VG98135
An Evaluation of the Effects of R&D of Integrated Pest Management in the Processing & Fresh Tomato Industries

Harley Juffs, *et al*
Harley Juffs & Associates Pty Ltd

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VG98135

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Partnership in horticulture

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An Evaluation of the Effects of R&D on Integrated Pest Management in the Processing and Fresh Tomato Industries

A Report on Project VG98135

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Horticultural Research and Development Corporation

September 1999

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Harley Juffs
Director, Harley Juffs & Associates Pty Ltd
15 September 1999

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Executive Summary

This report outlines the results of the consultancy project VG98135: *'Evaluating Effects of R&D on Integrated Pest Management in the Processing and Fresh Tomato Industries'*, commissioned by the Horticultural Research and Development Corporation. The project was conducted during the period December 1998 to April 1999 by Harley Juffs & Associates Pty Ltd, Brisbane, in conjunction with a team of four affiliates.

The main purpose of this study was to:

- measure the extent to which IPM has been adopted by producers;
- identify the barriers to adoption of IPM and opportunities to increase adoption of IPM;
- evaluate the overall net benefit due to adoption of IPM that can be assigned to R&D expenditure, including the public or social benefits that flow from the adoption of IPM; and
- investigate the impacts of individual projects on tomato IPM funded by the HRDC and to make recommendations on HRDC's future investment in tomato IPM.

The main sources of data for the study were:

- an initial series of eight grower meetings conducted in each of the main growing districts in January and February 1999;
- a follow-up grower survey by mail-out questionnaire to all growers;
- interviews with most of the IPM researchers and consultants and also with the tomato processors;
- a follow-up questionnaire to the researchers and consultants; and
- specific requests to key individuals and relevant organisations.

The study showed that Integrated Pest Management or, as it is more commonly known, 'IPM', has gained wide acceptance in both the processing and fresh (Queensland) sectors during the past decade. It was not possible to objectively measure the extent to which IPM-related practices were used a decade ago, but it is known that scouting was rarely used, there was heavy reliance on the use of broad-spectrum chemicals applied according to a pre-determined calendar program and the role of beneficials in pest management was poorly understood.

Grower focus groups and surveys showed that a very small number of growers (one or two) commenced to use what they then regarded as IPM about 1990, with numbers steadily increasing since that time. Many of the processing growers started to use IPM in about 1995, coinciding with an HRDC-funded IPM project managed by DNRE.

Rates of adoption of some of the elements of IPM by tomato growers (ie IPM used, but to varying extents) during the most recent season for which data were available were:

- Processing sector, 1997-98 season: 89%, based on grower numbers, and 93%, based on production area.
- Bowen region (fresh sector) 1999 season: 100%.
- Bundaberg region (fresh sector) 1999 season: about 77%, based on grower numbers, and about 95%, based on tonnage of production.

- Lockyer/Stanthorpe region (fresh sector) 1998-99 season: about 49%, based on grower numbers and about 70%, based on production area.

Quantitative data showed that IPM use had increased in both sectors during the last three seasons on both a grower number and production area/tonnage basis.

A grower survey showed that, on average, processing growers used 59% of 33 recognised IPM-related farm practices in the 1998-99 season. In the fresh sector, the equivalent figure was 61% for the 1999 or 1998/99 season. In both cases, use of these practices was higher than in previous seasons. Growers in both sectors rated practices related to beneficials the lowest. This was confirmed by independent ratings of IPM use on a sector/region basis provided by consultants and researchers.

The study thus showed that while IPM has gained a high and steadily increasing level of adoption by tomato growers, not all growers have adopted it. Furthermore, and perhaps more importantly, IPM has in fact only been partially adopted (to varying degrees) on many of the farms categorised as 'IPM farms'.

A definition of IPM, as applicable to tomatoes, was developed during this study. However, it was obvious that many growers do not have a good understanding of the totality of IPM. To some growers, 'adopting IPM' simply means employing a scout and perhaps making token use of the recommendations that their scout provides for them on pest management.

One reason for the differing views by growers and others on what constitutes adoption of IPM is the nature of IPM itself. IPM is basically a set of principles. The farmer has the task of translating these principles into a set of commercial farm management practices. As mentioned above, this list of practices can be quite long; a checklist of 33 IPM-related practices was developed during this study.

It was evident that to tag a farmer as a 'user' or 'non-user' of IPM can be misleading. For example, a case was encountered in this study where a farmer classed himself as a 'non-IPM' user (because he did not employ a scout), but our examination of the practices he was using convinced us that he was in fact using IPM to a substantial degree.

Some farmers also clearly resent being tagged as a 'non-IPM user'. Some of this resentment may be because farmers see the IPM extension effort as a form of intrusion into their private domain. There was even evidence to suggest that social divisions exist in some districts between groups of farmers stemming from their use or non-use of IPM.

Regardless of the terminology used to describe the system of pest management under consideration in this study, the focus needs to be on gaining maximum adoption of a suite of pest management practices that are consistent with sustainable and profitable crop production in the long term.

The main elements of an IPM program are: scouting of the whole production area, reduced used of chemicals wherever practicable, use of alternative chemicals (ie moving away from use of broad spectrum chemicals to use of more selective chemicals on a targeted basis) and recognition of the role of beneficials in pest management.

Growers, consultants and researchers from both sectors rated Heliothis as the most important insect pest of tomatoes. Powdery mildew was rated as the most important plant disease in the processing sector, and target spot in the fresh sector. Blackberry nightshade was rated the

most important weed in both sectors. Trichogramma was rated the most important beneficial in the processing sector, with Trichogramma and spiders sharing the highest rating in the fresh sector.

Conflicting theories were provided by various people in the industry about the impact of IPM on the level of grub damage in processing tomatoes. However, there was insufficient evidence to demonstrate any impact of IPM in this regard.

There was, however, sufficient evidence available to demonstrate a negative relationship between a numerical rating of the level of IPM use on processing tomato farms and the incidence of insecticides in fruit from the 1998 harvest, ie incidence of insecticide residues in the fruit declined as the level of IPM use increased. This relationship was even stronger when the analysis was restricted to S7 insecticides, and stronger again when restricted to just Endosulfan. This is clearly a positive outcome of the application of IPM, ie fewer insecticide applications and/or a move towards use of 'softer' chemicals. However, the incidence of fungicide residues in the fruit was fairly uniform regardless of the level of IPM use.

The overall net benefit to both sectors of the industry from investment in tomato IPM over the last 10 years was positive, with a Net Present Value at 6% of approximately $75 million. Thus the investment (collectively by the tomato industry, HRDC, State Departments of Agriculture and agribusiness) has been very profitable. The benefit cost analysis was based mainly on the history of pest-related events in each sector over the past decade and their economic impacts.

Results of the benefit cost analysis on a sector basis were strongly positive for the fresh sector, but very slightly negative for the processing sector. Reasons for this disparity include the higher value of fruit and the greater scope for IPM to prevent yield losses in the fresh sector.

However, IPM has not yet reached its full economic potential and greater positive pay-offs can be expected in the future.

In order to allow more rigorous benefit cost analyses to be conducted in the future, it is recommended that systems be put into place now for trapping and collecting the necessary data.

The most successful of HRDC's portfolio of IPM research projects over the past decade, in terms of 'getting IPM up and running', have been those that had strong links with consultants working directly with growers. However, it is also recognised that research on specific pests and diseases has been, and will continue to be, required.

Further research on IPM in tomatoes is required, mainly in two broad areas: (i) further development of IPM as a grower-friendly and effective field practice, and (ii) development of pest management measures that are both more effective and more compatible with a truly integrated pest management system than are present measures.

It is recommended that HRDC continues to fund research on tomato IPM. A series of specific recommendations has been provided on both the content and management of these projects. Some of the key themes underpinning these recommendations are: a need to ensure that all projects have a genuine and commercial IPM focus, greater technical support for consultants, greater input by growers into the management of projects and a focus on development of improved control measures for plant diseases.

There was little evidence of active collaboration between the IPM research programs conducted by the processing and the Queensland fresh sectors. Some recommendations on ways to redress this situation have been made.

Many factors influence the IPM adoption process. However, the availability of a well-trained and competent consultant is a key factor. In this regard it is recommended that HRDC and the industry develop a system for providing better and on-going technical support to consultants.

For their part, growers must remunerate scouts and consultants to properly recognise their professional skills and dedication. Only by this means will the industry be able to ensure that the services of these professionals are retained within the industry.

Entry of adequately-trained recruits into the IPM scouting and consultancy profession needs to be encouraged and supported. IPM will not survive unless the industry's on-going demand for well-qualified scouts and consultants is met.

Development of IPM protocols on a regional basis is recommended. This will ensure that the IPM programs are regional or even farm specific. It will also provide an objective benchmark against which IPM performance can be measured.

Further recommendations and suggestions on gaining further adoption of IPM are included in the report.

It may also be helpful, both in the planning of research on IPM and in the promotion of IPM to growers, to conceptualise IPM as a component of a wider risk management strategy at industry, sector, district and farm levels. In this regard, it is noted that some growers are already including IPM as a component of their formal on-farm quality assurance programs. It is also worth noting that while many of the problems that IPM is meant to address manifest themselves on the farm, they in fact have their origins beyond the farm boundary.

Key issues for the HRDC include:

- where to focus the research necessary to underpin successful IPM technology into the future; and
- how to support the tomato industries in their quest to achieve high rates of IPM adoption (an issue that extends well beyond simply looking at 'IPM adoption' by grower numbers or areas, to the actual and meaningful use of a minimum range of key pest management practices).

The results of this study, supported by a series of recommendations and observations throughout the report, will provide the HRDC with a focus on the issues that we believe need to be addressed.

1. Introduction

1.1 Context and purpose of the study

The processing and fresh tomato industries, with the support of the Horticultural Research and Development Corporation (HRDC), have invested significant funds in the development and implementation of Integrated Pest Management (IPM) over the past decade. Other stakeholders, particularly State agriculture departments in the three eastern mainland States and, to a lesser extent, agrochemical companies and Universities, have also invested significant funds to assist with the introduction of IPM to these industries.

To date, the research and development effort on IPM has been confined to the fresh tomato industry in Queensland and the processing tomato industry in Victoria and southern New South Wales.

To build on the progress with adoption of IPM achieved to date, the two sectors of the tomato industry under consideration have both developed aggressive strategies with respect to the wider adoption of IPM over the next few years. For example, the Processing Tomato Research and Development Plan for the period 1997 - 2001 has as one of its objectives: *'To enable implementation of an effective, industry-wide IPM system, incorporating control of weeds, diseases and insects/mites with 100% adoption by 2001'*. Similarly, the Tomato Sectional Group of Queensland Fruit and Vegetable Growers has identified adoption of IPM as one of the key R&D issues, and is also seeking to have IPM adopted as a standard management practice in the Queensland fresh tomato industry by 2001.

In view of the considerable investment by the HRDC and other agencies in the development of IPM programs in the tomato industries over the last decade, it, with the support of the processing and Queensland fresh industry sectors, commissioned a study to evaluate the effectiveness of its investment on tomato IPM to date. In particular, the purpose of this study was to:

- measure the extent to which IPM has been adopted by producers;
- identify the barriers to adoption of IPM and opportunities to increase adoption of IPM;
- evaluate the overall net benefit due to adoption of IPM that can be assigned to R&D expenditure, including the public or social benefits that flow from the adoption of IPM; and
- investigate the impacts of individual projects on tomato IPM funded by the HRDC and to make recommendations on HRDC's future investment in tomato IPM.

The complete terms of reference for the study and the expected outcomes are detailed in Attachment 1.

The study was conducted during the period December 1998 to April 1999 by a team comprised of:

- Dr Harley Juffs, Director, Harley Juffs & Associates Pty Ltd, Brisbane (lead consultant);
- Mr Ian Whan, Director, Alliance Resource Economics Pty Ltd, Brisbane;
- Associate Professor John Harden, Deputy Head, Department of Plant Production, University of Queensland, Gatton;

- Dr Peter Taylor, Director, TS Agricultural Consultants Pty Ltd, Melbourne, and Senior Lecturer (part-time) in Plant Protection, Institute of Land and Food Resources, University of Melbourne; and
- Mr Dan Papacek, Director, Integrated Pest Management Pty Ltd, Mundubbera, Adjunct Senior Lecturer, Department of Entomology, University of Queensland.

Contact details for the study team are also included at Attachment 1.

The study was supervised by an Industry Reference Group comprised of Dr Mark Smith, Program Manager, HRDC (Coordinator), Ms Lauren Thompson, Industry Development Manager, Australian Processing Tomato Industry Research Council, and Mr Peter Pearce, Executive Officer, Tomato Sectional Group, Queensland Fruit and Vegetable Growers.

1.2 Industry overview

The two industry sectors under consideration in this study, ie the Queensland fresh tomato industry and the processing tomato industry, located in northern central Victoria and southern central New South Wales, have different market requirements and production systems. The two sectors essentially operate as separate entities.

The Queensland fresh tomato industry supplies about 65% of Australia's fresh tomato requirements. Production is centred in four main areas: Bowen (62% of the State's production) Bundaberg (27% of production), Lockyer and Stanthorpe (11% of production on a combined basis). There are currently about 55 serious tomato growers in the State. However, a few large growers from the Bowen and Bundaberg areas produce the bulk of the State's crop. Crops in the Bowen and Bundaberg areas are generally planted in the late summer and autumn, while crops in the Lockyer and Stanthorpe areas are planted in spring and summer so as to avoid frost damage. Fruit is hand picked, though often with mechanical support systems to improve efficiency.

Most of Australia's tomato processing is conducted in northern Victoria, with about 95% of the crop directed to five plants located at Tatura, Girgarre, Echuca, Shepparton and Mooroopna. Three of these plants produce tomato pulp, while the main focus of the other two is on canning of whole peeled tomatoes.

About 68% of the processing tomatoes are produced in Victoria, with the remainder of supplies being drawn from earlier maturing areas in southern New South Wales. About 45 growers now specialise in the production of tomatoes specifically for processing. These growers are located in the following districts: Boort (6), Rochester/Echuca (8), Corop/ Colbinabbin (11), Goulburn Valley (3), Jerilderie ('Southern Riverina', 10), Leeton/Griffith ('MIA', 5). In addition, there are about five fresh tomato growers who also supply some surplus fruit to processors, however these were excluded from this study.

Processing tomatoes are planted in spring/early summer to provide a concentrated harvest period, which commences late January and finishes about the end of April. All processing tomatoes are mechanically harvested in a once-only operation. Green fruit are mechanically rejected on the harvester. All other fruit are then transported in bins to a processing factory where each bin is sampled and graded on arrival.

IPM in the Queensland tomato industry was largely pioneered by Crop Tech Pty Ltd (John Hall) in the Bundaberg district about 10 years ago in response to a pest crisis: out of control leaf miner. The IPM technology has been further developed from that point with HRDC

support. HRDC funded two 'IPM' projects commencing in July 1992, one in Bundaberg conducted by Crop Tech and one in Bowen conducted by Crop Monitoring Services (Dale Abbott). The first HRDC project specifically dedicated to IPM in processing tomatoes also commenced in July 1992 with Mark Smith of IHD Knoxfield as Chief Investigator. HRDC has since funded a series of about 10 research projects in each sector. Some of these projects were focussed directly on the development and field implementation of IPM as a commercial field management practice, while others were focussed on development of technology to support IPM such as the improved control measures for particular insect, plant disease or weed pests.

Research support for tomato IPM is delivered mainly through the Queensland Department of Primary Industries (Bundaberg), the Victorian Department of Natural Resources and Environment (IHD Knoxfield and ISIA Tatura) and NSW Agriculture (Yanco). The research effort of the State Departments is, however, heavily dependent on HRDC support. Hence the HRDC plays an important role leveraging input into IPM research by State agencies (and also universities and agribusiness/agrochemical chemicals).

One private consultant based in Brisbane conducts research on nematode control in tomatoes (and other crops) with the support of HRDC and other agencies.

Extension services provided by State Departments to the tomato industries have generally declined over the last decade. DNRE and NSW Agriculture no longer provide a dedicated 'whole of farm' extension service to tomato growers. In Queensland, the situation varies from region to region. There appears to be a reasonable level of service in the Bowen region, a moderate service in the Bundaberg region and no service in the Lockyer and Stanthorpe regions.

Specialist private IPM consultants are now an integral part of both the processing and Queensland fresh sectors of the industry. The introduction of IPM programs, coupled with the general withdrawal of Agriculture Departments from one-to-one extension, has created an opportunity for these consultants to 'grow a business'. Some of these consultants also advise growers on other aspects of tomato production, eg water and nutrient management.

Four 'recognised' IPM consultants presently operate in the processing sector, based at Griffith, Jerilderie, Boort and Rochester/Echuca. In Queensland three consulting operations conduct most of the IPM consultancy business. There are a couple of small operations in Bundaberg. In some regions, chemical resellers (other than those who provide a recognised scouting service) also offer 'IPM advice', though the quality of this advice is unknown and was not specifically investigated in this study. A few farmers are also attempting to provide their own 'do-it yourself' (DIY) scouting service.

1.3. Project design and methodology

This project was heavily dependent on the gathering of field data about the use of IPM by growers and the impacts of IPM use on a range of variables.

