including the introduction of 'softer' and more targeted chemistries, biological predators and use of resistant varieties) however there are still a number of issues impacting on the ability of vegetable producers to successfully implement this management approach on their property. These include:

- Decreasing profit margins (impacting on the ability of producers to use more expensive 'softer' chemical products)
- Intensification of cropping systems (reducing options for fallow periods and adequate paddock rotation)
- Lack of whole of industry/area-wide approach (which impacts on the effectiveness of an IPM approach)
- Conflicting market demands (consumers need to be educated on the benefit of minor blemishes and presence of beneficial insects in leafy vegetables)

The loss of effective chemical control (fungicides/insecticides/herbicides) was also nominated as a concern by all sectors of the industry. Potential threats to available chemical control includes:

- Regulatory control
- Lack of registration of products for horticultural crops
- Evolution of resistance to product through development of new biotypes of various common pests (multiple crops/multiple pests), or inappropriate use.

Reducing reliance on chemical control for management of pests is an important component of IPM, however there still needs to be effective options available, which ideally are used within an integrated resistance management strategy.

The decreasing capacity of the research community was cited as a potential impediment to ensuring the vegetable industry has the ability to effectively manage crop health issues into the future. Capacity has decreased in recent years due to:

- Lack of/continuity of funding
- Lack of new people in plant pathology/diagnostics
- No Industry Development Officers.

Vegetable producers felt that effectively managing pest and disease is the 'key to making money' and that while the cost to manage crop health issues is relatively small, it is the potential for total market failure that is the main concern.

"Pest management is a relatively small cost (probably less than 15% of variable costs), when it is effective. When it fails, or is marginal, then the cost is not the issue - it is the impact on quality and yield, which then significantly affects harvest and shed costs, and of course affects the $ return. When all is going well pest management costs is not the issue. When pests are difficult to manage when extremes of weather impact, then costs increase, and quality and yield decrease".

"A nutrition issue can potentially be corrected during the life of the crop. An irrigation scheduling issue can impact growth/yield and quality but may not result in market failure. A pest, weed or disease that is not managed can result in complete crop loss/rejection (market failure)."

4.3.2 Opportunities

The main concerns relating to crop health management within the vegetable industry can be loosely grouped into better management of existing pests, weeds and diseases (including greater implementation of an IPM approach), the prevention of new pests and diseases impacting on vegetable production and retention/expansion of chemical control options. A range of opportunities was nominated by vegetable producers, service providers and researchers to assist in addressing these issues.

Facilitating **greater implementation of an IPM approach** could be achieved through a mixture of research into new approaches and technology (such as biological control) and also increasing awareness amongst producers of the importance of already established techniques (such as appropriate crop rotations). Vegetable producers expressed significant interest in the expansion of non-chemical control options, which could include the development of:

- Biofumigants such as use of green manure crops that produce volatile compounds and anaerobic soil disinfestation (production of volatile fatty acids in water logged soils amended with different products)
- Naturally derived insecticides
- Pheromone and feeding attractant technology (better delivery systems combined with increased crop sizes could make mating disruption a potentially cost-effective alternative to insecticides for control of some key pests)
- Use of bacteriophages to control bacterial plant pathogens
- Increased use of products that enhance the plant's natural defences
- Increased development of resistance to pests and diseases through genetically modified crops

- Focusing on better monitoring (through automated insect monitoring and trapping technology) and diagnostic services (through further development of predictive models) to help manage the unknown. This can be on two levels:
  - Industry – informing issues at a national level i.e. changes to nematode population and distribution with climate change
  - Grower – assisting growers manage seasonal variation and specific crops
- Educating consumers on beneficial insects, their role in the environment and the benefits of seeing these insects in raw and processed vegetables
- Further education on soil health and effective crop management (including improving producer awareness of susceptible host crop ranges, appropriate crop rotations and benefit of site preparation prior to planting)
- Understanding the economic and biological thresholds for pests and diseases.

In order to **prevent new pests and diseases impacting on vegetable production** within Australia there needs to be:

- Maintenance of capacity within biosecurity departments to prevent the entry of new pests
- Rapid, easy-to-use diagnostic techniques/tools for accurate identification of pests and diseases both in-field and at the border (i.e. loop-mediated isothermal amplification (LAMP) diagnostic assays)
- Awareness of the potential impact of changes in seasonal conditions (due to climate change) and the movement of pests into new crops and production locations.

Ensuring **retention/expansion of effective chemical control options** to be used within a resistance management strategy could be achieved by:

- Increasing the range of chemical products available for use in vegetable crops through registration of products that are currently available in the USA and EU but not in Australia
- Supporting LOTE producers to ensure appropriate use of chemical products
- Surveillance of resistance in pests and diseases and active promotion of resistance management plans
- Use of GPS guided spraying system for accurately targeting weed and pest infestations
- Application of new nanotechnology to existing chemical products for increased efficacy.

4.3.3 Extension Approach

Vegetable producers nominated a range of sources for learning more about new crop health management techniques. These included:

- Publications (including Vegetables Australia, magazine articles, industry papers)
- On-line resources (including AUSVEG newsletters and forums)
- International travel
- Industry events (such as conferences, field days)
- Industry service providers (such as agronomists, consultants)
- Other producers.

Other producers and industry service providers (such as sales agronomists) were nominated as the two preferred sources of information.

Industry service providers sourced information either through scientific and industry publications (such as scientific journals, books, industry magazines, ute guides, fact sheets) or peers within the industry (AgChem reps, IPM consultants, researchers). They then generally pass this information onto vegetable producers face to face as they are often out on farms visiting producers.

It was felt that the outcomes of R&D programs could be more effectively extended to vegetable producers by:

Setting the right R&D priorities. There needs to be a two-way conversation between growers and researchers to determine the priorities for future investment. Service providers suggested that funding grower groups so that they can provide information on research priorities and assist in driving the adoption of research outcomes could be an effective method for achieving this.

Developing effective R&D programs which:

- Are across crop/commodity (big picture not crop specific)
- Have spill-over benefits (leverage of available funds and cross collaboration)
- Have long term timeframes
- Are driven by HAL e.g. using coordinated programs similar to the approach the potato industry has taken
- Allow for flexibility in extension/research models for projects.

Getting the information out there by:

- Focusing on better communication of outcomes to growers (projects should comprise at least 30 – 40% of the budget for extension, with extension specialists part of the system)
- Ensuring research programs include an extension component which involves/informs all sectors of the industry (this includes service providers such as agronomists, consultants and AgChem reps who have frequent and regular contact with vegetable producers). With decreasing capacity of state R&D departments, private industry will be the main conduit of information to growers and need to be better incorporated into the R&D loop to ensure the right information gets out to growers
- Embracing new technology (such as social media, internet, smart phones) to assist with the dissemination of research results and ensuring that on-line resources remain up-dated and relevant
- Including information on the economic impact of various crop health management options so that producers are aware of how implementation will affect profit margins within their business.

5 Situation Analysis – Economics of Plant Health

5.1.1 Crop and produce losses due to pests and diseases

Reasons for losses and their economic value

There is a lack of data on the level of and reasons for losses of vegetables due to pests, weeds and diseases on farm and throughout the supply chain. Data on the economic values of these types of losses, actual or modelled appears nearly impossible to come by.

An initial approach was to adopt the method approach of pest risk assessment used to judge the economic risk of pest incursions for biosecurity purposes. However, the vast majority of these assessments are based on general data like production statistics and broad assumptions, therefore this approach proved impractical. Some bioeconomic models have been developed for biosecurity risk assessments in agriculture[58]. However, the per unit damage estimate for lost production from agricultural systems is typically based on the associated cost of import replacement and is, therefore, largely unrelated to the extent to which the agricultural producers suffer economic loss.

Three Vegetable R&D reports funded through HAL included some economic data: VG07035 “Understanding Spatial Variation in Sweetcorn Production”, VG99014 “A model for lettuce industry development”, VG07070, actually looking at disease impact i.e. broccoli and white blister. A business case for IPM in lettuce was developed for the Innoveg project, which includes a calculator and is available from the AUSVEG website. Economic analyses about IPM benefits have been made elsewhere but they often compare limited data e.g. only product costs and costs of beneficials, not other costs such as application, crop management inputs and scouting. Many reports include yield comparisons of untreated or ‘control’ field plots and ‘treated’ field plots to show the effects of pest, weed or disease control. However, the method of yield assessment is usually not clear i.e. ‘marketable’ yields are not assessed based on actual market requirements; usually the researcher makes the call on what is considered to be marketable. Production costs are usually not compared. Economic impact assessments of field pests and diseases postharvest could not be found.

When and how do losses occur throughout the supply chain and what is the impact?

The following includes a description of when and how losses occur throughout the supply chain and their potential impact. Figure 5-1 illustrates the major issues.

Losses and costs are cumulative, and the later in a crop’s life cycle they occur, the greater the economic loss. Typically, the value of vegetables doubles with each major step through the supply chain (Figure 3-3) e.g. $1000/t at harvest goes to $2000/t after packing, and $4000/t at the retailer. For each step of the supply chain that is affected by crop loss, the affected business may face a loss of future customers e.g. as a consequence of not being able to supply. Rejected product may be returned to the supplier at his / her cost; disposal costs are incurred by the supplier of rejected produce.

[58] Cook D.C et al. 2011; Prioritising biosecurity investment between agricultural and environmental systems. Journal fur Verbraucherschutz und Lebensmittelsicherheit (Journal of Consumer Protection and Food Safety) DOI 10.1007/s00003-011-0689-0
Hodda M. and L. Lawrence 2009; Potato cyst nematode in Australia. Kondining Group Farming Ahead, May 2009

	Production stage	Issues arising from pest, weed or disease infestation	Factors influencing the extent of loss and costs	Main type of produce loss	Typical loss range %	Main type of cost due to losses
paddock	Seeding/planting	Seed & soil borne diseases, above ground pests & diseases and weed competition affect normal plant development and survival	1. Pest / pathogen type & genetics 2. Crop type & genetics 3. Production environment (soil, weather) 4. Pest, weed & disease control and management methods (success of control, potentially biosecurity issues - destroy crop) 5. General crop management decisions (esp. soil, rotation, nutrients, irrigation) 6. Timing of infestation	Reduced marketable yield via: reduced plant density (plant number per hectare) and or affected plants not reaching full yield and or quality potential	10 to 70% of crop may be lost at each step, total crop loss can occur	1. Increased number and or value of protective / corrective actions per hectare (costs of sprays, labour, equipment etc.), and or 2. Increased costs because all crop management inputs per hectare are spread over a reduced plant number or tonnage of marketable crop (plant death, damage)
	Establishment					
	Growth & development					
	Harvest	Pest & disease symptoms and resulting damaged, deformed, undersized produce that cannot be sold (waste)	Issues 1-6 above plus market specifications and consumer expectations	Reduced marketable crop due to decay, infestation and loss of quality	Up to 50% of crop may be lost at each step, however losses can be higher e.g. with severe infestations or market rejections	Increased labour costs (slowing down of harvest, grading & packing operations and or increased grading staff numbers); dealing with waste in paddock and from packing shed (inc. wastewater)
post harvest	Size & quality grading					
	Packing					
	Storage	Field diseases, damaged produce and post-harvest disorders develop rots in the supply chain (waste)	All issues listed above plus cool chain management, packaging type, time between harvest and sales			Re-grading (labour, equipment, resources), rejections by retailer / customer, cost of dealing with waste produce, packaging and resources, transport cost/unit increases.
	Transport / distribution					
	Retail / customer					

Figure 5-1: Potential losses due to pests, weeds and diseases throughout the supply chain and potential impact

Costs due to pests, weeds and diseases vary based on the type and magnitude of issues, their timing and costs incurred up to that point, the market value of the crop, fixed costs, cost of waste management, etc. All costs have to be spread over the final amount of marketable produce sold at market prices.

The current lack of sufficiently useful approaches and data made an economic prioritisation of RD&E needs based on potential crop losses impossible.

In order to develop a tool for future use an economic model was developed to enable a assessments of the effect of different inputs, management decisions and pests, weeds and diseases on vegetable crops and the industry by region (state).

5.1.2 The economic model

General Approach

The purpose of the economic modelling component of the project was to develop and apply a consistent method for:

1. Calculating the cost of weed, pest & disease control as part of overall production costs in vegetable crops and comparing (for a nominated crop) one production system (e.g. current) with an alternative
2. Calculating the cost of losses due to pests & diseases in postharvest management of vegetable crops and comparing (for a nominated crop) losses for one management system (e.g. current) with an alternative
3. Estimating the economic costs of weed, pest & disease control of key vegetable crops in Australia on a regional level based on production areas (for a nominated crop).

Who should use the models?

The models should be used by researchers when planning and evaluating projects.

Growers and their advisers can use the gross margin (GM) model to compare management strategies.

Supply chain members can use the postharvest model to calculate and compare the economic effect of crop losses due to pests and diseases.

Grower/packers can use the GM and postharvest models in conjunction.

Model Structure

The model is an Excel workbook comprised of five worksheets, a main menu which includes the capacity for crop selection, three sheets used for modelling and a data entry sheet. The structure is illustrated in Figure 5-2.

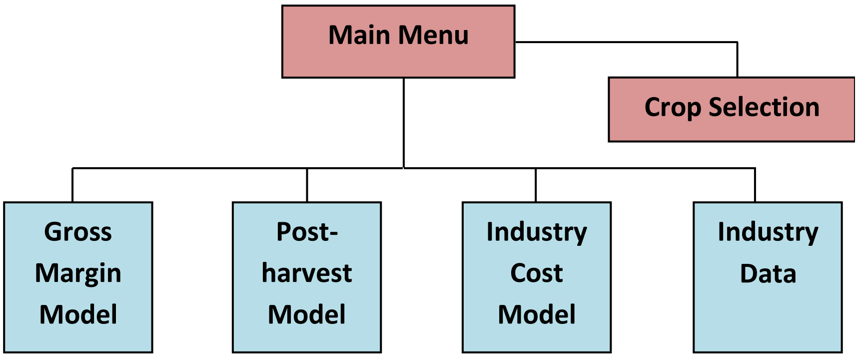


Figure 5-2: Menu structure for the vegetable weed, pest and disease economic model

The five main components of the model are briefly described below:

Main Menu/ Crop Selection

This sheet allows direct links to the other four sheets. It is also where the crop for analysis is selected. Crop selection is from either

- Large area vegetable levy crops (>3,000ha nationally)
- Small area vegetable levy crops (<3,000ha nationally)
- Other crops.

The distinction on area has been made because, for larger area crops, ABS collects and published data that can be used in the model; for smaller area crops, this information has to be collated from other sources.

For the first two categories (larger and smaller national area), the crop can be selected from pre-defined dropdown lists. If the crop for analysis is not included in either list the user can enter the crop name in the 'Other Crop' cell.

The industry data (area and production by region) for smaller area levy crops are less reliable than those for larger area crops and there are no readily available data for other crops. If a smaller area crop or other crop is selected, the industry data for that crop needs to be checked or entered (where no data exists) in the Industry Data sheet.

A copy of the Main Menu / Crop Selection sheet is shown in Figure 5-3.

Gross Margin (GM) Model

The GM model allows for comparison of two production systems and compares the calculated gross margins for each. The user must enter gross margin data for the nominated crop. Data entry is made through three separate panels as illustrated in Figure 5-4.

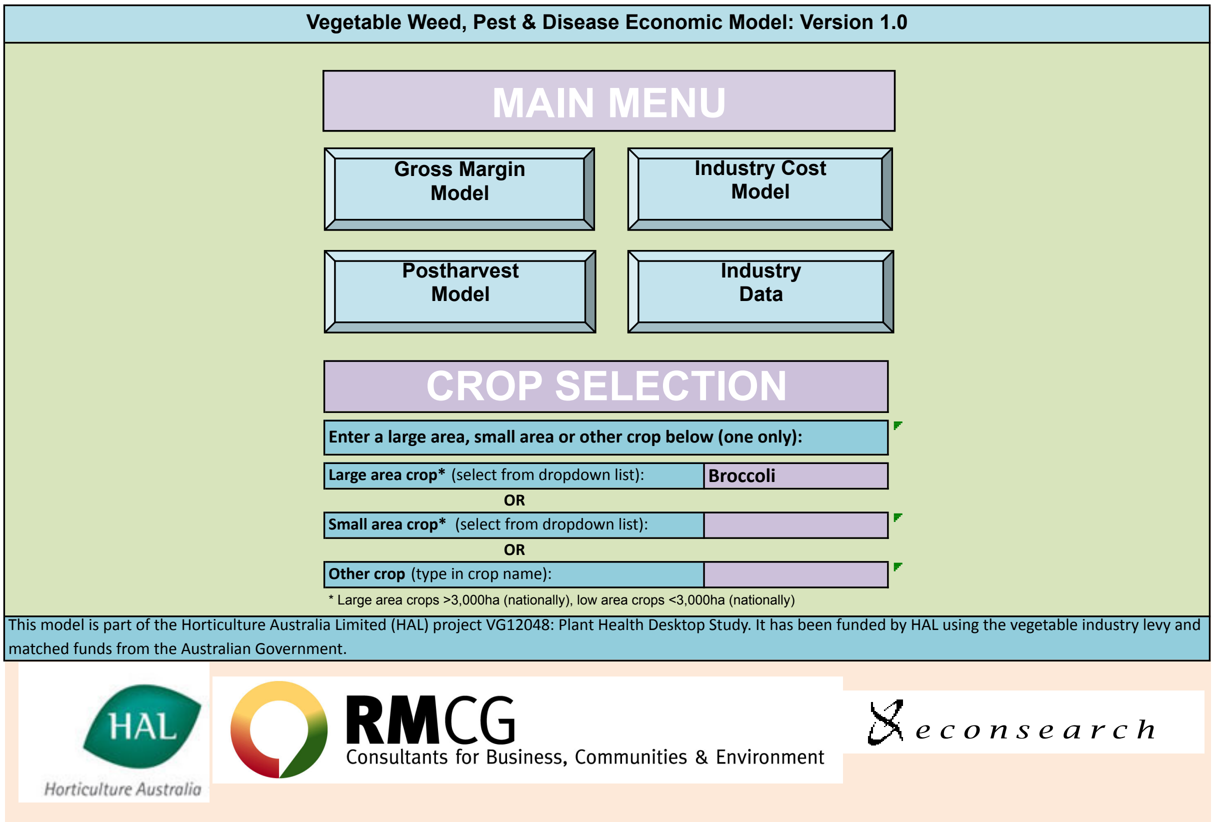


Figure 5-3: Main Menu and Crop Selection sheet for vegetable weed, pest and disease economic model

- In the first (left hand) panel the user enters a set of generic data for the crop under consideration. These data include:
  - Whether the crop is grown from seed or transplant
  - Quantity of seed or transplants required
  - Crop production and price by grade
  - Land preparation and planting/sowing costs
  - Cost of cover crops (biofumigation, green manure crops)
  - All pesticides (herbicides, fungicides, insecticides used and likely to be used under either production system) and their unit costs
  - Product application, crop monitoring, irrigation and harvest & cartage.
- In the middle panel the user enters the name of the first production system and data specific to that system (yield discounts, no. of chemical applications, etc.)
- In the right hand panel the user enters the name of the second production system and data specific to that system
- Once the data for the two production systems have been entered, the model indicates (immediately below the middle panel) whether the second production system is more profitable than the first and by how much.

Gross Margin Model for Broccoli					Enter name of Production System #1 in the cell below:			Enter name of Production System #2 in the cell below:		
Broccoli Baseline Assumptions					**Current System**			**New System**		
Crop Details										
Grow from	Seed									
Quantity of seed	37,000	kg/ha								
Harvest unit	bin									
bin weight	250	kg			**GROSS INCOME**			**GROSS INCOME**		
Target production per hectare			**Price per harvest unit**		**% of target production**	**Income per hectare**		**% of target production**	**Income per hectare**	
Ist grade:	32	bins	earning $500.00	per bin	95%	$15,200 /ha		95%	$15,200 /ha	
2nd grade:	4	bins	earning $300.00	per bin	95%	$1,140 /ha		95%	$1,140 /ha	
3rd grade:	0	bins	earning $0.00	per bin	100%	$0 /ha	$16,340 /ha	100%	$0 /ha	$16,340 /ha
Waste:	4	bins			**Total Production (excl waste):** 8,838 kg/ha			**Total Production (excl waste):** 8,838 kg/ha		

VARIABLE COST PER HECTARE					VARIABLE COST PER HECTARE			VARIABLE COST PER HECTARE		
Land Preparation and Planting					**Land Preparation and Planting**			**Land Preparation and Planting**		
Land preparation	$120.00	per hour			3.5 hrs/ha	$420 /ha		3.5 hrs/ha	$420 /ha	
Cover crop	$90.00	per ha			1 crop (no.)	$90 /ha		1 crop (no.)	$90 /ha	
Fertiliser	$900.00	per ha				$900 /ha			$900 /ha	
Fertiliser application	$35.00	per hour			1.0 hrs/ha	$35 /ha		1.0 hrs/ha	$35 /ha	
Seed	$48.50	per kg				$1,795 /ha			$1,795 /ha	
Sowing	$22.00	per ha				$814 /ha			$814 /ha	
Other		per				$0 /ha	$4,054 /ha		$0 /ha	$4,054 /ha
Herbicide	Rate/ha	Unit	Price/Unit		**Herbicide**			**Herbicide**		
Baron	1.0	kg	$215.00	per kg	1 application	$215 /ha		1 application	$215 /ha	
Herbicide 2					0 applications	$0 /ha		0 applications	$0 /ha	
Herbicide 3					0 applications	$0 /ha		0 applications	$0 /ha	
Herbicide 4					0 applications	$0 /ha		0 applications	$0 /ha	
Herbicide 5					0 applications	$0 /ha	$215 /ha	0 applications	$0 /ha	$215 /ha
Fungicide					**Fungicide**			**Fungicide**		
Amistar	0.5	L	$115.20	per L	1 application	$58 /ha		1 application	$58 /ha	
Tri-Base Blue	3.0	L	$21.80	per L	1 application	$65 /ha		1 application	$65 /ha	
Fungicide 3					0 applications	$0 /ha		0 applications	$0 /ha	
Fungicide 4					0 applications	$0 /ha		0 applications	$0 /ha	
Fungicide 5					0 applications	$0 /ha	$123 /ha	0 applications	$0 /ha	$123 /ha
Insecticide & other					**Insecticide & other**			**Insecticide & other**		
Xentari	0.5	kg	$76.40	per kg	2 applications	$76 /ha		1 application	$38 /ha	
Pirimor	0.5	kg	$80.00	per kg	2 applications	$80 /ha		1 application	$40 /ha	
Success	0.4	L	$480.00	per L	2 applications	$384 /ha		0 applications	$0 /ha	
Proclaim	0.3	kg	$220.00	per kg	2 applications	$110 /ha		0 applications	$0 /ha	
Insecticide/other 5					0 applications	$0 /ha		0 applications	$0 /ha	
Insecticide/other 6					0 applications	$0 /ha		0 applications	$0 /ha	
Insecticide/other 7					0 applications	$0 /ha		0 applications	$0 /ha	
Insecticide/other 8					0 applications	$0 /ha		0 applications	$0 /ha	
Insecticide/other 9					0 applications	$0 /ha		0 applications	$0 /ha	
Insecticide/other 10					0 applications	$0 /ha	$650 /ha	0 applications	$0 /ha	$78 /ha
Product application & crop monitoring					**Product application & crop monitoring**			**Product application & crop monitoring**		
Product application	$60.00	per application			8 applications	$480 /ha		3 applications	$180 /ha	
Soil & plant analysis	$150.00	per analysis/ha			1 analysis	$150 /ha		1 analysis	$150 /ha	
Crop scouting	$90.00	per scouting			0 scoutings	$0 /ha		1 scouting	$90 /ha	
Other		per				$0 /ha	$630 /ha		$0 /ha	$420 /ha
Irrigation										
Water	$140.00	per ML			4.0 ML/ha	$560 /ha		4.0 ML/ha	$560 /ha	
Labour	$25.00	per hour			5.0 hrs/ha	$125 /ha	$685 /ha	5.0 hrs/ha	$125 /ha	$685 /ha
Harvest & cartage										
Harvest	$65.00	per bin				$2,223 /ha			$2,223 /ha	
Cartage	$10.00	per bin				$342 /ha	$2,565 /ha		$342 /ha	$2,565 /ha
Note:	Enter data in green shaded cells				TOTAL VARIABLE COSTS		$8,922 /ha	TOTAL VARIABLE COSTS		$8,140 /ha
	Select from dropdown list in mauve-shaded cells				GROSS MARGIN PER HECTARE		$7,418 /ha	GROSS MARGIN PER HECTARE		$8,200 /ha
					Is the New System more profitable than the Current System?			Yes		
					By how much?			$782 /ha		

Figure 5-4: Gross Margin Model for comparison of alternative on-farm production systems for weed, pest and disease management

The Postharvest Model

In a similar format to the Gross Margin Model, this sheet allows for the comparison of two postharvest systems and associated losses, and compares the costs of each. Postharvest cost data for the nominated crop must be entered by the user. Data entry is made through three separate panels as illustrated in Figure 5-5.

- In the first (left hand) panel the user enters just two pieces of information:
  - The packaging/processing unit (this is selected from a dropdown list which includes options of containers (bag, bin, carton, crate and punnet) and weight (kilogram and tonnes)
  - The weight (in kilograms) of the selected packaging/processing unit
- In the middle panel the user enters the name of the first postharvest packing/processing system and data specific to that system. Data specific to each activity in the value chain are entered. Broadly these are in two categories:
  - Product loss for each activity (first column in the middle panel) – this is measured as a percentage of the quantity harvested so that 0% implies no product loss for that activity
  - Relevant costs of each activity (remaining columns in the middle panel) - costs are defined according to a set of cost categories (labour, water, materials, vehicle, waste management and other costs)
- In the right hand panel the user enters the name of the second postharvest packing/processing system and data specific to that system
- Once the data for the two postharvest systems have been entered, the model indicates (immediately below the middle panel) whether the second postharvest system is more profitable than the first and by how much
- The model also indicates (below the middle panel) the difference in product loss between the two systems and estimates the value of that difference.

The entries in the postharvest model can build on the GM models. This means comparisons can be made for the same two crop protection systems if e.g. pest and disease management in the field has an impact on postharvest costs and losses.