With the assistance of local industry organisations, growers were invited to attend a meeting in their district in January or February 1999. These meetings were conducted essentially as focus groups, with growers invited to discuss and respond to a series of questions about IPM. These questions covered topics such as what is IPM, changes in farm practice with IPM, why growers do or do not adopt IPM, and the costs and benefits of IPM. Two members of the

project team facilitated the meetings. In some cases, people from the local industry organisation or Agriculture Department also attended the meetings. In most cases, the local IPM consultant (by arrangement) did not attend the meeting.

Meetings were conducted at Colbinabbin, Boort and Rochester in Victoria, at Jerilderie, Whitton (Griffith), in New South Wales, and at Bundaberg, Bowen and Gatton in Queensland. Attendance of growers at these meetings was variable. Even though the meetings in the processing sector just preceded the start of the harvest, attendance at these particular meetings was good, with about 30 of the 45 growers attending in total. Interest in IPM was also high at the grower meetings. However, only eight growers in total attended the Queensland meetings, out of a possible 35 'serious' growers or 55 if small growers were counted. Reasons for the low attendance at the Queensland meetings could have included inclement weather, meetings held 'before the season', lack of interest and lack of active industry organisational infrastructure at the local level.

Following the grower meetings, a survey questionnaire was given or mailed to all 45 growers in the processing sector and to 55 in Queensland (refer example of the questionnaire proforma provided at Attachment 2). Returns of the questionnaire were also low though probably realistic: nine in the processing sector and seven in the Queensland fresh sector. However, the questionnaires that were returned provided valuable information. Reasons identified for the low returns from the processing sector included 'can't do it during the harvest', 'don't support IPM and HRDC's role in it' and 'too difficult to quantify the costs and the benefits'.

In conjunction with the grower meetings, all of the recognised IPM consultants and most of the key researchers and major processors were interviewed (refer example of the interview proforma provided at Attachment 3). This interview was followed up by a 'supplementary' questionnaire sent to researchers and consultants (refer example of the questionnaire proforma also provided at Attachment 3). The rate of participation in these interviews was high. Similarly, the rate of questionnaire returns was also high. These groups of industry stakeholders provided a valuable regional/sector perspective on IPM.

Additional information required for various aspects of the study was sought from a range of sources including tomato industry organisations, IPM consultants of long-standing, Agriculture Departments, individual researchers and processors. These sources are identified in the relevant sections of the report.

2. IPM in the tomato industries – what is it and where is it at?

2.1 Definition of Integrated Pest Management)

Integrated pest management has had a long history of development. It was first defined as 'integrated control' by Stern, Smith, van Bosch and Hagen (1959[1]) as follows: *'Applied pest control which combines and integrates biological and chemical control. Chemical control is used as necessary and in a manner which is least disruptive to biological control.'*

Stern *et al* used this definition to describe their work on lucerne in California, where they solved the problem of aphids' resistance to insecticides by reducing the dose of organophosphate insecticides, thus allowing biological control to play a significant part in the pest management program.

The above definition served to focus attention on (i) the importance of using chemical control, ie the use of pesticides, in a way that supported biological control, and (ii) the need for information from the field about both pests and beneficials. However, one of the shortcomings of this definition was that it focussed only on insects as the target pests and the biological and chemical control thereof.

During the 1960's and 70's the term 'pest management', as proposed by Geier and Clark[2] in 1961, gradually replaced the term 'integrated control'. In 1976, Apple and Smith[3] broadened the definition of pest management to include all pests. Today, 'integrated control' equals 'pest management' which, in turn, equals 'integrated pest management' in most people's minds (van Emden and Peakall, 1996[4]).

Many definitions of Integrated Pest Management (IPM) have been proposed since the initial concept of using pesticides to support biological control as a specific directed activity was first developed by Stern *et al* 1959.

Significant progress with the development of IPM as a practical field management tool has been made, but only during the last decade. This has allowed IPM to become a practical reality for many farmers. In parallel with the development of IPM as a field practice, the definitions of IPM appearing in the literature have changed; they now define IPM as a philosophy, rather than provide a description of how to implement IPM.

The following definitions of IPM, published in recent years, highlight contemporary thinking on what IPM is and what it is not:

1. The Global Crop Protection Federation supports IPM as defined by the FAO International Code of Conduct on the Distribution and Use of Pesticides (Article 2):
   'Integrated Pest Management (IPM) is a system that, in the context of the associated environment and the population dynamics of the pest species, utilises all suitable techniques and methods in as compatible a manner as possible and

[1] Stern V M, Smith R F, van den Bosch and Hagen K S (1959). Hilgardie, 29, pp 81-101.
[2] Geier P W and Clark L R (1961). *'An ecological approach to pest control'*. Proc.8th Technical Meeting of the International Union for Conservatioon of Nature and Natural Resources, Warsaw, 1960, pp 10-18.
[3] Apple J L and Smith R F, eds (1976). *'Integrated Pest Management'*. Plenum, New York.
[4] Van Emden A F and Peakall D B (1996). *'Beyond Silent Spring, Integrated Pest Management and Chemical Safety'*. Chapman Hall, pp 38-39.

maintains the pest populations at levels below those causing economically unacceptable damage or loss.' —(Global Crop Protection Federation, 1998[5])

2. AVCARE, the National Association for Crop Protection and Animal Health (in Australia), defines IPM as:
"A sustainable approach to managing pests by utilising biological, cultural, physical and chemical tools in a compatible manner that minimises economic, health and environmental risks. In this context 'pests' include damaging insects, mites, nematodes, molluscs, plant diseases and weeds." (Harden, 1996a[6])

Both of these definitions highlight the fact that IPM encompasses all pests. They also require that all pest management (control) methods are considered and included into pest management programs that are economically viable.

It is proposed that the following definition of IPM, which is based on an amalgam of the two definitions immediately above, is appropriate for the purposes of analysing and planning research on IPM in the fresh market and processing tomato industries in eastern Australia. It also takes into account feedback from growers on their perceptions of IPM.

> '*Integrated Pest Management is a system of sustainable crop management that, in the context of the associated environment and the population dynamics of the local pests, utilises all suitable biological, cultural, physical and chemical tools in a compatible manner to (i) maintain the pest populations at levels below those causing economically unacceptable damage or loss, and (ii) minimise risks to human health and the environment. In this context 'pests' include damaging insects, mites, nematodes, molluscs, plant diseases and weeds.'*

In a statement on what IPM is, Harden (1996b[7]) said: '*Integrated Pest Management is the use of information to manage pests in a sustainable way for profit. The information required for successful IPM is about pests, beneficial species, pest management (control) methods, crops, animals and the environment.*'

However, Avery (1996[8]) stated that the contemporary reason for using IPM is to make pesticides more effective. It uses fewer chemicals per kill and helps reduce the build-up of pest resistance. IPM may also help us farm with greater sensitivity to the local environment. But this must be secondary to minimising the land required for food production. Let us not make the mistake of believing that IPM is a substitute for pesticides.

Nor should we make the mistake of believing that using less pesticide is somehow a virtue in itself. Radical opponents of farm chemicals say the goal should be the complete elimination of pesticides. This is not possible, particularly in relation to the economic production of pest-prone perishable commodities such as tomatoes. The assessment of research projects and of

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[5] Global Crop Protection Federation (1998). *'Integrated Pest Management – The way forward for the crop protection industry.'* GCPF Brussels, pp 1-21.
[6] Harden J (1996a). 'Integrated Pest Management (IPM) Research and Development in Australia', pp 48-50 in *'AVCARE IPM The way forward'* edited by J Harden and J Whitehead. Proceedings of the 32nd Annual Convention of AVCARE, Perth.
[7] Harden J (1996b). 'Integrated Pest Management – The way forward', pp 5-7 in *'AVCARE IPM The way forward'* edited by J Harden and J Whitehead. Proceedings of the 32nd Annual Convention of AVCARE, Perth.
[8] Avery D T (1996). 'Integrating pest management with the environment', pp 75-86 in *'AVCARE IPM The way forward'* edited by J Harden and J Whitehead. Proceedings of the 32nd Annual Convention of AVCARE, Perth.

progress in the implementation of IPM programs for tomato production should be based on a consideration of what IPM is and what it is not. Some of the key criteria are set out below.

WHAT IPM IS:

- Gathering information on the incidence levels and location of pests and beneficials and the recording of this information.
- Whole farm planning and careful consideration of cultural practices in relation to pest management.
- Integration of the components of the system.
- Use of quarantine and hygiene.
- Use of pest resistant varieties.
- Use of crop rotations.
- Selecting pesticides to specifically support biological control.
- Applying pesticides strategically to specific sites in the crop canopy rather than blanket spraying the whole canopy, eg top spraying of trellis crops.
- Rotation of pesticide groups to minimise the development of pest resistance.
- Rational use of pesticides based on pest levels and pest/beneficial ratios.
- Managing beneficials including introduction thereof.
- Supporting biological control of pests.
- Use of as many methods as possible to suppress pests.

WHAT IPM IS NOT:

- Calendar spraying of mixtures of pesticides.
- Continuous use of pesticides (particularly of those that are broad spectrum in activity).
- Saving money by using fewer sprays.
- Biological control.
- No use of pesticides.
- Use of a set recipe for pest management.
- Using chemical control (pesticides) to the exclusion of other methods of pest management.
- Organic farming.

IPM CAN REQUIRE:

- A change of approach from pest control (kill them all) to pest management (keeping pest levels below economic thresholds).
- Use of professional consultants.
- A flexible approach to crop management.
- Identification and understanding of the biology and ecology of pests and beneficials.
- A detailed understanding of pesticides and their safe use.

Tomato growers made various statements at the grower meetings indicating that they (or at least some of them) have a practical understanding of IPM. Some typical statements are listed below.

- 'Managing the good guys to beat the bad guys.'
- 'Ten years ago we used a fixed schedule, now we don't.'
- 'It is critical to know what is happening in your crop.'
- 'Types of chemicals and rates have now changed.'
- 'Scouts monitoring several growers develop a collective view of what is happening in the district.'
- 'Industry needs to implement a host free period to reduce carry over of pests from season to season.'
- 'IPM can be difficult to implement in tomatoes because of the pressure of pests such as Heliothis and the high quality of fruit required (fresh market).'
- 'The emphasis is on monitoring, you need to do it.'

These statements indicate there is awareness and understanding of IPM by both processing and fresh fruit growers and that they are moving to adopt IPM strategies. However, it was also clear that many growers (at least amongst those in the processing sector who attended the grower meetings) are yet to appreciate the totality of IPM as per the definition proposed earlier in this section (see box).

2.2 Important pest targets for IPM in the tomato industries

All growers were asked to indicate, on the survey questionnaire, the pests they considered were the most important for tomato production on their farm. Pests were divided into three categories: insect pests, plant diseases and weeds. Growers were asked to nominate up to three pests in each category from lists provided on the questionnaire, with provision for them to add other pests (see questionnaire proforma at Attachment 2).

Information provided by the growers is summarised in Table 2.1 on a sector basis. The method of analysis was simply the 'number of mentions' on the nine questionnaire returns from the processing sector and the seven from the fresh sector.

Consultants and researchers were also asked to provide information on the important pests. However, in this case, they provided the information on a district or industry sector basis and ranked all of the relevant pests in each of the three categories in order of importance. Total number of responses from the processing sector was six and, from the fresh sector, four. (Note. These figures represent a high response rate.)

Because of the low number of data sets available, the data provided by the consultants and the researchers were combined on a sector basis. To provide a true reflection of the relative weightings of the combined responses and to allow between-sector comparisons, the responses were analysed by first summing the reciprocal of each of the individual scores for each pest (ignoring scores lower than 10). This total was then expressed as a decimal fraction relative to the maximum possible score and multiplied by 100. For the processing sector, the maximum possible total score was 60, ie a total of six responses with a maximum score per pest of 10. For the fresh sector, with four responses, the maximum total score was 40. The method of calculation can be demonstrated thus. For powdery mildew, the six processing

sector scores were 2, 1, 1, 2, 2 and 1, which converted to an overall ranking of 85, ie {(8 + 9 + 9 + 8 + 8 + 9) / 60} x 100.

The outcome of this method of calculation is that if all of the experts gave a particular pest a score of 1 (the most important), the overall ranking would be 100, ie the absolute highest in importance. Any number less than 100 equates directly to an importance that is proportionately lower.

Responses provided by the consultants and the researchers on the importance of pests are summarised in Table 2.2.

Information about the importance of beneficials (see definition in box below) was also gathered from growers, consultants and researchers. Growers were provided with a list of possible beneficials on the survey questionnaire and asked to indicate those they considered important on their farm. Consultants and researchers were provided with a similar list but were asked to rank the beneficials in order of importance. Scores were analysed in the same way as outlined for pests above. The numbers of responses were also the same. Results are summarised on a sector basis in Table 2.3.

The main points to be gleaned from the results in Tables 2.1, 2.2 and 2.3 are:

- The insect and mite pests of main concern at this time to processing growers are Heliothis, thrips, wire worms and cutworms and, to fresh growers, Heliothis, spider mite and leaf miner.
- Consultants and researchers also clearly ranked Heliothis as the most important pest in both the processing and fresh sectors. Ranked next in the processing sector were cutworms, wireworms and thrips and, in the fresh sector, silver leaf white fly, russet mites and spider/two spotted mites.
- The plant diseases of main concern to processing growers at this time are powdery mildew and bacterial speck, to fresh growers, target spot, spotted wilt, fulvia leaf mould and Fusarium wilt. (**Note.** Some of the processing growers completed the questionnaire before the outbreak of bacterial canker late in the 1998-99 season; hence this disease may have been under-rated.)
- The weeds of main concern to processing growers at this time are blackberry nightshade, heliotrope and Bathurst burr, to fresh growers, nutgrass, blackberry nightshade and pigweed.

Definition of the term 'beneficials'. Within the context of this report the term 'beneficials' is used to refer to insects and mites that are able to naturally regulate pest populations in agricultural ecosystems. The term covers both of the groups often referred to as 'parasites' and 'predators'. However, the former has been now largely replaced by the term 'parasitoids'.

Parasitoids are mostly small to very small wasps that develop fully on an individual host and destroy it in the process. In contrast, predators, which include such groups as ladybirds, lacewings and spiders, consume many prey during their development.

In any ecosystem there are numerous beneficial species, most of which occur naturally. Often they are capable of keeping potential pests to a level that is sub-economic and hence the grower is often unaware of their presence. When disruptive agents such as broad-spectrum pesticides eliminate the beneficial species, secondary pest outbreaks commonly occur. It is possible, in some situations, to introduce mass-reared beneficial species to augment or complement those that occur naturally.

Table 2.1. Pests considered by tomato growers in the processing and fresh (Queensland) sectors to be the most important on their farms.

Insect and Mite Pests	No. of mentions*		Plant Diseases	No. of mentions*		Weed Pests	No. of mentions*	
	Processing	Fresh		Processing	Fresh		Processing	Fresh
Aphids	2	2	Arboviruses	0	0	Bathurst burr	4	0
Cluster caterpillar	0	0	Bacterial canker	1	1	Blackberry nightshade	8	6
Cutworms	5	1	Bacterial speck	7	1	Black pig weed (Portulaca)	0	3
Leaf hoppers	2	1	Bacterial spot	1	0	Broad-leaf annuals	0	1
Leaf miner (potato tuber moth)	0	5	Bacterial wilt	1	1	Chinese lantern	1	0
Heliothis	9	7	Big Bud	2	0	Couch grass	0	1
Russet mites	0	1	Botrytis (grey mould)	0	0	Heliotrope	4	0
Rutherglen bug	1	0	Fulvia leaf mould	0	3	Johnson grass	1	1
Spider mite / Two spotted mite	1	5	Fusarium wilt	0	3	Nutgrass	0	7
Thrips	6	4	Powdery mildew	8	1	Oxtongue	1	0
Silver leaf white fly	1	5	Pythium	0	1	Volunteer tomatoes	1	0
Wire worms	6	1	Sclerotinia rot	3	2	Wild cape gooseberry	0	0
			Spotted wilt (Bronze wilt)	3	4	Wireweed	3	0
			Rhizoctonia rot	0	1			
			Root-knot nematode	0	1			
			Target spot (Alternaria sp.)	0	6			
			Verticillium wilt	0	0			

*Total number of mentions by growers who responded to the questionnaire. Total number of respondents was nine for the processing sector and seven for the fresh sector.

Table 2.2. Ranking by consultants and researchers of the important pests in the processing and fresh (Queensland) tomato sectors.

Insect and Mite Pests	Overall ranking *		Plant Diseases	Overall ranking *		Weed Pests	Overall ranking *	
	Processing	Fresh		Processing	Fresh		Processing	Fresh
Aphids	35	40	Anthracnose	5	0	Barnyard grass	10	0
Cluster caterpillar	28	32	Arboviruses	0	10	Bathurst burr	60	10
Crickets	0	10	Bacterial canker	27	20	Blackberry nightshade	100	60
Cutworms	73	35	Bacterial speck	60	22	Black pig weed (Portulaca)	16	22
Leaf hoppers	42	27	Bacterial spot	10	70	Bladder ketmia	13	0
Leaf miner (potato tuber moth)	0	50	Bacterial wilt	0	47	Caltrop (Yellow Vine)	0	12
Loopers	3	0	Big Bud	28	10	Datura (Thornapple)	0	12
Heliothis	100	100	Black fruit mould	7	0	Fat hen	0	40
Russet mites	60	67	Botrytis (grey mould)	22	60	Heliotrope	45	15
Rutherglen bug	8	27	Fulvia leaf mould	0	27	Johnson grass	30	42
Spider mite / Two spotted mite	38	60	Fusarium solani	0	10	Nutgrass	20	55
Thrips	55	52	Fusarium wilt	12	62	Oxtongue	13	0
Silver leaf white fly	16	72	Phytophthora root rot	28	0	Sow thistle	2	0
Wire worms	65	30	Powdery mildew	85	33	Summer grass	0	20
			Pythium	30	20	Volunteer tomatoes	7	0
			Sclerotinium rolfsii	0	15	Wild cape gooseberry	0	30
			Sclerotinia rot	35	15	Wireweed	45	7
			Spotted wilt (Bronze wilt)	53	30			
			Rhizoctonia rot	15	20			
			Root-knot nematode	0	30			
			Target spot (Alternaria sp.)	13	75			
			Verticillium wilt	13	27			

*See text above for explanation of the method used to calculate the overall ranking. A ranking of 100 indicates absolute highest importance. Numbers <100 indicate a lower importance in proportion to the value of 100, with 0 = not important. Total number of respondents was nine for the processing sector and seven for the fresh sector.

Table 2.3. Beneficials considered important in the production of tomatoes by growers, consultants and researchers on a sector basis.

Beneficial	Processing sector		Fresh sector	
	No. of mentions by growers* (max = 9)	Overall ranking by consultants and researchers**	No. of mentions by growers* (max = 7)	Overall ranking by consultants and researchers**
Aphidius colemani (parasite of aphids)	0	20	0	22
Assassin bugs (predator of caterpillars and plant sucking bugs)	2	33	2	0
Big-eyed bugs (predator of thrips and mites)	0	8	1	2
Brown shield Bug	1	10	0	0
Coccinella transversalis (a ladybird; predator of aphids)	3	35	4	15
Copidosoma spp. (parasite of tomato leaf miner)	0	0	1	10
Diaeretiella rapae (parasite of aphids)	0	13	0	20
Eretimoterous spp. (parasitoid of silver leaf white fly)	0	0	0	17
Hover flies (predator of aphids)	0	13	1	5
Lacewings (predator of aphids and mites)	3	40	2	0
Orgilus lepidus (parasite of tomato leaf miner)	0	0	0	12
Phytoseiulus persimilis (Chilean predatory mite)	0	0	0	17
Spiders (general predators)	0	43	4	70
Telenomus wasp	0	27	0	0
Trichogramma spp. (parasitic wasp)	7	100	5	45

*Total number of mentions by growers who responded to the questionnaire. Total number of respondents was nine for the processing sector and seven for the fresh sector.

**See text above for explanation of the method used to calculate the overall ranking. A ranking of 100 indicates absolute highest importance. Numbers <100 indicate a lower importance in proportion to the value of 100, with 0 = not important. Total number of respondents was nine for the processing sector and seven for the fresh sector.

- Consultants and researchers also ranked blackberry nightshade as the most important weed in both sectors. Next most important in the processing sector were Bathurst burr and heliotrope and, in the fresh sector, nutgrass, Johnson grass and fat hen.
- The beneficials of main interest to processing growers at this time are Trichogramma spp., lacewings and Coccinella transversalis and, to fresh growers, Trichogramma spp., spiders and Coccinella transversalis.
- Consultants and researchers also ranked Trichogramma spp. very highly in the processing sector, followed by spiders and lacewings. In the fresh sector, spiders were ranked the most important, followed by Trichogramma spp.

2.3 Changes in farm practices with IPM

Comment was sought from the growers who attended the various industry meetings and, in some cases, from researchers and consultants on the changes in farm practices that either accompany or follow the adoption of IPM.

A clear understanding of what IPM is or involves is fundamental to a consideration of any change in practices that can be associated with IPM. To many growers, adoption of IPM is synonymous with employment of a professional IPM scout, and perhaps little more.

A variation on employment of a scout is do-it-yourself (DIY) scouting. This was recognised by some growers, for personal interest and/or cost reasons, as a practical alternative to the employment of a professional scout. DIY scouting was being used in a few cases, but from the discussion at the grower meetings, DIY scouting is clearly not for everyone. To be successful, DIY scouting needs a regular allocation of time that cannot be comprised, a sound technical background, training, experience and a personal commitment to IPM principles. While recognising that there are some notable exceptions, most of the people attempting DIY would fail to meet one or more of these criteria. Professional scouts also have the added advantages of independence and regular access to a much wider information base, eg a district perspective on the current insect pest and plant disease situation.

There appears to be reasonable grounds for concern that some growers are not strongly committed to, or do not understand, the principles of IPM. Reasons for this include: a desire to be seen to be 'doing the right thing'; a lack of trust in the consultant's recommendations; an implicit belief in the infallibility of the chemical approach and an overriding fear that strict adherence to IPM might result in some crop losses or other disaster.

A smaller number of growers appeared to have an understanding of IPM that extended beyond 'low level' IPM. These growers appeared to have a reasonable grasp of both the concept and practical application of 'high level' IPM, ie use of softer chemicals, role of beneficials, management of resistance to chemicals, awareness of environmental and marketing considerations, etc. It was of interest that only one DIY grower was encountered who appeared to be using 'high level' (See Section 2.4 for more detail on categories of IPM use.)

Some of the additional pertinent comments from the **processing growers** on their changes to farm practices with IPM, other than simply employing a scout, are summarised below:

- Developing trust in a scout.

- Systematic observation of what is happening in the field via crop monitoring (fundamental to the whole process and will be done even if the savings in chemical applications do not always offset the cost of the monitoring).
- Greater awareness of the pest management practices that are available for use on the farm and of emerging pest and disease problems at the district level (shared knowledge via the scout).
- Timing of chemical applications now based on field observations, in contrast to spraying on a pre-determined pattern prior to IPM (money saved on sprays, especially early in the season).
- Types of chemical and rates of use (but there is still an occasional need to use a hard chemical).
- Methods of applying chemicals.
- Integration of the application of insecticides and fungicides.
- Farmers now know why they need to spray.
- Application of pesticides as dusts (as opposed to liquid sprays) has ceased.
- A greater awareness of the dynamics of insect pests and plant diseases (especially important in Heliothis management).
- Less likely to treat, on a 'just in case' basis, pests or diseases that may not be present or at least are not a problem.
- Less reliance on the advice of a chemical reseller.
- Farms are much bigger now than in earlier years, resulting in a need for farm owners/ managers to employ a scout to free up their time to do other things.
- Resistant tomato varieties are used where available (role for the seed companies).
- Training in IPM which, in itself, is not a huge task. (Basic training can be done in a week.)
- Plant tissue samples for nutrient analysis can be taken by the scouts during the monitoring for IPM purposes; hence IPM merges with ICM (Integrated Crop Management).
- Economic return at the end of the day is the ultimate test on any changes to farm practices.

A few growers, however, took a rather more cynical approach to the changes that accompany IPM than those outlined above. For example: *'Just do what you have always done and give it a name'*. However, when challenged (and putting aside the sensitive [for some growers] issue of the 'IPM' tag) even the cynics admitted a lot of changes to farm practices have in fact been made in recent years and these have been for the better.

Some of the additional pertinent comments from the **fresh (Queensland) growers** on their changes to farm practices with IPM are summarised below:

- Monitoring is absolutely fundamental to IPM, but some farmers are still reluctant to pay a realistic fee for a professional service.
- Growers in the Bundaberg district are covering the ground with their spray rigs more frequently now than they were 10 years ago, but the chemicals used now are more targeted with respect to the actual bush and particular pests.
- Chemicals comprise only 5% of production costs but have the biggest bearing on marketable yield.

- The average pack-out of tomatoes may have declined in recent years due to the use of higher thresholds with the refinement of IPM practice.

Some of the observations made by **Queensland consultants and researchers** on the changes to farm practices with IPM included:

- IPM in Queensland still has a high chemical component due to the high Heliothis load. These is some scope early and late in the season to reduce chemical use but not during the middle of the season when it is still necessary to spray 2-3 times per week. Careful management can reduce sprays by up to 5-6 per season. Heliothis is the main spray target.
- Production breaks and paddock hygiene are regarded as sound strategies for reducing pest populations and hence are key elements of IPM practice.
- The focus of pest R&D at Bundaberg has switched over the past 10 years from chemical control to treatment thresholds and the biology and ecology of pests. Changes in tomato varieties must be accompanied by revision of pest management strategies, eg treatment thresholds.
- Strategic spraying based on monitoring and presence of beneficials, eg predatory mites and lace wings, are the key elements of the IPM program in the Bowen district.

2.4 Level of adoption of IPM by growers

Grower responses regarding their use of specific IPM-related practices. All growers were asked to indicate, as part of the mail-out survey questionnaire (see example at Attachment 2), the IPM-related practices that they were using in the current/last season (depending on the sector), had used in the past and planned to use in future seasons. For this purpose, the growers were provided with an extensive checklist of practices considered by the project team to be consistent with the IPM philosophy. The checklist was based on a concept for evaluating adoption of IPM practices developed by the New York State Agricultural Extension Service for use with sweet corn growers (CH Petzoldt and AM Shelton. *IPM labelling: communicating with consumers about pest management.* Sixth Australasian Applied Entomological Research Conference, pp117-125).

Nine of the 45 processing growers and seven of the 55 fresh growers who were included in the survey responded. Information provided by the respondents on their assessment of whether they were 'IPM' or 'non-IPM' growers, the year they started to use IPM and their production tonnage in the last season is summarised in Table 2.4.

Grower responses on their use of specific IPM-related practices are summarised on a sector basis in Table 2.5. Note that a distinction between 'IPM' and 'non-IPM' growers has <u>not</u> been made in this case.

Researcher and consultant responses on grower use of specific IPM-related practices. Researchers and consultants were also given the same checklist of IPM practices that the growers were given. However, the researchers and consultants were asked to score each practice in a different way. They were asked to numerically rate each IPM-related practice according to its importance in their region/district, its use by 'IPM' growers and its use by 'non-IPM' growers (see example of questionnaire at Attachment 3). For this exercise, use of 'IPM' was essentially equated with use of scouting either by a commercial scout or by growers on a DIY basis.

Table 2.4. Summary of general information supplied by growers[a] about the history of IPM use on their farms and production of tomatoes in the last season.

Sector	Production area (ha)					Farm production (kt)					IPM user		Year IPM commenced					
	< 10	10 - 30	31 - 50	51 -70	> 70	< 1	1 - 2	2 - 3	3 - 4	> 4	Yes	No	< '91	'91	'92	'93	'94	'95
Proc.	0	1	4	1	3	0	1	0	2	6	9	0	2	1	0	1	1	4
	< 10	10 - 30	31 - 50	51 -70	> 70	< 0.1	0.1 -05	0.5 - 1	1 - 2	> 2	Yes	No	< '91	'91	'92	'93	'94	'95
Fresh	1	0	1	2	3	2	1	0	2	2	4	3[b]	1[c]	1	1	0	1	0

[a]Growers who responded to the survey questionnaire. (Nine from the processing sector and seven from the fresh sector.)

[b]One of these growers self-assessed as a 'non-IPM' grower but his response to the checklist of IPM practices indicated that IPM was in fact being used to a substantial degree.

[c]Recorded IPM as commencing in 1988-89 but actually commenced monitoring in 1976.

In view of the small numbers of people involved, even with a near 100% response rate, the responses by researchers and consultants were combined on a sector basis. Total number of responses from processing sector was five and, from the fresh sector, four. The responses are also summarised in Table 2.5 to allow a direct comparison with the grower responses.

Combined responses from researchers and consultants on their assessment of the importance of specific practices to IPM and of the use of these practices by growers generally in their regions/districts are summarised in Table 2.5.

Ratings by the researchers and consultants in Table 2.5 were based on the following criteria:

- **'Importance to IPM'**: Importance of the listed practice to IPM in their district or region, where:

  1 = very important (shown as 'high' in Table 2.5);

  2 = moderate importance (shown as 'mod.' in Table 2.5);;

  3 = low importance (shown as 'low' in Table 2.5);;

  4 = not relevant (shown as 'NR' in Table 2.5);.

- **'Use by IPM growers'**: Extent to which the listed practice is currently used by 'IPM' growers in their district or region, where:

  1 = used in the majority of cases (75% of growers or more, ie 'high use');

  2 = used by about half the growers, ie 'moderate use';

  3 = used but only to a limited degree (less than 25% of growers, ie 'low use');

  4 = not used at all, ie 'no use'.

- **'Use by non-IPM growers'**: Similar ranking as outlined above for 'IPM' growers, except applied to growers classed as 'non-IPM' users. (**Note.** Limited information was available for growers in this category, due either to a lack of 'non-IPM' growers in some districts, or to a general lack of detailed knowledge about the farm management practices of these growers.)

The individual ratings for each practice were subjected to visual inspection and an overall rating assigned on a 'best fit' basis for presentation of the data in Table 2.5. Insufficient data were available to assign sensible ratings to the 'Use by non-IPM growers' category.
Some of the key points from the data in Table 2.5 are:

- Growers from the processing and fresh sectors both achieved about a 60% 'compliance rate' with the checklist of nominated IPM-related practices in the1999-89/1999 season. While no 'pass mark' has been set, a compliance rate of 60% would have to be considered 'good' or 'very encouraging'. However, for a variety of reasons, each additional incremental gain in compliance rates is probably going to be become increasingly difficult to achieve.
- Growers from the processing sectors seem to be on an upward trend in terms of their use of the nominated IPM-related practices, with good intentions for future seasons. In contrast, however, growers from the fresh sector, while showing an upward trend to date, indicated that they would be using fewer of these practices in the future.
- In terms of performance within the various categories of IPM-related practices, processing growers performed best in the 'Crop Production' category and worst in the 'Insect management' category. Fresh growers performed best in the 'Seedlings' category and worst in the 'Insect management' category also. In both cases, the main weakness in the 'Insect management' category was in the beneficials area.
- The independent ratings by researchers and consultants of growers' use of the IPM-related practices on a sector/regional basis were generally in line with those provided by the sample of growers who 'self-assessed' via the survey questionnaire. Nevertheless, a comparison of the two sets of data in the Table will reveal some differences, eg use of suitable weed management practices was rated much lower by the researchers and consultants from both sectors than by the growers themselves.

Additional comments provided by processing growers about management of pests and diseases on their farms are summarised below:

- 'The scout has a big role in the IPM process.'
- 'Pest and disease pressure depends on your proximity to other tomato paddocks and also to paddocks of other crops.'
- 'A list of 'beneficial insect-friendly' chemicals should be available to growers.'
- 'Little or no information is available to growers on the incidence of beneficial insects, eg lacewings.'
- 'Predators to counter Heliothis do not appear to be commercially available.'