Postharvest Model for Broccoli

Packing/processing unit: bin
bin weight: 250 kg

Enter name of Postharvest Packing/Processing System #1 in the cell below:

Current Postharvest System

	Enter product loss for each activity:		Enter average variable costs for each postharvest activity:								
	Loss per activity (%)	**Unit Loss (kg/bin)**	Labour ($/bin)	Water ($/bin)	Other materials ($/bin)	Vehicle ($/bin)	Other equipment ($/bin)	Waste ($/bin)	Energy ($/bin)	Other costs ($/bin)	**Total costs ($/bin)**
Field and packing / processing											
Harvesting and field handling	5.0%	**12.5**	10.00			10.00		5.00			**$25.00**
Transport to packing shed / processing facility	1.0%	**2.5**	40.00			5.00					**$45.00**
Storage prior to packing shed / processing facility (ambient or cold)											**$0.00**
Washing (if required)	2.0%	**5.0**	20.00	1.00			1.00	5.00		1.00	**$28.00**
Grading	10.0%	**25.0**	130.00	0.50	0.20	0.20	0.20	10.00		1.00	**$142.10**
Pre-cooling			20.00					5.00		5.00	**$30.00**
Packing / Packaging	2.0%	**5.0**	150.00		200.00		20.00	5.00			**$375.00**
Use of in-package desiccants etc. *											**$0.00**
Disinfecting treatment-fungi, bacteria *											**$0.00**
Decontamination treatment-insects *											**$0.00**
Other treatments *				20.00							**$20.00**
Low temperature storage pre freighting out										5.00	**$5.00**
Transport to distributor / merchant or market						275.00					**$275.00**
Other field and packing / processing costs											**$0.00**
Sub-total	***20.0%***	**50.0**	***$370.00***	***$21.50***	***$200.20***	***$290.20***	***$21.20***	***$30.00***	***$0.00***	***$12.00***	***$945.10***
Supply chain - fresh produce (at each step):											
Low temperature storage during marketing *			10.00			10.00		5.00	20.00		**$45.00**
Transport						450.00		5.00			**$455.00**
Handling			10.00			5.00		5.00		5.00	**$25.00**
Re-sorting, packing (esp. if spoilage occurs) *						150.00					**$150.00**
Marketing											**$0.00**
Other costs											**$0.00**
Sub-total	***0.0%***		***$20.00***	***$0.00***	***$0.00***	***$615.00***	***$0.00***	***$15.00***	***$20.00***	***$5.00***	***$675.00***
TOTAL POST HARVEST COSTS	**20.0%**	***50.0 kg***	**$390.00**	**$21.50**	**$200.20**	**$905.20**	**$21.20**	**$45.00**	**$20.00**	**$17.00**	**$1,620.10**
***POST HARVEST PEST & DISEASE CONTROL COSTS ($/bin)**			**$10.00**	**$20.00**	**$0.00**	**$160.00**	**$0.00**	**$5.00**	**$20.00**	**$0.00**	**$215.00**

Enter name of Postharvest Packing/Processing System #2 in the cell below:

New Postharvest System

	Enter product loss for each activity:		Enter average variable costs for each postharvest activity:								
	Loss per activity (%)	**Unit Loss (kg/bin)**	Labour ($/bin)	Water ($/bin)	Other materials ($/bin)	Vehicle ($/bin)	Other equipment ($/bin)	Waste ($/bin)	Energy ($/bin)	Other costs ($/bin)	**Total cost**
Field and packing / processing											
Harvesting and field handling											**$0.0**
Transport to packing shed / processing facility											**$0.0**
Storage prior to packing shed / processing facility (ambient or cold)											**$0.0**
Washing (if required)											**$0.0**
Grading											**$0.0**
Pre-cooling											**$0.0**
Packing / Packaging											**$0.0**
Use of in-package desiccants etc. *											**$0.0**
Disinfecting treatment-fungi, bacteria *											**$0.0**
Decontamination treatment-insects *											**$0.0**
Other treatments *											**$0.0**
Low temperature storage pre freighting out											**$0.0**
Transport to distributor / merchant or market											**$0.0**
Other field and packing / processing costs											**$0.0**
Sub-total	***0.0%***		***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.0***
Supply chain - fresh produce (at each step):											
Low temperature storage during marketing *											**$0.0**
Transport											**$0.0**
Handling											**$0.0**
Re-sorting, packing (esp. if spoilage occurs) *											**$0.0**
Marketing											**$0.0**
Other costs											**$0.0**
Sub-total	***0.0%***		***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.00***	***$0.0***
TOTAL POST HARVEST COSTS	**0.0%**		**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.0**
***POST HARVEST PEST & DISEASE CONTROL COSTS ($/bin)**			**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.0**

Note: **Enter data in green shaded cells**
Select from list in mauve-shaded cells

Product Loss (kg/bin)	
New Postharvest System	0.0
Current Postharvest System	50.0
Difference	**-50.0**

Is the New Postharvest System more cost effective than the Current Postharvest System?	**Yes**		
By how much?	**$1,620 /bin**	**OR**	**$64,804 /ha planted**
Does the New Postharvest System have less product loss than the Current Postharvest System?	**Yes**		
What is the value of the reduced product loss (valued at farm-gate price)?	**$100 /bin**	**OR**	**$4,000 /ha planted**

Figure 5-5: Postharvest Cost Model for comparison of alternative management systems for pest and disease management

Industry Cost Model

This model enables estimation of the cost of weeds, pests and diseases for each region (state) based on data entered for two on-farm production systems defined in the "Gross Margin Model" sheet and the two postharvest systems defined in the "Postharvest Model" sheet. Consequently, the model as illustrated in Figure 5-6 is comprised of two main sections:

- An on-farm (upper) section which is entitled "On-farm Weed, Pest & Disease Control", and
- A postharvest (lower) section which is entitled "Postharvest Pest & Disease Control".
- The on-farm section summarises the on-farm results providing on a per hectare basis:
    - Gross income for both on-farm production systems and the difference between them, and
    - Weed, pest and disease related costs, summarised according to the following categories:
        - Herbicides
        - Fungicides
        - Insecticides
        - Product application and crop monitoring.

The model then applies these per hectare costs for each production system to the relevant area of crop in each region (specified as the six states and two territories). The proportion that the farm production system comprises of each region's total production area needs to be entered by the user for the "current system" (e.g. 80% NSW, 60% Vic, etc.) and the proportion of the area where the "new system" is likely to be adopted.

The model then calculates the estimated cost of weed, pest and disease control in each region for each production system. The model also calculates the difference between the two sets of costs for that area where the "new system" is likely to be adopted.

Similarly, in the postharvest (lower) section of the model:

- Postharvest pest and disease costs are summarised for each postharvest management system (in terms of $/kg and $/ha planted)
- The proportion that the postharvest management system comprises of each region's total production needs to be entered by the user for existing production (e.g. 80% NSW, 60% Vic, etc.) and the proportion of the area where the "new system" is likely to be adopted
- The cost of weed, pest and disease control in each region for the two postharvest management systems is estimated
- The difference between the two sets of costs is also calculated for that production for which the "new system" is likely to be adopted.

Industry Cost Model for Broccoli

On-farm Weed, Pest & Disease Control for Broccoli: Regional Costs

On-farm Production System	Current System	New System	Difference
Gross Income ($/ha):	**$16,340**	**$16,340**	**$0**
Weed, pest & disease related costs ($/ha):			
Herbicides	$215	$215	$0
Fungicides	$123	$123	$0
Insecticides & other	$650	$78	-$572
Product application & crop monitoring	$630	$420	-$210
Total weed, pest & disease related costs	**$988**	**$416**	**-$572**

Region	Proportion of regional on-farm production that is: using Current System	likely to adopt New System	Regional Cost of Current System ($m)	Regional Cost of New System ($m)	Cost saving* from adopting New System ($m)
NSW	80%	10%	0.27	0.01	-0.02
Vic.	60%	10%	2.00	0.14	-0.19
Qld	100%	10%	1.90	0.08	-0.11
SA	50%	10%	0.12	0.01	-0.01
WA	50%	10%	0.42	0.04	-0.05
Tas.	70%	10%	0.26	0.02	-0.02
NT	0%	0%	0.00	0.00	0.00
ACT	0%	0%	0.00	0.00	0.00
Australia			**4.96**	**0.30**	**-0.41**

*neg've value = savings

Postharvest Pest & Disease Control for Broccoli: Regional Costs

Postharvest Packing/Processing System	Current Postharvest System	New Postharvest System	Difference
Field and packing / processing ($/t):			
Use of in-package desiccants etc.	$0	$0	$0
Disinfecting treatment-fungi, bacteria	$0	$0	$0
Decontamination treatment-insects	$0	$0	$0
Other treatments	$80	$0	-$80
Sub-total	**$80**	**$0**	**-$80**
Supply chain - fresh produce ($/t):			
Low temperature storage during marketing	$180	$0	-$180
Re-sorting, packing (esp. if spoilage occurs)	$600	$0	-$600
Sub-total	**$780**	**$0**	**-$780**
Total postharvest pest & disease costs ($/t)	**$860**	**$0**	**-$860**

Region	Proportion of regional production that is: using Current Postharvest System	likely to adopt New Postharvest System	Regional Cost of Current Postharvest System ($m)	Regional Cost of New Postharvest System ($m)	Cost saving* from adopting New Postharvest System ($m)
NSW	80%	0%	1.54	0.00	0.00
Vic.	60%	0%	11.75	0.00	0.00
Qld	100%	0%	11.02	0.00	0.00
SA	50%	0%	0.55	0.00	0.00
WA	50%	0%	2.74	0.00	0.00
Tas.	70%	0%	2.19	0.00	0.00
NT	0%	0%	0.00	0.00	0.00
ACT	0%	0%	0.00	0.00	0.00
Australia			**29.79**	**0.00**	**0.00**

*neg've value = savings

Note: **Enter data in green shaded cells**

Figure 5-6: Industry Cost Model for comparison of alternative management systems for pest and disease management

Industry Data

This sheet contains industry level data by crop and by region. The data are presented for two categories of crops: large area crops (mostly more than 3,000 ha nationally) and small area crops (mostly less than 3,000 ha nationally). The following points should be noted about the industry data:

- The data for large area crops are sourced from the 2011 ABS Agricultural Census
- The 2011 Census data are only available for the nine large area levy crops
- The data for small area crops are sourced from the Australian Horticulture Statistics Handbook 2012 (data reference year 2007-08)
- The data for small and large areas crops include production in tonnes and area in hectares
- The data for each crop are provided on a regional basis. The “regions” are the six states and the two territories
- For some small area crops, area data were not available on a regional basis and these were estimated on the basis of regional production.

Figure 5-7 shows the vegetable production and area data by crop and region. The modelling to estimate the industry level costs for the nominated crop is dependent on the data provided in this worksheet. The user can update or modify the data as more recent or more accurate data becomes available.

As noted above, the economic analysis approach has involved the development of an Excel spreadsheet based model that can be used for any vegetable crop. If the nominated crop is not in the list of large area or small area crops, the user can enter the relevant production and area data in bottom row of the production and area tables. Once the name of the “Other Crop” has been entered in the Main Menu worksheet, it will appear automatically in the Industry Data worksheet, where the relevant data needs to be entered.

Model Improvements

There are a number of ways in which the model could be further developed.

- Sensitivity analysis – in its present form any sensitivity analysis requires manual changes to the uncertain or target variables. This process could be automated. Once the model has been used for a period of time, the design of the sensitivity analysis could be enhanced (e.g. critical variables identified) with feedback from model users
- Cost database – currently the model requires the user to input all relevant costs (whether on farm or postharvest). The task for the user would be made easier if the model included generic costs of weed, pest and diseases that were available to the user as a starting point.

Producing a similar model for protected cropping is possible.[59]

[59] Hassall & Associates Pty Ltd, 2011;
Hydroponics as an Agricultural Production System. A report for the Rural Industries Research and Development Corporation, RIRDC Publication No 01/141 RIRDC Project No HAS-9A

Vegetable Industry Production and Area Data

Production (t)	Large Area Crop	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Aust.
	Broccoli	2,234	22,779	12,809	1,289	6,366	3,636	0	0	49,112
	Capsicums	1,660	1,647	39,556	3,815	3,352	831	2	0	50,862
	Carrots	3,979	48,054	24,758	28,925	64,896	53,958	0	0	224,570
	Cauliflowers	11,245	20,018	17,771	5,857	8,426	3,606	10		66,933
	French & Runner Beans	269	4,418	22,707	55	1,120	4,258	59	0	32,886
	Green Peas	116	404	398	8	18	13,260	0	0	14,205
	Lettuce	15,800	49,435	54,351	7,139	14,961	2,768	182	0	144,637
	Pumpkins	36,322	2,990	41,183	4,301	13,453	1,176	3,509	0.0	102,934
	Sweet Corn	25,675	9,026	25,822	189	10,096	0	0	0	70,808
	Small Area Crop									
	Asian Vegetables	8,921	5,629	17,946	684	4,173	876	733	0	38,962
	Beetroot	2,879	25,604	8,943	1,164	2,205	2,266	0	0	43,061
	Cabbage	18,178	25,678	20,076	6,054	7,156	888	3	0	78,033
	Celery	0	31,470	12,811	468	11,116	973	0	0	56,838
	Cucumber	2,170	59	5,397	2,765	1,297	22	233	0	11,943
	Parsley	458	289	921	35	214	45	38	0	2,000
	Spring Onion & Shallot	1,557	982	3,132	119	728	153	128	0	6,800
	Sweet Potato	6,234	0	36,199	0	22	0	0	0	42,455
	Zucchini	1,333	1,845	17,651	1,457	1,538	64	76	0	23,964
	Other Crop									
										0

Area (ha)	Large Area Crop	NSW	Vic.	Qld	SA	WA	Tas.	NT	ACT	Aust.
	Broccoli	342	3,370	1,920	236	846	375	0	0	7,089
	Capsicums	165	108	1,768	175	150	5	1	0	2,372
	Carrots	160	1,179	671	614	1,301	712	0	0	4,637
	Cauliflowers	477	1,011	841	174	399	216	1		3,119
	French & Runner Beans	113	895	4,199	10	467	812	9	0	6,505
	Green Peas	67	159	104	4	9	2,990	0	0	3,333
	Lettuce	1,018	4,000	2,390	299	891	470	4	0	9,072
	Pumpkins	2,127	270	3,233	217	924	69	145	0.0	6,985
	Sweet Corn	1,456	692	3,739	25	831	2	0	0	6,745
	Small Area Crop									
	Asian Vegetables	695	439	1,399	53	325	68	57	0	3,037
	Beetroot	108	959	335	44	83	85	0	0	1,613
	Cabbage	480	678	530	160	189	23	0	0	2,060
	Celery	0	670	273	10	237	21	0	0	1,210
	Cucumber	83	2	207	106	50	1	9	0	457
	Parsley	46	29	92	4	21	4	4	0	200
	Spring Onion & Shallot	114	72	229	9	53	11	9	0	497
	Sweet Potato	104	0	603	0	0	0	0	0	708
	Zucchini	123	171	1,635	135	142	6	7	0	2,220
	Other Crop									
										0

Gross Margin Model | Postharvest Model | Industry Cost Model | MAIN MENU

SOURCE
Large Area Crops: 71210DO004_201011 Agricultural Commodities, Australia, 2010-11
Small Area Crops: The Australian Horticulture Statistics Handbook 2012 (data reference year 2007-08)

Figure 5-7: Vegetable production and area data by crop and region

6 The Australian Levy Vegetable RD&E Investment Plan

6.1 Purpose of the RD&E Investment Plan

The RD&E Investment Plan aims to prioritise activities to deliver effective Plant Health and Crop Protection approaches for the vegetable industry. The Plan focuses on building upon previous industry wide programs, and investigating in integration and innovative, new production technologies. The Plan encompasses economic principles, and addresses adoption needs.

The Plan provides direction for future investment into RD&E that is aligned with the Australian Vegetable Industry Strategic Investment Plan (SIP) 2012 – 2017.

Delivery of this Plan will ultimately result in *an informed industry that has the necessary tools (technologies and management practices) and capacity (knowledge and skills) to manage pest and disease risks from a production and biosecurity perspective, and meets market requirements and consumer expectations.*

6.2 Situation Analysis

The analysis of background information and targeted consultation feedback conducted to develop this Plan[60] has highlighted the current position in relation to plant health and crop protection, and the direction that the industry would like to be heading.

It has enabled us to undertake a SWOT (strengths, weaknesses, opportunities and threats) analysis. The SWOT considers the **current position** (strengths and weaknesses) and the **future influences** (opportunities and threats). These elements have been considered for both the vegetable industry and RD&E.

Our initial framework for the Plant Health Desktop Study (VG12048) guided our analyses and synthesis of information, which enabled us to formulate fundamental questions and conduct the SWOT analysis to set a base for the RD&E investment plan.

6.2.1 Fundamental questions

The investment plan was guided by the following questions:

- What resources, information and capacity do vegetable producers and the vegetable supply chain need to make good crop protection decisions for their business[61]?
- What can levy and government funded RD&E do to provide resources, information and capacity that help making good crop protection decisions for the business?

This investment plan does not attempt to answer the following question:

- Apart from outputs from levy and government funded RD&E what other resources, information and capacity are required to help vegetable producers and the vegetable supply chain making good crop protection decisions for their business and who should provide what is needed?

[60] VG12048 Plant Health Desk Top Study
[61] 'Business' includes: profitability and business ethics as well as considering the needs of people and the environment

6.2.2 Current Position

The key strengths and weaknesses for plant health and crop protection in relation to the vegetable industry and RD&E are provided in Table 6-1.

Table 6-1: Strengths and weaknesses in relation to the vegetable industry and RD&E

Strengths	
Industry	**RD&E**
▪ Industry is moving towards an integrated approach because it makes good business sense ▪ Generally, industry is ready to adopt innovative practices and technologies including ICP/IPM and focus on food safety ▪ Industry is open to alternatives – with a focus on managing risks and managing costs ▪ Many in the industry have a long-term vision and a focus on sustainability and family succession ▪ Generally, industry is familiar with the importance of postharvest management	▪ Significant investment in plant health and crop protection RD&E ▪ Extensive knowledge bank and skills base (including informed agronomists and technology companies) ▪ Access to RD&E undertaken by other RDCs and overseas ▪ Linkages with other interested groups e.g. CMAs and initiatives e.g. DAFF Carbon Farming Futures ▪ Partial integration within the industry in relation to RD&E including seed and crop protection companies

Weaknesses / Limitations	
Industry	RD&E
▪ Industry can be risk averse and conservative ▪ Competitiveness within industry and some non-collaborative culture ▪ Extensive pressure on industry from markets (demands & prices) ▪ Participants often have minimal time availability, some undertake little planning and have poor skills/ little training in new technologies and practices (BMP) ▪ Often insufficient monitoring, record keeping and preventative activities ▪ Often looking for lowest cost options / short term wins rather than focusing on profitability ▪ Tendency to rely on pesticides only (risk management) and creating chemical resistance issues ▪ Poor strategies for dealing with acute problems ▪ Chronic pest, weed and disease problems ▪ Lack of good background data/statistics and good economic data on profitability of practice change	▪ Lack of collaboration and communication and potential for duplication and repetition of R&D ▪ Lack of interdisciplinary programs or project inputs e.g. inclusion of economics and market information. Minimal integration of programs within industry and across industries ▪ What success looks like differs between R&D providers and industry ▪ Limited use of industry service providers in directing programs, involvement in applied R&D and influencing adoption ▪ Minimal focus on extension/adoption and understanding the need for a route to market for new technologies ▪ Rewards for RD&E promoting a focus on scientific excellence rather than adoption ▪ Minimal utilisation/synthesis of previous information and reviews ▪ Lack of background data/statistics ▪ Minimal focus on risk management and helping industry with complex decision-making ▪ Declining skills base (inc. diagnostics) ▪ Poor strategies for dealing with acute problems

6.2.3 Future Influences

Table 6-2: Opportunities and threats in relation to the vegetable industry and RD&E

Opportunities	
Industry	**RD&E**
▪ Increasing use of new technologies / ICP ▪ Protected cropping enables introduction of effective control methods ▪ Align industry focus on risk management, good decision making and long-term profitability of ICP ▪ Consideration of the production system and focus on economics of these systems ▪ Improvements in practices and technologies e.g. spray technology, IPM/ICP, resistance management ▪ Positive culture developing towards use of innovative methods and implementation of IPM/ICP – 'time is right' ▪ Influence of younger farmers with education ▪ Potential for training and capacity building ▪ Interest by consumers and markets in ICP ▪ Need for biosecurity measures and protection of industry ▪ Strong industry representation	▪ Application of integrated research programs (e.g. like potatoes and apples) ▪ Potential to integrate RD&E with a focus on extension and route to market ▪ Inclusion of economic analysis and market needs in RD&E programs ▪ Potential to utilise service providers and consultants to inform and support R&D and industry to use new technologies and ICP ▪ Increased relevance of applied research including regional demonstration and participatory research approach (linking with growers and supply chain) ▪ Recognition of continuum of practices (regulation, GPPP, ICP) ▪ Collaborative utilisation of existing RD&E structures and substantial knowledge base ▪ Potential to link with other RDC's, international organisations and regional bodies (e.g. CMAs) ▪ Potential to foster/mentor students

Threats	
Industry	**RD&E**
▪ Market pressure requiring balance between profit maximisation and intensification ▪ Future economic viability of industry associated increasing costs (e.g. labour) and price pressures ▪ Continued use of old technology and practices ▪ Conflicting market demands including changes in market and consumer requirements ▪ Changes in market access rules e.g. MRLs and regulation (e.g. environmental issues) ▪ Lack of whole industry approach with minimal collaboration ▪ Lapse in biosecurity with introduction of new pests/diseases/weeds in different regions ▪ Poor responsiveness to acute issues ▪ Loss of current 'simple' field control e.g. resistance, deregistration ▪ Minimal capability to develop integrated methods without RD&E ▪ Not embracing new technologies e.g. protected cropping	▪ Silo approach to RD&E which lacks integration and collaboration ▪ Competition for limited R&D funds ▪ Decreased capacity in undertaking of RD&E due to retirements and deployments ▪ Lack of agronomic skills to integrate RD&E into vegetable productions systems ▪ Reluctance to build on current knowledge ▪ Inability or reluctance to change the way RD&E is undertaken ▪ Lack of involvement of whole industry including service providers

The key opportunities and threats for plant health and crop protection in relation to the vegetable industry and RD&E are provided in Table 6-2.

The analysis of the current position and future threats has highlighted a number of areas for improvement in relation to plant health and crop protection RD&E for the Australian vegetable industry.

These include:

- Consideration of the whole vegetable production system rather than aspects or disciplines (e.g. pests, weeds and diseases) in isolation and the understanding of the associated complexity which affects decision making processes on-farm
- Consideration of the complexity of the industry with a wide range of crops, growing environments, business sizes, structures, and profitability, different networks, supply chain partnerships, alliances, skills, knowledge, attitudes, expectations and other attributes
- Generation and utilisation of knowledge for the industry through RD&E and the requirement to focus on the needs of growers and the supply chain
- Consideration of the vegetable business as a whole and as part of a supply chain rather than the agronomic aspects including business and market analysis
- Integration of relevant disciplines in the undertaking of RD&E to include economics and market understanding
- Inclusion of all industry participants such as agronomists, seed companies, agribusiness, advisors and crop protection companies
- Improving the skills of all industry participants including service providers through training and regional demonstration
- Improving the capacity for delivering multidisciplinary, collaborative research and development through fostering education and training
- Reforming the means for and approach to determining RD&E priorities and delivering on industry needs under consideration of external drivers (economics, markets, policies).

The strategic investment planning (SIP) process identified key issues for the vegetable industry associated with plant health and crop protection including:

- Increasing levels of regulation concerning the use of chemical pesticides
- Expectations of growers to use integrated pest management
- Pressure from markets demanding ‘chemical-free’ foods
- Consumers’ growing concerns about health and environmental issues due to chemical pesticides requiring consideration of alternatives.

6.3 Vision for RD&E

A well-coordinated, collaborative and participatory national approach to plant health and crop protection RD&E programs for levy vegetables that includes:

- Response to market failure

- A commitment to move along the ICP/IPM continuum
- Consideration of economic and market imperatives
- Regionally significant components
- Flexibility to deal with emerging and acute issues efficiently
- Focus on adoption of known and newly developed technologies
- Implementation of continuous improvement through the plan-do-review cycle (incorporating planning and evaluation)
- Commitment to capacity building in industry and R&D community.

This integrated approach aims to take the following view:

- How the crop experiences pest, disease and weed pressures and their management, and
- How the grower has to think about and manage plant health and crop protection (involving complex decision-making, risk management and dealing with uncertainties).

6.4 Priorities and objectives

The priorities and objectives for the RD&E investment plan are:

- Understanding of key pest, weed and disease risks for major production systems from the view of those who have to manage them and their prioritisation (likelihood and consequences, including economics)
- Application and development of technologies and management practices that identify, quantify and reduce risks in production systems
- Increasing the capacity of industry to make well-informed decisions about integrated management practices through concerted extension programs that include economic information and consider market pressures
- Targeted, coordinated RD&E investment decisions and programs, with effective extension being part of the program delivery
- Improving feedback mechanisms on the efficacy of RD&E programs and RD&E needs through making evaluation a part of RD&E programs.

Activities undertaken through the Plant health and crop protection RD&E investment plan should ultimately result in an:

> *Informed industry that has the necessary tools (technologies and management practices) and capacity (knowledge and skills) to manage pest, weed and disease risks from a production, economic and biosecurity perspective and meets market requirements and consumer expectations.*

This is achieved through RD&E activities that fill knowledge gaps, integrate existing and new knowledge from a crop management viewpoint and be prepared for the future, considering the main elements for pest, weed and disease risk and control:

1. Pest and pathogen type and genetics
2. Crop type and genetics
3. Production/postharvest environment
4. Control and management methods
5. Crop management and business decisions
6. Market access and consumer expectations
7. Biosecurity and emerging pests and disease threats.

6.5 Direction - Integrated Plant Health and Crop Protection RD&E

The vegetable industry requires a more coordinated and cohesive approach that focuses on integration at all levels including:

- Development of knowledge associated with management of vegetable production systems (e.g. soils, pests, diseases, water, nutrition) – **The Plant View**
- Inclusion of aspects related to production, economics, marketing and decision making – **The Grower View**
- Technical disciplines in the undertaking of R&D (e.g. pathology, soil science, entomology)
- Implementation and skills associated with the delivery of RD&E (e.g. research, extension).

Integration of these aspects will facilitate improved decision making for plant health and crop protection.

The framework for delivery of specific integrated RD&E programs is described in Figure 6-1.

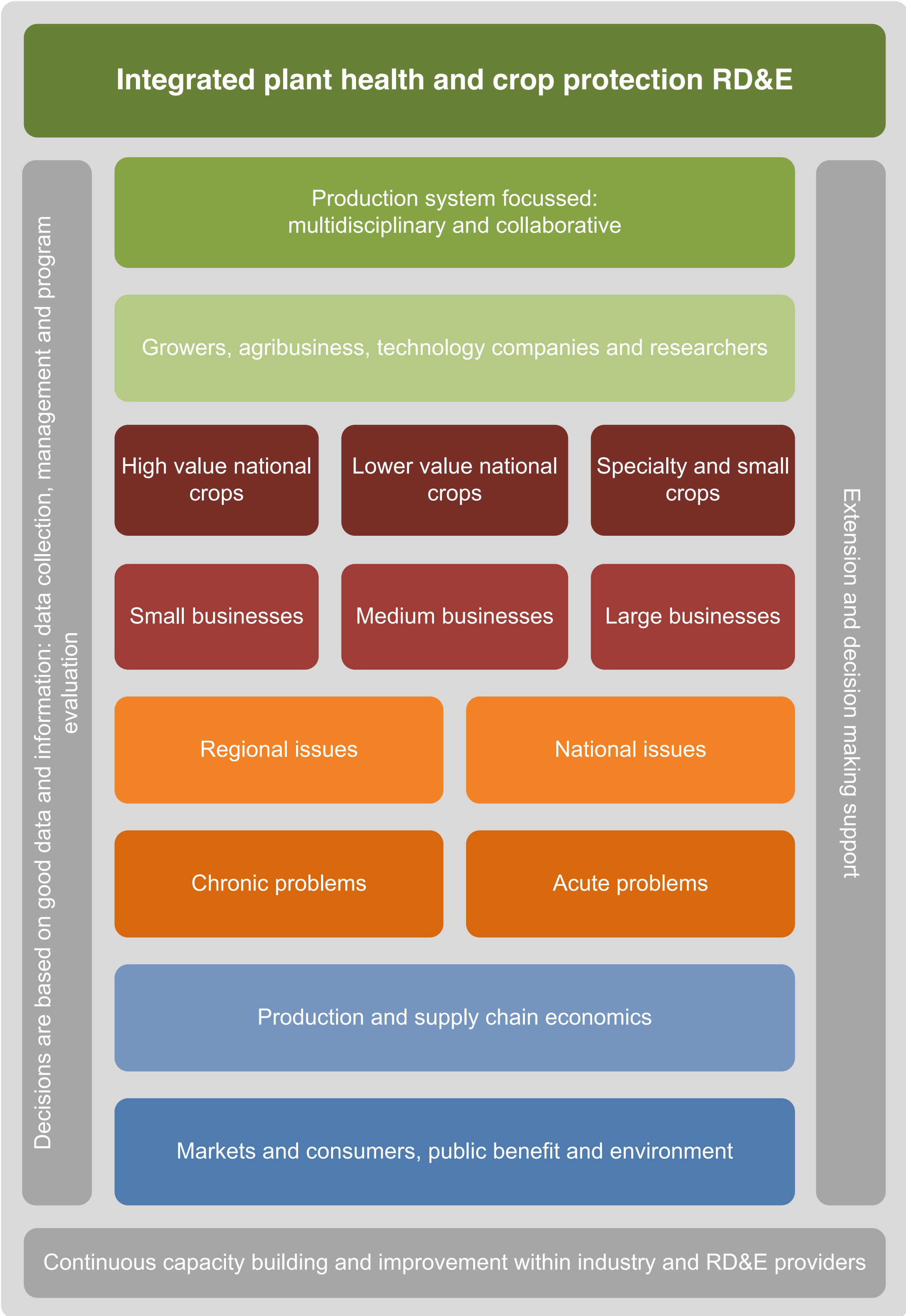


Figure 6-1: Integrated plant health and crop protection RD&E framework

The framework is explained in the following section. Coloured sections highlighted in the text correspond with colours used in the diagram (Figure 6-1).

Integrated Production Systems

The fundamental theme of integration relates specifically to the production systems focus (The Plant View) and is essential to decision making for the business (The Grower View).