Table 2.5. Use of specific IPM-related practices in the processing and fresh (Queensland) sectors of the tomato growing industry, as assessed by (i) growers and (ii) researchers and consultants

Specific IPM-related practices	Processing Sector						Fresh Sector (Queensland)					
	Number of positive responses by growers (max 9)			'Best fit' rating by researchers and consultants (refer text above)			Number of positive responses by growers (max 7)			'Best fit' rating by researchers and consultants (refer text above)		
	1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers	1998 or 1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
A. Pre-season treatments:												
1) Land selected for tomato production (including leased land) has a history of cropping with non-solanaceous plants, ie plants other than tomatoes, potatoes, capsicum, eggplant and similar.	5	5	6	high	high	NA*	5	5	5	high	high	NA*
2) Irrigation system designed to avoid poor drainage and long periods of soil saturation.	9	9	9	high	high	NA*	7	6	6	high	mod.	NA*
3) A crop rotation that includes non-solanaceous plants used.	7	8	8	high	high	NA*	4	4	4	high	high	NA*
4) Organic matter build-up of the soil, eg rotary hoe in a non-solanaceous off-season crop.	6	7	7	high	high	NA*	4	4	5	high	low	NA*
5) Use of methyl bromide avoided.	9	9	9	high	high	NA*	5	3	5	mod.	mod.	NA*
6) If metham sodium is used, application band is narrow.	6	7	7	high	mod.	NA*	2	2	2	high	high	NA*
7) Use of pre-plant insecticides minimised.	3	2	4	high	high	NA*	4	4	5	mod.	mod.	NA*
8) Sequentially planted blocks separated (eg later plantings up wind of earlier plantings).	0	1	1	low	nil	NA*	4	5	6	high	high	NA*
9) Whole farm planning used.	7	7	8	high	mod.	NA*	6	5	5	mod.	low	NA*
10) Surrounding vegetation included in management program for pest & diseases, eg pre-planting release of beneficial insects.	2	2	4	high	mod.	NA*	0	1	1	low	low	NA*
Percentage of positive grower responses for Section A	**60%**	**63%**	**70%**	XXX	XXX	XXX	**59%**	**56%**	**63%**	XXX	XXX	XXX
B. Seedlings:												
1) Choose most disease resistant variety(ies).	5	3	5	high	high	NA*	6	5	5	high	high	NA*
2) Purchase seedlings from accredited supplier (QA product) or produce pest-free seedlings in own Nursery. Consider and use plant quarantine.	4	1	4	high	high	NA*	6	5	5	high	high	NA*
Percentage of positive grower responses for Section B	**50%**	**44%**	**50%**	XXX	XXX	XXX	**86%**	**71%**	**71%**	XXX	XXX	XXX

Table 2.4 continued

Specific IPM-related practices	Processing Sector						Fresh Sector (Queensland)					
	Number of positive responses by growers (max 9)			'Best fit' rating by researchers and consultants (refer text above)			Number of positive responses by growers (max 7)			'Best fit' rating by researchers and consultants (refer text above)		
	1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers	1998 or 1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
C. Crop production:												
1) Keep detailed records of production procedures (fertiliser type & use, date of growth stages, and max. & min. temperatures).	5	5	6	high	mod.	NA*	4	3	3	high	high	NA*
2) Conduct regular (min. fortnightly) foliage analysis to determine and implement nutritional management program.	6	7	6	high	mod.	NA*	4	3	4	high	mod.	NA*
3) Base nutrient program on soil analysis and foliage analysis reports.	8	8	9	high	mod.	NA*	5	4	4	high	mod.	NA*
Percentage of positive grower responses for Section C	**71%**	**74%**	**78%**	XXX	XXX	XXX	**62%**	**48%**	**52%**	XXX	XXX	XXX
D. General pest management:												
1) Remove old crops immediately following last harvest.	6	7	7	high	nil	NA*	7	5	6	high	high	NA*
2) Sow inter-row plants that favour beneficials.	0	0	0	mod.	nil	NA*	0	0	0	low	low	NA*
3) Monitor at least weekly for insects, plant diseases and weeds.	8	9	9	high	high	NA*	7	6	6	high	high	NA*
4) Maintain monitoring and spray records. (To include levels of pests & beneficials)	8	7	8	high	high	NA*	6	5	5	high	high	NA*
5) Calibrate spray machinery at start of each growing season.	8	8	8	high	high	NA*	6	5	5	high	high	NA*
6) Keep records of release / application of beneficials.	2	2	3	high	nil	NA*	2	2	1	high	nil	NA*
Percentage of positive responses for Section D	**59%**	**61%**	**65%**	XXX	XXX	XXX	**67%**	**55%**	**55%**	XXX	XXX	XXX
E. Disease management												
1) Select varieties with disease resistance and with open canopy.	3	2	3	high	high	NA*	4	3	3	high	high	NA*
2) Choose fungicides with least impact on beneficial species.	6	6	9	high	mod.	NA*	3	2	2	high	high	NA*
3) Apply fungicides only if weather data and monitoring indicates it is necessary.	7	7	8	high	high	NA*	6	5	5	low	mod.	NA*
4) Use weather data, crop growth stage and thresholds for deciding when to apply curative fungicides.	8	7	8	high	high	NA*	5	4	4	mod.	low	NA*
Percentage of positive responses for Section E	**67%**	**61%**	**78%**	XXX	XXX	XXX	**64%**	**50%**	**50%**	XXX	XXX	XXX

Table 2.4 continued

Specific IPM-related practices	Processing Sector						Fresh Sector (Queensland)					
	Number of positive responses by growers (max 9)			'Best fit' rating by researchers and consultants (refer text above)			Number of positive responses by growers (max 7)			'Best fit' rating by researchers and consultants (refer text above)		
	1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers	1998 or 1998-99 Season	Past Seasons	Future Seasons	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
F. Insect management:												
1) Monitor insects by counts and with yellow sticky cards or pheromone traps. Check weekly. Change monitoring devices when needed.	4	5	5	high	high	NA*	4	3	3	high	high	NA*
2) Release appropriate natural enemies at recommended rates and intervals at the first sign of insect activity.	0	0	1	mod.	nil	NA*	0	1	0	low	low	NA*
3) Use insecticides only for those pests for which effective natural enemies are not available or pest/beneficial ratios indicate action required.	6	6	7	high	high	NA*	3	2	2	high	high	NA*
4) Monitoring includes assessment and recording of beneficial activity.	5	5	6	high	high	NA*	3	2	2	high	low	NA*
5) Treatment decisions based on perceived impact of beneficials and the effect of insecticide sprays.	6	6	7	high	high	NA*	3	2	2	mod.	low	NA*
Percentage of positive responses for Section F	**47%**	**49%**	**58%**	XXX	XXX	XXX	**37%**	**29%**	**26%**	XXX	XXX	XXX
G. Weed management:												
1) Use plastic mulch to reduce weed competition.	NR	NR	NR	NR	nil	NA*	6	5	5	high	high	NA*
2) Apply herbicides only if indicated by monitoring and previous paddock history.	6	5	6	high	mod.	NA*	5	4	4	high	mod.	NA*
3) Select herbicides with minimal impact on beneficial organisms and the environment.	5	4	5	high	low	NA*	5	3	5	mod.	low	NA*
Percentage of positive responses for Section G	**55%**	**50%**	**55%**	XXX	XXX	XXX	**76%**	**57%**	**67%**	XXX	XXX	XXX
Percentage of positive responses for all categories combined	**59%**	**58%**	**67%**	XXX	XXX	XXX	**61%**	**51%**	**54%**	XXX	XXX	XXX

- 'Release of beneficials has been tried numerous times in conjunction with the use of "softer" insecticides that are supposed to cause minimal harm to the beneficials. However, this was not successful. Neither the beneficials nor the chemicals had any impact on the level of insect pests and the crop was destroyed.'
- 'The professional scout does not count beneficials.'
- 'IPM is an amalgam of cultural practices, chemicals, hygiene, beneficials and selection of varieties.'
- 'Seasonal conditions have a big impact on the pest situation.'

Estimate of IPM adoption at the sector/regional level. In addition to the assessment of the use of individual IPM-related practices via the checklist-questionnaire approach outlined above, an 'expert' rating of the use of IPM as a deliberate farm management practice by each grower was also obtained. It was originally intended that the data gathered from individual growers via the mail-out questionnaire would be aggregated to provide sector-level information. However, the low level of questionnaire returns precluded the use of this method.

Instead, some key industry people (selected for their good overall knowledge of the local industry situation) were requested to provide an IPM rating for each grower in their sector/region over the last three seasons. Ratings were based on the following criteria:

0 = no use of IPM practices (uses calendar spraying)

1 = nominal use of IPM (uses scouting but does not utilise the information provided in any organised way OR scouts his own crop to decide spray timing only)

2 = uses IPM principles but only has part of the area scouted (typically 25-75% of area scouted, but uses these results for spraying decisions on the whole area) OR has full area scouted but doesn't seem to follow scout's chemical recommendations

3 = 'full adoption' of IPM, ie scouting (of whole area) + reduced use of chemicals (in general) + use of alternative chemicals + recognition of biologicals

Estimates of the production area/tonnage were also obtained from the same sources.

These rankings were then aggregated to provide an estimate of the overall use of IPM in the processing sector, and in each of the three main regions in the fresh sector in Queensland, based both on grower numbers and on production areas or tonnages.

Use of IPM by each grower in the **processing sector** during the 1996/97, 97/98 and 98/99 seasons was rated by Lauren Thompson, Industry Development Officer, Australian Processing Tomato Research Council, Shepparton. Results based on grower numbers are summarised in Table 2.6.

The data in Table 2.6 indicate that:

- there is wide grower-to-grower variation in the level of adoption of IPM within the processing sector, with all four categories of IPM adoption well represented; and
- adoption of IPM across the sector is steadily increasing.

Table 2.6. Estimate of the overall level of adoption of IPM in the processing sector during the period 1996/97 – 98/99, based on grower numbers.

IPM rating*	Growing season		
	1996-97	1997-98	1998-99
0 (no use of IPM)	9/45	5/45	5/46
1 (nominal use of IPM)	8/45	9/45	9/46
2 (uses IPM principles but only part of area scouted)	13/45	12/45	11/46
3 (full adoption of IPM)	15/45	19/45	21/46
Weighted average rating	**1.75**	**2.00**	**2.04**

*Refer text above for full explanation of the rating criteria.

It is worth noting, however, that for a few growers, the level of IPM use did not show a consistent year-to-year trend.

A further analysis of the IPM ratings taking into account estimates of the production area of each processing grower was then carried out by staff at the Institute for Horticultural Development, DNRE Knoxfield. This was done by linking the IPM ratings as outlined above to the area data in the Chemical Spray Use Database for the 1996/97 and 1997/98 seasons. Note however that grower information in the database is incomplete, due to the failure of some growers to submit their annual returns. For the 1996/97 year, data are available for only 37% of the total production area and, for 1997/98, 93%. Results of the analysis using the available data are shown in Table 2.7.

Table 2.7. Estimate of the overall level of adoption of IPM in the processing sector during the 1996/97 and 1997/98 seasons, based on production area available in the Chemical Spray Use Database.

IPM rating*	Percentage of production area**	
	1996-97	1997-98
0 (no use of IPM)	4%	7%
1 (nominal use of IPM)	36%	23%
2 (uses IPM principles but only part of area scouted)	31%	32%
3 (full adoption of IPM)	29%	28%
Weighted average rating	**1.85**	**2.01**

*Refer text above for full explanation of the rating criteria.
**Based on a sample of 37% of the total production area in 1996/97 and 93% in 1997/98.

The data on IPM use calculated on a production area basis, as presented in Table 2.7, show a good correlation with the data calculated on a grower number basis in Table 2.6. In particular, the weighted average rating on IPM use for 1997/98 (grower production data available for 93% of the total production area) is almost identical for both methods.

Ratings for growers in the **Bowen region** (which accounted for 62% of Queensland tomato production in 1998) were provided by Phil Anning, Extension Horticulturist, QDPI, Bowen, for the 1997, 1998 and 1999 seasons based on both grower numbers and aggregate production areas. Data for this region are summarised in Table 2.8.

Table 2.8. Estimate of the overall level of adoption of IPM in the Bowen region during the 1997, 1998 and 1999 growing seasons, based on grower numbers and aggregate production areas.

IPM rating*	Growing season					
	1997		1998		1999	
	Numbers	Area	Numbers	Area	Numbers	Area
0 (no use of IPM)	0/25	0	0/24	0	0/21	0
1 (nominal use of IPM)	21/25	75%	17/24	65%	13/21	55%
2 (uses IPM principles but only part of area scouted)	4/25	25%	7/24	35%	7/24	42%
3 (full adoption of IPM)	0/25	0	0/24	0	1/24	3%
Weighted average rating	**1.16**	**1.25**	**1.29**	**1.35**	**1.43**	**1.48**

*Refer text in Section 2.4.1 for full explanation of the rating criteria.

The data in Table 2.8 indicate that:

- there has been universal adoption of IPM in the Bowen region, though mostly at a basic level;
- full adoption of IPM (at least in the eyes of the person who provided the data) is only being achieved to a very limited degree and only for the first time this season;
- adoption of IPM across this region is steadily increasing; and
- adoption is slightly higher when calculated on an area basis than on grower numbers, indicating that the larger growers are more receptive to IPM.

Ratings for growers in the **Bundaberg region** (which accounted for 27% of Queensland tomato production in 1998) were provided by John Maltby Extension Horticulturist, QDPI, Bundaberg, and staff of Crop Tech, Bundaberg, for the 1997, 1998 and 1999 seasons. In this case, ratings were based on grower numbers and aggregate production tonnages.

Definitive information on the use of IPM by seven small growers could not be obtained. However, as the small growers in the Bundaberg region do not use professional scouts, it was assumed, for the purpose of this exercise, that their level of IPM use would be rated at either 0 or 1 (shown in Table 2.9 as rating category '0-1'). The aggregate production of these seven growers is estimated to be about 5% of the region's total tomato production.

Five growers account for 75% of the region's tomato production. Of these, one accounts for 30% of the production (use of IPM rated at 3), two for 15% each (both rated at 2), one for 10% (rated at 2) and one for 5% (rated at 3).

Data for the Bundaberg region are summarised in Table 2.9.

The data in Table 2.9 indicate that:

- there has been a high level of adoption of IPM in the Bundaberg region, though at varying levels;
- average ratings calculated on a per area basis are higher, by a considerable margin, than those calculated on a grower number basis, reflecting the fact that the five growers who account for 75% of the region's production were ranked at 2 or 3 on their IPM use;
- adoption of IPM across this region is gradually increasing.

Table 2.9. Estimate of the overall level of adoption of IPM in the Bundaberg region during the 1997, 1998 and 1999 growing seasons, based on grower numbers and production data (cartons).

IPM rating*	Growing season					
	1997		1998		1999	
	Numbers	Prodn.	Numbers	Prodn.	Numbers	Prodn.
0-1 (little/no use of IPM)[a]	7/31	5%	7/31	5%	7/31	5%
1 (nominal use of IPM)	3/31	17%	2/31	2%	3/31	2%
1-2	5/31	3%	5/31	3%	2/31	3%
2 (uses IPM principles but only part of area scouted)	10/31	40%	11/31	55%	13/31	50%
3 (full adoption of IPM)	6/31	35%	6/31	35%	6/31[b]	40%
Weighted average rating	**1.68**	**2.09**	**1.71**	**2.24**	**1.73**	**2.29**

*Refer text in Section 2.4.1 for full explanation of the rating criteria.

[a]Nominal rating for 7 small growers for which no definitive information on IPM use was obtained (see text above).

[b]Not all of the same 6 growers as in the previous year.

Further evidence to corroborate the last point above is that is in 1989, Crop Tech (John and Penny Hall) started out in the tomato scouting business with one scout. This year, 1999, the company is employing five scouts (though other crops are now scouted in addition to tomatoes) and there are three other scouts operating in the region as well. In contrast to the increase in the number of scouts, the area planted to tomatoes in the Bundaberg region has in fact declined by 60% since 1989. All of the 'serious' tomato growers in the region now employ a professional scout.

Julian Winch, Valley Crop Monitoring Services, Gatton, provided information for his clients in the **Lockyer/Stanthorpe region** the 1996/97, 1997/98 and 1998/99 growing seasons. (This region accounted for 11% of Queensland tomato production in 1998.) Ratings for the remainder of the growers were estimated, using the best available information. (QDPI was unable to provide any assistance with estimates in this region.) The estimate of IPM adoption in this region, based on both grower numbers and production areas, is summarised in Table 2.10.

Table 2.10. Estimate of the overall level of adoption of IPM in the Lockyer/Stanthorpe region during the 1996/97, 1997/98 and 1998/99 growing seasons, based on grower numbers and aggregate production areas.

IPM rating*	Growing season					
	1996/97		1997/98		1998/99	
	Numbers	Area	Numbers	Area	Numbers	Area
0 (no use of IPM)	19/37[b]	40[b]%	19/36[b]	35.0[b]%	18/35[b]	30%
1 (nominal use of IPM)[a]	9/37[b]	15[b]%	8/36[b]	17.5[b]%	8/35[b]	20%
2-3 (uses IPM principles but falls short of full adoption)	9/37	45%	9/37	47.5%	9/35	50%
Weighted average rating	**1.07**	**1.28**	**1.07**	**1.36**	**1.10**	**1.45**

*Refer text in Section 2.4.1 for full explanation of the rating criteria.

[a]Includes DIY scouts and field activity by chemical resellers.

[b]Based on a reasonable extrapolation from an incomplete data set.

The data in Table 2.10 indicate that, on a grower number basis, IPM adoption has been fairly static in recent years. The average rating is quite low, due to a preponderance of small, non-IPM growers in this region. However, in the 1998/99 season, 50% of the production area was subject to a high level of IPM (serviced by a professional IPM consultant), with possibly another 20% subject to nominal IPM (DIY scouting and some field activity by chemical reseller staff).

Note. Specific comparisons of IPM between the three regions in Queensland and between the processing and fresh sectors have been avoided, due to the lack of a simple methodology for standardising ratings. This matter was considered to be beyond the scope of the present study.

2.5 Impact of IPM on fruit quality

An overriding consideration in all tomato production is fruit quality. The fresh market and whole fruit canning sectors demand fruit free of skin blemishes, eg grub damage and sunburn, while the pulping sector allows some tolerance in this area. Both grub damage and sunburn are aspects of quality upon which IPM has the potential to have either a negative or a positive impact.

A further aspect of quality upon which IPM has the potential to impact is in the area of chemical residues. All food products must at the very least comply with maximum residue limits specified in the Australia New Zealand Food Standards Code.

In terms of this evaluation of IPM in tomato production, it is reasonable to pose the following null hypothesis: *'IPM has no adverse economic impacts on the quality of tomato fruit.'* Thus, at the very least, use of IPM should not result in any deterioration in quality (ie 'quality neutral' as defined). It would be of benefit, of course, if use of IPM actually resulted in quality improvement.

Information was sought from growers and other stakeholders on the impact of IPM on fruit quality. Opinions were offered in relation to 'field quality', eg levels of grub damage, but there was little hard data available to back up these opinions. However, some objective information was available on the incidence of chemical residues, though even this was limited in the case of the fresh tomato industry in Queensland.

The available information on the impact of IPM on tomato quality is presented and analysed below on sector basis.

2.5.1 Processing sector

The following comments were typical of those obtained from growers via the survey questionnaire:

- 'There is a slight increase in grub damage under IPM but there has been no effect on price.'
- 'As we work to a threshold on grub eggs, there might be a slight increase in grubby fruit under IPM, but minimal.'
- 'Fruit grading parameters seem to vary from year to year and between processors, depending upon the availability of fruit. Hence it is difficult to quantify effects of

IPM on fruit quality. However, there is surely less visible fruit damage due to grubs at harvest.'

- 'IPM has had no effect on fruit quality. Quality improvements have mainly come from other changes to management, eg timing of fruit harvest.'
- 'Unsure of the effects of IPM on fruit quality.'

One researcher observed that there was no objective system in place for measuring impact of pest management on aspects of quality such as grub damage. Furthermore, increased damage may be quite acceptable in some cases if it resulted in improved profitability. Another researcher thought that it was quite feasible for grub damage to increase under IPM, but not to any significant degree.

All of the consultants indicated that IPM was neutral in its impact on grub damage. One also observed that fruit produced under IPM definitely have a 'cleaner' appearance.

The processors advised that grub damage was only one of several defects generally categorised as 'blemishes' or similar. For this reason, most of the processors could not provide hard data on the incidence and trends in grub damage over the years. However, the general consensus of opinion amongst the processors was that grub damage has not been a major problem in recent years. Some noted that overall fruit quality has steadily improved, but mainly for reasons such as changes in varieties; it was certainly not possible to specifically attribute this improvement in fruit quality, either in total or in part, to IPM.

One processor suggested that IPM had a part to play in reducing sunburn on fruit. Sunburn results from defoliation of the plant, in turn caused by powdery mildew and russet mite.

One of the tomato canners was able to provide some limited data on the rejection of incoming loads of tomatoes due to grub damage and on consumer complaints related to evidence of grubs in product. This data is summarised in Table 2.11.

Table 2.11. Data on incidence of grubs in incoming tomatoes and retail canned tomato products provided by a Victorian canning firm.

Year	Incoming tomatoes		Retail product	
	Total no. of loads received	No. of loads with detected grub damage	No. of consumer complaints about grubs	No. of complaints per million cans sold
1987	na*	na	1	na
1988	na	na	2	na
1989	na	na	2	na
1990	na	na	2	na
1991	na	na	0	na
1992	na	na	2	na
1993	na	na	3	na
1994	na	na	5	na
1995	951	34	7	0.9
1996	898	0	4	0.5
1997	856	12	4	0.2
1998	931	23	8	0.6
1999	775	1	na	na

*not available

Unfortunately no conclusions can be drawn from the data in Table 2.11, particularly with respect to any impact of the introduction of IPM into the industry. Grub damage has been extremely variable from year to year. Consumer complaints related to grubs in products have certainly increased over time, but there could a number of reasons for this. The available data on the number of complaints per million cans of retail product sold do not show any particular trend.

The tomato processing industry has an excellent record with respect to chemical residues. It also has its own monitoring program in place.

The monitoring program commenced in 1991 with HRDC project TM201 *'Chemical residue analysis of processing tomatoes'*, which ran for two years. On conclusion of the project, the program was picked up by the industry and is now administered by the APTRC. The sampling plan and the residue screen have varied from year to year, depending on funding. However, in broad terms the program is now based on one sample per grower per year and a test screen of 30 insecticides and fungicides.

No sample tested under this program has ever yielded a result that has exceeded the MRL. However, there have been many detections of residues at levels <MRL. Chemicals most frequently detected were Dithiocarbamates, Chlorothalonil and Endosulfan. Incidence of one or more of these three pesticides during the period 1993 – 1998 is summarised in Table 2.12.

Table 2.12. Incidence of residues of one or more of the three pesticides most frequently detected in tomatoes tested under the APTRC's residue monitoring program, 1993 - 1998 (dithiocarbamates, chlorothalonil and endosulfan).

Detections per sample	Percentage of samples with detected residues each year					
	1993	1994	1995	1996	1997	1998
0	50	28	25	30	43	2
1	35	56	44	55	50	60
2	15	10	31	15	4	32
3	0	6	0	0	3	6

The data in Table 2.12 indicate that the percentage of samples containing one or more detectable residues has been quite variable on a yearly basis, with a marked jump from 25-50% during the period 1993-97 to 98% in 1998. Dithiocarbamates (fungicides) were detected most frequently.

To gain further insight into any possible link, positive or negative, between use of IPM and incidence of chemical residues in tomatoes, an analysis was conducted by staff at the Institute of Horticultural Development, DNRE Knoxfield. This analysis simply involved establishing a linkage between the rating of IPM use on individual processing tomato farms (see Section 2.4 above for details) and the detections of chemical residues in the APTRC monitoring program as described above. Available data for the 1997 harvest (based on 28 samples from 16 growers) and the 1998 harvest (based on 45 samples from 37 growers) were used in the analysis.

Data for the 1997 and 1998 harvests were analysed separately. In 1997, samples were analysed for Chlorothalonil, Dithiocarbamates and Endosulfan only, whereas in 1998 samples were analysed for a 'full screen' of 30 different residues. Samples from the two years may also have been analysed by different laboratories. Detections were confirmed as valid by reference to the Chemical Spray Use Database.

For the purposes of this study, each detection was treated as a separate incident, eg if a sample contained residues of two different chemicals, it was entered twice within its category. To allow comparison of data sets with unequal numbers of samples in them, results were expressed as the average number of detections per grower within each of the four IPM categories.

The analysis was first conducted using data of the insecticides and fungicides, then repeated using all data for all insecticides only, S7 insecticides only (Endosulfan and Monocrotophos), Endosulfan only and all fungicides only (but predominantly Dithiocarbamates). Results are presented in Figures 2.1 to 2.5 respectively.

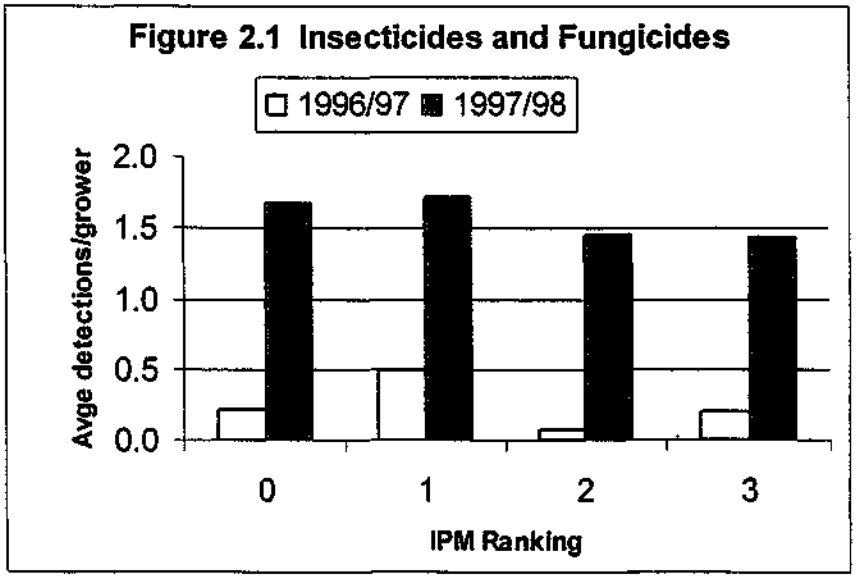
Figure 2.1 shows that the detection of residues of all insecticides and fungicides included in the test screen did not show any particular trend relative to IPM rating for samples from the 1997 harvest, but slowed a slightly negative (downward) trend for the 1998 harvest.

Figure 2.2 shows that for the 1998 harvest, detections of all insecticide residues showed a clear overall negative trend relative to IPM ranking, ie detections per grower decreased as IPM ranking for the growers increased. Total number of detections in samples from the 1997 harvest was very small.

Figure 2.3 shows that the negative trend of insecticide detections vs. IPM rating evident in Figure 2.2 for 1998 samples was more accentuated when the analysis was restricted to residues of S7 insecticides. This trend was accentuated even further when the analysis was further restricted to Endosulfan only.

The trends for 1998 data evident in Figures 2.2 – 2.4 are a strong endorsement of IPM, ie as growers progressively increase their use of IPM practices, their use of insecticides, and more particularly the broad-spectrum chemicals, declines.

Figure 2.5 shows that the use of fungicides was fairly uniform across all of the IPM rankings. One interpretation of this is that non-chemical solutions for control of plant diseases are yet to be found.



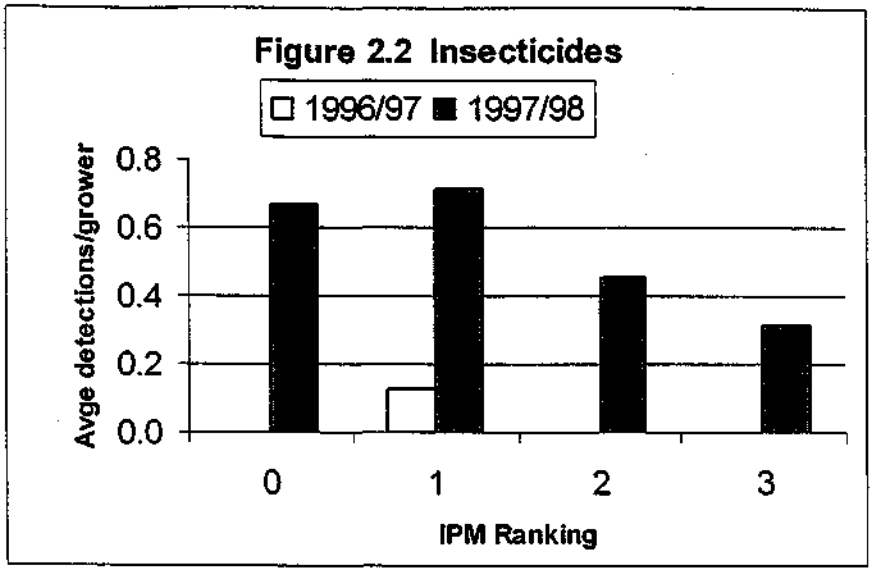


Figure 2.2 Insecticides
1996/97
1997/98
Avge detections/grower
0.8
0.6
0.4
0.2
0.0
0
1
2
3
IPM Ranking

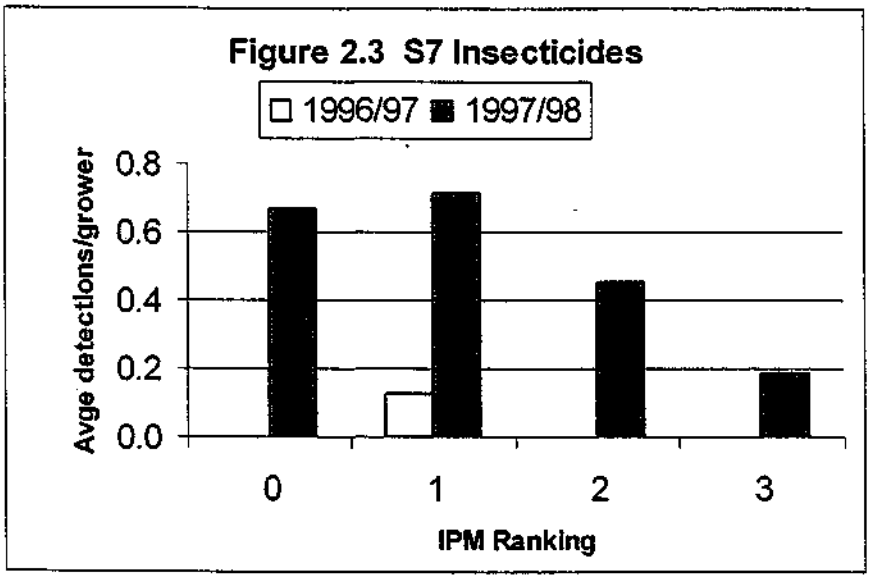


Figure 2.3 S7 Insecticides
1996/97
1997/98
Avge detections/grower
0.8
0.6
0.4
0.2
0.0
0
1
2
3
IPM Ranking

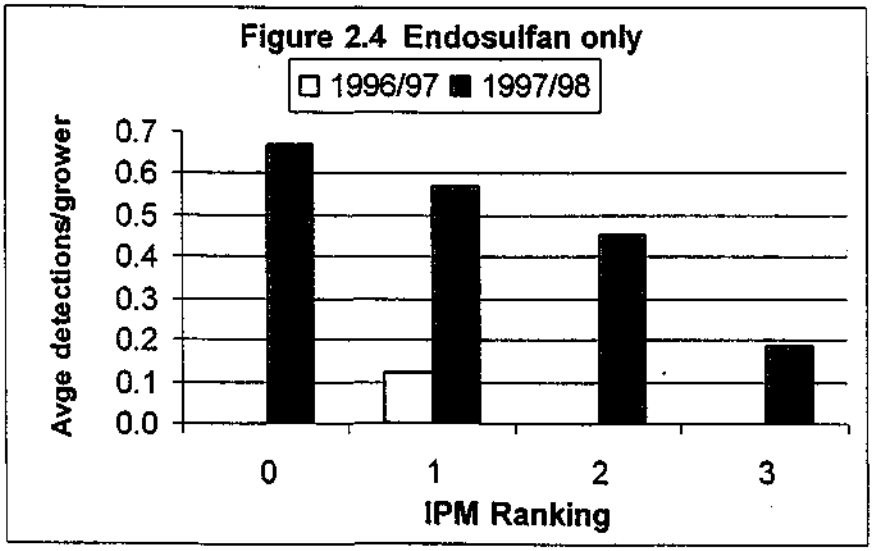
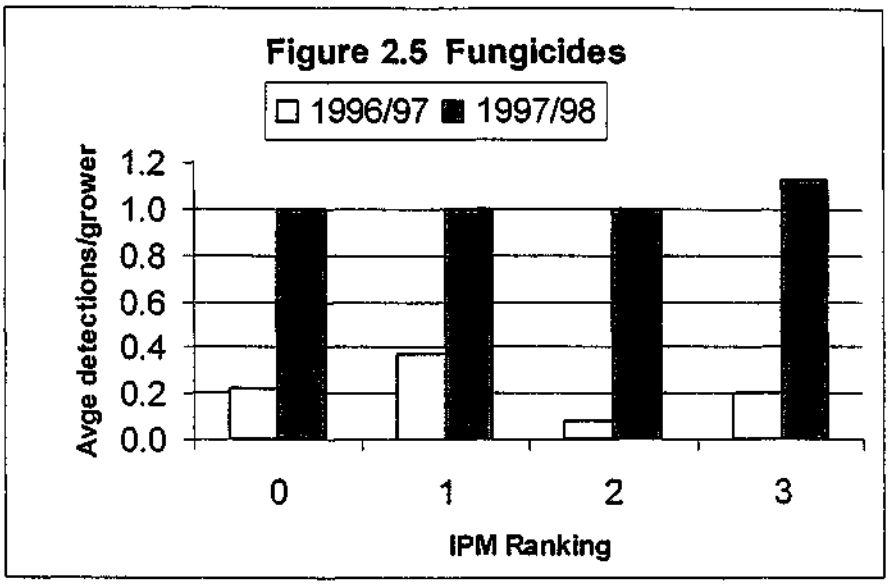


Figure 2.4 Endosulfan only
1996/97
1997/98
Avge detections/grower
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
IPM Ranking



2.5.2 Fresh sector

The following comments were typical of those obtained from fresh market growers via the survey questionnaire:

- 'Pest pressures have been so high in recent years that it has been impossible to quantify any quality differences with IPM'
- 'We are unwilling to compromise quality based on unproven practices. Financial success depends on quality.'
- 'Our quality has improved under IPM. We try and grow the crop "green", using the IPM program to protect it.'

The main message from the above comments is that, at the end of the day, the production of unblemished fruit takes precedence over all other considerations.

No systematic monitoring of chemical residues in Queensland-grown tomatoes is carried out either by the Queensland industry or the Queensland Department of Primary Industries. However, it was established that NSW Agriculture and City Markets Ltd have been jointly conducting a residue testing program of all produce going through Sydney's Flemington Markets since 1989 (with HRDC support 1992-95). This program has included tomatoes grown in Queensland. Each sample is a case of produce from a single grower. Sampling of growers is rotated.

A summary of the residue data on Queensland tomatoes obtained under this program was made available by NSW Agriculture and is presented in Table 2.13.

The data in Table 2.13 show that the rate of detections in recent years has been generally similar to that in processing tomatoes, though of course no samples of processing tomatoes have been above MRL.

The chemicals most consistently detected throughout the sampling period were Endosulfan, Dimethoate, Chlorpyrifos and Methamidophos. The chemical with the highest incidence over the period was Endosulfan, followed by Methamidophos and Dithiocarbamates.

Table 2.13. Summary of NSW Agriculture's residue survey results for Queensland tomatoes sampled at Sydney's Flemington Markets, 1989-98.

Year	No. of samples of Queensland tomatoes	No. of samples		
		0-50% MRL	50-100% MRL	>MRL
1989-92	52	19 (37%)	0	0
1992-93	14	7 (50%)	0	0
1993-95	17	13 (76%)	0	0
1995-96	11	6 (55%)	0	1 (9%)
1997	14	7 (50%)	0	0
1998	12	5 (42%)	0	2 (17%)

Information to link detections back to particular farms, and hence the use of IPM, was not available to this study. Hence it was not possible to draw any conclusions about the impact of IPM on the incidence of chemical residues in fresh tomatoes.