Integrated RD&E Delivery

This focus on integration greatly influences what and how RD&E is undertaken. This is explained in more detail in the following:

Integration Focus	Details
Integration of industry participants	The terms 'multidisciplinary' and 'collaborative' refer to the need for involving growers, agribusiness, technology companies, researchers, agronomists and other stakeholders at different levels and various times. It does not necessarily mean that each research team must be multidisciplinary, however it would be expected that a specialised researcher or team seek advice and guidance on how new approaches, technologies or practices integrate into production systems. This may be done via existing advisory groups (e.g. VTAG) or a reference group specifically set up for a program.
Integration of research and extension to enable adoption	R&D Adoption and practice change can only happen through extension as integral part of the R&D program. It has to be focussed on helping growers, their advisers and supply chain members to make good decisions about plant health and crop protection. Good decisions are possible if the information provided fits production systems, and considers complexities within the industry (e.g. business size, crop value, regionality, capacity). RD&E programs have to acknowledge that the vegetable industry is multilayered. Distinctions should be made by crop values, business size and production region.
Integration of technical disciplines	The integration of disciplines ensures that RD&E considers the how plant health and crop production fits in with the broader production system in its environment particularly: ▪ Soils ▪ Water ▪ Nutrition ▪ Genetic potential (plants and 'harmful organisms') Regional differences need to be addressed. **Chronic issues:** chronic problems have been around for a long time. They usually have been researched over many years so that general management approaches are known. Still, new technologies and practices can be developed for chronic issues, especially to better understand and mitigate risks. Lessons from other industries should be investigated, and advanced products and integrated management techniques will need to be developed. **Acute issues:** issues may become acute due to changing conditions

Integration Focus	Details
	(e.g. climate, pesticide registration or resistance) or new pests, weeds or diseases may occur. Acute problems are those with high economic, environmental and/or social impact that do not have known or effective management options. New issues that are biosecurity risks may be dealt with under a specific biosecurity approach set out in the Biosecurity Plan for the Vegetable Industry, available from Plant Health Australia. Acute and chronic issues may require different RD&E approaches, especially regarding the speed of delivering outcomes for industry.
Integration at business level	The focus on integrated RD&E means that programs must consider the potential impacts of plant health and crop protection RD&E on: ▪ Production and supply chain economics (e.g. costs of production, profitability) ▪ Markets and consumers (e.g. consumer acceptance of technologies and practices) ▪ Environment (e.g. resource use efficiency)
Integration of knowledge and skills	The integration also refers to the application of RD&E through: ▪ Extension programs focused on practice change and decision making support ▪ Capacity building activities (e.g. education and training) ▪ Knowledge and information (e.g. data collection and analysis, RD&E program evaluation) All RD&E programs need to be based on good data and information. This includes base data such as production statistics, economics, spatial data and known information on the pests, weeds and diseases in question. Data and information gathering on how a program is performing against its objectives is also required (evaluation). Each RD&E program should include an evaluation component that monitors adoption and practice change. Programs must have the flexibility to adapt to evaluation results (plan - do - review – adapt/improve). The RD&E program must be underpinned by a drive for continuous improvement and capacity building within industry and RD&E providers. This means that the need for supporting education and training must be addressed on all levels. The capacity of industry to adopt or adapt new technologies and continue moving towards ICP may not increase without targeted training, especially for some groups. While industry cannot fund many types of education and training, e.g. vocational education and training (VET) or courses for research and extension providers, it must be aware of the impact that a lack of adequately trained people on all levels can have on the industry.

6.6 Strategies

6.6.1 What – Integrated Plant Health and Crop Protection RD&E

What key RD&E areas should HAL invest in to increase the ability of the vegetable industry to effectively and profitably manage plant health and crop protection?

Table 6-3: Key RD&E investment areas and levels (% of available RD&E funds) for vegetable plant health and crop protection

<table>
<tr><th>Program
(% of RD&E funds)</th><th>Sub-program</th><th colspan="2">Integration/Conditions</th></tr>
<tr><td rowspan="2">1. Vegetable Production Systems
(50%)</td><td>a) Response to chronic problems
- Progress ICP/IPM continuum
- Risk management systems</td><td rowspan="2">Inclusion of elements from areas 2, 3, & 4 in planning and delivery</td><td rowspan="10">**Monitoring and Evaluation** included in planning and throughout delivery</td></tr>
<tr><td>b) Responses to acute problems
- New and emerging issues
- Biosecurity (internal and external)</td></tr>
<tr><td rowspan="3">2. Business implications
(10%)</td><td>Production and supply chain economics</td><td rowspan="3">Inclusion of elements from areas 1, 3, & 4 in planning and delivery</td></tr>
<tr><td>Markets and consumers</td></tr>
<tr><td>Public benefit and environment</td></tr>
<tr><td rowspan="2">3. Information management
(20%)</td><td>a) Foundation data and information</td><td rowspan="5">Inclusion of elements from areas 1 & 2 in planning and delivery</td></tr>
<tr><td>b) Knowledge resources/products/tools</td></tr>
<tr><td rowspan="3">4. Good decision making
(20%)</td><td>a) Capacity building activities</td></tr>
<tr><td>b) Education and training facilitation</td></tr>
<tr><td>c) Extension programs</td></tr>
</table>

Investment levels

Suggested investment levels are indicated as % of RD&E funds available (for plant health and crop protection RD&E) in Table 6-3. Focus will be on areas 1, 3 and 4. Program 2 will need to be considered in planning, budgeting and delivery of Programs 1, 3 and 4. Information from Programs 1, 3 and 4 will need to be considered in planning, budgeting and delivery of Program 2.

Each project must include a budgeted monitoring and evaluation (M&E) component to guide RD&E as the project evolves i.e. check whether objectives are met via monitoring key indicators, and ensure effectiveness for industry. This allows adjustments and adaptive decisions to be made while a project is running and thus permits planning for longer project timeframes.

Investment levels have been chosen based on information from other industries and programs in other countries. The level for areas 3 and 4 should be reassessed and may be reduced after 3-5 years to 10-15% each, assuming that by then, information that currently is 'on the shelf' has been made available to industry and is used in GPPP and ICP.

The potential savings should then be invested into innovative RD&E with a focus on new technologies and following the integrated model of including economics, consideration of market and customer requirements, extension and capacity building and evaluation into program design.

Program activities

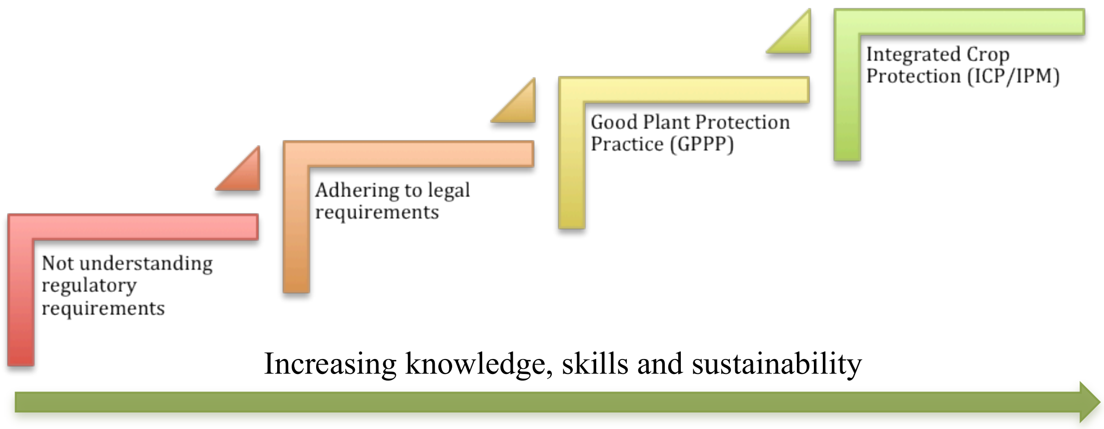
The activities to be supported in each of the programs are described in further detail in Table 6-4.

Table 6-4 Program activities

Program 1: Vegetable production systems

Sub-Program	Activities
a) Response to chronic problems	The RD&E supported under this sub-program relates primarily to supporting the move towards IPM/ICP through integrated production practices as described in the below diagram. This will include a focus on: ▪ Supporting capacity to meet regulatory requirements and achieve GPPP[62] (inc. avoiding pesticide resistance through considered use of products, beneficial friendly IRM[63] plans, implementation of better spray technology and other technologies) ▪ Enabling risk based decision making based on monitoring ▪ Providing an understanding of and practical monitoring systems on the influence of soil condition, rotation, tillage, water management, nutrition and other crop management decisions on pests, weeds, and diseases, following on from findings and discussion in the report VG12048 ▪ Building on SARP[64]to capture information relevant to IPM/ICP, to advise on gaps in pest, weed and disease control, and supporting the minor use program ▪ Filling R&D gaps identified during review and consultation for VG12048 in a coordinated approach ▪ Supporting continued innovation and access to new technology e.g. biological control options, predictive models to assist IPM/ICP, protected cropping, landscape effects on incidence and severity (new technologies are discussed in the report VG12048).
b) Response to acute problems	The response to acute problems involves addressing new and emerging issues (that may have been chronic problems) and biosecurity management for both external and internal pest, disease and weed threats. RD&E activities will need to focus on: ▪ Emergency response planning in line with the current crisis management plan for the industry, the SARP process may be used to identify crops and pests, weeds or diseases which potentially lead to an emergency situation ▪ Emergency fund for addressing acute issues (e.g. due to a known pest re-emerging, pesticide resistance, product removal, pest incursion) requiring rapid response in RD&E.
c) General	RD&E activities will need to: ▪ Consider industry complexity and potential market failure ▪ Address pertinent regional problems ▪ Use different types of support for small and large businesses (e.g. LOTE growers vs. large scale producers with technical capability).

[62] Good plant protection practices
[63] Integrated resistance management
[64] Strategic Agrichemical Review Process



The crop protection continuum on farms

Program 2: Business implications

Sub-Program	Activities
a) Production and supply chain economics	The project must consider the broader economic implications of the RD&E and how it will influence the grower and potentially the industry. Activities supported under this program will include: ▪ Economic prioritisation of pest, weed and disease problems based on good data e.g. using the model prepared for VG12048 ▪ Understanding the impact of new technologies on cost of production and profitability through the supply chain.
b) Markets and consumers	The potential impact of a project on the market and consumer responses need to be considered. Activities in this area related to plant health and crop protection will include: ▪ Understanding market and consumers requirements and impacts on crop protection options ▪ Understanding public good including health and environmental impacts.
c) Public benefit and environment	Projects must consider the potential public benefit aspects of RD&E (support for government investment) and the potential to link with broader landscape based outcomes.

Program 3: Information management

Sub-Program	Activities
a) Foundation data and information	There is a need across the industry to have data and information that enables a description of current practices and pest, weed and disease threats (status quo) and evaluation of change in practices (e.g. using the ADOPT model). Projects that facilitate the collection of foundation data and information should be supported. These may be components of other RD&E projects or stand alone projects including: ▪ Information on pesticide usage ▪ Improving objective background data on plant health issues/surveillance/biosecurity ▪ Production statistics and economics (including data on crop losses due to pests, weeds and diseases) ▪ Information contributing to evaluation of RD&E programs – measure adoption and practice change
b) Knowledge resources/products/ tools	A vast amount of R&D information exists that requires interpretation, synthesis and presentation in a form that is readily useable for growers and their advisers. Projects would be supported that include: ▪ Development of best practice guides esp. GPPP and ICP/IPM, prioritised via economic importance, adoption potential and risk (e.g. pesticide resistance, lack of control options, lack of good practice), the SARP process may assist in prioritisation ▪ Development of Apps for easy use on phones ▪ Presentation of existing information in visual and engaging modes, media and during industry events.

Program 4: Good decision making

Sub-Program	Activities
a) Capacity building	There is a need for industry participants to continue to increase their knowledge and understanding of plant health and crop protection. Guidance may be taken from the latest skills review[65]. The EnviroVeg manual may be used as a resource or platform. Capacity building projects could relate to: ▪ Maintaining of knowledge and skills in entomology and pathology in the research community ▪ Increasing the ICP/IPM knowledge of industry service providers traditionally involved in product sales ▪ Improving the understanding of growers and the supply chain in relation to good plant protection practices.
b) Education and training	The industry requires a continued focus on education and training across the board (e.g. growers, supply chain members, service providers, researchers) Direct investment from levy funds will not be applicable for many aspects of training and education; still industry should support what it can within given boundaries including e.g.: ▪ Encouraging young people in the industry to continue education, training and professional / personal development activities ▪ Feeding R&D outcomes to education and training providers (e.g. UNI, TAFE, pathway programs) ▪ Fostering industry placement for students
c) Extension programs	Extension programs need to be tailored to the needs of different grower and adviser groups within the industry. Activities should be supported in relation to: ▪ Providing coordinated extension programs and services for growers and advisers on existing information as a matter of priority and as integral part of R&D projects ▪ Use of regional demonstration sites or farms ▪ Use of crop or regional champions / IDOs ▪ Utilisation of existing knowledge products and resources ▪ Utilisation of existing integrated management extension resources / platforms such as EnviroVeg ▪ Initiating commercialisation (route to market) of new technologies from R&D so they become available as services or products to growers There is potential to work collaboratively with research providers to ensure that the knowledge is relevant and can be readily adopted.

The process of linking with industry in RD&E is illustrated in Figure 6-2. Levy funding should be predominantly invested into applied research, development and extension. Industry participation in applied research should be encouraged e.g. through using representative commercial farms for trials, checking with growers and or supply chain members that R&D concepts are practical and or using a technical reference group (especially for large multidisciplinary projects). Relevant basic research should be supported via co-investment; outcomes for the vegetable industry should be clearly defined and monitored.

[65] AUVEG 2012; Review of skills and training in the vegetable industry. Prepared with HAL funding

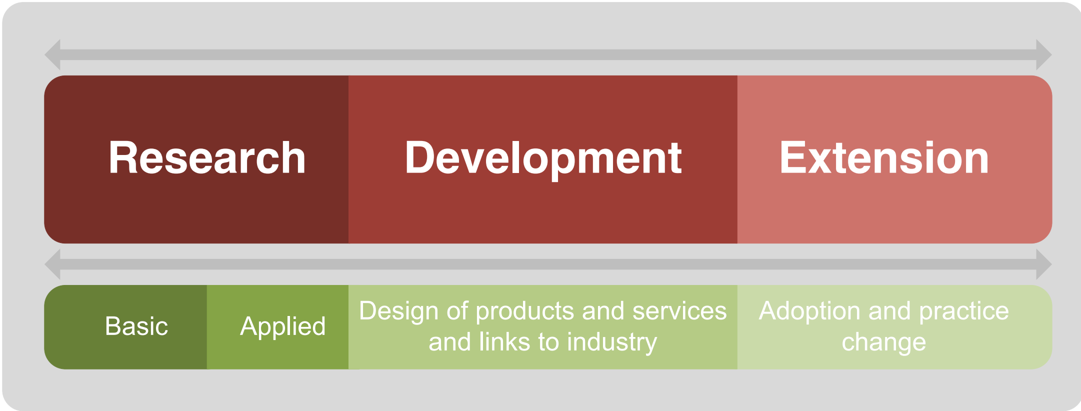


Figure 6-2 Working with industry in aspects of RD&E

6.6.2 How – Development and prioritisation of RD&E investment programs for new projects

To deliver on the proposed integrated approach, some reform of the current process for development and prioritisation of RD&E investment programs is required.

Table 6-5: General components

Component	Details
Program justification	Assessment of market failure to be maintained as part of the planning process i.e.: ▪ Would the particular RD&E project otherwise not receive funds and or adequate in-kind support that is sufficient to achieve an industry objective or need? or ▪ Is there an identifiable benefit to the industry broadly and/or the Australian community after taking into account all costs.”
Program design and planning	Development of a program logic that demonstrates how the project will deliver on the broader objectives. Planning will also require formulating: ▪ Fundamental questions to be answered by the research ▪ A budget that includes extension and capacity building and M&E[66]
Program evaluation	Inclusion of an evaluation and monitoring (M&E) plan to enable adaptation of activities throughout the program (based on plan, do, review, adapt/improve and go/no go principles). Key evaluation criteria and measurements need to be formulated.
Industry support and involvement	Demonstrated support and involvement from industry (growers, service providers, agribusiness) indicating there is a need for the activity and results are practical within growing systems. This may be demonstrated through confirmed commitment from relevant people and/or organisations.
Multidisciplinary, collaborative, participatory approach	Advice from or involvement of relevant disciplines and industry partners[67] through collaborative and or participatory research and or a reference group and or RD&E partners. The final approach will depend on the focus area and required outcomes. The integration between technical disciplines should be demonstrated as appropriate.
Review of existing knowledge base and data	Assessment of existing data and information nationally and internationally (including other industries). Indication on how this will be used and added to.
Capturing new knowledge and data	Inclusion of a plan on how outputs, other than reports prepared for HAL, will become available to industry throughout the project and especially after its completion. This may include but not be limited to fact sheets, manuals, electronic tools (Apps, calculators etc.) and resources, new analytical procedures and products.

[66] Monitoring and Evaluation
[67] These include growers, consultant, agronomists, technology companies, agribusiness, supply chain members

Component	Details
Drivers and barriers for adoption	Consideration of the key factors that will influence the adoption of the technology or management practices and how some of these barriers may be overcome, considering the stratification of industry. Application of the ADOPT tool would greatly assist the understanding of potential issues at the commencement of the project and contribute to the analysis of whether to proceed. The ADOPT model or a modified version of it should be used to estimate adoption times and levels. This will produce information to be used in the economic model.
Economic analysis	Assessment of the potential and actual economic impact of the activity e.g. using the tool developed thought this project or an adapted version to demonstrate economic benefit.
Integration within vegetable production systems	Demonstration of how the approach considers production systems, regional or national issues and industry complexities, and how intended outputs fit with these. If field trials are part of the program, these have to be set up in representative crops and areas, preferably on farm. Scale of projects (time and area coverage) may need to be adjusted as discussed in VG12048 to provide integration with production systems e.g. landscape scale or regional scale integration
Integration within business	Demonstration that activity includes considerations of economic and market drivers e.g. using a cost / benefit analysis.

Reporting

Currently a substantial amount of time and funds is spent on final project reports. However, industry members and service providers rarely utilise them, even though they are a main project output[68]. The resources spent on large reports may be better allocated to generate material useful for extension as requested by industry, and useful for researchers who are required to produce publications from their research by employers. The option of substituting lengthy final project reports with a set of other outputs that demonstrate completion of the work, relevance to and use by industry, and scientific rigour, should be investigated. HAL requirements need to be taken into account when investigating options. Appropriate outputs could include a combination of, but may not be limited to:

- Milestone reports including methodology and performance against budget as well as practice change evaluation (per M&E plan) and description of economic benefits
- Annual evaluation reports and work plans
- Extension resources (factsheets, databases, manuals, DVDs, Apps, calculators, tools, products, services, presentations, conference papers)
- Publications in magazines and (refereed) scientific journals.

Researchers should not be obliged to report more intensively than required to achieve the stated objectives of the program. Outputs should ensure materials and methods are documented, results are presented and discussed and conclusion and recommendations are made to the levy paying industry and other audiences as appropriate. A scientific publication would also be a desired output for the researcher and should be supported.

[68] The desktop review for VG12048 found that for 49% of research projects conducted since 1996, a final project report was the only output.

Governance structure for RD&E projects

It is important that the governance of individual projects is established to ensure an appropriate level of industry involvement.

The industry currently has three levels of potential input into projects:

Design Teams - there are three Design Teams, each relating to a key Objective in the strategic investment plan. The role of the Design Teams is to assist in developing, implementing and reviewing the R&D program.

The Design Teams make project recommendations to the IAC.

Vegetable Technical Advisory Group (VTAG) - the VTAG's role is to provide technical advice on (primarily) Productivity or Production related proposals. The VTAG provides detailed technical advice to the IAC on projects as directed/requested by the IAC.

Special advisory groups may be appointed, if required**.**

Industry Advisory Committee (IAC) – the IAC is primarily grower based committee with a range of skills along the supply chain. The IAC is the final point of endorsement on all projects prior to contracting by HAL. The IAC has responsibility for providing advice to HAL on the vegetable sector and ensuring the preparation of:

- Strategic Investment Plan
- Annual Investment Plan
- Annual Report.

6.6.3 Why – Evidence to Support the Plan's Approach

Background analysis

This RD&E investment plan has been developed based on extensive review of current information produced over the past 15+ years, assessment of previously used processes to determine RD&E gaps and RD&E reviews, and consultation with industry, agronomists, researchers and crop protection industry. The supporting documentation for the investment plan is provided in the report VG12048 Plant Health Desktop Study; it includes:

- Rationale for an RD&E investment plan
- Target audience for the investment plan
- Approach to developing the plan
- Situation analysis of plant health and crop protection in vegetables including:
  - *Analysis of available information including some new technologies*
  - *Important factors impacting on plant health and crop protection*
  - *Extension and adoption*
- Wider industry consultation and views
- Economic impact model
- Highlighting of priorities for the development of RD&E Investment Plan.

Alignment with rural RD&E directions

This RD&E investment plan aligns with the national rural R&D priorities as shown in Table 6-6.

Table 6-6 R&D Priorities

<table>
<tr><th colspan="2">National Rural R&D Priorities</th><th colspan="2">RD&E Investment Plan</th></tr>
<tr><td>Productivity and Adding Value</td><td>Improve the productivity and profitability of existing industries and support the development of viable new industries</td><td rowspan="2">Program 1: Vegetable Production Systems
Program 2: Business implications
Program 3: Information management
Program 4: Good decision making</td><td rowspan="2">1a) Response to chronic problems
2a) Production and supply chain economics
2b) Markets and consumers
3a) Foundation data and information
3b) Knowledge resources/products/tools
4a) Capacity building
4b) Education and training facilitation
4c) Extension programs</td></tr>
<tr><td>Supply Chain and Markets</td><td>Better understand and respond to domestic and international market and consumer requirements and improve the flow of such information through the whole supply chain, including to consumers</td></tr>
<tr><td>Natural Resource Management</td><td>Support effective management of Australia’s natural resources to ensure primary industries are both economically and environmentally sustainable</td><td rowspan="2">Program 2: Business implications</td><td rowspan="2">2c) Public benefit and environment</td></tr>
<tr><td>Climate Variability and Climate Change</td><td>Build resilience to climate variability and adapt to and mitigate the effects of climate change</td></tr>
<tr><td>Biosecurity</td><td>Protect Australia’s community, primary industries and environment from biosecurity threats</td><td>Program 1: Vegetable Production Systems</td><td>1b) Response to acute problems</td></tr>
<tr><td>Innovation Skills</td><td>Improve the skills to undertake research and apply its findings</td><td rowspan="2">Program 3: Information management
Program 4: Good decision making</td><td rowspan="2">3a) Foundation data and information
3b) Knowledge resources/products/tools
4a) Capacity building
4b) Education and training facilitation
4c) Extension programs</td></tr>
<tr><td>Technology</td><td>Promote the development of new and existing technologies</td></tr>
</table>

6.7 Measurement and Evaluation – KPIs

Critical to the effectiveness of any investment plan is the ability to assess what has been achieved through the investment and where the funding has been particularly successful. To assist in the evaluation and adaptive management of the program and number of measures of success have been established.

These overall measures of success are described in Table 6.7.

Table 6-7 Measures of success

Program 1: Vegetable Production Systems	
1a) Response to chronic problems	▪ Projects successfully addressing strategic industry priorities ▪ Practice change has occurred
1b) Response to acute problems	▪ Rate of response to new threats ▪ Practice change has occurred
Program 2: Business implications	
2a) Production and supply chain economics	▪ Inclusion of economics in analysis of projects and in their implementation
2b) Markets and consumers	▪ Consideration of market and consumer expectations in projects
2c) Public benefit and environment	▪ Projects to show public benefit and environmental outcomes
Program 3: Information management	
3a) Foundation data and information	▪ Establishment of robust foundation data ▪ Information is available to industry and RD&E providers
3b) Knowledge resources/products/tools	▪ **Development of resources that meet industry needs** ▪ **Resources are easily available to industry and used**
Program 4: Good decision making	
4a) Capacity building	▪ Increase capacity of industry participants in ICP ▪ Practice change has occurred
4b) Education and training facilitation	▪ Education and training facilities meet industry needs ▪ RD&E outputs are provided to education and training providers
4c) Extension programs	▪ Targeted programs for different industry sectors / regions improve practices and address risks

7 Appendices

Appendix 1: Communications & Consultation Plan

Appendix 2: Crop Health Review Database

Appendix 3: Crop Protection and Plant Health Surveys

Appendix 4: The Strategic Agrochemical Review Process

Appendix 5: Adoption of IPM

Appendix 6: Smart Phone Technology

Appendix 1: Communications & Consultation Plan

Scope

The project involves communication amongst the project team, with the client (HAL, AUSVEG) and with many stakeholders and other audiences. The Consultation component of the project is a critical component of the overall project communications.

The communications plan includes but is not limited to:

- Purpose of the communication - why is the communication being undertaken
- What information will be communicated - content, detail and format
- How the information will be communicated - e.g. meetings, email, telephone, surveys etc.
- When information will be distributed - the frequency of project communications both formal and informal
- Responsibility for communicating project information
- Communication requirements for all project stakeholders and other audiences
- How changes in communication or the communication process are managed
- The flow of project communications
- Any templates, formats, or documents the project must use for communicating
- Any potential constraints, internal or external, which may affect project communications including how any sensitive or confidential information is communicated and who must authorise this
- A process for resolving any communication-based conflicts or issues.

Objectives

The Communications Plan has the following objectives:

- Ensure the project team, clients, stakeholders and other audiences have adequate, objective information about the project, its progress, any risks, conflicts or constraints, and outputs
- Assist in providing targeted information in a timely manner
- Guide stakeholder consultation
- Ensure that all communication is traceable e.g. by using project codes and filing systems.

Environmental Scan

Effective communication will be a key factor determining the success of the project. All stakeholders need to understand that the main objective of the project is to prepare a strategic Plant Health and Crop Protection Research, Development and Extension (RD&E) Plan to guide investment for the vegetable industry based on economic principles, including an effective approach to capacity building and adoption. When implemented the Plan will provide benefits to growers through effective plant health management and reduced input costs. It must be clear to all stakeholders and other audiences that there are no other motives or overriding objectives for this work.

Context

Plant Health projects have mainly been conducted on a 'needs basis' rather than following an overall strategic approach and considering holistic economic benefits for the vegetable industry.

The recent VIDP project included compiling and reviewing information from previous projects including an emphasis on plant health projects. These reviews, information and factsheets are available through the AUSVEG website.

Communication must comply with HAL requirements listed under 'References' in this document.

Publications / Announcements

The project approach, key messages and project outputs will be publicised broadly through articles in 'Vegetables Australia' and presentations of project findings e.g. at the annual AUSVEG conference, and through a final report to Horticulture Australia. Horticulture Australia or AUSVEG may decide to publicise further information from the project.

Responsibilities

The Project Manager is the primary communicator for the project and is responsible for circulating information according to this Project Communications Plan.

Changes to communication needs, due to constraints, conflicts or other emerging issues, will be dealt with as explained under 'Issues' below, and by updating the Plan if required.

The availability and use of any sensitive or confidential information will be determined by HAL; HAL may consult with AUSVEG.

Issues

Diversity in the vegetable industry and interests amongst stakeholder groups may add complexity to expectations from the project, and affect how communication is perceived. Therefore, communication should be conducted as per this plan and any issues or conflicts should be reported to the project manager immediately for resolution.

Depending on matters arising, the HAL industry services manager may be involved in resolving any issues in regards to misinterpreted communication. The HAL industry services manager will decide whether AUSVEG needs to be involved.

Traceability of communication

All communication will be marked with the HAL project number VG12048. RMCG internal communication should also show the RMCG project number 55-H-04. All emails to and from the RMCG project team will be filed in the 55-H-04 e-mail folder. Other communication will be saved in the RMCG client files under 55-H-04 and the relevant subfolder. Hard copy letters / documents will be scanned for that purpose.

Consultation contacts and timings of consultation will be recorded in a central register in the 55-H-04 folder. One hard copy of interview notes will be kept in the 55-H-04 project folder, and survey findings will be consolidated in a central electronic file under 55-H-04.

RMCG QA procedures (ISO 9000) apply to all communications, reporting and other project management tasks.

Evaluation

Insufficient information will lead to negative feedback, good communication to positive feedback about the project. Feedback will be a measurement of how well project communication has been handled and how successful the project has been i.e. whether communication and project objectives have been achieved. Feedback will be recorded as it is received in a project feedback folder located in the RMCG project folder 55-H-04 under Communication. Formal feedback may be sought separately; evaluation is not part of the project VG12048.

References

HAL Communications Approval, Branding and Recognition Requirements

HAL Strategic Investment Planning Guidelines, Version 2

RMCG QA documents.

Communication with Stakeholders

Stakeholders include all individuals and organisations that are affected by the project and its outputs.

Levels of participation in stakeholder engagement using the IAP2 framework[69]:

	Inform	Consult	Involve	Collaborate	Empower
Engagement goals	Provide objective, accurate and consistent information to assist understanding of progress, issues, alternatives, opportunities and/or solutions.	Obtain feedback on issues, analyses, alternatives and/or outcomes.	Work through part or all of the process to ensure that concerns and needs are consistently understood and considered.	Partner including the development of alternatives, making decisions and the identification of preferred solutions.	To place final decision-making in the hands of the stakeholder. They are enabled/equipped to actively contribute to the achievement of outcomes.
Promise to stakeholders	We will keep you informed.	We will keep you informed, listen to and acknowledge concerns and aspirations, and provide feedback on how stakeholder input influenced the outcome.	We will work with you to ensure that your concerns and aspirations are directly reflected in the alternatives developed and provide feedback on how stakeholder input influenced the outcome.	We will look to you for advice and innovation in formulating solutions and incorporate your advice and recommendations into the outcomes to the maximum extent possible.	We will implement what you decide. We will support and complement your actions.
Methods of engagement	Direct communication via e-mail / phone Publications inc. articles, fact sheets etc.	Focus group Survey One to one discussions	Workshop Forum	Facilitated consensus Facilitating deliberation and decision-making	Dialogue, Joint planning Provision of data Shared ideas Capacity building

[69] Refer to http://www.dse.vic.gov.au/effective-engagement/developing-an-engagement-plan/a-model-for-engagement for information on IAP2

Engagement of project stakeholders

Stakeholders	Engagement level	Purpose Expected main questions / issues	Management
HAL	Empower	Is the project on track? Are research and communication methods appropriate and following guidelines?	Weekly communication Following HAL guidelines
AUSVEG	Empower	Is the project on track? Does industry get the required outcomes?	Follow project plan, communication through HAL industry liaison manager
TAG (IAC, Design Team)	Involve		Direct communication after project steps 1 & 2
Industry project partner	Collaborate		Direct communication at critical project stages (beginning and end of each 'project step')
Vegetable growers	Inform, consult	What is in it for me? How will an economic focus for vegetable RD&E affect my business?	Clear communication in 'Vegetables Australia' and other AUSVEG channels Consultation (phone, TAG, industry partner)
Vegetable crop health research providers	Inform, consult	What is in it for me? How will an economic focus for vegetable RD&E affect my organisation / my work?	Communication via networks such as associations / organisations Consultation (workshop)
Project team	Empower	Are we on track? Can we manage & meet expectations?	Effective team and stakeholder communication, avoiding creating unrealistic expectations

Other audiences

Other organisations include all individuals and organisations that may be able to contribute to the project and its outputs.

Engagement of other audiences

Audience	Engagement level	Expected main questions / issues	Management
Agronomists	Consult	What is in it for me? How will an economic focus for vegetable RD&E affect my business?	Clear communication in 'Vegetables Australia' and other AUSVEG channels, targeted consultation (phone)
Private consultants	Consult	What is in it for me? How will an economic focus for vegetable RD&E affect my business?	Clear communication in 'Vegetables Australia' and other AUSVEG channels, targeted consultation (phone / email)
AgChem producers	Consult	Will future RD&E support our operations / fit with our goals?	Understand drivers and communicate clearly during targeted consultation (phone / email)
Government departments	Inform	What will project outcomes mean for our funding situation? Will this affect our staff and what they do?	Provide access to final report

Communication matrix

The Communications Matrix guides the communication objective (what is the purpose and content of information), the format and frequency of communication, the key target and responsibility.

Engagement of stakeholders and other audiences

Communication Type	Communication Objective	Description/ Medium/ Format/ Tools	Frequency/ Timing	Participants/ Distribution/ Audience	Deliverable/ Key Content	Responsibility
Status Report(s) to HAL and project team	Keep informed on progress and work plan	Email summary of project status	Weekly	HAL, Team	Status Report	Project Manager
Project Team Meetings	Work planning, progress review discussion of issues arising	Hook-up / meetings to review action plans and status	Fortnightly	Project Team	Updated work plan	Project Manager
Project Step Reviews (mainly milestone reports)	Ensure that stakeholders are up-to-date as per the required engagement level	Close off of project steps and start of next steps by email or phone or face to face	Milestone report timings	HAL, Project Team and Project Partner(s)	Milestone report(s)	Project Manager
Consultation / give information to vegetable industry (growers, project partners TAG) & other audiences	Obtain feedback on issues, reviews, status quo and plans; understand views and attitudes, inform about project activities, progress and findings	Interviews, presentation(s) & forum discussions, phone, meetings with TAG & industry partners, industry forum magazine article(s)	Each target group as per Project Plan	Growers, agronomists, consultants, Agchem industry	Survey(s) Project update(s) Magazine articles Presentation at AUSVEG conference	Project Manager, with project team members assisting
Consultation – plant health researchers & extension providers	Get feedback on reviews, industry consultation and issues, understand view and attitudes, inform	Workshop or forum, phone, email	As per Plan, mid February 2013	Pathologists (inc. nematologists, virologists), entomologists, weeds researchers	Presentation on findings and potential plans	Project Manager, project team members assist

Appendix 2: Crop Health Review Database

BEANS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	**Field**	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity	Grafting snake beans to control fusarium wilt	2002	Web	Fact sheet
				Snake bean grafting	2007	Web	Fact sheet
				Managing bean root and stem diseases	2007	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Genetics				
			Integrated Control	Integrated bean rust management	2001	Web	Research report
				Best practice - Sclerotinia in beans	2009	Web	Guide
				Integrated management of sclerotinia disease in beans	2001	Web	Research report
				Red root rot of beans	1999	Web	Web page
				Anthracnose of beans	1999	Web	Web page
				Brown spot of beans	1999	Web	Web page
				Common blight of beans	2010	Web	Web page
		Insects	Chemical	The generation of chlorantraniliprole residue data in beans, peas and sweet corn	*2010*	Web	Research report
			Cultural				
			Crop Management / Productivity	Thrips management in the green beans industry	2011	Web	Research report
				Thrips in green beans	N/A	Web	Fact sheet
			Business Improvement				
			Biological				
			Environment				
			Biological control	Microplitis demolitor and ascovirus: Important natural enemies of Helicoverpa (part of website titled: IPM - Understanding helicoverpa ecology and biology in southern Queensland: know the enemy to manage it better)	2005	Web	Web page
			Varietal Improvement				
			Integrated Control	Integrated pest management in the green bean industry	2007	Web	Research report
		Weeds	Chemical	Control of amaranthus and other weeds in beans	1999	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				

BEANS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Integrated Control				
	Protected	Diseases	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	Diseases	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				

BEANS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Extension to VG02030 Integrated pest management in the green bean industry	2009	Web	Research report
				Production of fresh beans (VIC)	2009	Web	Web page
				Pests and diseases of green beans (QLD)	2011	Web	Web page
				Integrated pest management for greeen beans	2010	Web	Web page
				Green beans: insect pests, beneficials and diseases	2008	N/A	Book
Biosecurity							
Market Access							
Business Improvement							

Topic Summary			**%**
Field	Diseases	10	48
	Insects	5	24
	Weeds	1	5
Post-harvest		0	0
Protected		0	0
Integrated		5	24
Biosecurity		0	0
Market Access		0	0
Business Improvement		0	0
Total		**21**	**100**

Currency Summary		**%**
1996 - 2001	6	29
2002 - 2007	5	24
2008 - 2013	10	48
Total	**21**	**100**

Resource Type Summary		**%**
Poster	0	0
Presentation	0	0
CD/Video	0	0
Webpage	8	38
Guide	1	5
Fact sheet	3	14
Research report	8	38
Book	1	5
Total	**21**	**100**

Main issues investigated	**Host range**
Fusarium wilt	Wide host range
sclerotinia	Wide host range
rust	Sweet corn, onions, spring onions, beets, celery, silverbeet
red root rot	
brown spot	
common blight	
thrips	Wide range of vegetables
heliothis	Beans, peas, lettuce, brassicas, greenhouse vegetables (wide host range)

BROCCOLI	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	**Field**	**Diseases**	Chemical	Developing alternate fungicides to control white blister disease in brassica crops	2007	Web	Research report
				Alternative options for white blister rust control	2010	Web	Presentation
				New fungicides and strategies for sustainable management of Sclerotinia and Rhizoctonia diseases on vegetable crops	2012	Web	Research report
			Cultural				
			Crop Management / Productivity	Benchmarking models, aerial spore sampling, irrigation and nutrients for downy mildew of lettuce and white blister on brassicas	2007	Web	Poster
				A Scoping Study For Race Identification, Sources Of The Epidemic And Management Of White Blister Disease On Brassica Vegetables	2004	Web	Research report
				An Investigation On Head Rot Disease Of Broccoli Crops Grown For Processing	2004	Web	Research report
				A Rapid Diagnostic Test For Clubroot	2002	Web	Research report
				Scoping study to determine the soil borne diseases affecting brassica crops	2006	Web	Research report
				Developing on-farm diagnostic kits for brassica diseases	2007	Web	Research report
				Enhancing the plant immune response for improved disease control	2010	Web	Research report
				Virus diseases of vegetable brassica crops	2006	Web	Factsheet
				Evaluation of new seed dressing technologies for improved disease and insect control in vegetable crops	2009	Web	Research report
			Biological				
			Environment				
			Varietal Improvement	Biofumigation - Bioactive Brassica Rotations For IPM Of Soil-Borne Pests And Diseases	2000	Web	Research report
				Improved management of black rot of Brassicas	2004	Web	Research report
				Pyramiding genes for clubroot resistance in brassica vegetable crops	2009	Web	Research report
				Biofumigation - Optimising Biotoxic Brassica Rotations For Soil-Borne Pest And Disease Management	2004	Web	Research report
			Integrated Control	A guide to the prevention and management of clubroot in vegetable brassica crops	2000	Web	Factsheet
				Managing clubroot in vegetable brassica crops	2006	Web	Factsheet
				Managing brassica stem canker	2009	Web	Research report
				Managing brassica stem canker phase 2	2012	Web	Research report
				Integrated control of clubroot for the production of quality export and domestic crucifers	2000	Web	Research report
				Total crop management of clubroot in brassica vegetables	2003	Web	Research report
				Integrated management of bacterial head rot of broccoli	1999	Web	Research report
				White blister	2006	Web	Presentation
				Clubroot of cruciferous crops/Clubroot factsheets	2006	Web	Factsheet
				White blister control in vegetable brassica crops	2006	Web	Factsheet
				Management strategies for white blister (rust) in brassica vegetables	2007	Web	Research report
				Downy mildew of Brassicas	1997	Web	Factsheet
				Diseases of vegetable brassicas	2006	Web	Factsheet
		Insects	Chemical	Impact of insecticides on natural enemies found in Brassicas	N/A	Web	Factsheet
				Brassica crop protection products – a guide to potential impacts on beneficials	2010	Web	Poster
			Cultural				
			Crop Management / Productivity	National Diamondback Moth Project Website (Links to Diamondback Moth Newsletter and Handbook)	2002 - 2007	Web	Web page
				Pests of vegetable brassica crops in WA	2006	Web	Guide
			Business Improvement				
			Biological				

BROCCOLI	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Environment				
			Biological control	Development of Hippodamia and Micromus biocontrol agents for use in Brassica and other vegetable crops	2011	Web	Research report
				Investigating the potential of an ascovirus for biological control of DBM	2008	Web	Research report
				Using Hippodamia ladybird in brassica integrated pest management	2007	Web	Research report
			Varietal Improvement				
			Integrated Control	Control of Diamondback Moth in brassica vegetables with fungi	2004	Web	Research report
				Advancing the integrated management of Diamondback Moth (DBM) in brassica vegetables (July 1997 - June 2000)	2001	Web	Research report
				Demonstrating integrated pest management of IPM in brassica crops	2009	Web	Research report
				Identification of immune-suppressors of Diamondback Moth (DBM)	2011	Web	Research report
				Why Diamondback moth is hard to control	N/A	Web	Factsheet
				Sustainable cropping systems in brassicas (pest management)	1996	Web	Research report
				A guide to common pest and beneficial insects in brassica crops	1997	N/A	Guide
				Pests and beneficials in brassica crops	1997	N/A	Guide
				Brassica problem solver and beneficial identifier	2004	Web	Guide
				Implementing pest management of Diamondback Moth	2004	Web	Research report
		Weeds	Chemical	Weed management in Brassicas - Improving postharvest quality	2002	Web	Research report
			Cultural				
			Crop Management / Productivity	Controlling weeds in broccoli, cauliflower, and Brussels sprouts: a guide to effective weed control in Australian brassicas	2011	Web	Guide
				Managing weeds in broccoli, cauliflower and cabbage	2008	Web	Web page
				Control of Amaranthus in green bean and summer brassica crops in Tasmania	1996	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				

BROCCOLI	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management/ Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management/ Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Best practice production models (brassicas)	2010	Web	Research report
				Developing sustainable solutions for integrated brassica crop management	2010	Web	Research report
				Integrated pest management 'research to practice' for brassicas	2004	Web	Research report
				Brassica Best Practice – Integrated Pest Management Guide / Ute Guide	2010	Web	Guide
				Brassica integrated pest & disease management	2003	Web	Factsheet
				IPM for Brassica	2002	N/A	CD
				Brassica grower's handbook	2004	Web	Guide
				Integrated pest management for brassicas	2002	N/A	Video
				Field guide to pests, diseases and disorders of vegetable brassicas	2000	Web	Guide
Biosecurity							
Market Access							
Business Improvement							

Topic Summary			%
Field	Diseases	29	49
	Insects	17	29
	Weeds	4	7
Post-harvest		0	0
Protected		0	0
Integrated		9	15
Biosecurity		0	0
Market Access		0	0
Business Improvement		0	0
Total		59	97

Currency Summary		%
1996 - 2001	9	15
2002 - 2007	30	51
2008 - 2013	20	34
Total	59	100

Resource Type Summary		%
Poster	2	3
Presentation	2	3
CD/Video	2	3
Webpage	2	3
Guide	8	14
Fact sheet	10	17
Research report	33	56
Total	59	100

Main Issues Investigated	Host range
White blister	Brassicas
Sclerotinia	Most vegetable crops
Rhizoctonia	Many vegetable crops including leafy vegetables, brassicas, carrots, beetroot, cucurbits, eggplant, tomato, coriander, spring onions beans
Head rot/black rot	Wide range of vegetables including lettuce, brassicas, cucurbits, tomato, capsicum, potato, sweet potato, carrots, herbs
Clubroot	Brassicas
Stem canker	Brassicas
Downy mildew	Wide host range including onions (peas, lettuce, celery, spinach, kale, herbs, cucurbits, brassicas, asian leafy brassicas)
Diamondback Moth	Brassicas

CAPSICUM	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	**Field**	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity	Understanding the causes of sudden wilt of capsicum	2003	Web	Research report
				Control of sudden wilt in capsicum	2005	Web	Research report
				Development of guidelines for sustainable management of powdery mildew in capsicums	2007	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Genetics	Investigation of capsicum genetic resistance to tomato spotted wilt virus, tospovirus serotype IV and bacterial spot	2001	Web	Research report
			Integrated Control	Bacterial spot of capsicum: What to expect from resistant varieties	2007	Not available	Web page
				IPM strategy to reduce TSWV in the dry tropics	2002	Web	Research report
				Tobamoviruses - tobacco mosaic virus, tomato mosaic virus and pepper mild mottle virus - Integrated virus disease management	2010	Web	Fact sheet (English, Vietnamese and Khmer)
				Capsicum virus diseases	2005	Web	Fact sheet
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity	Pest management in north queensland vegetables	2000	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Biological control	Feasibility of mating disruption for heliothis species in tomatoes and capsicums	2004	Web	Research report
				Rearing Orius for vegetable industry	2012	Web	Research report
			Varietal Improvement				
			Integrated Control	Development and implementation of integrated pest management systems in eggplant and capsicum	2005	Web	Research report
				Heliothis and fruit fly integrated pest management strategies for tomato, vegetable and melon crops	2004	Web	Research report
				Increasing adoption of IPM by WA vegetable growers and development of an ongoing technical support service	2011	Web	Research report
		Weeds	Chemical	Weed management in capsicums and chillis	2004	Web	Research report
				Evaluation of new herbicides for capsicums and chillies	2006	Web	Research report and presentation
			Cultural				
			Crop Management / Productivity				
			Business Improvement				

CAPSICUM	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Integrated management of greenhouse cucumber and capsicum diseases	2004	Web	Research report
				Sustainable integrated control of foliar diseases in greenhouse vegetables	2010	Web	Research report
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				

CAPSICUM	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Pests and diseases of capsicum and chilli (QLD)	2011	Web	Web page
				Capsicum (peppers) and chillies (VIC)	2009	Web	Web page
				Capsicum and chilli information kit	1999	Web	Guide
Biosecurity							
Market Access				Fruit fly disinfestation of cucurbits and capsicums with insecticides for New Zealand	1997	Web	Research report
				Heat disinfestation of capsicums for export to New Zealand and interstate	2009	Web	Research report
Business Improvement							

Topic Summary			%
Field	Diseases	8	35
	Insects	6	26
	Weeds	2	9
Post-harvest		0	0
Protected		2	9
Integrated		3	13
Biosecurity		0	0
Market Access		2	9
Business Improvement		0	0
Total		**23**	**100**

Currency Summary		%
1996 - 2001	4	17
2002 - 2007	12	52
2008 - 2013	7	30
Total	**23**	**100**

Resource Type Summary		%
Poster	0	0
Presentation	1	4
CD/Video	0	0
Webpage	3	13
Guide	1	4
Fact sheet	2	9
Research report	16	70
Total	**23**	**100**

Main issues investigated	Host Range
WFT	Eggplant, tomato, beans, peas, lettuce, celery, potato, parsley, beet, spinach, choy sum, bitter melon
Heliothis	Beans, peas, lettuce, brassicas, greenhouse vegetables (wide host range)
Fruit fly	Wiude range of fruit and vegetables
Bacterial spot	Beet, spring onions, leeks, rocket, coriander
Bacterial wilt	Potato, tomato, eggplant
Powdery mildew	Wide host range and very common
Tomato Spotted Wilt Virus (TSWV)	Tomato, eggplant, lettuce, celery, peas, potatoes, sweet basil
Capsicum chlorosis virus (CCV)	Tomato, chillies
Tobamoviruses (TMV, ToMV and PMMV)	Eggplant, tomato, bok choy, choy sum, bitter melon, chinese mustard, long melon, snake bean, chinese cabbage, chillies

CARROTS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	Field	Diseases	Chemical	The addition of root and hydroponic vegetables to the Belt (flubendiamide label) for the control of Lepidoptera sp.	2011	Web	Research report
			Cultural				
			Crop Management / Productivity	An investigation of carrot diseases in north-western Tasmania and their control	2001	Web	Research report
				Cavity spot disease of carrots	2007	N/A	Fact sheet
				Management of carrot diseases	2004	N/A	Fact sheet
				Managing alternaria blight in carrots	2004	N/A	Research report
				Powdery mildew - a new disease of carrots	2009	N/A	Fact sheet
				Carrot diseases and other factors affecting carrot packout	N/A	Web	Poster
				Carrot Virus Y	2003	Web	Fact sheet
				Leaf blight diseases of carrots	2005	Web	Fact sheet
			Business Improvement				
			Biological				
			Environment				
			Genetics	Carrot variety screening for cavity spot tolerance	2005	Web	Web page
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity	Improved control of nematodes in carrot production	2004	Web	Research report
				Nematode control in carrots	2005	N/A	Fact sheet
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity	Weed management in carrots	2005	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	Diseases	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				

			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Biosecurity				A national industry pest specific incursion management plan (PSIMP) for carrot rust fly (Psila Rosae)	2009	Web	Research report
				Carrot rust fly Psila rosae: exotic threat to Western Austra	2001	Web	Fact sheet
				Carrot weevil Listronotus oregonensis and L. texanus: exotic threat to Western Australia	2001	Web	Fact sheet
				Pest specific incursion management plan and pest risk asssessment for carrot cyst nematode	2008	Web	Research report
Market Access							
Business Improvement							

Topic Summary			%
Field	Diseases	10	59
	Insects	2	12
	Weeds	1	6
Post-harvest		0	0
Protected		0	0
Integrated		0	0
Biosecurity		4	24
Market Access		0	0
Business Improvement		0	0
Total		**17**	**100**

Currency Summary		%
1996 - 2001	3	18
2002 - 2007	9	53
2008 - 2013	5	29
Total	**17**	**100**

Resource Type Summary		%
Poster	1	6
Webpage	1	6
Guide	0	0
Fact sheet	8	47
Research report	7	41
Total	**17**	**100**

Main Issues Investigated	Host range
Cavity spot	Carrots
Powdery mildew	Wide host range and very common, especially in greenhouse crops, cucumber, melons, pumpkin, zucchini, parsnip, beetroot, potato, herbs, peas, bitter melon, tomato, capsicum, Brussels sprouts, cabbage and swedes.
Carrot virus Y	Carrots
Leaf blight	Carrots
Downy mildew	Wide host range including onions (peas, lettuce, celery, spinach, kale, herbs, cucurbits, brassicas, asian leafy brassicas)
Root-knot nematode	Carrots, potatoes, beetroot, sweet potato, parsnip, tomatoes, eggplant, capsicum, celery, peas, beans, onions, spinach, herbs, cucumber, Brussels sprouts, radish
Carrot rust fly	Carrots
Carrot cyst nematode	Carrots

CELERY	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	**Field**	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity	Evaluation of a disease forecasting model to manage late blight (septoria) in celery	2006	Web	Research report
				Validation of a disease forecasting model to manage light blight (septoria) in celery	2008	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Genetics				
			Integrated Control	Management of celery mosaic virus	2002	Web	Research report
				Extension of an integrated management strategy for celery mosaic virus in celery crops in western australia	2003	Web	Research report
				Celery mosaic virus	2006	Web	Fact sheet
				Celery mosaic virus	2000	Web	Web page
		Insects	Chemical	The addition of celery to the Movento (spirotetramat) label for the control of aphids and thrips	*2011*	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Biological control	Development of cultural control methods for pests of leafy vegetables	2008	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Development of an integrated pest management program in celery	2004	Web	Research report
				Integrated pest management in celery	2004	Web	Fact sheet
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				

CELERY	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				

CELERY	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Biosecurity							
Market Access							
Business Improvement							

Topic Summary			**%**
Field	Diseases	6	60
	Insects	4	40
	Weeds	0	0
Post-harvest		0	0
Protected		0	0
Integrated		0	0
Biosecurity		0	0
Market Access		0	0
Business Improvement		0	0
Total		**10**	**100**

Currency Summary		**%**
1996 - 2001	1	10
2002 - 2007	6	60
2008 - 2013	3	30
Total	**10**	**100**

Resource Type Summary		**%**
Poster	0	0
Presentation	0	0
CD/Video	0	0
Webpage	1	10
Guide	0	0
Fact sheet	2	20
Research report	7	70
Total	**10**	**100**

Main issues investigated	**Host range**
Septoria	
CMV	Coriander, celery, parsley, parsnip

LETTUCE	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Issue Specific	**Field**	**Diseases**	Chemical	Control of lettuce downy mildew	1996	Web	Research report
				New fungicides and strategies for sustainable management of sclerotinia and rhizoctonia diseases on vegetable crops	2012	Web	Research report
				Reduced pesticide use on lettuce	1996	Web	Research report
			Cultural				
			Crop Management / Productivity	Effective management of root diseases in hydroponic lettuce	2008	Web	Research report
				Scoping study on the management of varnish spot in field and hydroponic lettuce	2005	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Biological control	Development of biological controls for sclerotinia diseases of horticultural crops in Australia	2004	Web	Research report
			Genetics	Cause and control of new lettuce diseases	1997	Web	Research report
			Integrated Control	Common diseases of lettuce	2006	Web	Poster
				Best practice - Sclerotinia in lettuce	2009	Web	Guide
				Developing a strategy to control Anthracnose in lettuce	2011	Web	Research report
				Improvement in lettuce quality by reduction in losses due to soil borne diseases	2004	Web	Research report
		Insects	Chemical	Improving lettuce insect pest management - Victoria	*2005*	Web	Research report
				Insecticide resistance detection and management in currant lettuce aphid	2010	Web	Research report
				Generation of efficacy and residue data for Imidacloprid (Confidor) in lettuce to control lettuce aphid	2007	Web	Research report
			Cultural				
			Crop Management / Productivity	Development of cultural control methods for pests of leafy vegetables	2008	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Corn earworm control in lettuce	2005		Guide
				Investigation of vectors and alternate hosts of tomato spotted wilt virus (TSWV) in lettuce crops	1996	Web	Research report
				Western flower thrips (WFT) insecticide resistance management plan	2007	Web	Guide
				Thrips and Tospovirus: a mangement guide	2007	Web	Guide
				Western Flower Thrips	2004	Web	Factsheet
				Lettuce IPM	2003	Web	Factsheet
				Integrated pest management in lettuce: information guide	2002	Hardcopy	Guide
				Further developing IPM for lettuce	2008	Web	Research report
				Integrating lettuce aphid into integrated pest management strategies	2006	Web	Research report
				Providing an IPM advisory service for Tasmania	2008	Web	Research report
				The delivery of IPM for the lettuce industry - an extension to VG05044	2012	Web	Research report

LETTUCE	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
		Weeds	Chemical	Weed management in lettuce	2005	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical	The addition of root and hydroponic vegetables to the Belt (flubendiamide) label for the control of Lepidoptera sp.	2011	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Development of IPM strategies and tools for Western Flower Thrips (Frankliniella occidentalis) in hydroponic lettuce	2011	Web	Research report
				Extension to greenhouse IPM program	2007	Web	Research report
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity	A study of post harvest bacterial rots and browning in lettuce and the development of control methods	2002		Research report
			Business Improvement				

LETTUCE	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Pests, beneficials, diseases and disorders in lettuce: field identification guide	2003	Hardcopy	Guide
				Lettuce Leaf newsletter	2002-2010	Web	Newsletter
				Lettuce Ute Guide	2010		Guide
				Pests and diseases of lettuce		Web	Website
				Growing Lettuce	2009	Web	Website
				Adapting to Change: Enhancing skills through collaboratively developing an integrated pest management strategy for lettuce	2002	Web	Research report
				Best practice production models (lettuce)	2010	Web	Research report
				Improving lettuce insect pest management - NSW and QLD	2006	Web	Research report
Biosecurity							
Market Access				Lettuce - Best management production practice to meet the market requirements of consistent product quality and shelf life	2002	Web	Research Report
				Reducing listeria contamination from salad vegetable farms	2010	Web	Research report
Business							

Topic Summary			**%**
Field	Diseases	11	27
	Insects	15	37
	Weeds	1	2
Post-harvest		1	2
Protected		3	7
Integrated		8	20
Biosecurity		0	0
Market access		2	5
Business Improvement		0	0
Total		**41**	**100**

Currency Summary		**%**
1996 - 2001	4	10
2002 - 2007	20	49
2008 - 2013	17	41
Total	**41**	**100**

Resource Type Summary		**%**
Poster	1	2
Newsletter	1	2
Book	0	0
Webpage	2	5
Guide	7	17
Fact sheet	2	5
Research report	28	68
Total	**41**	**100**

Main Issues Investigated	**Host range**
Downy mildew	Wide host range including onions (peas, lettuce, celery, spinach, kale, herbs, cucurbits, brassicas, asian leafy brassicas)
Sclerotinia	Most vegetable crops
Rhizoctonia	Many vegetable crops including leafy vegetables, brassicas, carrots, beetroot, cucurbits, eggplant, tomato, coriander, spring onions beans
Anthracnose	Wide range of crops including lettuce, celery, cucurbits, tomato, capsicum, potato and globe artichoke
Varnish spot	Lettuce
Powdery mildew	Wide host range and very common, especially in greenhouse crops, cucumber, melons, pumpkin, zucchini, parsnip, beetroot, potato, herbs, peas, bitter melon, tomato, capsicum, Brussels sprouts, cabbage and swedes
Currant lettuce aphid	Lettuce, endive, radicchio and chicory
Corn earworm (Heliothis)	Sweet corn, beans, peas, lettuce, brassicas, greenhouse vegetables (wide host range)
Western flower thrip	Capsicum, eggplant, tomato, beans, peas, lettuce, celery, potato, parsley, beet, spinach, choy sum, bitter melon
Tomato spotted wilt virus	Tomato, eggplant, lettuce, celery, peas, potatoes, sweet basil