3. BENEFIT COST ANALYSIS OF IPM IN TOMATOES

3.1 Purpose of Benefit Cost Analysis (BCA)

BCA is an analytical tool used to capture the net effect of all the economic factors relevant to the decision making surrounding a defined project or program. In this case, '*Should the tomato industry maintain its funding of research, development and extension in the area of Integrated Pest Management?*' This RD&E includes all public sector research, development and extension as well as all the costs and benefits incurred directly by growers. The answer will be 'yes' if the BCA shows that IPM has generated net economic gains since its introduction and has the potential to generate further gains. Of course the analysis will also attempt to say exactly how rewarding IPM has been and what aspects of IPM should be targeted for maximum returns.

A benefit cost analysis of the type described here is only relevant because the tomato industry is structured so that it can take collective decisions. Thus all growers pay levies and HRDC and the industry's representatives are able to make decisions as to how the funds are spent. In 1998 the HRDC decided that the tomato IPM program should be reviewed for its economic efficacy. It is understood that, over the next few years, practically all of the HRDC's major programs will be reviewed in much the same way.

We assume implicitly in this analysis that all the past and potential benefits stemming from IPM are due to industry, private and publicly funded research, development and extension (RD&E). Departments of agriculture, the universities and private companies have performed this RD&E[9]. Whilst acknowledging the possibility that numerous agencies and individuals could claim some credit for IPM, this analysis will simply assume that all of any gains due to IPM can be credited to industry and publicly funded RD&E. From a national perspective, we are less interested in who bears the costs or reaps the benefits than in the net difference between benefits and costs, regardless of how these are distributed.

3.2 Explanation of the Benefit Cost Method

BCA captures all the benefits and costs particular to a project and reduces these to a single figure so that we can clearly see whether the decision was, or will be, a good one from the economic perspective. The performance criteria commonly generated by BCA are as follows:

Net Present Value: This gives the current dollar value of a past/future cost and income stream. Past sums are factored up to their present day equivalence by compounding while future sums are reduced to their present day equivalence by discounting. The compound/discount rate equates past/future dollars with present day dollars commensurate with the community's preference for saving/consumption. Providing all benefits and costs have been included, a positive NPV will indicate the project is economic considered on its own.

Internal Rate of Return: This is the rate that equates the present value of cash inflows with the initial investment, thereby causing the NPV to equal zero. To be acceptable, the project's IRR will need to exceed the opportunity cost of capital.

[9] It needs to be established at the outset that HRDC's IPM program has included extension activities. Thus the abbreviations R&D and RD&E have been used interchangeably throughout this report.

Benefit-Cost: This expresses the relationship between the benefit stream and the initial investment, as a ratio. It is calculated by dividing the present value of cash inflows by the initial investment (including any opportunity losses). To be economic, a project must indicate a ratio greater than one. While the BC ratio has the appeal of simplicity, it gives no indication of the absolute magnitude of the project. In the case of the present analysis, most reliance is placed on the NPVs.

Break-even Period: This is the period (in years) required by the project for the sum total of benefits to equal the sum total of costs. Obviously the shorter this period, the more viable and attractive the project at all levels

The following steps generate the above criteria:

1. Estimate the stream of actual and potential benefits and costs particular to the project. All inputs and outputs will be valued in present day dollars. With BCA, projects are presumed to have a particular life. For this project, we are most interested in the IPM benefits and costs streams over the past 10 years.
2. Calculate the Net Value stream by deducting costs from benefits for each year of the project's life.
3. Reduce the stream of Net Values to a single figure or performance criteria by compounding (of past results) or discounting (of future results). As the present study is considering IPM over the past decade, it will be necessary to compound the dollar outcomes from past years to make them comparable to present-day dollar outcomes. The reduction process generates particular performance criteria such as Net Present Value or Internal Rate of Return.

In general terms, the economic impact of IPM will be given by the net difference between price, cost and yield outcomes from using IPM relative to using conventional crop management. Thus tomato growers have the **opportunity** to select IPM over conventional management and if they take this opportunity, they may reap benefits in the following areas:

- Any increase in **price** associated with the opportunity to use IPM. If the market place perceives the quality of IPM product as superior, and is prepared to pay a premium, users of IPM will be rewarded accordingly. As it turns out, there is no evidence at this time that trademarked tomatoes can attract a premium from the mainstream Australian consumers or processors.
- Any reduction in **costs** associated with the opportunity to use IPM. If IPM can lead to a reduction in the number of sprays or better targeting of sprays compared to routine spraying, there will be a cost saving. Some growers presently perceive this as the main benefit from IPM.
- Any increase/saving in **yield** associated with the opportunity to use IPM. If adoption of IPM can prevent a loss in yield that would have occurred using conventional management, gross income will increase. For the fresh and tomato canning sections of the industry, yield is measured simply by the weight of product that is sold. However, with tomatoes sold for pulp, it is necessary to draw a distinction between fruit yield and solids yield. In this case, the processors are primarily interested in yield of fruit solids and they pay a premium to growers for 'additional' solids content. In practice, field yield and solids yield are often inversely related. Variations in solids yield (typically within the range of 4 to 5 kg per 100 kg of tomatoes) can be due to a range of factors including variety, method of irrigation and possibly plant disease. The premium paid to growers for fruit with high solids yield is probably insufficient to induce growers to sacrifice field yield for solids yield (Bryce Merrett, H J Heinz

Co, pers. comm.). Potentially, IPM has role to play in raising the solids content of pulping tomatoes.

- Any reduction in externalities (a social benefit – see below).

For IPM to generate a profit, however, the above benefits must exceed the contiguous costs. These costs will stem from:

- RD&E to develop, prove and maintain the IPM technology. This cost falls upon tomato growers, processors (in the case of the processing sector) and the taxpayer. All the grower contributions are channelled through HRDC while taxpayer funds are channelled through HRDC (in the form of matching funds from the Commonwealth Government) and through the State Departments of Agriculture. Quantifying the contribution of the States to IPM in tomatoes is difficult because the staff and facilities are often shared among many industries.
- The cost to the grower of acquiring IPM knowledge and changing his/her management system from conventional to IPM.
- Any extra monitoring of pests and extra management to practice better crop hygiene.
- The extra cost of any special purpose machinery (eg spray rigs) and the cost of creating breeding grounds and sanctuaries for beneficials.

Most of the impact of IPM will start and finish at the farm gate, ie the grower will bear the application costs and reap the rewards. It is likely, however, that IPM will generate benefits beyond the farm gate. If IPM means fewer chemicals are used, there could be improvements in the general environment, a reduction in threats to human health and less hazardous waste that has to be safely dumped. Each of these benefits has a social dimension. Where private actions give rise to social benefits, a case exists for direct involvement by the State. This case is explicitly recognised by the Government's dollar for dollar contribution to R&D. Government contributions to the practice of IPM amount to acknowledgement of the social and environmental benefits IPM brings about.

The investment costs of the RD&E that were responsible for bringing about, and maintaining IPM, can be identified and quantified from the record. HRDC, for example, have an accurate record of their investment over the past 10 years in IPM projects. Also, it is possible to get cost data from the other institutions involved in the RD&E of IPM. Given, however, that IPM can be broadly defined (to take in any project that affects pests) the inclusion or exclusion of some projects becomes a matter of judgement.

Furthermore, on-going R&D will be required in order to maintain the efficacy of the technology. Thus research into beneficial organisms, pest specific chemicals and 'softer' chemicals will all serve to strengthen adoption of IPM. Quite apart from the IPM technology, there is a need to 'sell' the IPM message to all tomato growers so that adoption becomes universal. In 1999, adoption of IPM is by no means universal and it is clear that extension of the concept is equally important as the basic research. Suggestions are made later in this report as to how the rate of IPM adoption among growers can be expedited.

Beyond the investment cost of IPM there is the cost to adopters of actually using the technology. Once the grower has made a mental commitment to IPM management, the major IPM 'application' cost is monitoring and recording of the pests and beneficials and the crop environment to determine the scope and detail of IPM application. This will involve practices including paddock hygiene, provision of safe harbours for beneficials, eliminating sprays because beneficials are active (ie achieving control) or determining the optimal timing

and pesticides to be used for particular pests. For the purposes of this analysis it is necessary to estimate the average cost of IPM application.

Despite some variation in the year to year cost of applying IPM, the major challenge for this project is estimation of the benefit stream due to IPM. Among the difficulties are the following:

1. **Defining the practices and outcomes that separate IPM from conventional crop management.** There is often a weak link between the strict definition of IPM and the practices applied by growers who consider themselves 'adopters'. Furthermore the definition of IPM has not been static over the past 10 years. The complex and dynamic nature of the IPM definition causes problems for quantifying the adoption rate for IPM. The 'contemporary' definition of IPM – used by this analysis – includes the use of monitoring, narrow spectrum chemicals, cultural practices, reduced rate and number of applications of chemicals and supporting the use of beneficials. Application of this definition helps to make the distinction between adopters, partial adopters and non-adopters[10]. However it would probably have been unreasonable to apply such a (strict) definition 5-6 years ago when IPM was interpreted more 'liberally', eg as just scouting and strategic spraying.

2. **Market constraints.** Like all management tools, IPM has to satisfy the expectations of the customer. At this point in history, it seems the tomato industry's customer is not particularly interested in trading off appearance with measures that would make the practice of IPM easier. These measures would include much greater integration of chemical, cultural and environmental pest control but may result in some visual assessment to the fruit. In the case of processing tomatoes, the growers' customer is a processing factory that converts fresh tomatoes into various canned and pulp products. In the case of pulp, the customer can tolerate a degree of insect damage. But with fresh tomatoes, appearance is deemed to be paramount. Thus the mainstream market channels will tolerate no damage by pests. These different performance standards affect the grower's capacity to apply IPM and suggest a need to analyse each sector separately. There is little evidence at this time that mainstream consumers are prepared to pay more for IPM tomatoes, at least in Australia[11]. Even so, the demand for organically grown fruit and vegetables – presently sold through specialist outlets – may serve as a barometer of consumer preferences for the mainstream production system. Should the demand for organically grown products strengthen significantly, there would exist a case for differentiating IPM tomatoes in the mainstream market[12]. This could be done by establishing an auditable Code of Practice or quality assurance program for the field production of tomatoes based on the principles of IPM, supported by a program of residue testing. Clearly if IPM product can attract a premium, the technology would experience a pull-through effect.

3. **Identifying the particular cost and yield effects that are strictly due to IPM.** An 'accurate' benefit cost analysis will match up the costs that give rise to the benefits. Since IPM was introduced, there have been many collateral changes in production

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[10] We know IPM is much easier to apply in tree crops where a permanent leaf mass may exist, thus allowing beneficials to build up and achieve some form of balance with pests.

[11] Evidence is mounting overseas that mainstream consumers will pay a premium for IPM fruit – see references at the end of this section.

[12] The supermarkets would probably have to lead the way with IPM differentiation by 'demanding' it in the first instance. There is evidence of this happening overseas. For the concept to work, however, IPM suppliers would have to receive a premium at least equal to the physical cost of grading and identifying the IPM product.

technologies, which make it difficult to separate those due to IPM from changes due to other inputs or structural change. Separating effects is also confounded by large year to year variations caused by seasonal conditions. Neither is the measurement of changes in spray costs straightforward. If IPM is defined in terms of the relative amount and toxicity of chemical used, then the recording process has, at the very least, to account for the number, type, volume and cost of chemicals applied per tonne of tomatoes marketed.

4. **Scale of the analysis.** This analysis does not cover all the tomatoes produced in Australia but it follows the methodology of a 'regional' analysis. Thus it will capture the impact of IPM for the entire processing sector (centered in northern Victoria and southern NSW) and the fresh sector in Queensland (specifically the production centres of Bowen, Bundaberg, Lockyer Valley and Stanthorpe). IPM benefits and costs will be estimated relative to the gross volume and value of production for the two sectors (see Tables 1 and 2).

5. **Once-off versus cumulative gains.** Since IPM can depend on the capacity of beneficials to emerge and persist, there will be a lag before IPM realises its full potential. There is also the issue of build-up in resistance of pests to chemicals. Thus, in terms of quantifying the benefit steam, we need to determine whether the IPM impact stabilises after a time or escalates through time, ie generates benefits beyond the adoption years. As noted in the introduction, IPM has become a metaphor for 'sustainable crop production' and long term risk management. However, IPM is designed to mitigate the risk of failure by chemicals to control pests now. The other major risk is rejection, at some stage, of produce by markets that are increasingly adopting 'clean-green' quality standards. To the extent that IPM is a risk management tool, it will continue to evolve and improve through time.

6. **Farm record keeping.** Apart from all the difficulties above, data capture relies on growers, consultants and researchers keeping accurate records. For the purposes of this project, the records must isolate the particular impacts due to IPM. In the absence of accurate performance records, it is necessary to rely on estimates and expert opinion. Fortunately, the industry's consultants have well-developed powers of observation and are often able to quantify the changes and savings due to application of IPM even when specific records are not available.

7. **Sustainability of IPM.** To use the present analysis to make recommendations, it is necessary to understand the technology's sustainability. Fortunately, IPM is a technology for the future because it is designed around the concept of ecological sustainability. Predicting the future efficacy of IPM is clearly difficult, but it must be kept in mind that IPM emerged in the first instance because of recurring failures by conventional crop management. If the rationale for IPM is to rest upon risk mitigation, then the analysis should attempt to value this in terms of opportunity savings.

3.3 Data

The original intention with this analysis was to collect cost and benefit data directly from growers (see survey questionnaire at Attachment 2). As the response to the grower survey was generally poor, it has been necessary to rely to a large extent on the expert opinion of the industry's consultants and IPM researchers. In any event, it has been necessary to make various simplifying assumptions with respect to data. The primary emphasis has been upon

demonstration of a rigorous methodology that can be re-run once better quality data comes to hand.

Structure and size of the industry: As previously noted, the tomato industry falls into two sectors. Statistical profiles that form the baseline for the study are provided in Tables 3.1 and 3.2.

Table 3.1: Profile of the processing sector (total for northern Victoria and southern NSW)

Year	Area (ha)	Volume ('000 t)	Value ($m)	No. of Growers
1990	3,950	237	27	120
1991	4,300	262	30	107
1992	3,400	205	22	92
1993	2,500	150	14	84
1994	4,000	244	26	76
1995	4,100	243	25	72
1996	4,450	275	27	57
1997	4,668	287	29	55
1998	4,141	326	31	48
1999	4,400	315	32	48

A strong trend in both sectors has been the decline in numbers of 'serious' growers. There are many reasons for this decline but the significance for IPM is that there is a greater capacity and need for adoption by the larger enterprises. As any business grows in size, there is a tendency for its management to become far more specialised and professional. However, these influences also mean that a business has to achieve a certain minimum size in order to absorb the overhead cost imposed by specialised and professional management. Given the management demands implicit in adoption of IPM and quality control generally, the trend toward larger production units should be viewed as a positive. It can reasonably be assumed that the trend toward larger production units will continue as the demands on managerial expertise, brought about by production and market place complexities, continue to increase.

Table 3.2: Profile of the fresh sector (total for Bowen, Bundaberg, Lockyer Valley and Stanthorpe)*

	Area (ha)	Volume ('000 t)	Value ($m)	No. Growers
1990	4,290	110	134	195
1991	4,110	108	114	160
1992	3,885	98	99	140
1993	3,743	111	104	110
1994	3,438	106	105	97
1995	3,778	120	126	85
1996	4,224	134	132	70
1997	4,535	135	113	57
1998	4,450	128	109	43
1999	4,550	129	114	39

* Figures from 1997 onwards estimated – only larger scale growers included.

The 'volume and gross value of the crop' figures provided in Tables 3.1 and 3.2 serve as a basis for estimating opportunity savings that can be made by the adoption of IPM. Opportunity savings translate into a real benefit. The estimation details are explained later.

The Brisbane Market (Rocklea) is an important outlet for fresh fruit and vegetables. But as illustrated in Table 3.3, a substantial proportion of the tomatoes produced in the State is either sold in other terminal markets or sold directly to retail outlets. The figures suggest that the volume of tomatoes sold through the Brisbane Market is not much more than one-third of the total Queensland production.

Table 3.3: Tomatoes sold through the Brisbane Market relative to total production from Bowen, Bundaberg, Lockyer and Stanthorpe (1992-98)

Year	Queensland production ('000 tonnes)	Brisbane Markets throughput	
		('000 tonnes)	% of Qld prod.
1992	98	37	38
1993	111	38	34
1994	106	42	40
1995	120	43	37
1996	134	48	36
1997	135	46	34
1998	128	40	31

Adoption of IPM: We have already discussed the difficulties of defining IPM and the implications this has for quantifying the industry adoption rate. For this analysis it is convenient to relate IPM benefits and costs to the total area under production. Table 3.4 shows the adoption rate of IPM as a proportion of the total area. In the case of the processing sector, the adoption rate was taken from the work by Jean Bentley (*Development of IPM in processing tomatoes*, in Australian Processing Tomato Grower, Vol. 19, October 1998). In the absence of past estimates, the same rates of adoption have been assumed for the fresh sector.