PUMPKINS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	Field	Diseases	Chemical				
			Cultural				
			Crop Management / Productivity	Developing and communicating strategies for controlling virus	2012	N/A	Research report
				Diseases of cucurbit vegetables	2009	N/A	Fact sheet
				Etch resistance development in butternut pumpkins	1998	Web	Research report
				Gummy stem blight of rockmelons and other cucurbits	1997	Web	Research report
				Scoping study on the importance of virus diseases in australian vegetable cucurbit crops	2005	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Genetics				
			Integrated Control	Virus diseases of cucurbit crops	2006	Web	Fact sheet
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity	Common insect pests of cucurbits	2003	Web	Fact sheet
				Determining the level of resistance to silverleaf whitefly in cucurbits	2009	Web	Research report
				Insect pests of cucurbit vegetables	2009	Web	Fact sheet
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical	Weed management in pumpkin and other cucurbit crops	2001	Web	Research report
			Cultural				
			Crop Management / Productivity	An investigation into improved methods of weed control in kabocha and pumpkins	1997	Web	Research report
				Scoping study for sustainable broadleaf weed control in cucurbit crops	2011	Web	Research report
			Business Improvement				
			Biological				

PUMPKINS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				

PUMPKINS	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity	Pests, beneficials, disorders and diseases in cucurbits: field identification guide	2009	Web	Research report and User Guide
				Pests and diseases of cucurbits	2011	Web	Web page
				Growing pumpkins	2011	Web	Web page
				Management of powdery mildew in field and greenhouse cucurbits	2009	Web	Research report
				Protect your cucurbits	1994	N/A	Guide
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Biosecurity							
Market Access							
Business Improvement							

Topic Summary			**%**
Field	Diseases	6	35
	Insects	3	18
	Weeds	3	18
Post-harvest		0	0
Protected		0	0
Integrated		5	29
Biosecurity		0	0
Market Access		0	0
Business Improvement		0	0
Total		**17**	**100**

Currency Summary		**%**
1996 - 2001	5	29
2002 - 2007	3	18
2008 - 2013	9	53
Total	**17**	**100**

Resource Type Summary		**%**
Webpage	2	12
Guide	2	12
Fact sheet	4	24
Research report	9	53
Total	**17**	**100**

Main Issues Investigated	**Host range**
Powdery mildew	Wide host range and very common, especially in greenhouse crops, cucumber, melons, pumpkin, zucchini, parsnip, beetroot, potato, herbs, peas, bitter melon, tomato, capsicum, Brussels sprouts, cabbage and swedes.
Silverleaf whitefly	Cucurbits, capsicum, tomato, eggplant, brassicas, lettuce, sweet potato, beans, beets

SWEET CORN	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
Crop	**Field**	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity	Fusarium cob rot management in sweetcorn	2004	Web	Research report
			Business Improvement				
			Biological				
			Environment				
			Genetics				
			Integrated Control	Managing northern corn leaf blight in processing sweet corn	2006	Web	Research report
		Insects	Chemical	Pest management in north queensland vegetables	*2000*	Web	Research report
				The generation of chlorantraniliprole residue data in beans, peas and sweet corn	2010	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Insect pest management in sweet corn (Heliothis)	2003	Web and hardcopy	Research report and CD
				Integrated pest management in sweet corn (NSW)	1997 - 2001	Web	Web page
				Sweet corn integrated pest management (IPM)	2003	Web	Fact sheet
				Sweet corn pests and their natural enemies: an IPM field guide	2000	Hardcopy	Guide
				Sweet corn problem solver and beneficial identifier (sweet corn information kit)	2004	Web and hardcopy	Guide
		Weeds	Chemical	Weed management in sweet corn	2001	Web	Research report
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Protected	**Diseases**	Chemical				

SWEET CORN	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
		Weeds	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
	Post-harvest	**Diseases**	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				

SWEET CORN	Production Environment	Issue	Driver	R&D Output	Uptake of Information		
					Currency	Availability	Final Communication Product
			Integrated Control				
		Insects	Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control				
Integrated Crop Protection			Chemical				
			Cultural				
			Crop Management / Productivity				
			Business Improvement				
			Biological				
			Environment				
			Varietal Improvement				
			Integrated Control	Improved IPM systems in the Australian sweet corn industry	2009	Web	Research report
				Sweet corn production (VIC)	2009	Web	Web page
				Sweet corn (QLD)	2013	Web	Web page
				Sweet corn grower's handbook (sweet corn information kit)	2005	Web and hardcopy	Guide
				Commodity growing guides - sweet corn (NSW)	2007	Web	Web page
Biosecurity							
Market Access							
Business Improvement							

Topic Summary			**%**
Field	Diseases	2	13
	Insects	7	47
	Weeds	1	7
Post-harvest		0	0
Protected		0	0
Integrated		5	33
Biosecurity		0	0
Market Access		0	0
Business Improvement		0	0
Total		**15**	**100**

Currency Summary		**%**
1996 - 2001	4	27
2002 - 2007	7	47
2008 - 2013	4	27
Total	**15**	**100**

Resource Type Summary		**%**
Poster	0	0
Webpage	4	27
Guide	3	20
Fact sheet	1	7
Research report	6	40
CD	1	7
Total	**15**	**100**

Main issues investigated	**Host range**
Fusarium	Brassicas, carrots, cucurbits, onions, potato, tomato, herbs, peas, beans (wide host range)
Northern corn leaf blight	Sweet corn
Heliothis	Beans, peas, lettuce, brassicas, greenhouse vegetables (wide host range)

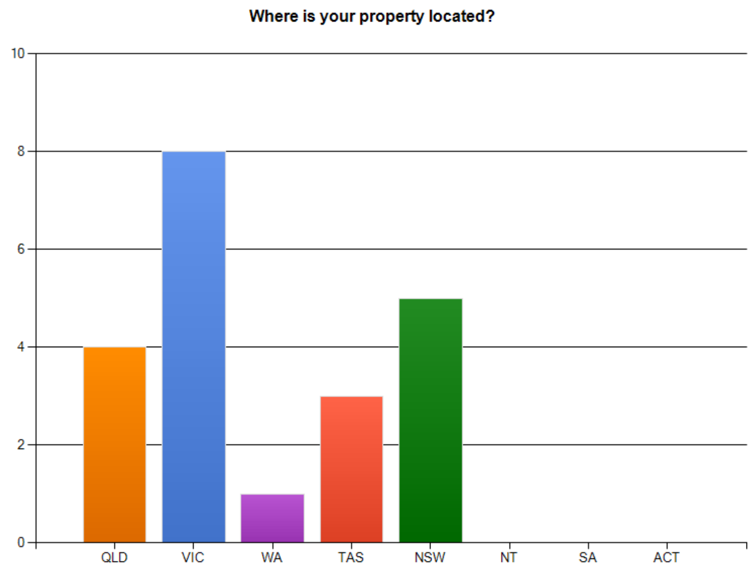
Appendix 3: Crop Protection and Plant Health Surveys

1 On-line Survey – Vegetable Producers

A total of 21 vegetable producers responded to the crop health survey available on-line. A summary of the responses to each question is provided below.

- **Where is your property located?**

The majority of respondents are located within the eastern states of Australia.



- **What is the current size of your property (ha)?**

Property size of respondents ranged from 2 through to 500 hectares.

- **What is your annual area (ha) of vegetable production?**

Annual cropping area ranged from 0.5 through to 500 hectares.

- **What are the main vegetable crops you produce?**

Crops grown by producers were representative all of the major vegetable commodity groups including:

- Brassicas
- Leafy vegetables
- Root and tuber vegetables
- Cucurbit vegetables
- Greenhouse and solanaceous vegetables.

- **What are the major weed, pest and disease issues on your property? Why?**

  The major issues cited by vegetable producers, and the reasons for these issues, are summarised in the table below:

Weed	Pest	Disease	Reason
Nightshade	Mites (including broad mite, russet mite, two-spotted mite)*	Soilborne diseases (including sclerotinia and rhizoctonia)	* Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.
Nettle	White fly	Powdery mildew	
Pigweed	Thrips (western flower thrip)	Bacterial leaf spot*	* Introduced through planting material and/or endemic to susceptible crops and favourable conditions.
Grasses	Aphids (currant lettuce aphid)*	White blister	* Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.
Wild radish	Diamondback moth	Anthracnose*	* Introduced through planting material and/or endemic to susceptible crops and favourable conditions.
Fat hen	Heliothis*	Downy mildew	* Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.
Amaranthus	Soldier beetles*	Leaf blight (stemphylium)	* Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.
Shepherd's purse	Vegetable weevil*	Damping-off (including fusarium and phytophthora)	* Pest has rapid life-cycle or customers have zero tolerance for foreign insect bodies in product.
Double gee	Fruit fly	Late blight	
Charlock/wild mustard*	Caterpillars	Target spot	*Currently registered herbicides do not provide control.
Thistle*	Vertebrates (such as rabbits and ducks)		*Currently registered herbicides do not provide control.
Fumitory*			*Currently registered herbicides do not provide control.
Cape weed*			*Currently registered herbicides do not provide control.
Nut grass			

- **How do you manage these issues? How do you decide which control methods to use?**

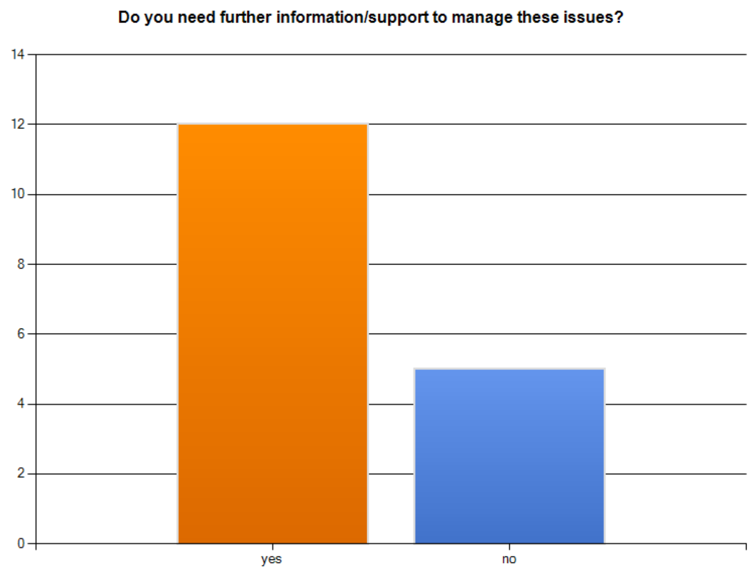
  Vegetable producers utilise a range of control options for managing these pests as discussed in the table below:

Chemical	Cultural	Integrated
Use of currently registered herbicides, insecticides and fungicides	Good hygiene	Selection of resistant cultivars
	Hand weeding	Appropriate rotations
	Fallow periods	Targeted use of 'soft' chemistry
		Use of biological predators

- **Do you need further information/support to manage these issues?**

  The majority of respondents (75%) indicated that they would like further support to manage issues. This included:

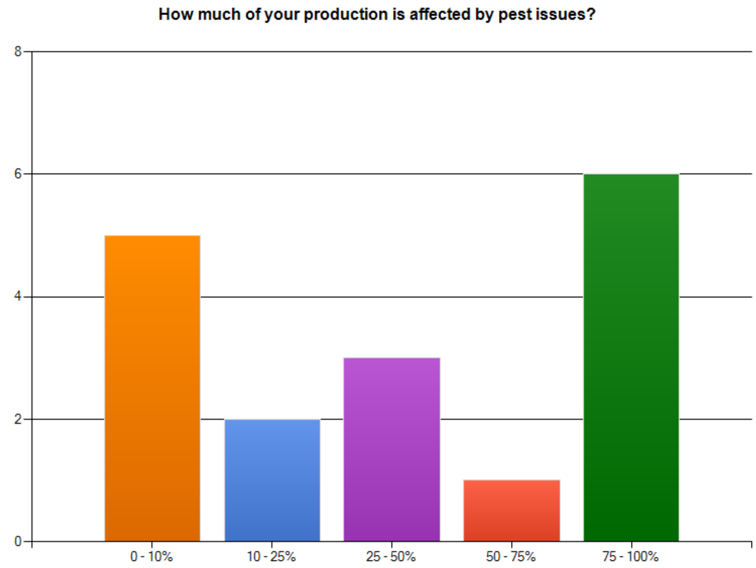
  - Widening the range of chemical products available to manage crop health issues through:
    - Registration of products available in the US and/or Europe but not currently in Australia
    - A more responsive minor use permit scheme
  - Development of more resistant plant varieties
  - Further R&D into alternative control measures.



- **How much of your production is affected by pest issues?**

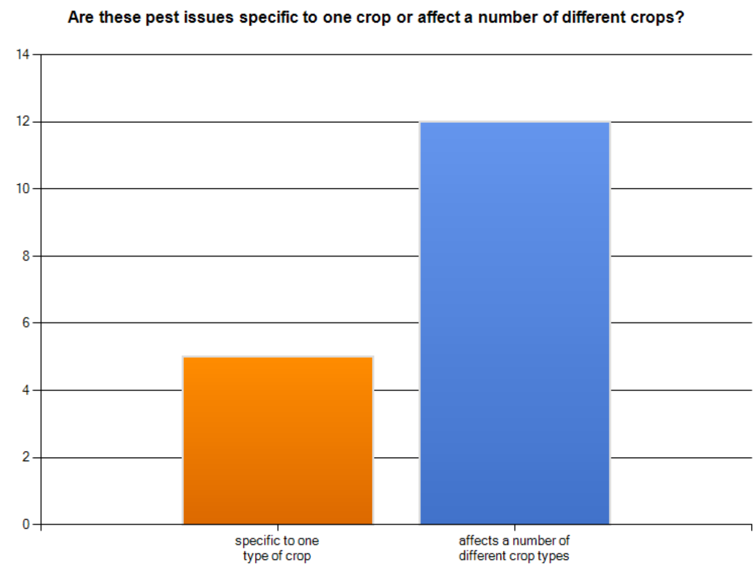
  The percentage of production affected by pest issues was cited to vary according to the seasonal conditions and pest pressure in the local area. A number of producers commented that if they did not commit considerable resources to managing crop health issues, the level of production affected would be considerably higher.

"This would be considerably higher if it were not for proactive strategies in management".



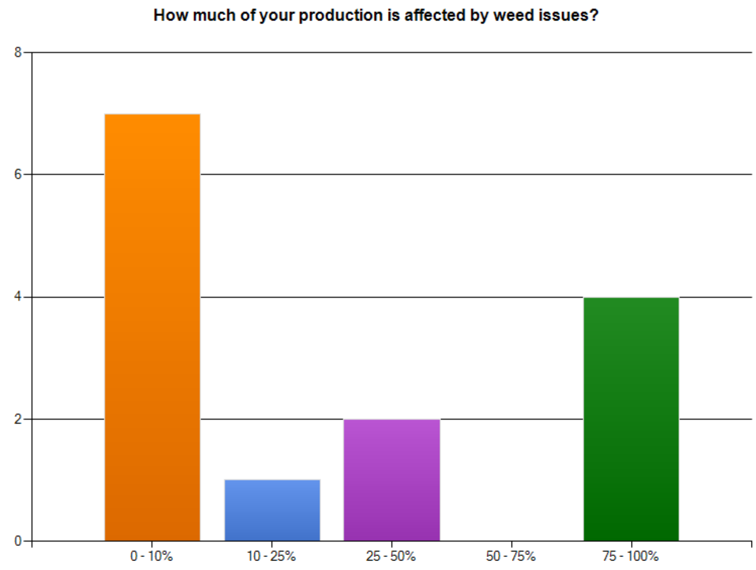
- **Are these pest issues specific to one crop of affect a number of different crops?**

  The majority of pests issues cited (73%) were common to a number of different vegetable crops.



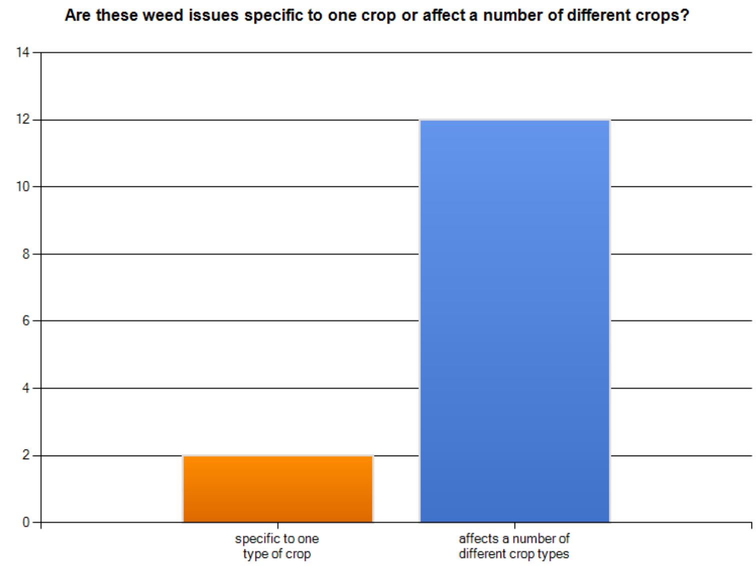
- **How much of your production is affected by weed issues?**

  Some producers felt that weeds could be effectively managed by application of pre-emergent herbicides, hence a smaller percentage of production is affected. However there was concern about the use of non-registered products and the use of products in Australia, which are no longer used in the USA and EU. The use of these products has the potential for a 'bad news story' that may impact negatively on Australian horticulture.



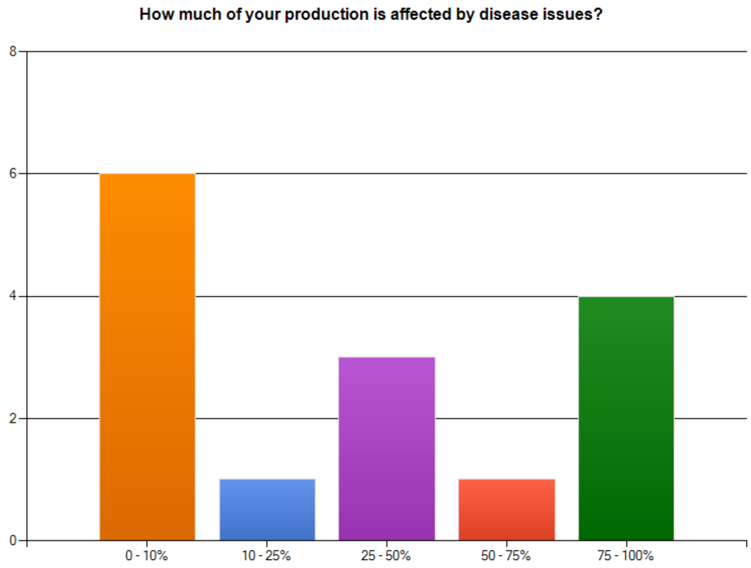
- **Are these weed issues specific to one crop of affect a number of different crops?**

  The majority of weed issues discussed (85%) are common to a range of different vegetable crops.



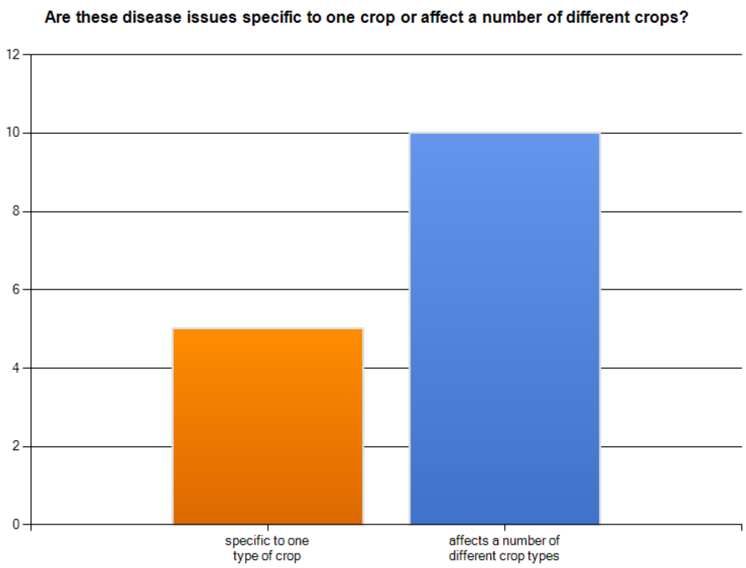
- **How much of your production is affected by disease issues?**

  The diseases causing greatest concern to vegetable producers were cited as soilborne diseases, white blister in broccoli (due to blemishes on the head), pythium and stemphyllium leaf spot in spinach and potentially anthracnose in lettuce.



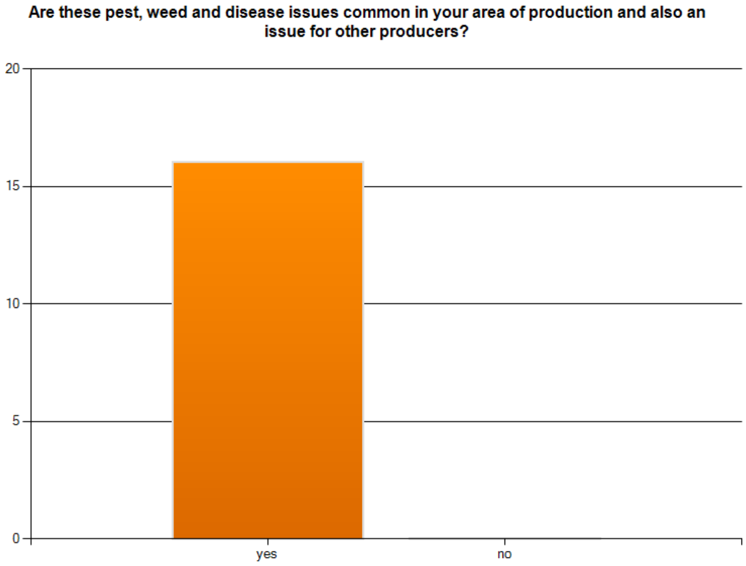
- **Are these disease issues specific to one crop of affect a number of different crops?**

  The majority of disease issues (64%) were cited as being common to a number of different vegetable crops.



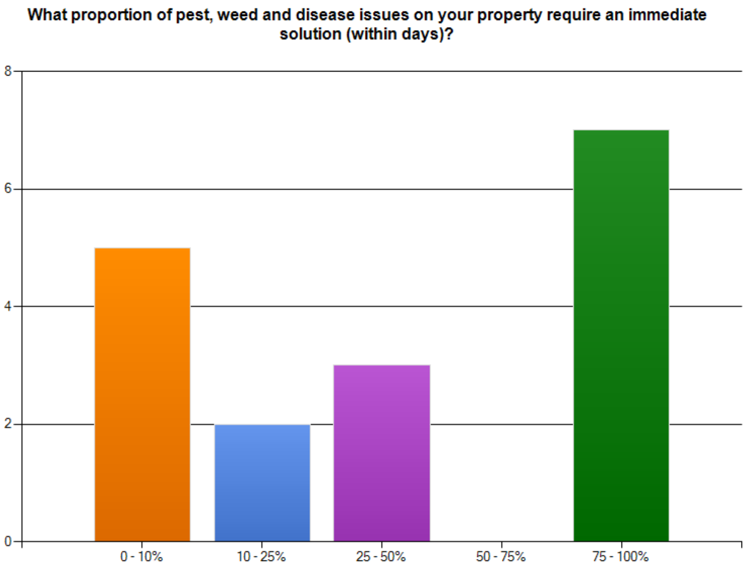
- **Are these pest, weed and disease issues common in your area of production and also an issue for other producers?**

  These crop health issues were cited as being a problem for all producers in the local area of production.



- **What proportion of pest, weed and disease issues on your property require an immediate solution (within days)?**

  44% of respondents felt that 75 – 100% of their crop health issues required an immediate response due to the rapid multiplication rate of pests, which if not controlled quickly can result in major crop damage.

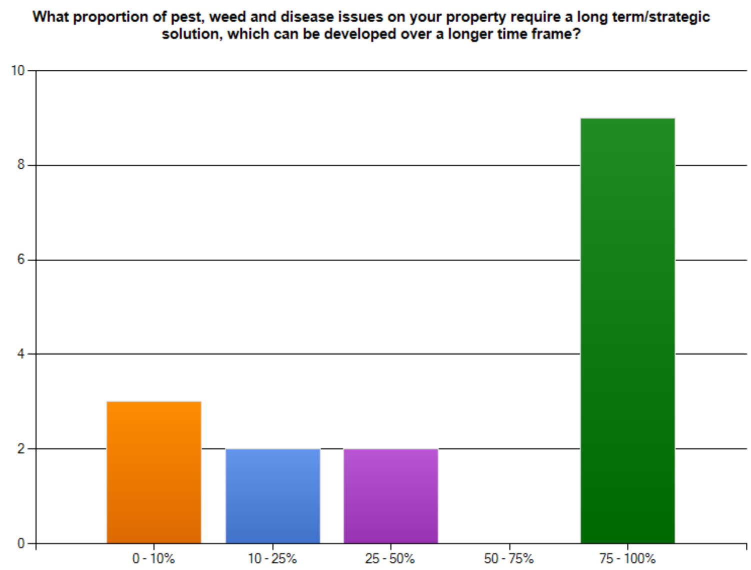


- **What proportion of pest, weed and disease issues on your property require a long term/strategic solution, which can be developed over a longer time period?**

  60% of respondents believed that 75 – 100% of their crop health issues required a long term/strategic solution. Comments included:

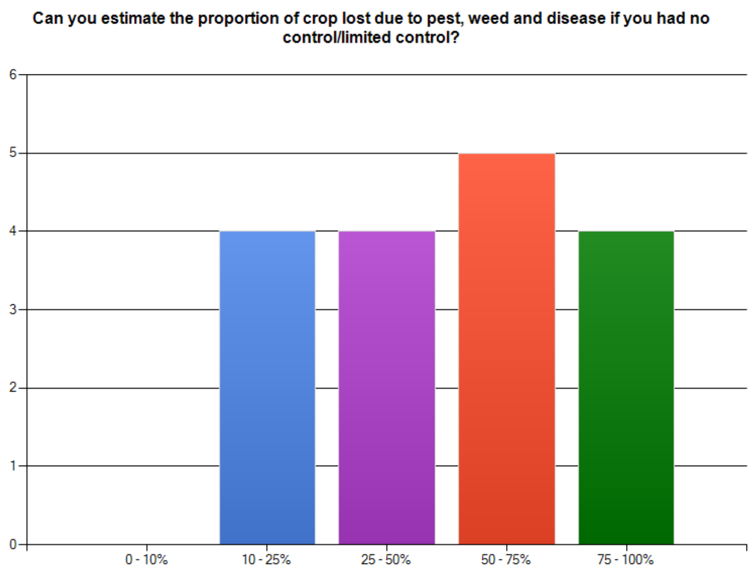
  "An immediate solution is the highest priority but ultimately long term solutions need to be sought so that constant chemical applications can be reduced or avoided."

"Pests and diseases evolve/mutate to become resistant to available controls. The best examples are Downy mildews in Spinach and Lettuce. Breeders are working constantly to stay ahead, spinach is now up to Race 14 resistant varieties in the EU and there are almost annual varietal changes as a result".



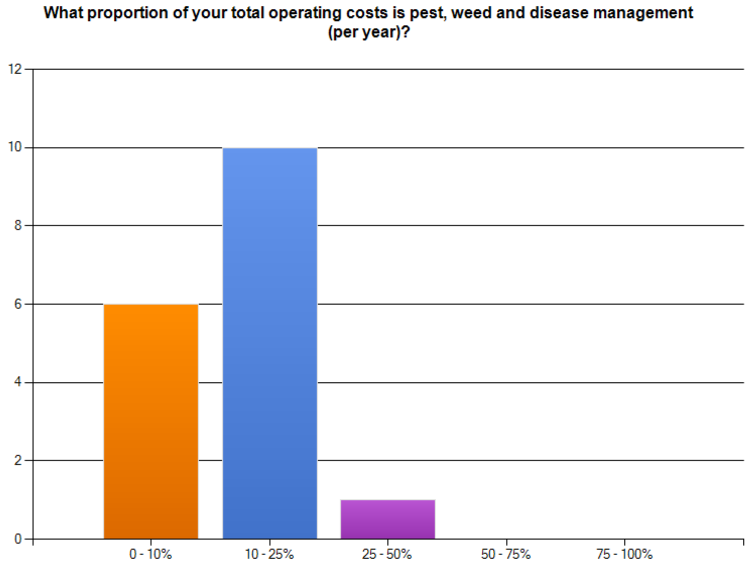
- **Can you estimate the proportion of crop lost due to pest, weed and disease if you had no control/limited control?**

Producers commented that preventative and curative measures are routine since customers have zero tolerance of defects in product appearance. However if no control was available then 100% crop loss is possible in years when pest pressure is high.



- **What proportion of you total operating costs is pest, weed and disease management (per year)?**

  Despite the potential impact of pests on vegetable crops, the cost of control in comparison to other operating costs remains relatively low.



- **How important is good pest, weed and disease control compared to other crop management issues?**

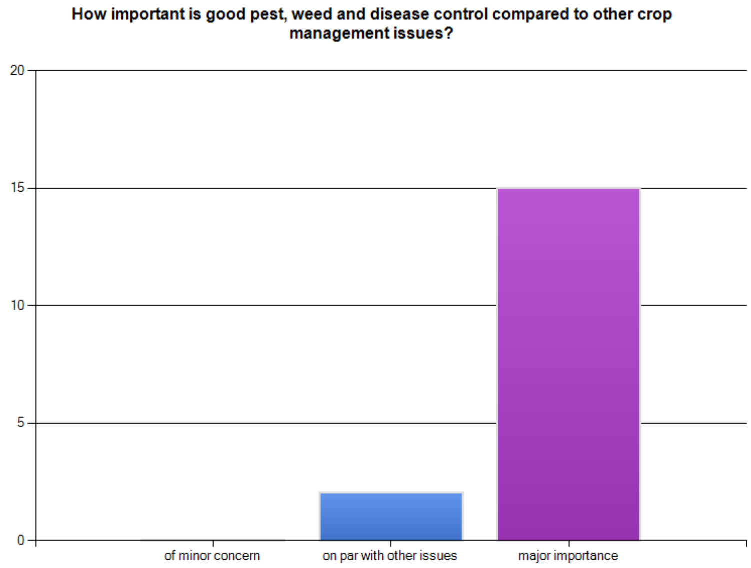
  88% of vegetable producers felt that effective management of crop health issues was of major importance to their business. Comments included:

  "Managing this risk is the key to making money."

  "We are suppliers to the retail sector - crop appearance is paramount as is food safety (being primarily spray residues and micro status). All three are dramatically impacted by pest, disease and weed issues".

  "Profit margins are so slim that any yield or quality compromise is unsustainable."

  "A nutrition issue can potentially be corrected during the life of the crop. An irrigation scheduling issue can impact growth/yield and quality but may not result in market failure. A pest, weed or disease that is not managed can result in complete crop loss/rejection (market failure)."



- **What are the emerging and/or pest, weed and disease risks for the vegetable industry?**

  A number of vegetable producers felt that managing current crop health issues was still their primary concern however increasing resistance to chemical products and the introduction of new disease vectors were cited as the major future crop health risks.

- **What do you need to best deal with these new challenges? Why?**

  Vegetable producers felt that the following was required in order to best manage these new challenges:

  - Good biosecurity
  - An increased range of chemical products (that are environmentally safe and suited to a variety of cropping environments)
  - Alternative (non-chemical) control options
  - Further R&D into prevention, IPM technologies and strategies, and understanding what is happening internationally with similar crop types and production areas.

- **When you think about developments in weed, pest and disease management technology over the last 10 years, what new practices or approaches have been the most important for you?**

  The new practices and approaches that were cited as being the most beneficial included:

  - Development of ‘softer’ and more targeted chemistries for management of crop health issues
  - The introduction of an Integrated Pest Management (IPM) approach.

- **How did you first hear about these new practices or approaches?**

  There was a wide variety of ways in which vegetable producers first became aware of these new practices. These included international travel, the Internet, peers, service providers (such as agronomists, consultants, agchem representatives) and industry/commercial advertising.

- **What made you start using the new approach/technology? How long did it take you to get it right?**

  Vegetable producers cited the following as reasons for starting to use IPM. These included:

  - OH&S issues/health concerns *"I am knowledgeable in regard to chemicals and therefore concerned with my health and that of my workers."*
  - Environmental concerns *"Don't want poisoned food, soil or water."*
  - Regulatory *"MRLs being regularly checked by both EPA and Chain Stores."*
  - Lack of effective chemical control *"The realisation that broad spectrum chemical controls were not effective".*

  There was general consensus that the implementation of a new approach is an on-going process.

- **What are the new developments/R&D projects in pest, weed and disease management that interest you today?**

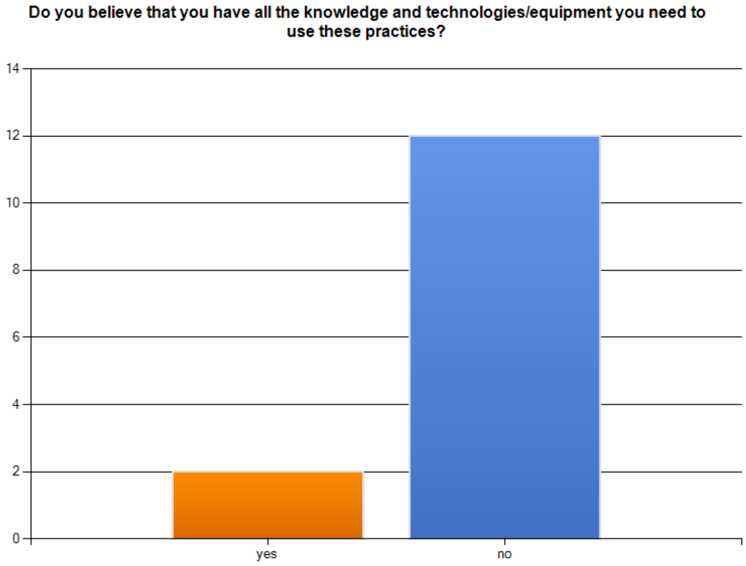
  - Use of biological control measures
  - New varieties
  - Softer chemistry
  - Gene manipulation
  - Export ready protocols and systems approach.

- **Do you believe that you have all the knowledge and technologies/equipment you need to use these practices?**

  The majority of respondents (92%) felt that they did not have all the knowledge and technologies/equipment required to use these practices. Producers commented that they required:

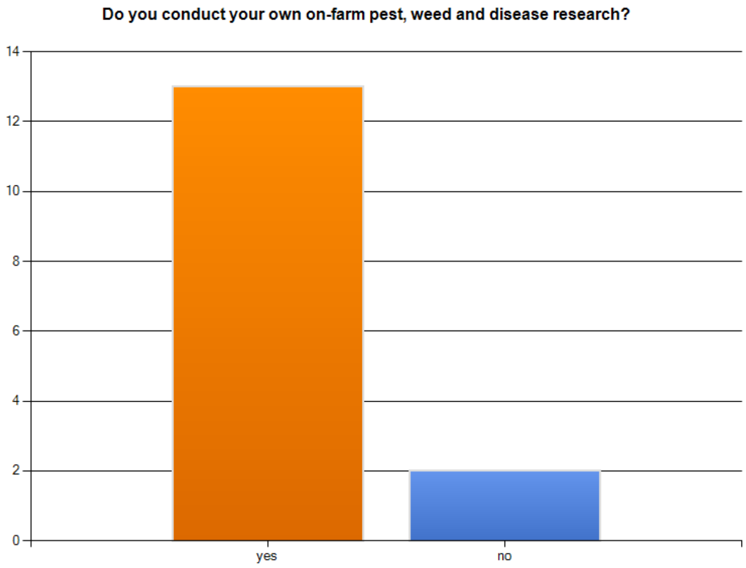
  "Better access to technology and better explanation of new technologies as they become commercially available. Particularly in year before full commercialisation so you can look at equipment purchase".

  "R&D and a regulatory process that facilitates responsible chemical use i.e. new ai's with lower health and environmental impact".



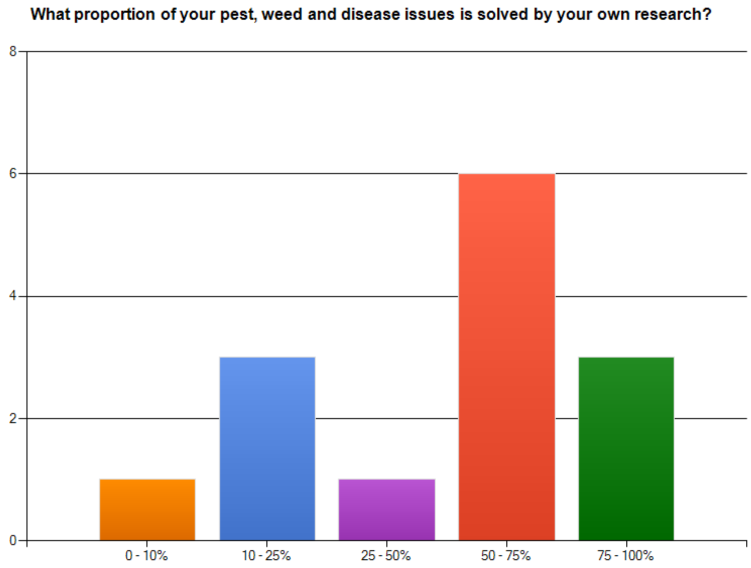
- **Do you conduct your own on-farm pest, weed and disease research?**

  92% of respondents said they conduct their own on-farm crop health research.



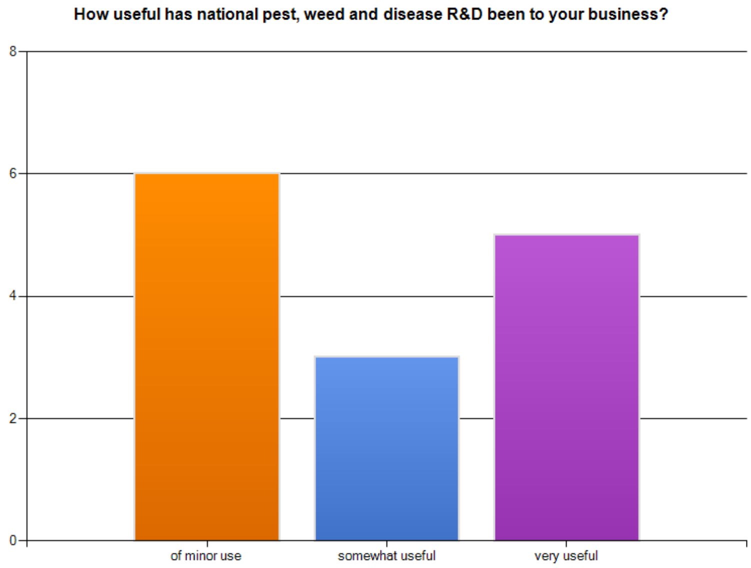
- **What proportion of your pest, weed and disease issues is solved by your own research?**

  Nearly half of the respondents (46%) believed that this research solved 50 – 75% of their crop health issues.



- **How useful has national pest, weed and disease R&D been to your business?**

  Nearly half of the respondents (46%) felt that national R&D had only been of minor use to their business.



- **Is there a pest, weed and disease HAL project that made a big difference to how you control pests, weeds or diseases?**

  The majority of respondents could not name a project, which had made a big difference to how they manage crop health (this is likely to be partially due to a number of respondents not sure which projects could be attributed to HAL). Projects that were cited as useful included R&D on:

  - Western Flower Thrip
  - Diamondback Moth

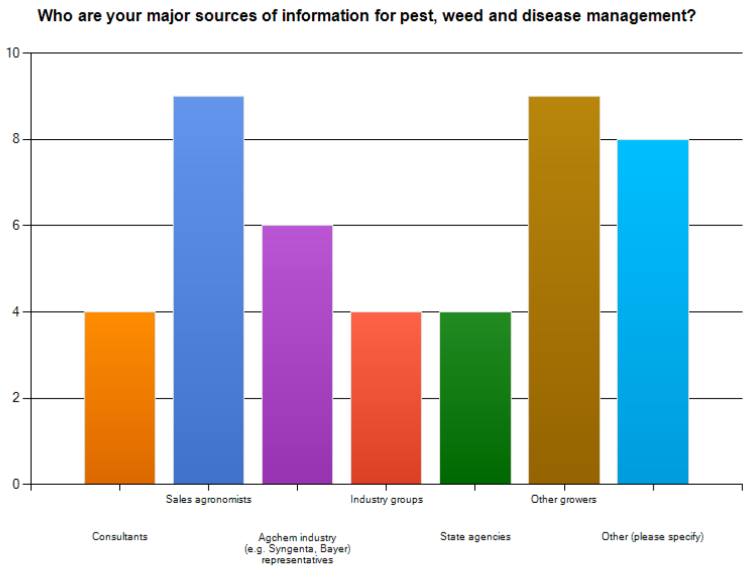
- White blister.

- **How do you learn more about new crop health management techniques?**

  There is a variety of ways in which vegetable producers learn more about new crop health management techniques. These include:

  - Publications (including Vegetables Australia, magazine articles, industry papers)
  - On-line resources (including AUSVEG newsletters and forums)
  - International travel
  - Industry events (such as conferences, field days)
  - Industry service providers (such as agronomists, consultants)
  - Other growers.

- **Who are your major sources of information for pest, weed and disease management?**

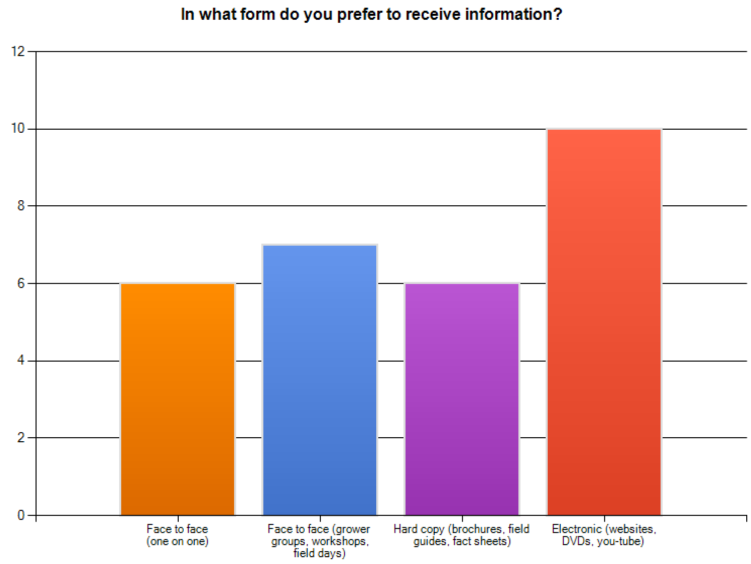


  Other sources of information included:

  - On-line resources (including AUSVEG newsletters and forums)
  - International travel
  - Industry events (such as conferences, field days).

- **In what form do you prefer to receive information?**

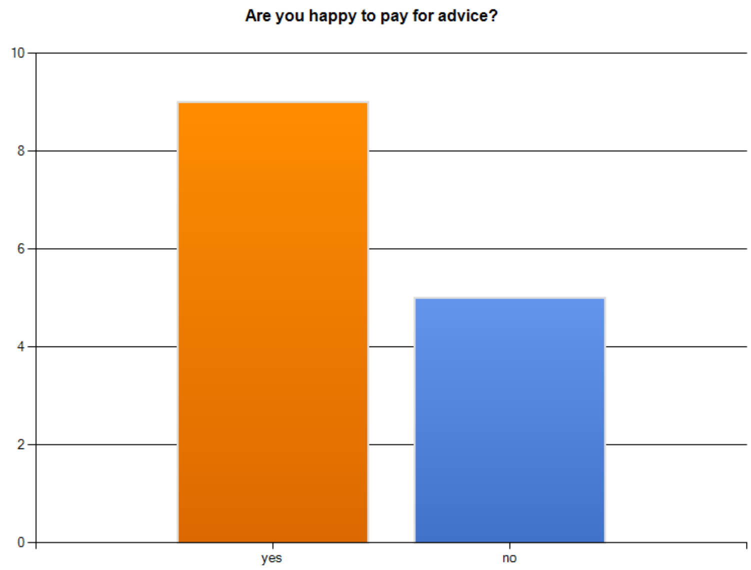
  Access to electronic forms of information was nominated as the preferred method of receiving information by 77% of respondents.



- **Are you happy to pay for advice?**

  Those respondents that were happy to pay for advice felt that it was worthwhile if they themselves lacked the time or the skills to conduct the research, assimilate the IP and act upon it.

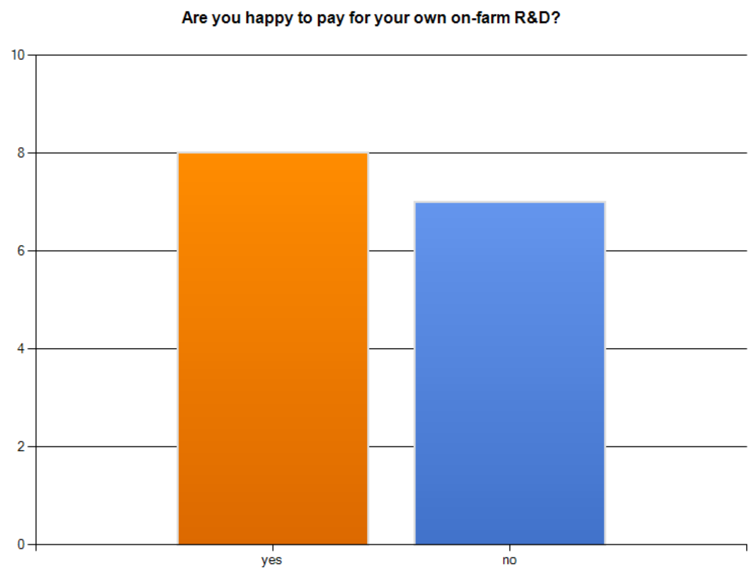
  A number of respondents felt it wasn't worth paying for advice as they felt they were as qualified and experienced as most consultants and felt that they quality of advice provided by consultants was often poor.



- **Are you happy to pay for your own on-farm R&D?**

  The majority of vegetable producers said that they paid for their own on-farm R&D only because they felt there was no alternative.

"It would be encouraging to see focused R&D coming out of the levy system, specifically targeted at current issues. The vegetable industry SIP is targeted at this. It is now essential to demonstrate this in practice".



- **What do you think are the priority areas for investment by the vegetable industry in plant health and crop protection?**

  The priority areas for future investment were identified as:

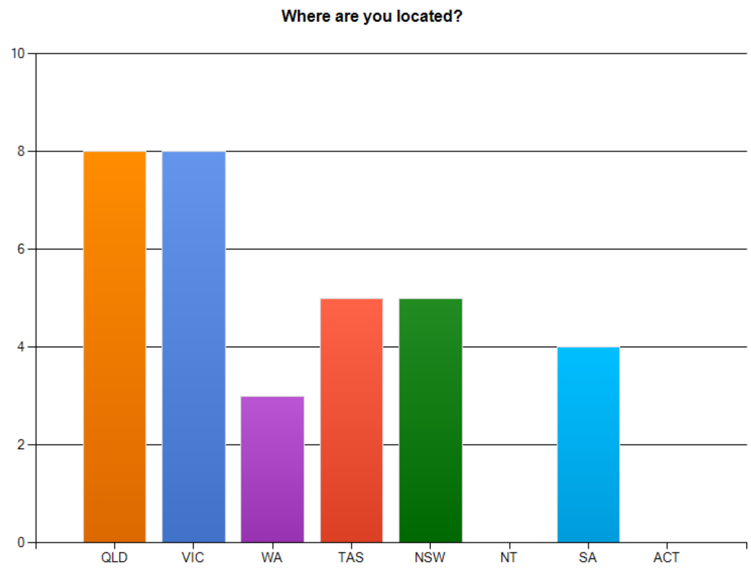
  - Alternative control options (non-chemical) including the development of more biological predators
  - Biosecurity to prevent the entry of new pests
  - Registration of chemical products that are currently available in the USA and EU but not here
  - Further research into existing diseases such as white blister, club root and soilborne diseases.

2 On-line Survey – Vegetable Industry Service Providers

A total of 33 vegetable industry service providers responded to the crop health survey available on-line. A summary of the responses to each question is provided below.

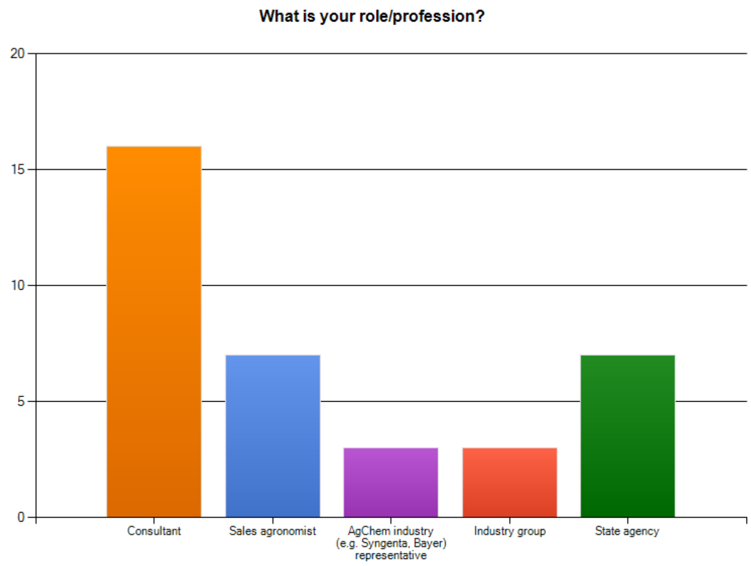
- **Where is your property located?**

The majority of respondents are located within the eastern states of Australia.



- **What is your role/profession?**

The majority of respondents are either a consultant, sales agronomist or work for a state agency such as DPI VIC.



- **What are the main vegetable crops you advise on/work in?**

  The crops that industry service providers advised on were representative of all of the major vegetable commodity groups including:

  - Brassicas
  - Leafy vegetables
  - Root and tuber vegetables
  - Cucurbit vegetables
  - Greenhouse and solanaceous vegetables.

- **What are the major weed, pest and disease issues/challenges for the vegetable industry? Why?**

  The major issues cited by industry service providers, and the reasons for these issues, are summarised in the table below:

Major weed, pest and disease issues

Weed	Pest	Disease	Reason
Fumitory	Mites (including broad mite, russet mite, two-spotted mite)*	Soilborne diseases (including sclerotinia, pythium and rhizoctonia)*	* Intensification of production systems.
Pigweed	White fly*	Powdery scab	* Poor understanding of/skills for implementing true IPM. Small profit margins reduce investment in pest management.
Fat hen	Thrips (western flower thrip)*	Damping-off (including fusarium and phytophthora)	*Lack of control options due to pesticide resistance.
Chickweed	Aphids (currant lettuce aphid and green peach aphid)	White blister*	* Limited control options. Extremes of rainfall and temperature resulting in appearance of diseases such as white blister in areas where not previously found (Qld).
Nut grass	Diamondback moth	Viruses*	* Emerging new vectors for virus-like organisms pose a threat in sub-tropical crops such as capsicums and tomatoes.
Stinging Nettle*	Heliothis	Anthracnose	* Contaminant in leafy vegetable crops – significant food safety issue for supermarkets.

Weed	Pest	Disease	Reason
Groundsel*	Fruit fly	Powdery mildew	* Weeds in general are difficult to control due to limited chemistry and labour costs to hand weed.
	Slugs and snails*		* IPM options are required for control of slugs and snails.

- **Do you think the vegetable industry needs more information/support (e.g. through R&D programs or technology transfer initiatives) to manage these issues?**

  The majority of respondents (96%) indicated that further support is required to manage these issues. Suggested support included:

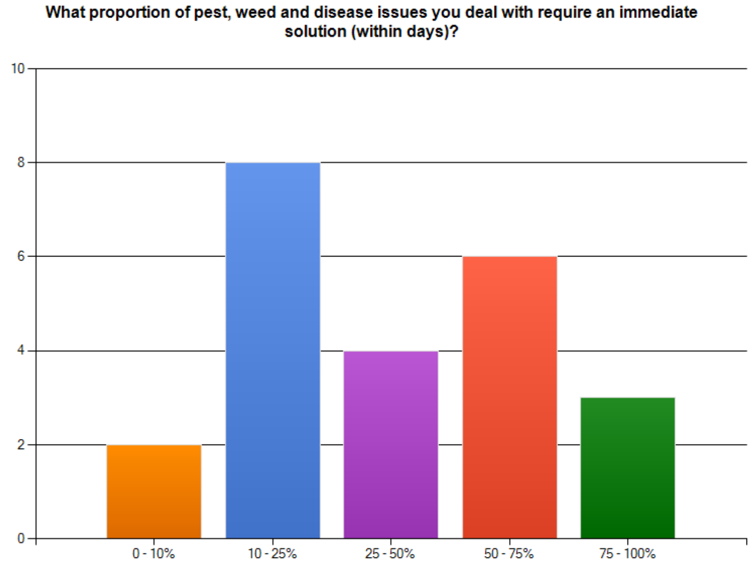
  - Practical and targeted research programs with on-ground support to facilitate on-farm changes
  - Provision of educational material (i.e. through AUSVEG website)
  - A simpler and more responsive chemical registration system (APVMA and minor use permits)
  - Maintenance of biosecurity departments
  - Increasing producer awareness of the importance and use of pheromone traps for major pests as a monitoring tool and to plan control programs
  - Further research on in-crop weed control
  - Use of grower groups to source and collate information on the priorities for future R&D
  - Further R&D into IPM as new pesticides become available and old ones are removed, and as new technologies become available.

  "Increasing temperatures under our changing climate will ensure that pests and diseases will arrive in production districts where they are currently not experienced - SLWF is a case in point - it is only a matter of time before SLWF becomes a pest of concern in NSW (whereas it is currently confined to mostly Queensland)".

- **What proportion of pest, weed and disease issues you deal with require an immediate solution (within days)?**

  Respondents felt that most emergencies could be avoided with preventative and strategic management. However a number of issues do make control more difficult. These include:

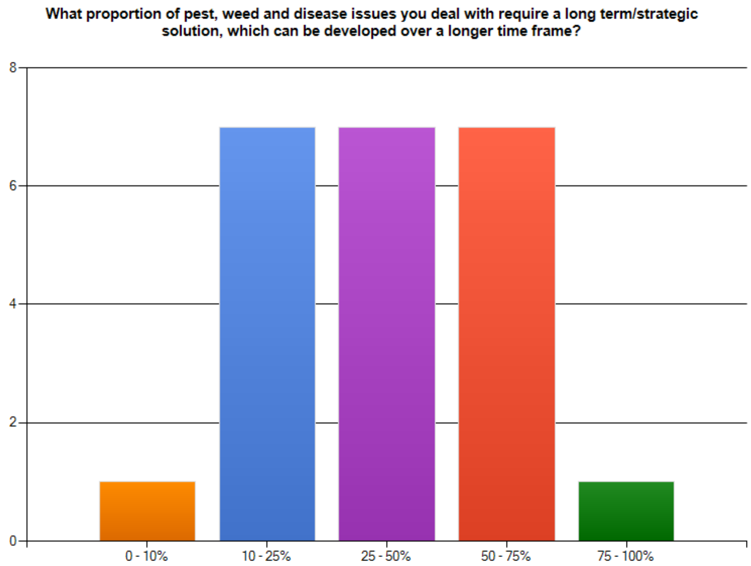
  - The majority of small to medium sized growers having insufficient land or protected cropping facilities to allow for sufficient breaks/fallow periods in their cropping program
  - Changes in seasonal weather patterns i.e. disease such as white blister in broccoli was not seen in Queensland until a few seasons ago as it was too dry, whereas it is now a major issue during summer production
  - Short term crops such as baby leaf crops, which require attention to detail and immediate action.



- **What proportion of pest, weed and disease issues you deal with require a long term/strategic solution, which can be developed over a longer time period?**

  Respondents identified that may disease, weed and pest issues can be better managed with a long term plan developed for a paddock 12 – 24 months before planting the crop. It was also felt that farm planning, skills development and implementation of IPM are routinely ‘glossed over’ by vegetable producers.

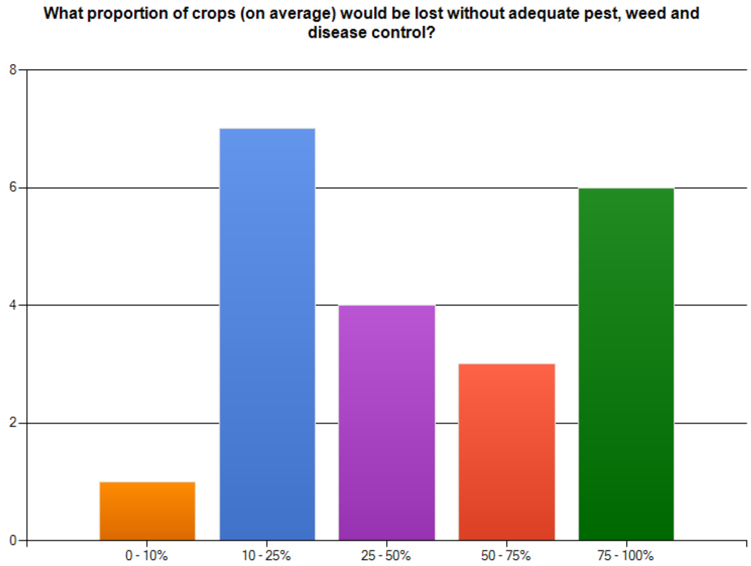
  Farm/glasshouse hygiene and soil health are examples of issues, which should be managed strategically over a longer time period.