Table 3.4: Estimate of adoption of IPM in the tomato industry 1990 - 1999

Year (% IPM adoption)	Processing Sector		Fresh Sector	
	Gross area	Area under IPM	Gross area	Area under IPM
	(ha)	(ha)	(ha)	(ha)
1990 (0%)	3,950	-	4,290	-
1991 (0%)	4,300	-	4,110	-
1992 (10%)	3,400	340	3,885	389
1993 (20%)	2,500	500	3,743	749
1994 (30%)	4,000	1,200	3,438	1,031
1995 (40%)	4,100	1,640	3,778	1,511
1996 (50%)	4,450	2,225	4,224	2,112
1997 (55%)	4,668	2,567	4,535	2,494
1998 (57%)	4,141	2,360	4,450	2,536
1999 (60%)	4,400	2,640	4,550	2,730

Time period: For the purpose of analysis, it is necessary to view IPM as a defined project with a beginning and an end. The analysis will be *ex post*, and will consider the period from 1990 to the present (1999). In reality, some of the benefits from past investments in IPM will emerge in the future. For example, preserving the efficacy of insecticides is one of the goals of IPM but the payoff to this strategy will inevitably lag behind the investment phase. It is not possible to be certain about the timing or extent of such benefits, so no attempt will be made to assign the IPM investment with some notional salvage value. It simply needs to be

recognised that for any grower wanting to stay in business, IPM can be part of his/her strategy for effective management of the risk due to pests.

Ten years is a sufficiently long period to capture the natural cycle of 'light' and 'heavy' years from the perspective of pest threats. In low pressure years conventional crop management, with routine application of chemicals, will be capable of producing an average to good crop of tomatoes. In other years, however, when the natural conditions favour pest proliferation, conventional crop management may fail. In these years IPM adopters should enjoy an opportunity saving relative to non-adopters.

As suggested above, the processing and fresh sectors are vastly different and this will necessitate a parallel BCA for each sector. Table 3.5 reveals some of the elementary differences between the two sectors. Perhaps the most critical difference is the proportion of potential yield that is graded out on-farm (row 3). In the fresh sector, on-farm grade-out can be up to half the potential yield. At this rate, opportunity losses of up to $25,000 per ha are not inconceivable. Naturally, this loss has several causes but a large proportion could be saved by effective IPM. In the processing sector, the on-farm grade out figure is of negligible proportions. It is this fundamental difference that determines the target of IPM. As noted in row 9 of Table 3.5, the benefits from IPM will arise primarily from cost savings in the processing sector and from yield savings in the fresh sector.

Table 3.5: Elementary differences between the processing and fresh sectors

Characteristic	Processing Sector	Fresh Sector
1) Location	Northern central Victoria and southern central NSW	Mainly regions in coastal Queensland
2) Yield (delivered)	Up to 130 t/ha	Trellis up to 60 t/ha, ground up to 40 t/ha
3) On-farm grade-out	Average 5% on farm for dirt and green, plus factory dockages for dirt, rotten fruit, foreign matter and blemishes of about 4%.	20-50% depending on season and variety. Some selection at picking against insect damage, poor shape, too ripe, etc. Heavy grading in shed before packing.
4) Harvests per crop	Once by machine	Bowen 2-3 (ground) Bundaberg 15-20 (trellis)
5) Gross income	Up to $12,000 per ha	Up to $60,000 per ha
6) Market tolerance to pest damage	Some (varies with product)	None
7) Insect pest life cycle	Relatively long	Short
8) Number of sprays per crop	Up to 10	Up to 40
9) Main source of short term IPM benefit	Cost savings *vs* non IPM	Yield savings *vs* non IPM

3.3.1 Benefits

IPM generates short and long-term benefits, with the former being of most interest to this study. The short-term benefits take the form of opportunity savings in the areas of cost and yield. This means if a grower takes the opportunity to use IPM, they make savings or gains

relative to the grower who does not take the (IPM) opportunity. Two opportunity savings are identified below.

Opportunity saving due to reduced spraying costs: On average, IPM will allow some reduction in chemicals due to a more precise match between pest burden and use of chemical control. This opportunity applies particularly in the processing sector and particularly in lower-pressure years. A 'more precise match' takes several forms eg, narrow spectrum chemicals, zonal spray on the bush, different concentrations, different groups of chemicals. For the processing sector, it is assumed chemicals and applications valued at $120 per ha can be saved in eight years out of 10. In the other two years (taken to be 1996 and 1998 for the purposes of this exercise) it is assumed spray costs for IPM adopters were actually higher (see following section regarding yield savings).

Relative to total production costs, $120 is a small amount – approximately 3% of total growing costs in the processing sector. As such, the cost savings that IPM can bring about are not a strong attraction on their own. The 'total savings' figures shown in Table 3.6 were derived from the IPM adoption areas shown in Table 3.4.

Table 3.6: Opportunity cost savings in the processing sector due to reduced spraying

Year	Processing Sector		
	Area under IPM	Savings on spray	Total saving
	(ha)	($) per ha	($'000)
1990	-	120	-
1991	-	120	-
1992	340	120	40.8
1993	500	120	60
1994	1,200	120	144
1995	1,640	120	196.8
1996	2,225	-	-
1997	2,567	120	308
1998	2,360	-	-
1999	2,640	120	317

Opportunity yield savings in high-risk seasons: For the fresh sector, the major benefit generated by IPM is yield savings. Indeed a belief expressed by several growers was that without IPM, they would not be 'in' tomatoes. Thus a major benefit from IPM is the yield saved in those years when the pest load is heavy and conventional management fails. This sum will be given by the performance differential between adopters and non-adopters in high-risk years. Quantifying this saving is clearly difficult, and relies on expert opinion, but the dollars could be large indeed. Examples of how the opportunity savings due to IPM come about in practice are provided below.

IPM may call for additional spaying in some years. Under 'average' conditions in the processing sector, a 10-day spray cycle will produce acceptable fruit. But in a high-pressure year, this cycle will suffer losses of 20% on more. This loss could be saved by an IPM approach that increased the application frequency to every 5-6 days (Brian Walker, pers. comm.).

A further example – based on a small-scale trial – of IPM in a high pressure year was provided to this project by Iain Kay. *'Sulprofos (helothion) applied routinely every seven days resulted in about 22% damaged fruit, but when applied at three and four day intervals*

there was only 5% damaged fruit. After allowing for the cost of the extra 10 sprays, the net gain (due to the intelligent spray program) was about $7,700 per ha'.

On other occasions, extra spraying is not the answer. When potato moth (leaf miner) was a major problem in the Bundaberg area (in the early 1990s) growers reported yield losses of up to 50%. The leaf miner problem was brought under control by paddock rotations, destruction of crop residues and reduced insecticide usage early in the crop life. In 1999 silver leaf white fly was a major pest in the fresh sector. However this pest was contained (by beneficials) where growers adopted the IPM approach, eg a leaf dwelling spider will consume up to four white flies per week while wasp larvae bore holes in the white fly nymphs and eat them. Using IPM strategies offers growers the opportunity to avoid the yield losses due to potato moth, white fly and other pests that have considerable potential to reduce marketable yield.

Table 3.7 shows the opportunity savings over the past 10 years. The benchmark for these estimates is the yield that would have been lost if IPM had not been applied/adopted to the extent it was. The rate of adoption of IPM by growers has been taken into account as well as the efficacy of IPM at the time, and the actual incidence of pest risk in each year over the period.

In the case of Heliothis and strategic spraying, the following scenario was assumed in preparing the data presented in Table 3.7:

- High-pressure Heliothis events occur in 1996 and 1998 (two years in ten chosen at random).
- IPM adopters in the processing sector apply six more sprays and adopters in the fresh sector apply 10 more sprays at a cost of $360 and $800 per ha respectively.
- IPM adopters make a gross opportunity yield saving of 15% worth $1,275 per ha in the processing sector and $7,500 in the fresh sector.
- The net opportunity savings by IPM users in 1996 and 1998 were $915 per ha and $6,700 per ha in the processing and fresh sectors respectively.
- Given the IPM adoption rates in 1996 and 1998, the whole sector opportunity savings were $4.2 million in the processing sector and $31.1 million in the fresh sector.

The fresh sector has had the opportunity to make massive yield savings over the past 10 years due to the use of IPM strategies in managing specific pests. In the case of potato moth and silver leaf white fly, the following scenarios were assumed in preparing the data presented in Table 3.7:

- A high pressure Leafminer event in 1993 (one year in ten chosen at random).
- A high-pressure Silver Leaf White Fly event in 1997 (one year in ten chosen at random).
- IPM adopters in the fresh sector practice paddock rotations and intensive hygiene measures at a cost of $1,000 per ha over 10 years.
- IPM adopters make a gross opportunity yield saving in 1993 of 20% worth $10,000 per ha. Based on an IPM area of 749 ha, the net benefit was $7.415 million.
- IPM adopters make a gross opportunity saving in 1997 of 25% worth $12,500 per ha. Based on an IPM area of 2,494 ha, the net benefit was $31.2 million.

Table 3.7: Opportunity yield savings due to IPM

Year	Processing sector	Fresh sector
	$'000	$'000
1990	-	-
1991	-	-
1992	-	-
1993	-	7,415
1994	-	-
1995	-	-
1996	2,036	14,150
1997	-	31,175
1998	2,159	16,991
1999	-	-

Long term opportunity savings: A further benefit, not always apparent within a particular season, is preservation of the efficacy of registered chemicals (particularly insecticides)[13]. Due to their short life cycle and metabolic processes, insects quickly develop resistance when a particular chemical is used repeatedly. For example, cotton production was eliminated from the Ord River in 1972 due to the inability of insecticide use to control Heliothis. Another example of resistance was the failure of dicarboximide fungicides to control *Botrytis cinerea* in the Bundaberg area in 1984 due to acquired resistance.

Helicoverpa spp in particular is highly destructive and has developed resistance to several classes of insecticides. It has developed pyrethroid and OP resistance in cotton and in other crops in the same growing region with, at times, devastating results. The 'grub' is foremost in every tomato growers' mind as a potential cause of yield loss.

IPM is the mainstay in the prevention and management of insecticide resistance in insect pests and should be an integral part of the tomato industry's long-term risk management strategy. This benefit is also difficult to value, but were resistance to develop suddenly, it is not unrealistic to assume total crop failure. From the perspective of this (*ex post*) analysis, the possibility of disaster associated with large-scale resistance lies in the future. Were this analysis to project the outcomes of IPM by considering (say) the next 10 years, it would be reasonable to factor in 'very large' benefits associated with the need to minimise acquired resistance to insecticides.

Social benefit: No particular attempt has been made to quantify the IPM benefits that have flowed beyond the farm gate. However the public sector stake in R&D makes it important to consider the nature and extent of any spillover benefits[14]. Thus growers and advisors were asked whether they believed IPM had given rise to social benefits and what form these might have taken. Several possibilities were nominated by respondents and these are fleshed out below:

- **Greater worker safety:** The cost of endemic health problems is ultimately borne by the community. R&D that reduces the likelihood of occupational health problems

[13] Acquired resistance is not such a problem with fungicides due to their limited movements within the soil and longer life cycle. However fumigants are being withdrawn from the market for environmental reasons (eg, methyl bromide for ozone depletion) so the need to develop more integrated control measures is important for soil borne pests including plant pathogens, weeds and insects.

[14] The possibility of spillover benefits, which can be enjoyed by the community at large, is one justification for the government's practice of matching industry funding of R&D.

will provide a social dividend. IPM, for example, can lead to more responsible use of chemicals including personnel protection equipment.

- **Improved food safety:** Since the health and productivity of the population can be positively linked to a wholesome food supply, it is valid for R&D to pursue objectives that will enhance food safety. It is likely a spillover benefit from IPM will be safer tomatoes with direct benefits for the population at large.
- **Greater food security:** To the extent that IPM fits into the philosophy of sustainable production, it will enhance long term food security. It is likely that the outcomes from IPM research in tomatoes will benefit the IPM research programs being conducted in other industries, particularly considering the advanced state of IPM for tomatoes. Any increase in food security will benefit future generations.
- **Less environmental contamination:** The chemicals used to manage pests have residues which may remain in the environment. At critical levels, these residues are harmful to many species. The bulk disposal of hazardous waste, some of which may be banned product, is well managed by industry and governments in this country.
- **More local employment:** Chemical solutions can be characterised as 'easy'. The practice of IPM is not easy in this sense. In general it requires more managerial effort, greater vigilance and more manual labour for the practice of paddock hygiene. The most visual evidence of increased employment due to IPM is more crop care consultants to monitor crop health and recommend appropriate action. But IPM will also create more jobs on the farm. In this sense, IPM can be seen as a technology that is out of step with 'modern' agriculture where the trend has been away from labour and towards mechanisation. But our regional communities are very keen to preserve jobs as a means of equitably distributing rewards. To the extent that IPM creates more jobs, it is generating a social benefit. It is also bringing professionals and technology into local communities.

While identification of spillover benefits is important for justifying of the government's contribution to R&D, Australia's tomato growers are most interested in the direct benefits generated by R&D. As such, no quantification of the spillover benefits from IPM will be attempted on this occasion.

3.3.2 Costs

R&D cost: Most the R&D investment for IPM has come from a combination of public and private sources and has been channeled through various research organisations. Table 3.8 provides a breakdown of the expenditure on IPM by HRDC, industry and others[15] (chiefly the Agriculture Departments in Victoria, New South Wales and Queensland) over the past decade. The figures shown for HRDC and industry are 'actual' while those given for the departments and others are approximations based on multiples of the salaries of staff working directly on IPM for tomatoes. The departmental expenditure was estimated by taking the total salaries of personnel known to have worked directly on IPM – in each of the past 10 years – and multiplying them by a factor of 2.6. This factor was considered to give a reasonable approximation of the total cost of IPM-related work by the particular department.

By 2000 the total HRDC expenditure on IPM will amount to $2.23 million for the 10-year period. This equates to slightly more than half the amount spent by the State Departments from their own resources over the same period. Assuming growers contribute half the HRDC

[15] 'Others' can be taken to include private consultants and institutions other than those directly funded by HRDC.

budget, their proportional contribution to the total R&D expenditure on IPM over the last 10 years amounts to 14%.

Actual use cost: The first requirement for IPM is crop monitoring. This task is usually out-sourced to a consultant, often trained initially in horticultural technology, with many hours of practically experience. Crop monitoring in its broadest sense can be taken to include objective analysis and interpretation of all the technical dynamics of crop production including plant nutrition, water and soil management. The cost of scouting for pests and beneficials can be charged out on an hourly or a per hectare basis. The monitoring season in the processing sector lasts about 20 weeks and each block will be monitored once or twice per week depending on the pest pressure and the grower-scout business arrangements in a particular year. In the processing sector, therefore, crop monitoring costs work out at $60 to $100 per ha depending on frequency across the season.

Monitoring costs in the fresh sector are derived in a similar fashion but the rate itself is somewhat higher due to the need for more protection. It is assumed the average cost of monitoring for adopters in the processing sector throughout the period was $60 per ha while the figure in the fresh sector was $150 per ha. The analysis assumes that the unit cost of monitoring has remained unchanged over the entire period.

Table 3.8: Investment in Integrated Pest Management R&D over the Past Decade

Year	Processing Sector*			Fresh Sector		
	HRDC		DNRE + NSW Agriculture	HRDC		QDPI
	Industry	C'wealth Govt		Industry	C'wealth Govt	
	($)	($)	($)	($)	($)	($)
1990	29,483	29,483	250,000	-	-	234,000
1991	38,729	38,729	300,000	-	-	234,000
1992	53,002	53,002	300,000	49,465	49,465	234,000
1993	67,668	67,668	300,000	45,155	45,155	234,000
1994	59,480	59,480	300,000	33,866	33,866	234,000
1995	68,480	68,480	300,000	63,832	63,832	312,000
1996	36,480	36,480	350,000	63,681	63,681	312,000
1997	68,094	68,094	350,000	67,453	67,453	312,000
1998	96,058	96,058	350,000	66,635	66,635	234,000
1999	82,882	82,882	350,000	29,977	29,977	234,000
2000	76,162	76,162	350,000	25,915	25,915	234,000

* Includes a nominal 'allocation' of $47,480 from HG97007 *National strategy for the management of western flower thrip and tomato spotted wilt virus*, which was 5% of its total budget. Also includes $194,000 or 20% from HG319 *Evaluation of petroleum spray oils.*

In addition to the cost of monitoring, adoption of IPM can lead to an increase in management and labour for improved paddock hygiene. The re-organisation of clean-up procedures following the leaf miner outbreak at Bundaberg in the early '90s provides a good example. Following that event, there have been more paddock rotations and slashing and growers have made a practice of removing all structures and plant material immediately following harvest. It is assumed the learning, timeliness and organisational stresses associated with these IPM (cultural) practices cost adopters $100 per ha. This amount has been added to the monitoring costs shown in Tables 3.9 and 3.10.

The cost data in Tables 3.9 and 3.10 were derived from information provided by growers and experienced IPM consultants.