- **What proportion of crops (on average) would be without adequate pest, weed and disease control?**

  Industry service providers commented that total crop failures are rare but with increasing cost of production and pressure on price of vegetable product, management costs associated with managing crop health are significant.

  It was also noted that the loss of strategic pesticides, and the lack of strategic pesticides for some crops and pests, means that ongoing crop loss occurs despite having the 'best that might currently be available' to growers. With increasing costs pressures, pest management needs to be continually improved.



- **How much does pest, weed and disease control cost your vegetable producer client base (per year)?**

  Estimates of cost varied significantly, with 10 – 30% of operating costs, the general consensus. One service provider noted that:

  "Pest management is a relatively small cost (probably less than 15% of variable costs), when it is effective. When it fails, or is marginal, then the cost is not the issue - it is the impact on quality and yield, which then significantly affects harvest and shed costs, and of course affects the $ return. When all is going well pest management costs is not the issue. When pests are difficult to manage when extremes of weather impact, then costs increase, and quality and yield decrease".

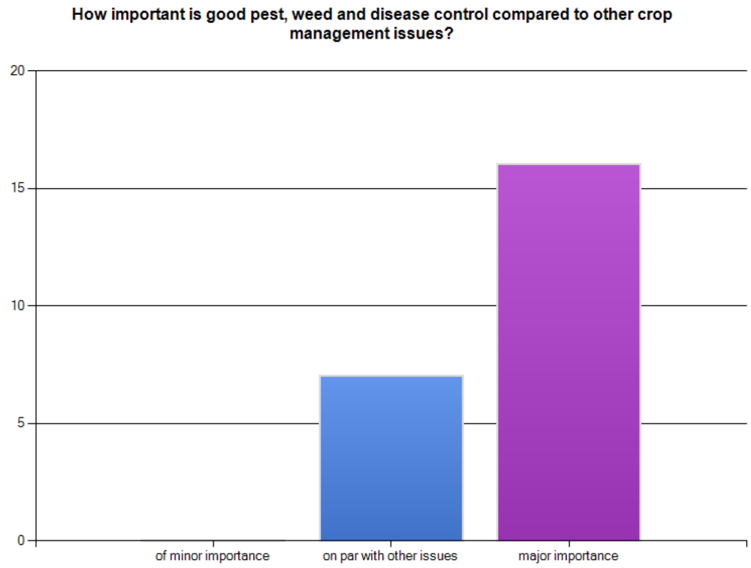
- **How important is good pest, weed and disease control compared to other crop management issues?**

  70% of industry service providers felt that effective management of crop health issues was of major importance to the vegetable industry. Comments included:

"Of major importance, as are crop rotation, nutrition, paddock preparation, soil organic matter management".

"In protected cropping, appropriate selection and use of technology is most important and contributes significantly to pest and disease management".

"Input costs are the major limitation to profitability in the vegetable industry, but the economic management of "pests" would come a close second. This is especially the case in the minds of growers when they are having a specific pest issue to deal with. This has been the case in the past when DBM, Helicoverpa and SLWF were major issues - they still remain issues at times when very high pest pressure exists an/or when weather conditions make for difficulties in applying pest management measures".



- **What are the emerging and/or pest, weed and disease risks for the vegetable industry?**

  The primary new risks for the vegetable industry were nominated as:

  - Introduction of 'new' pests (including incursion of exotic pests and disease and movement of endemic pests such as SLWF into new regions as seasonal patterns change)
  - Loss of chemical control options (due to increasing pest resistance and reduced availability and efficacy of conventional pesticides)
  - Management of contaminants (insects and weeds) in raw materials
  - *"Major issue with chain stores causing major losses to producers & processors. Ultimately pressure to control these contaminants is passed down the supply chain to the grower".*
  - Decreasing return on investment, which results in the control of pests, weeds and disease becoming reactive rather than pro-active.

- **What is required to best deal with these new challenges? Why?**

  Vegetable industry service providers felt that the following was required in order to best manage these new challenges:

  - An 'area-wide' management approach, which depends heavily on co-operation between vegetable producers, together with a good understanding of the seasonal abundance of major pests.
  - Effective monitoring and diagnostic services.
  - Further RD&E (which incorporates a responsive and well-funded research body, effective dissemination of information to vegetable producers, development of vegetable producer skills and knowledge to facilitate the implementation of feasible, preventative and integrated management plans and industry wide cooperation).
  - Consumer education on beneficial insects, their role in the environment and the benefits of seeing these insects in raw and processed vegetables.

- **When you think about developments in weed, pest and disease management technology over the last 10 years, what new practices or approaches have been the most important for the vegetable industry?**

  The new practices and approaches that were cited as being the most beneficial included:

  - The introduction of an Integrated Pest Management (IPM) approach
  - Breeding of resistant plan varieties e.g. downy mildew tolerance in lettuce and spinach
  - Seed coating products
  - Introduction of biofumigation crops
  - 'Softer' chemistry and improved application technologies.

- **How did you first hear about these new practices or approaches?**

  There was a wide variety of ways in which industry service providers first became aware of these new practices. These included information from plant breeders, chemical suppliers, scientific journals, grower magazines, on-line research, farm field days.

- **How well have these new approaches/technology been implemented in the vegetable industry?**

  The response to this question ranged from limited/low implementation through to exceptionally well. Reasons provided for low implementation included:

  - *"That funded programs are too short-term"*
  - *"Some growers, who probably won't be in the industry in a few years (for a range of reasons), still want a simple approach - i.e. a pesticide that works in all situations and is simple to apply - the world of pest management has moved on past this type of thinking"*
  - *"IPM uptake is restricted by consumer, processor & chain store understanding & acceptance. Growers will use the technology if they can sell produce affectively".*

Service providers felt that IPM had been implemented quite well on individual farms, particularly with 'good' growers but that overall as an industry adoption had been poor.

- **How long has it taken to get it right?**

  The majority of respondents indicated that the implementation of new technologies and approaches is an on-going process that industry is still 'getting right'.

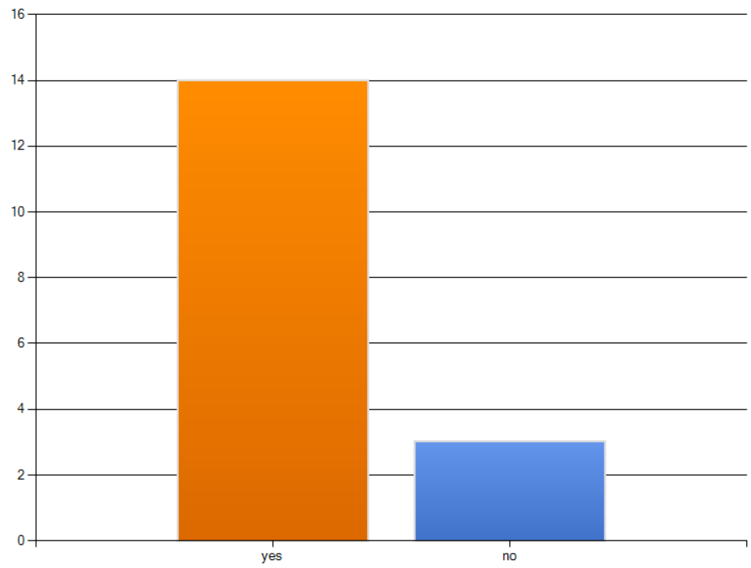
- **What are the new developments/R&D projects in pest, weed and disease management that interest you today?**

  Control options which can be incorporated into an IPM approach, such as:

  - Use of genetically modified varieties
  - Improving soil health
  - Farm hygiene
  - Biological controls
  - Soil solarisation.

  Use of technology such as smart phones and apps for data gathering/monitoring and information dissemination.

- **Do you believe that the vegetable industry has the capacity to start using these practices?**



82% of industry service providers felt that the industry did have the capacity to use these practices. Where respondents replied negatively they felt that more breeding, one on one assistance and enhanced public awareness was required.

- **Who/what are your major sources of information for pest, weed and disease management?**

  Major sources of information included:

  - Scientific and industry publications (including scientific journals, books, industry magazines, ute guides, fact sheets)
  - Agronomists, agchem re-sellers, IPM consultants, researchers.

- **How do you pass on this information to vegetable producers?**

  Industry service providers pass this information onto vegetable producers either:

  - Verbally via one-on-one meetings, field days, grower groups
  - Using printed material such as email, newsletters, text messages, brochures, newspaper articles.

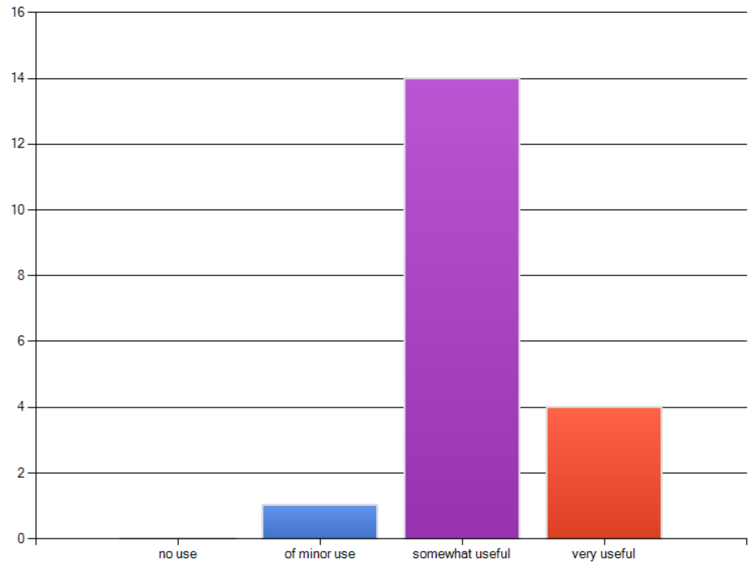
- **What would assist you in transferring information to producers/encouraging adoption of new technology?**

  RD&E programs which incorporate:

  - Longer-term extension and objective-focused development that accommodate the contracting of discrete R&D as required to meet knowledge gaps
  - Genuine independent trial results
  - Localised demonstration sites and field days to illustrate the benefits of new technology
  - Acceptance of new technology by processors, chain stores and consumers
  - Greater use of social media, internet and email technologies.

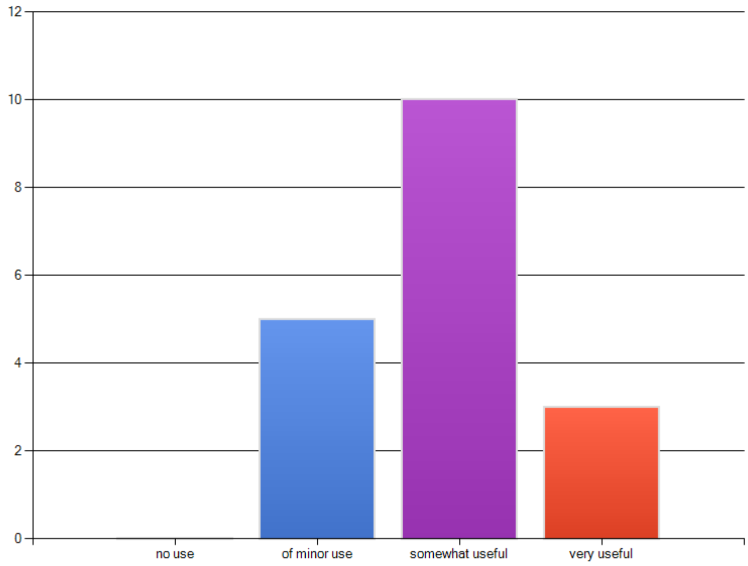
- **How useful has national pest, weed and disease R&D been to your business?**

  The majority of respondents (78%) felt that national R&D had been somewhat useful to their business and their clients.



- **Do you have a suggestion on how HAL funded pest, weed or disease programs can be most effective for you and your clients?**
  - Ensure research includes extension activities which incorporates all components of the vegetable industry
  - Fund grower groups so that they can provide information on research priorities and drive the adoption of research outcomes. "*Growers are happy to provide the information if some one else does the legwork"*
  - Public dissemination of information produced as part of HAL funded projects *"not hidden behind a grower only section of the AUSVEG website"*
  - Provision of interactive access to information via full time operators keeping websites, blogs, email newsletters, tweets current and informative.

- **How useful is the information on pest, weed and disease management available on the AUSVEG website?**



Approximately half of the respondents (56%) indicated that they had found the information on crop health issues on the AUSVEG website as being somewhat useful. A number of respondents indicated that the R&D database was 'awkward' to navigate and that some sections were difficult to access. It was also noted that the information on the web site needed to be more applied (not in a final report format) and links to experts in the content area would be helpful.

- **What do you think are the priority areas for investment by the vegetable industry in plant health and crop protection?**

The priority areas for future investment were identified as:

- Fully funded biosecurity resources capable of minimising border incursions and capable of conducting epidemiological analysis of outbreaks of existing and new pests and diseases, so as to respond appropriately
- Registration of chemical products that are currently available in the USA and EU but not here
- Plant breeding programs (to develop varieties suited to Australian conditions)
- Targeted R&D for protected cropping.

3 Telephone Interviews – Vegetable Industry Service Providers

Responses to each of the questions asked during the phone interviews has been summarised below.

- **What are the major challenges/issues for weed, pest and disease management in the vegetable industry? Why?**

The major pest, weed and disease challenges for the vegetable industry were identified as:

- Lack of time
- Lack of chemical control options for minor crops such as leafy vegetables
- Lack of new herbicides
- Viruses and vectors (thrips)
- Lack of market outlets due to supermarket duopoly and high Australian dollar
- Lack of 'whole of industry approach' to implementing IPM – major reason why soilborne diseases continue to be an issue
- Increasing resistance of pests to chemical products.

- **Do you think the industry needs more information/support e.g. through R&D programs or extension initiatives to manage these challenges?**

The vegetable industry does require further information to manage these challenges. In particular LOTE growers require support (through training to understand labels, rates, WHPs etc) to ensure appropriate management of chemical products and reduce the threat of increased chemical resistance.

There also needs to be an increased focus on integrated resistance management strategies to assist in managing crop health issues (such as that developed for DBM).

- **Would you / your company be interested in conducting R&D?**

The majority of agronomists interviewed indicated that their company is already involved in conducting crop health R&D, although this is mainly confined to on-farm testing of new chemical products in conjunction with AgChem companies, and testing of new plant varieties.

- **Can you estimate the cost to the growers if there was no control/limited control of major pests, weeds and diseases?**

The cost to growers of having no or limited control varied, however most agreed that vegetable production would not be economically viable without effective pest control due to the significant crop losses that would occur.

- **How important is good pest, weed and disease control compared to other crop management issues?**

All of the agronomists interviewed felt that the majority of vegetable producers would view good pest, weed and disease control as very critical.

- **What proportion (%) of pest, weed or disease problems you deal with are immediate, i.e. need to be solved ASAP?**

  The immediacy with which pests, weeds and disease needed to be managed tended to depend on the vegetable producer and seasonal conditions. However it was felt that the majority of issues (80%) required immediate action, and that these were usually established pests and diseases, whereas it was the emerging, or minor 20% of pests and diseases that required a longer term solution.

- **What do you think are the emerging and/or future pest, weed and disease risks for the vegetable industry?**

  There was general agreement that emerging and/or future pest, weeds and diseases were not a major issue for vegetable producers and their advisors. Their main concern was the implementation of good management programs and efficient processes to manage existing crop health issues. Of potential concern in the future was:

  - The movement of existing pests into new crops (i.e. powdery mildew moving into tomatoes and capsicum) and a lack of products registered for those crops
  - Lack of effective chemical control options due to increasing resistance and chemical companies not registering products for horticulture crops due to a lack of economic incentive.

- **What is required to best deal with these new challenges? Why?**

  The industry service providers interviewed felt that there was a need for:

  - Further education on effective crop management (i.e. improving producer awareness of susceptible host crop ranges and the requirement for break/fallow periods)
  - Emphasising the importance of integrated weed management to prevent major weed issues (including prior preparation of ground, use of green manure crops, structured herbicide program).

- **When you think about developments in weed, pest & disease management technology over the last 10 years, what new practices or approaches do you think have been the most important for the vegetable industry?**

  The most important developments over the last ten years were nominated as:

  - Softer and more targeted chemical products – particularly for caterpillar control
  - IPM
  - Integrated resistance management strategies (such as that developed for the control of DBM)
  - Improved spray application technology

- **How did you first hear about these new practices or approaches?**

  Agronomists heard about these new approaches from a variety of sources which included reading international publications and talking to R&D personnel within the Agchem industry.

- **How well have these new approaches/technology been implemented in the vegetable industry? How long has it taken to get it right?**

  It was observed that the majority of vegetable producers do attempt to implement an IPM approach to some extent however the degree to which it is successfully implemented often depends on:

  - The prices producers are receiving for their product (if their profit margin is low then they are less likely to spend money on more expensive 'softer' chemicals
  - On personal attitude and confidence in the approach.

- **What are the new developments/R&D projects in pest, weed and disease management that interest you today?**

  New developments of interest included biological control products and microwave technology for weed control.

- **Do you believe that the vegetable industry has the capacity to start using these practices?**

  Service providers generally felt that vegetable producers do have the capacity to start using these practices. This has been evidenced by the implementation of IPM to varying degrees by producers (at a basic level this has included a better understanding of the biology of pests and moving away from calendar spraying). The impetus for implementing IPM has been due to a range of factors, including:

  - Economic reasons - tighter profit margins mean that producers cant afford to lose large proportions of their crops
  - OH&S issues/health concerns "I am knowledgeable in regard to chemicals and therefore concerned with my health and that of my workers."
  - Environmental concerns "Don't want poisoned food, soil or water."
  - Regulatory "MRLs being regularly checked by both EPA and Chain Stores."
  - Lack of effective chemical control "The realisation that broad spectrum chemical controls were not effective".

  A number of agronomists noted that IPM needs to focus on economic benefit in order to encourage adoption by producers.

- **How helpful have previous pest, weed or disease RD&E programs funded by HAL been for you?**

  While it was agreed that there has been some helpful RD&E programs in the past, major issues included:

  - Duplication of research by state R&D departments and private industry (AgChem)
  - The time taken to get results out to vegetable producers was considered too long.

  Funding for grower/study tours was considered very helpful as it enables producers to see what others are doing.

- **Do you have a suggestion on how HAL funded pest, weed or disease can be most effective for you and your clients?**

  Suggestions on how to improve the effectiveness of these R&D programs included:

  - Involve private agronomists and the agchem industry into the R&D loop. This could involve the delivery of training/forums specifically for re-sellers who can then pass this information onto growers. With decreasing capacity of state R&D departments, private industry will be the main conduit of information to growers and this sector therefore needs to be better incorporated into the R&D loop to ensure the right information gets out to growers
  - The funding of grower groups to provide information on grower priorities and assist in driving the adoption of research outcomes
  - Work with larger growers to develop crop health strategies (filtering down of information to smaller growers).

- **How do you rate information on pest, weed or disease available from the AUSVEG website?**
  - Getting better
  - Never thought of website as a reference point.

- **Who/what are your major sources of information for pest, weed and disease management?**
  - Publications (both national and international)
  - Peers (other agronomists within the business and industry in general)
  - Internet
  - AgChem R&D personnel
  - State R&D departments.

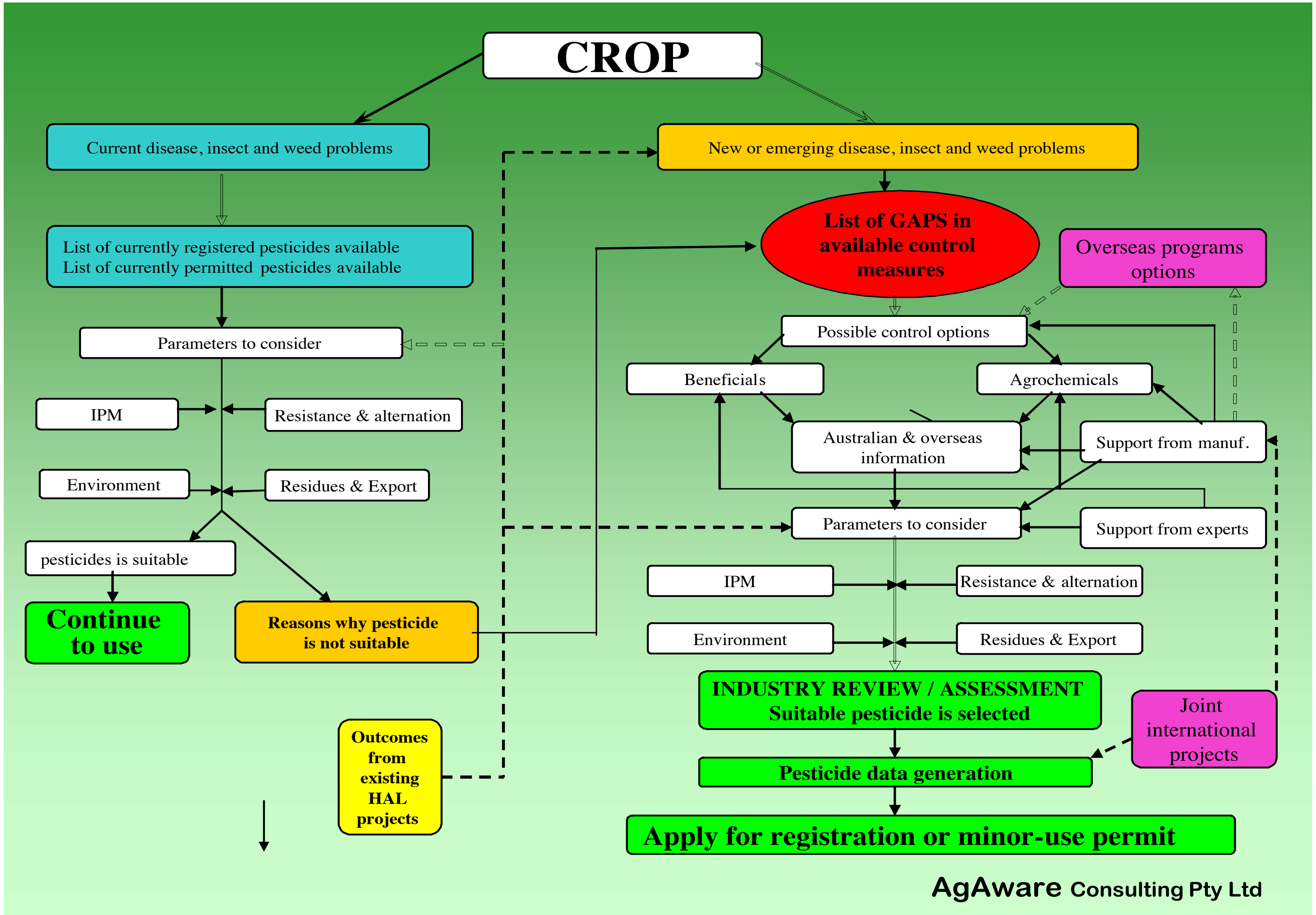
- **How do you pass on this information to vegetable producers?**
  - One-on-one
  - Use a mixture of hardcopy and electronic resources (fact sheets etc).

- **What would assist you in transferring information to growers/encouraging adoption of new technology / R&D results?**
  - Time
  - Good relationships with growers
  - R&D information which includes statistics/economic information
  - Industry embracing technology
  - Case studies.

- **What do you think are the priority areas for future investment by the vegetable industry in plant health and crop protection?**

    1. Look to see what is being done internationally (i.e Zebra chip in NZ potatoes) no need to reinvent the wheel
    2. Biofumigation/green manure crops
    3. Biosecurity
    4. Integrated crop management
    5. Soil Health
    6. Biological controls

Appendix 4: The Strategic Agrochemical Review Process



Appendix 5: Adoption of IPM

www.publish.csiro.au/journals/ajea
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When will integrated pest management strategies be adopted? Example of the development and implementation of integrated pest management strategies in cropping systems in Victoria

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Abstract. This paper discusses the development and implementation of integrated pest management (IPM) strategies for broadacre cropping in Victoria, Australia, with reference to other crops and also the levels of adoption of IPM in Australia and overseas. Levels and rates of adoption are mostly low but with some exceptions. The reasons for differing levels of adoption include the failure of strategies to successfully deal with all pests, the lack of motivation to change to using IPM given current successful pesticide-based controls, and the poor availability of IPM advisors in the field. This paper outlines how IPM strategies for wheat, barley and canola crops were developed and implemented using a collaborative approach between farmers, agronomists and entomologists. It was found that although there were no existing specific IPM strategies for the crops grown in the region of south-eastern Australia, there was sufficient information for farmers to start using an IPM approach. This paper gives a case study of implementing change to IPM from conventional pesticide spraying, including the development of a course in IPM for growers and agronomists. It focuses on the process of changing practices and information transfer rather than on entomological details.

Integrated pest management

There are at least 21 definitions of integrated pest management (IPM) (Bajwa and Kogan 1996; Food and Agriculture Organisation 2000) but the term is taken here to mean using biological, cultural and chemical control methods in a compatible way to manage pest problems (Alston and Reading 1998; Horne and Page 2008). Some definitions are presented in Table 1. IPM is an approach that is widely seen as desirable and is promoted by many agencies worldwide, including the United Nations, the World Bank and the Food and Agriculture Organisation (Maredia 2003; Olsen *et al*. 2003) and also government agencies in Australia (Williams and Il'ichev 2003). The term 'pest' can be applied to invertebrates, vertebrates, weeds or diseases, but the emphasis in this work was on invertebrate pests and the reduction in use of insecticides. The toxicity of insecticides to a wide range of organisms makes reduction of these products an important first step in an integrated approach.

IPM is well known and used in many horticultural industries but is a relatively unknown and little-adopted concept in broadacre farming in Australia. A recent summary of IPM in Australia made no mention of IPM in broadacre cropping (Williams and Il'ichev 2003). Despite the perceived advantages of IPM there are also disadvantages (Table 2) and despite the efforts of many research entomologists, studies worldwide have often shown poor rates of adoption (e.g. Wearing 1988; McNamara *et al*. 1991; Herbert 1995; Sivapragasam 2001; Bajwa and Kogan 2003; Olsen *et al*. 2003). Even in horticulture, where the theory of IPM is well developed, achieving widespread adoption on farms remains a challenge (Boucher and Durgy 2004; Page and Horne 2007). The present paper describes how IPM strategies in broadacre crops in Victoria were developed and implemented by entomologists using proven extension principles.

Adoption or non-adoption of IPM by farmers

One likely factor for the poor rates of adoption in some cases is that researchers have concentrated on a single pest and have not dealt with all pests in a crop (Blommers 1994; Sivapragasam 2001; Olsen *et al*. 2003). Integrated mite management in apples (Albajes *et al*. 2003) is one example of this approach. Also, when the current pesticide-based strategies work, then there is an absence of a crisis to demand an alternative approach. When pesticide-based strategies work and when information given to farmers is complex, and is given without contact with an IPM expert to help with implementation, then it is easier for a farmer to use an established, proven and simple pest-control method that relies totally on pesticide application. For an IPM strategy to be effective it must deal with all pests in the crops (Trumble 1998; FAO 2000) and ideally would be as easy to implement as a pesticide-based strategy.

A survey of Australian potato growers showed that adoption rates varied from nearly 0–100%, depending on the presence or absence of an advisor on IPM (Horne *et al*. 1999). It has also been noted that the rate of adoption measured depends largely on the definition of IPM used (Bajwa and Kogan 2003). Studies in fruit (Alston and Reading 1998), brassicas (Sivapragasam 2001), vegetables (Page and Horne 2007) and other crops (Herbert 1995; Maredia 2003) also found that the presence of a

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Table 1. Some definitions of integrated pest management
Source: Bajwa and Kogan (1996)

Definition	Reference cited
Applied pest control that combines and integrates biological and chemical control.	Stern *et al*. (1959)
Integrated control is a pest population management system that utilises all suitable techniques, either to reduce pest populations and maintain them at levels below those causing economic injury, or to so manipulate the populations that they are prevented from causing such injury. Integrated pest management is a strategy of pest containment that seeks to maximise natural control forces such as predators and parasites, and to utilise other tactics only as needed and with a minimum of environmental disturbance. Integrated pest management, in its simplest form, is a control strategy in which a variety of biological, chemical and cultural control practices are combined to give stable long-term pest control.	Smith and van den Bosch (1967); Glass (1975); Ramalho (1994)
IPM means 'intelligent pest management'.	Zweig and Aspelin (1983)

Table 2. Advantages and disadvantages of adopting integrated pest management

Advantages	Disadvantages
Reduced dependence on pesticides	More complex than control by pesticide alone and requires a shift in understanding
Increased safety to farm workers, spray operators and the community	Requires a greater understanding of the interactions between pests and beneficials
A slower development of resistance to pesticides	Requires a greater understanding of the effects of chemicals
Reduced contamination of food and the environment	Increased time and resources
Improved crop biodiversity	Level of damage to the crop may initially increase during transition to an integrated pest management program, in some horticultural crops

specialist IPM advisor working closely with small groups of farmers is necessary for successful adoption of IPM (Olsen *et al*. 2003). These reports give a range of reasons for the poor rates of adoption and some of these are listed here:

- Too few entomologists as advisors
- Focus on research rather than implementation
- Too complex
- No local advisor
- Not enough information
- Chemical-based control still works

To improve the rate of adoption of IPM it is necessary to deal with each of these issues. However, it is also well known that the chemical industry supports pesticide-based approaches to pest control whereas the support of IPM depends on a lesser (public)-funded strategy (Herbert 1995; Bajwa and Kogan 2003). As shown in Table 3, there are usually large differences between the features of pesticide technology and IPM that help explain the often slow rate of change to using IPM. However, the two main factors are that pesticides are still easy to apply and are relatively cheap (Albajes *et al*. 2003).

Table 3. Comparison of integrated pest management and chemical-based supports
Derived from Bajwa and Kogan (2003)

Pesticides	Integrated pest management
Compact technology	Diffuse technology with multiple components
Easily incorporated into regular farming operations	At times difficult to reconcile with normal farming operations
Promoted by private sector	Promoted by public sector
Aggressive sales promotion supported by professionally developed advertising campaigns	Promoted by extension personnel usually trained as educators not as salespersons
Results of applications usually immediately apparent	Benefits often not apparent in the short-term
Consequently, pesticide technology was rapidly adopted	Consequently, adoption of integrated pest management technology has been slow

In broadacre cropping and grazing in Australia the regular use of broad-spectrum insecticides and miticides has been viewed as being good farm practice (e.g. TimeRite sprays for *Halotydeus destructor* (Tucker) (red-legged earth mite) (http://www.timerite.com.au/, verified 22 October 2008) and calendar-based sprays for aphids using synthetic pyrethroids (Thackray *et al*. 1999). The routine spraying of synthetic pyrethroids on wheat crops (*Triticum aestivum* L. em. Thellin) is also advised in the USA (Roberson 2007). In general the products used are low cost compared with other farm treatments, they usually achieve immediate results and their application can be combined with other farm applications such as herbicide spraying and fungicide treatments.

The small cost and convenience aspect of the current system has encouraged the regular use of insecticides, even if the application may not have been necessary. Application of insecticides even when no pests were observed has been known from other crops before IPM was adopted [e.g. rice (*Oryza sativa* L.) production in Indonesia (Oka 2003)]. The addition of an insecticide was also seen as an 'insurance policy' (Stoner *et al*. 1986), to guard against potential pest build-up in the future. Insecticide treatments are widely adopted and are currently the basis for most pest-control activity in cropping in Australia (Gu Fitt and Baker 2007; J. Cameron, Independent Consultants Australia, pers. comm.). The type of insecticides used are broad spectrum and known to kill beneficial species such as carabid beetles (Coleoptera : Carabidae) (Curtis and Horne 1995), which are important biological control agents (Horne 2007).

Case study: examples of IPM being implemented in Victoria, Australia

Conventional practice

The established practice (before adopting IPM) within the group of farmers and agronomists discussed in the present paper can be summarised as follows. Synthetic pyrethroid or organophosphate insecticides were sprayed at or near the time of planting to control establishment pests such as *H. destructor* in *Brassica napus* L. (canola) crops. These were used routinely on most paddocks or as a reaction to observed damage. Similarly, molluscicide baits were usually applied routinely or at the first signs of damage by slugs such as *Deroceras reticulatum* (Muller) (Mollusca : Limacidae) or *Milax gagates* Draparnaud (Mollusca : Milacidae) in *B. napus* (canola) crops. Repeated applications of insecticide or bait were made if damage continued. *T. aestivum* (wheat) was sprayed with a synthetic pyrethroid insecticide at 3 and 6 weeks after crop emergence for control of aphids and barley yellow dwarf virus. *Hordeum vulgare* L. (barley) was often sprayed with insecticide for armyworm.

Advice on pest control has been given by agronomists who were also advising on a range of agronomic issues. However, most agronomists are not trained in entomology and, in the absence of expert entomologists, relied on accepted pesticide-based recommendations. Advice that was unproven in the absence of specialist entomological support was considered risky. The result was that the routine use of cheap broad-spectrum insecticides had become standard practice.

Except for the few cases of control failure (e.g. with insecticide-resistant pests such as *Plutella xylostella* (L) diamondback moth) the insecticides usually worked with no apparent disadvantages. Control of invertebrate pests is just one part of farm management and when the insecticide approach works it is seen as a fairly minor part. So the problem in proposing an IPM approach in the absence of a crisis is why would farmers and their advisors want to change from something that is simple and that works to something more complex and risky?

IPM in Victorian cropping systems

In 2002, entomologists from IPM Technologies (Hurstbridge, Vic.) began working with a group of 15 collaborating farmers and their agronomists near Inverleigh, Victoria (38°06′00″ : 144°03′00″) to investigate the practicality of an IPM approach in broadacre cropping. There was interest amongst this group in sustainable farm practices, including reducing reliance on insecticides. A basic IPM strategy was developed from existing entomological information, discussions with collaborating farmers and agronomists and field observations. It aimed to increase populations of resident beneficial species to deal with resident (establishment) pests and also to use transient beneficial species to help control transient pests without disturbing populations of either resident or transient beneficial species. The approach involved: (i) correct identification of pests and beneficials; (ii) eliminating insecticide sprays when insufficient pests were present; (iii) using insecticides in the least-disruptive way; and (iv) using cultural controls such as time of planting. There was also interest in controlling pests in stubble-retained systems, as there was a perception of increased pest problems with this method, as has also occurred overseas (Stinner and House 1990).

Collaborating farmers agreed to nominate three paddocks [one each of *B. napus* (canola), *T. aestivum* (wheat) and *H. vulgare* (barley)] on which they would follow a basic IPM strategy on a commercial scale. The farmer received regular monitoring of the nominated paddocks by entomologists and an agronomist. Monitoring was achieved using standard techniques including pitfall traps, direct searching and suction sampling in addition to the agronomist's regular monitoring. The monitoring led to the identification of beneficial insects and mites, correct identification of pests and the trend in numbers of pests relative to numbers of beneficials. A collaborative decision was made each week during establishment of canola and at key times for both wheat and barley, based on the results of monitoring, past experience and implications of pesticide applications on the biological control of other pests. The results of the first year of trialling this approach on a commercial scale were a reduction in insecticide use (no insecticides were sprayed compared with routine applications the year before) and better pest control, primarily through better identification of pests [e.g. *Forfucula auricularia* L. (European earwigs) were recognised as causing damage that had previously been blamed on slugs]. The farmers and agronomists were satisfied with the results and decided to apply the IPM approach on more paddocks the following year.

Although the answers to the pest problems on these farms were in fact quite simple the outcomes have been massive. The farmers have greatly reduced their reliance on insecticides and are now using IPM on the whole farm. On some of these farms no insecticides at all have been applied via a boom spray in the last 5 years (Horne and Page 2008).

Development of IPM to a wider audience

These successful trials of IPM on a commercial scale led to the development of an IPM training course for farmers and their agronomists as part of a project called 'Grain and Graze' being conducted in the Glenelg-Hopkins and Corangamite catchment management areas in Victoria (Land and Water Australia 2008). The course was based on the elements of a pasture productivity program conducted in southern Australia in the 1990s (Tromph 2001). Twenty-two people enrolled in the course, with approximately half being district agronomists. It was considered important to have both farmers and their agronomists involved at the same time, so that any decisions in this new approach were taken jointly. Following initial training workshops, the course involved field observations and decision making using an IPM approach in commercial crops over a cropping season.

The aim of the course was to keep the information clear and concise and, most importantly, to change insecticide usage. The participants needed to understand how insecticides fit within an IPM strategy, including the effect that they have on beneficial species. Although the course included a component on insect identification it was not an entomology course. Its purpose was to show that there are a whole range of insects that live in crops, many of which are beneficial and can be of great value or benign and neither a pest nor biological control agent.

Where possible the course involved group discussion. The combination of entomologists with specific IPM knowledge, agronomists with good understanding of local issues and farmers with their own experiences resulted in the development of very achievable and practical IPM strategies for the crops nominated using the combined available knowledge. All participants developed a comprehensive IPM strategy for each of their crops, which they were able to implement and test with support from IPM specialists. An example of an IPM strategy for canola has been given by Horne and Page (2008). Each grower and agronomist was able to highlight specific issues to address, and it was noted that the farmers were often willing to take more risks until a compatible set of proven control options was developed for each farm.

It was acknowledged in the course that the most difficult aspect of implementing an IPM strategy would be the decision making during the season, and in particular for control of establishment pests in canola. Damage to the plants during the cotyledon stage could result in crop loss and possibly require replanting. The strategies developed tried to ease this pressure as much as possible by planning ahead and possibly using seed dressings. However, at some point the decision to use an insecticide or not would have to be made. The questions to be answered would be: Will the crop suffer economic loss this week if an insecticide is not used? If we are spraying a fungicide or herbicide should we include an insecticide? These are the very real and very stressful decisions that need to be made in order to implement IPM.

Field sessions were required as part of the course follow up. Course participants and entomologists met in nominated paddocks at critical times to discuss and answer any questions or concerns of the group. These visits were often followed by several phone calls until an agreed decision was made.

The answers to most of the questions raised did not require detailed scientific data but did require confirmation that there was no immediate cause for concern. It is important to remember that insecticides were used because they are cheap, effective and the accepted practice. It was changing this attitude that was the barrier to adoption of IPM and not a demand from farmers for more data.

All participants successfully implemented the IPM strategies on the nominated paddocks and have continued to do so. After the initial year of trialling this approach the decision making has become considerably easier. Some farmers now value their populations of beneficial insects so much that it is harder for them to decide to use a broad-spectrum insecticide even if some pest damage may occur, because they know what they will lose and the other pest problems that may arise as a result.

Discussion

Successful examples of IPM adoption have usually involved several key elements – collaboration between farmers and advisors, local demonstrations and availability of expertise (e.g. Horne *et al.* 1999; Sivapragasam 2001; van Lenteren 2003; Heisswolf and Kaye 2007). The adoption of IPM in crops and pastures described in the present paper has been achieved through a combination of available knowledge, rapid testing of IPM approaches at a farm scale and the application of proven extension principles. The use of such a farmer-participatory approach is recognised as an important tool in extension generally (Black 2000; Murray 2000) and is also known to be a successful means of delivering IPM training and research (Dent *et al.* 2003). Critical in the successful adoption of IPM was the willingness of growers to be involved in commercial-scale trials following their acceptance of the IPM principles outlined in workshops and courses. An essential part of this adoption has been the close one-on-one relationships developed with experts in the paddock. It enabled uncertainty over observations to be resolved and allowed tactics to be discussed. The effective answering of questions by experts in the paddock and the access to experts to give an immediate response at any time has underpinned the adoption at the whole farm scale.

The main outcome aimed for in the course was changed insecticide use, and so the farm practice change model used in the Sustainable Grazing Systems program (Nicholson *et al.* 2003) was applied to the development and implementation of IPM. This model described a continuous three-stage process of motivation, trialling exploration and farm practice change, and recognised the importance of supporting decision making in achieving practice change (Fig. 1).

The initial workshops provided a non-threatening learning environment, which is known to assist in creating motivation to change (Fell 1997). The workshops and in-field training were intended to give growers and agronomists the principles of IPM and then to give enough new information to apply it on the farm.

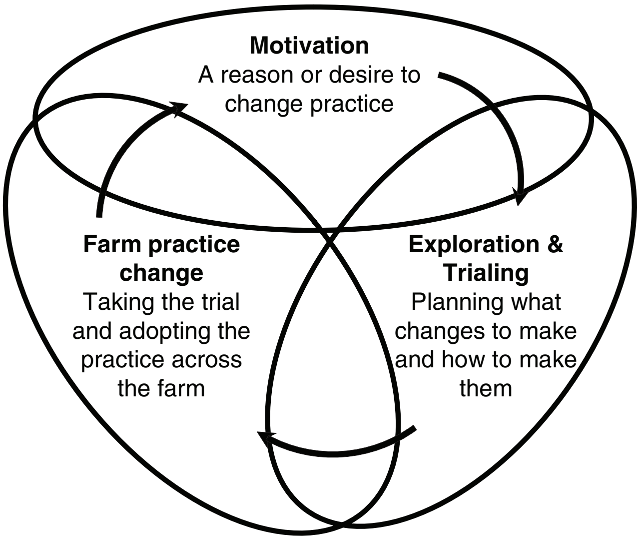

Fig. 1. The three stages of the sustainable grazing systems farm practice change model: motivation, exploration and trialling, and farm practice change.

The course was not a detailed entomological course as it is known that too much detailed information given to farmers can be overwhelming and so deter farmers from attempting IPM (Lynch Greene and Kramer-LeBlanc 1997; Heisswolf and Kaye 2007). Instead, on-going support was available from entomologists whenever needed. All participants (100%) who attended the course understood the concept and were prepared to trial it, and at the end of the season had seen IPM work. That is, they had used naturally occurring biological control agents, had decided on particular cultural controls, and had eliminated the use of broad-spectrum insecticides. Those involved in the course were then, as described by van de Fliert (2003), 'able to make better, informed decisions for location-specific agro-ecosystem management'.

As confidence has grown in the application of IPM, farmers and agronomists have become willing to apply the same principles to more paddocks. For example, it has been reported that since 2006 all insect control decisions for clients across 40 000 ha of crops inspected by one agronomy company have been considered within an IPM context and control recommendations made accordingly (Watson 2007). This company sees that it has a marketing advantage of being able to offer an IPM service. The concept of motivation created by advantage is not new (Frank 1995; Barr and Cary 2000).

Recent studies recognise the significant influence that stress can have on decision making (Shrapnel and Davie 2001; Pannell *et al.* 2006). Any change is stressful, and this includes changing to use IPM. In some cases the potential economic losses were large if the IPM approach did not work, adding to the anxiety not only for the farmer but for those who were advising them. It has been pointed out that until there is confidence in an IPM strategy, a farmer is unlikely to risk 100% of the crop for a possible 10% gain (Trumble 1998). The approach described here gave that confidence to allow adoption. Direct access to entomologists (including mobile phone number) was provided to help minimise the stress felt by farmers and advisors. Many called at key times and the farmers involved have since become strong advocates for IPM.

Changed use of insecticides

A successful implementation of any IPM strategy will require the provision of support for the farmer. In most cases manuals and fact sheets alone cannot provide the support needed; it must come from direct contact with experts. The previous insecticide approach provided peace of mind that all necessary actions to control pests had been taken and so it is up to the IPM experts, as much as possible, to provide the same level of reassurance. On-going entomological support is essential as without this support it is known that interest in IPM falls and the availability of pesticides leads to loss of adoption (Herbert 1995; Sivapragasam 2001; Oka 2003).

The most important result of the process that is described here was changing the attitude that existed: 'spray an insecticide, just in case'. Growers and agronomists involved in the IPM work now know that this can cause problems such as killing beneficial insects and mites and causing secondary pest problems. It is important to note that sublethal effects of insecticides can also be seriously detrimental to populations of beneficial species (Desneux Decourtye and Delpuech 2007) and so those beneficials that survived an insecticide application could still be seriously affected.

There had previously been no consideration that such practices could cause problems with populations of beneficial species. There is a wealth of information in the scientific literature about beneficial species of invertebrates and certainly enough to begin using the knowledge. The approach taken was to apply IPM principles to specific sites, which enabled the basic interactions to be observed without establishing major research trials, as was described by Kemmis and McTaggart (1988). However, the IPM strategies discussed here are seen as just the starting point and there are many opportunities for research to improve them.

Conclusions

There are several points that will conclude this paper, and these are listed below. The results described here are well founded in the scientific literature and deal with the problem of implementing IPM. Herbert (1995) described most of these issues and more than a decade later the same issues are present. The problems are still present but now there are alternative answers present if we want to use them.

(1) There is sufficient entomological information to begin successful IPM in commercial broadacre cropping and to deal with problems as they arise.
(2) The case study outlined here demonstrates a successful approach, consistent with known approaches to IPM adoption, with an unusually rapid rate of adoption compared with overall world trends. The success described requires close collaboration between farmer, agronomist and entomologist advisor.
(3) 'IPM cannot be packaged like seeds' (FAO 2000) and needs to suit the individuals involved. In the case study presented, site-specific advice was given by entomologists direct to farmers and agronomists.
(4) If IPM is complex then it is the role of advisors to interpret the information available and make it simple.

(5) After IPM has been adopted, there is still a requirement for constant collaboration between entomologists, farmers and agronomists to avoid IPM being seen as simply an alternative insecticide program. After IPM for invertebrate pests has been adopted, there is further opportunity to increase the scope to deal with a range of other pests in a holistic approach.

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Appendix 6: Smart Phone Technology

The following smart phone Apps could be used within the vegetable industry to assist in the management of crop health issues.

Production

Title	Features	
Farm Manager	Farm Manager allows farmers to record cropping, livestock, and machinery procedures, and access this information with ease. Features include: d) Record full history of crops from when they are sown through to harvested e) Record chemical and fertilizer use, including type, rate, and date applied f) Keep track of livestock, with full details of stock including ear tag numbers, bloodlines, breed, and year born g) Record shearing and crutching dates, plus all drenching, dipping, and jetting details h) Keep track of machinery maintenance, including engine oil and filter changes, transmission oil and filter changes, and hydro oil changes	iPhone only
Field Notes	Field Notes is an agricultural app that allows you to keep pesticide records on your iPhone. Each record created is for a specific field on a specific date. Features: i) Field management by Grower/Farmer/Field allows all field information to be stored and recalled once the field is created j) Create a product database with all pesticides used on your farm and then pick them as needed k) Take detailed information of the pesticide and record crop being sprayed and current weather conditions l) Data is easily reproduced in hard copy form by emailing the records in a .html format (open with any web browser) or csv (open with many database programs) then printing it from your computer	iPhone only
F-Track Live	F-Track is a farm management app which allows multiple users to record and access all their farm information. Through synchronisation with an online server, all data entered is constantly updated and when out of range, data is stored locally and updated when possible. This app can be utilised for individual farmers but farms with multiple users will see the real benefit, with all managers and staff able to input data. Features: Livestock manager tracks any animal enterprises, recording movements, treatments, events, purchases and sales over multiple properties m) Crop Manager tracks all farming events, such as spraying, sowing, tillage, spreading, harvesting etc n) Task management feature allows users to allocate tasks between users, generate weekly, monthly, yearly plans and track their completion o) Paddock Mapping and tracking function enables users to know what paddock they are close to and current paddock histories	iPhone only

Title	Features	
	relating to them p) Silo Manager records on/off farm grain information, quality, type and location q) Fuel Inventory feature allows tracking of on farm fuel usage and storage with the ability to allocate to vehicles, and warnings when fuel is low r) Lists current market prices for livestock and grain commodities s) Fully integrated chemical inventory system to record and track chemical use with every application	
iPlanta	This app was designed for farmers, agriculture researchers, and gardeners, and includes a calculator, a data logger, and a GPS mapping function. The calculator solves for the amount of pesticide, land, or plants based on the information provided. The user chooses to input either US or metric units, but the end calculations are given in both unit systems along with a timestamp and the ability to email the results. The data logger stores information that is manually entered by the user and also includes a timestamp. Easily input the amount of pesticide you applied that day or a disease you observed, for example, and this information will be saved for later. You can view a specific entry by the date, or view all entries together in a log format and then easily email this information. The GPS mapping function can store the current location, which is named by the user. After traveling away from the location, the app will give street directions to the specified saved location. This is designed to find and label farms for agriculture researchers.	iPhone only
ScoutDoc Record Keeping App	This is a field scouting/record keeping app for farmers and professional crop agronomists. The app allows you to create or import a field map and save information collected when scouting or inspecting field crops. Features: t) Data entry fields are provided to input crop and field identification details plus weed, insect, and disease pressure u) Field map section allows the user to draw a representative map of each field they are scouting on the iPad using a stylus v) Field map images can also be uploaded from Photos folders on iPad w) Customizable area allows the user to add information, comments and action plans for each location and crop issue x) Each scouting document can be saved as a pdf file or a ScoutDoc file (.sdr) which can be stored on the device, shared by email and/or reloaded for future updates	iPad only
Weeds: The Ute Guide	This app is designed to be used in the paddock by growers to assist in identifying the most common, annual, biennial and perennials weeds in Southern Australia. Where possible photographs have been provided of the weed at various growth stages to ensure correct identification. Each weed has a calendar to show which month/s the weed is likely to be present in the paddock. The app allows you to search, identify, compare and email photographs of weeds to their networks.	iPhone only

Tank Mixing and Spray Application

Title	Features	
Chemical Safety Data Sheets	This app displays International Chemical Safety Cards [ICSC] produced by the United Nations Environment Programme (UNEP), the International Labour Office (ILO), and the World Health Organization (WHO). An ICSC is very similar to an Material Safety Data Sheet [MSDS], a standard reference document from the manufacturer for chemical information and is required, for safety purposes, to be kept in any place where workers face possible exposure to those chemicals. Use the information in this app to augment occupational health and safety when working with the applicable chemicals as an adjunct to MSDS or when MSDS are unavailable. Features: y) Fully indexed and searchable chemical list by Name, CAS# or RTECS# z) Saved history of previously viewed chemicals aa) Email and Airprint capability bb) No Internet connection required	iPhone only
Spray	Features: cc) Replaces the manual spray log dd) Records & Stores Spray sheets in one place ee) Exports data in CSV format ff) Stores Chemical details gg) Stores all historical chemical applications hh) Filing Cabinet in the iPad ii) Live feed of information from the operator as it happens jj) Dropbox upload support	iPhone only
Tank Mix by DuPont	The DuPont TankMix Calculator App allows you to easily calculate the amount of product you will need to treat a specific field area, the amount of product you need to apply to a specific tank size, the amount of water you'll need to treat a specific field area or the amount of product you need to get the desired Volume to Volume ratio. It offers a wide selection of Units of Measure to make it useful anywhere in the world and it gives you the flexibility to enter information using both decimals or fractions.	iPhone only

Title	Features	
Syngenta Tank Calc	The Syngenta TankCalc is a unique tool for easy and efficient calculation of filling plans for spraying. It saves time and ensures high accuracy in the tank mixing based on area, tank size, product, dosage and driving speed. Features: kk) Filling plan with the amount of products, water and number of tanks ll) Summary with the total consumption of products and water mm) Recommendation for choice of ISO nozzles nn) Special features minimizes filling and driving time oo) All previous entry of products can easily be recalled when calculating a new filling plan. The calculations can be saved and exported and send to your PC – for administrative simplifications and filing of the spraying journals. The app can be personalized with individual language settings, date format, tank size and wind speed settings	iPhone and Android
Tank Mix Calculator	This app allows a farmer to use a mobile device to quickly and easily generate a tank mix. Just enter your acreage, tank size, and carrier volume, then select your chemicals from the list or add your own. Tank Mix Calculator will then provide you with the number of loads required to spray your acreage, along with full and partial load mixes of the chemicals you selected.	iPhone and Android

Weather

Title	Features	
Elders Weather	A comprehensive weather app which includes over 2000 locations, key international locations and the ability to add up to 10 favourite locations. Features: pp) Delta T (Traffic light style Indicators for Delta T suggesting ideal spraying conditions) qq) 7 day forecasts rr) 12 month rainfall ss) Past 24 hours temperature tt) Nino 3.4 Index uu) Local radar vv) UV ratings ww) 3 hourly forecasts for the next 48 hours xx) Sunrise/Sunset yy) Tides zz) Minimum and maximum temperature aaa) Chance of rain bbb) Wind (gusts) ccc) 12 month forecast for district ddd) National Satellite eee) 7 Day synoptic GFS 0-7 and 7-14 day fff) Rain forecast maps ggg) Radar maps with pause & play function hhh) Tailor your weather settings: Temp Co or Fo Km/h or knots, mm or inches	iPhone only
Australian CliMate	Australian CliMate is a suite of climate analysis tools for iPhone, iPad and iPod touch devices. The App allows you to interrogate climate records (over the last 60 yrs) to ask a number of questions relating to rainfall, temperature, radiation, as well as derived variables such as heat sums, soil water and soil nitrate. It is designed for decision makers who use past climate statistics, forecasts and knowledge of system status (e.g. soil water, heat sum) to better manage their business	iPhone and iPad

Title	Features	
Oz Radar	Oz weather radar allows you to view the BOM (Bureau of Meteorology) weather radar information located through Australia. Each radar image can be panned and zoomed to get a better look at the area you are interested in. Approximately 50 radars cover a large proportion of Australia to bring you the most up to date weather information. Features: iii) Uses GPS to show your location on the radar jjj) Supports full screen landscape view kkk) National cloud and synoptic charts lll) All views show the latest feeds directly from the BOM web site mmm) Listing nearby radars nnn) Selection of surrounding radar by direction ooo) Animated national weather chart ppp) Animated national synoptic chart	iPhone only
Pocket Weather AU	Weather sourced directly from the Australian Bureau of Meteorology (BOM) - an Australian Source for Australian Weather, from an Adelaide company. Features: qqq) Forecast & observation data for hundreds of areas around Australia. Select it via GPS, Map or list rrr) Push current temp, text forecasts and state, regional and local warnings sss) 5 custom themes, that complete change the way the app looks ttt) Tide graphs for hundreds of locations around Australia uuu) National Rain, Satellite and Synoptic Chart vvv) Animated weather icons www) Sunrise/sunset times xxx) All of the BOM rain and wind doppler radars with Find/Track me function as well as the ability to have it auto update (see 'Live Radar' in settings) yyy) Detailed 6 day forecast, tap on a day to see the full forecast text, as well as sunrise/sunset times zzz) Give your locations custom names aaaa) Realtime UV support for some locations bbbb) History for the last 72 hours, as a table or graph cccc) Last update is always cached, so you don't need a network connection to check the weather for the week, once you've got it once	iPhone and Android
Rain? Australian Rain Radar	A simple, easy to use app which shows you the latest rain radar data in your area, as supplied by the Bureau of Meteorology.	iPhone only

Title	Features	
The Weather Channel	Features: dddd) Interactive maps with animated radar eeee) Severe weather alerts for your location ffff) Hourly and 10-day forecasts gggg) Pinpoint your location for exact weather conditions hhhh) Hurricane Central within Maps section includes active storm, projected path, and satellite maps for the Atlantic, Gulf of Mexico, Caribbean, and Pacific iiii) Video of breaking news and amazing weather coverage jjjj) View and post local weather tweets for your location in the Social tab kkkk) Upload and view photos and videos for weather in your area llll) Post local weather to your Facebook wall	iPhone and Android
Weatherzone Plus	Weatherzone uses Bureau of Meteorology forecasts and our meteorologists to produce accurate forecasts for Australia and the world. Features: mmmm) Real-time observations for temperature, wind speed, gusts and direction, dew point, relative humidity, rainfall, pressure and rain since 9 am nnnn) Push Notifications for Warnings, forecasts and App Badge oooo) Easily cycle through nearby locations pppp) GPS search for current location qqqq) Sunrise and Sunset times rrrr) Max UV rating ssss) Tide Charts tttt) Moonrise /Moonset for 7 days uuuu) Marine forecast vvvv) Dynamic animated backgrounds that change as the weather does wwww) Real-time weather warnings xxxx) Animated Interactive radar from 58 locations around Australia yyyy) Animated National and State composite radars zzzz) Animated satellite of Australia aaaaa) Can store and display UNLIMITED favourite locations bbbbb) Exclusive 3 hourly temperature, icon, wind and rain probability forecasts for the next 48 hours for all major Australian locations from Opticast® ccccc) Lightning on radar animators using your Weatherzone Pro subscription or in-app purchase ddddd) 7 day forecasts for 2000+ Australian locations min, max temperature, icon, rain probability/likely amount and 9am/3pm wind	iPhone only

Pest and Disease

Title	Features	
Yates Garden Problem Solver	The Yates Garden Problem Solver app will help you find solutions to a range of common garden problems such as insect pests, diseases and weeds in the home garden.	iPhone only
ABC Vegie Guide	ABC Vegie Guide is an essential tool for all vegetable gardeners – from the novice to the experienced - to help you find out what vegie should be planted when, no matter the climate zone you're in. ABC Vegie Guide will give you all the information you need to produce healthy crops throughout the year, including growing tips, pest and disease control pointers and harvest guides. In your 'Patch' you can keep a running record of notes about what's going on in your garden. You can keep track of what you planted and when, take photos & make notes on progress and be prompted when your plants should be ready to harvest.	iPhone and iPad

Source: Apps-Book (2012) Produced by Ag Excellence Alliance Inc, with funding from the Department of Environment and Natural Resources