Table 3.9: Cost of IPM adoption in the processing sector

Year (% IPM adoption)	Gross Area (ha)	Area under IPM (ha)	Cost of IPM (monitoring + other costs)	
			($ per ha)	($'000 total)
1990 (0%)	3,950	-	160	-
1991 (0%)	4,300	-	160	-
1992 (10%)	3,400	340	160	54.4
1993 (20%)	2,500	500	160	80.0
1994 (30%)	4,000	1,200	160	192.0
1995 (40%)	4,100	1,640	160	262.4
1996 (50%)	4,450	2,225	160	356.0
1997 (55%)	4,668	2,567	160	410.7
1998 (57%)	4,141	2,360	160	377.6
1999 (60%)	4,400	2,640	160	422.4

Table 3.10: Cost of IPM adoption in the fresh sector

Year (% IPM adoption)	Gross Area (ha)	Area under IPM (ha)	Cost of IPM (monitoring + other costs)	
			($ per ha)	(Total $'000)
1990 (0%)	4,290	-	250	-
1991 (0%)	4,110	-	250	-
1992 (10%)	3,885	389	250	97.3
1993 (20%)	3,743	749	250	187.3
1994 (30%)	3,438	1,031	250	257.8
1995 (40%)	3,778	1,511	250	377.7
1996 (50%)	4,224	2,112	250	528.0
1997 (55%)	4,535	2,494	250	623.5
1998 (57%)	4,450	2,536	250	634.0
1999 (60%)	4,550	2,730	250	682.5

3.4 Benefit cost estimation

To this point, the analysis has focused on explaining the concepts that lie behind economic analysis and assembling the data specific to the case of IPM in tomatoes. It will be recalled that the benefit stream from application of IPM is given by the different price, cost and yield outcomes compared to conventional crop management. Because tomato growers can choose between IPM and non-IPM, any positive differences (in price, cost saving or yield) due to the application of IPM are said to be 'opportunity' gains. Clearly the magnitude of these gains is difficult to estimate but all the assumptions and estimation procedures used in the analysis have been clearly stated. A logical framework has now been developed that can be re-used when further data comes to hand.

The IPM cost stream simply reflects the actual outlays on R&D and the cost of adoption of on-farm practices that go with IPM. All the benefits and costs derived above are summarised in Tables 3.11 and 3.12 and net present values for the IPM technology estimated.

The net present values are derived by compounding the net values shown at the end of each year and summing the 10 values. Compounding has the effect of bringing past values to the present, with the strength of this effect being greatest for those values furthest in the past.

Assuming a 6% rate, the compound factor applying after one year is 1.0600 while after 10 years it is 1.7908.

3.5 Discussion

This analysis has attempted to quantify the economic merit of IPM from a regional and national perspective. Past attempts to do this have focused on the cost savings due to reduced spraying in low-pressure years. In point of fact, these savings are small (eg 3% of total growing costs) and as such are a relatively minor attraction to the grower. This is especially the case when we consider the risk to fruit quality associated with applying higher pest action thresholds, a central plank of IPM practice.

However, it is generally accepted that IPM is the most effective way to:

- encourage beneficials which can suppress pest activity;
- slow the build-up of in-field pests;
- use strategic combinations of chemical, biological and cultural management that are highly effective against particular pests in particular years; and
- minimise a build-up in resistance to insecticides.

IPM, when and where applied, has the capacity to prevent yield losses in high-risk years. Unless these benefits are factored into economic analyses, the true value of IPM will not be recognised and the technology will be under-rated. The corollary is that unless these benefits can be factored into the analysis (because they exist) it will be difficult to justify IPM on economic grounds.

The central challenge for this analysis, therefore, has been to identify and quantify any savings due to the opportunity to adopt IPM over the past 10 years. Based on our research, it is apparent there have been pest-related events over the past decade that have had the potential to reduce yield and could be influenced by the adoption of IPM strategies. While accurate specification of the yield and cost differences between IPM and non-IPM was clearly difficult, plausible scenarios were developed. Indeed the large between-year variations in Present Values (due to adoption of IPM) shown in Tables 3.11 and 3.12, amply demonstrate the real-world (episodic) nature of pest attack and control in tomato production.

It will be appreciated that the benefit and cost streams used by this analysis were particular to the past 10 years. If the analysis were to be extended into the future, it would reasonable to include the possibility of very large pay-offs due to adoption of IPM in both the fresh and processing sectors. This is the case because long-term risk management is implicit in the practice of IPM.

Based on the assumptions adopted, the analysis indicated that IPM has been very profitable from a national perspective. The pay-off over the past 10 years from the combined processing and fresh sectors has been over $75 million[16].

[16] This result is based on a compound rate of 6%. The result would be better if a higher rate was used (eg, over $75 million at 8%) but worse at lower rates.

Table 3.11: Summary benefit cost analysis for the processing sector

Year	Benefits ($'000)			Costs ($'000)			Net Values
	Opp. Cost savings	Opp. Yield savings*	Total benefits	R&D cost	On-farm IPM costs	Total costs	($'000)
1990	-	-	[illegible]	176	-	176	-176
1991	-	-	[illegible]	194	-	194	-194
1992	40.8	-	40.8	340	54.4	394.4	-354
1993	60	-	60	369	80	449	-389
1994	144	-	144	353	192	545	-401
1995	196.8	-	196.8	487	262.4	749.4	-552
1996	-	2,036	2,036	423	356	779	1,257
1997	308	-	308	486	410.7	896.7	-589
1998	-	2,159	2,159	542	377.6	919.6	1,240
1999	317	-	317	516	422.4	938.4	-621
Net Present Value @ 4% compound rate over the project life							-$1,204
Net Present Value @ 6% compound rate over the project life							-$1,431
Net Present Value @ 8% compound rate over the project life							-$1,119

* The timing and size of these savings have been structured to reflect reality. Thus pest damage/savings occur periodically and randomly through time (see earlier derivation of benefits).

Table 3.12: Summary benefit cost analysis for the fresh sector

Year	Benefits ($'000)			Costs ($'000)			Net Values
	Opp. Cost savings	Opp. Yield savings	Total benefits	R&D cost	On-farm IPM costs	Total costs	($'000)
1990	-	-	[illegible]	234	-	[illegible]	**- 234.0**
1991	-	-	[illegible]	234	-	[illegible]	**- 234.0**
1992	-	-	[illegible]	333	97.3	[illegible]	**- 430.3**
1993	-	7,415	[illegible]	324	187.3	[illegible]	**6,903.7**
1994	-	-	[illegible]	302	257.8	[illegible]	**- 559.8**
1995	-	-	[illegible]	440	377.7	[illegible]	**- 817.7**
1996	-	14,150	[illegible]	439	528	[illegible]	**13,183.0**
1997	-	31,175	[illegible]	447	623.5	[illegible]	**30,104.5**
1998	-	16,991	[illegible]	367	634	[illegible]	**15,990.0**
1999	-	-	[illegible]	294	682.5	[illegible]	**- 976.5**
Net Present Value @ 4% compound rate over the project life							**$71,679**
Net Present Value @ 6% compound rate over the project life							**$76,421**
Net Present Value @ 8% compound rate over the project life							**$81,426**

However the analysis has revealed a marked difference in the economic performance of IPM in the two sectors of the tomato industry. In the processing sector, IPM over the period 1990-99 has suffered a negative return (NPV = minus $1.4 million using a rate of 6%). In the fresh sector, however, IPM appears to have delivered a large benefit (NPV = $76.4 million using a rate of 6%). There are many reasons for this divergent performance including:

- **Potential for economic gains:** The potential for gains in the fresh sector is relatively high due to the greater size of the industry, high growing costs and high unit value of the crop. Both the growing costs and farm gate price of processing tomatoes are only about one tenth of what they are for the fresh fruit.
- **Yield saving versus cost saving:** The traditional reliance on cost saving as the economic justification for IPM can be shown to be erroneous. The cost of a single spray is negligible compared to the total growing costs and almost infinitesimal compared to the gross returns that are 'at risk' from pests. On the other hand, if yield can be positively saved, it becomes relatively easy to demonstrate a benefit due to IPM. The pest events over the past 10 years suggest that yield savings have been much more a feature of the fresh sector than in the processing sector.
- **Expenditure on R&D:** The data in Table 3.8 shows that more has been spent on IPM R&D in the processing sector than in the fresh sector. From a financial perspective, R&D can be thought of as an overhead cost. Thus the tomato 'business' has to recover this cost before it can make a profit. In practice, the challenge of recovering overhead costs will be directly related to the size of the industry and the size of its R&D budget. The significance of 'where the R&D dollars are spent' will be lessened if it can be demonstrated there are useful transfers of R&D outcomes between the two sectors. Our own research has not allowed us to make a judgement, one way of the other, about the extent of outcome transfers.

While there is no apparent price premium for IPM fruit at this time, the benefit, if this became the case, would be far greater for the fresh sector since it could conceivably add 10-20% to the retail price of fresh tomatoes. In the meantime, IPM may help the processing sector with access to export markets if it provides the means for conforming with import/export protocols.

So what do these results mean? Do they suggest, for example, that IPM has been a poor option for the processing sector or that the R&D emphasis has been inappropriate? Firstly, there is a strong case for directing more R&D budget to the fresh sector. However, the results do not imply there should be any reduction of IPM research and development in the processing sector. It is conceivable, for example, that without IPM the industry would have been even worse off. Furthermore, IPM is integral to sustainable crop production and as such, integral to the long-term viability of the tomato industry. Unfortunately, the sustainability concept does not lend itself to 'clear economic proof' in the short term. Thus the yield savings we have been able to demonstrate for the fresh sector are likely, also, to apply to the processing industry in the fullness of time. Indeed IPM will deliver significant yield savings for the processing sector if effective management strategies can be developed for bacterial canker and powdery mildew.

While our study found little disagreement with the concept and methods of IPM, the technology's rate of adoption throughout the tomato industry is far from universal. This suggests a need to re-assess the balance between researching and applying IPM. Clearly the quickest way to get a return on the past investment in IPM is to increase the rate of adoption of IPM. In the present analysis, it was assumed that IPM was not being practiced at the beginning of the decade and the rate had levelled-off at 60% by 1998. If the industries can

achieve the adoption rates stated in their strategic plans, the return to the IPM R&D over the past decade will be strong indeed.

The major conclusions from this analysis are as follows:

- IPM will be undervalued unless the risk of massive yield losses due to periodic failure by conventional management is explicitly recognised by any benefit cost analysis. The risk of yield losses is greatest in the fresh sector but also exists in the processing sector.
- IPM has been an economically viable technology for the Australian tomato industry. To date the processing sector has not shown a return on R&D investment (under the conditions and assumptions as stated in the foregoing) but when the two sectors are considered as one (ie, the national perspective as distinct from the regional perspective) the position is profoundly positive. While the benefits from IPM exceed the costs, some of the R&D cost burden is presently borne by the taxpayer. This analysis has not attempted to prove whether IPM has been a 'good' investment for the individual grower. We suspect this is the case, however, because all of the $75 million net benefit from IPM (identified in this analysis) has gone to growers but they have not met all the costs associated with generating this return. Most of the R&D expenditure has been provided by the taxpayer (either through the Commonwealth's dollar for dollar funding of HRDC or through the State Departments). On the other hand the analysis did not include the many social benefits that flow from IPM. These social benefits provide a real return to the taxpayer for their investment in Integrated Pest Management R&D.
- IPM has not yet reached its full potential for delivering economic benefits. The gap between opportunity and potential gains will not be closed until more growers adopt and apply IPM. This suggests greater emphasis should be given to actual adoption of IPM. It would be difficult to exaggerate the importance of the commercial consultants in translating IPM from a 'neat concept' to an integral facet of commercial tomato production.
- We were attracted to the idea of an 'open learning' program for growers where they would be introduced to IPM protocols. One of the existing barriers for growers is the difficult business of converting from conventional management to IPM. A step by step protocol would go a long way towards breaking down this barrier. Further detail on this subject is provided elsewhere in the report.

3.6 Observations and recommendations

- **BCA is highly data dependent.** To do his/her job properly the analyst needs access to reliable data on the rate of IPM adoption, the costs associated with the practice of IPM and the comparative impacts on yield. Presently these data are weak and the present analysis was forced to make many assumptions and suppositions. However the industry is now equipped with a fully specified model for evaluating the economics of IPM, and future upgrades will be relatively easy, provided the necessary data are available.
- **Trapping the data:** Decisions about where to invest are typically based on the available statistics. Clearly, therefore, good decision making is reliant on the data being accurate. We know, however, that ABS data often understate the actual volume of production, especially for vegetables. Furthermore, industry statistics are rarely made available for the purpose of research due to confidentiality agreements. Finally,

the experience of this study has convinced us that seeking data direct from growers, using questionnaires, is mostly a futile exercise. On the other hand, transport manifests appear to offer scope for trapping accurate data relating to product, volume, source and destination. Possibly, therefore, the fruit and vegetable industry should investigate the feasibility of cementing formal relationships with transport companies for the purpose of data compilation[17]. The offer of financial incentives would help with gaining cooperation.

It is recommended that all of the data necessary to conduct a rigorous benefit cost analysis at any time in the future be progressively captured on a database. This database should be interactive, with authorised people able to add or access data at any time. Commercial database systems such as Microsoft Access would be quite adequate for this purpose. If set up appropriately, such a database would help make data gathering, storage and retrieval independent of particular individuals.

Data stored in the system could include, on a sector basis, tonnage and value of annual production, costs of pest management at the grower level each season, and magnitude and value of losses each season due to pests. A representative network of growers, consultants and other relevant parties could be established to record the raw data in a systematic way and to then submit it to the database manager or possibly enter it directly onto the database.

[17] A working model for this system already exists. Mr J Lovatt QDIP has collected high quality data for the Bundaberg fruit and vegetable industry based on transport manifests since 1980.

4. HRDC's research program on IPM in tomatoes

Since 1992 the HRDC has funded, with industry support, a series of R&D projects on or related to IPM in tomatoes. Some of these projects were focussed on development and implementation of practical systems in the hands of farmers and their consultants, while others were focussed on the more technical aspects of specific pest problems and management in an IPM context.

HRDC nominated a list of 20 projects that warranted consideration in the context of its IPM program. Some of these projects have been completed and some are still in progress. Of the 20 nominated projects, 12 are associated with the processing sector (identified in most cases by the prefix 'TM') and eight with the fresh sector in Queensland (identified in all cases by the prefix 'VG'). Due to problems with the definition of 'IPM', a couple of projects considered to be relevant to but not central to IPM were included in the evaluation of projects described in this section of the Report.

Comment was sought from growers (via the series of grower meetings referred to earlier in the report) and from the various categories of other stakeholders (via interviews with researchers, extension officers, consultants and processors as applicable) in the processing and fresh sectors. Using a largely unstructured and open-ended approach, two issues were addressed:

- The value of HRDC-funded IPM projects to date; and
- The future directions for HRDC-funded research on IPM in tomatoes.

The comments obtained have been collated on a group x sector basis and are summarised below in Sections 4.1 – 4.8.

In addition, the project team conducted a more thorough, technical evaluation of the projects. A description of the process used and a summary of the findings are described in Section 4.9, with further detail provided in Attachment 4.

4.1 Growers' views on the value of HRDC-funded IPM projects

4.1.1 Processing sector

Comments on the value of HRDC-funded IPM projects were sought from the growers who attended the five grower meetings held at various district centres in January 1999. Comment was solicited during an open-ended discussion with the growers. As the emphasis was on 'first recall', the comments will tend to reflect those projects that made the greatest impression – good or bad – on the growers.

The collated views of the growers on HRDC IPM projects for the processing tomato industry funded to date are summarised below.

> **Note.** Comments are included where available for two HRDC projects of relevance to but not central to HRDC's IPM research program. These projects are TM137 and TM405.

TM041 (Phythophthora root rot):

- This project did not actually solve anything, but it did demonstrate that the disease could be controlled by attention to cultural practices, crop layout and irrigation management.
- Outcome of the project regarded as useful.
- 'The Phytophthora work went on for six years without a result'.

TM043 (Residue analysis):

- Adopted by the industry and seen as an essential safeguard for marketing purposes (majority view).
- A minority view was that residue testing is not relevant.

TM137 (Soil fumigation with Metham sodium):

- 'Banded fumigation with Metham sodium has been the most successful of all projects' (several mentions). But some growers queried why the HRDC had to fund this research, as 'research already done in America'. This comment highlights the observation that some growers do not understand the need to generate 'local data' for registration of agricultural chemicals in this country.
- More work on application of Metham sodium needed, eg through trickle irrigation system or as a band.
- Metham sodium project good in more southerly regions, but too wet and cold in the Griffith area at time of planting for it to be effective. (**Note.** Soils in the area are heavy clays and it is difficult to get a good seal of the soil surface, leading to poor efficacy of the treatment.)

TM201/95001/98009 (dedicated IPM projects):

- These projects were 'the best of the lot' (one group).
- The most important factor in adoption of IPM was personal contact with researchers who promoted it.
- Results of these projects have filtered through to growers very quickly, often via consultants.
- TOMCAST system helps with disease control.

TM301 (Study trip to US on mechanical weed control):

- One grower developed shielded spraying equipment for spraying Round Up between rows close to tomato plants, which has proved to be more successful than the US system.

TM405 (Evaluation of Titus for weed control):

- Research on this selective herbicide was regarded as very useful (several mentions).

TM602 (Selection of Trichogramma):

- This project was regarded as a 'fizzer' but reasons for this have been identified and are understood.

TM97004 (IPM in tomatoes - research into practice):

- This was perhaps the most useful of the projects (according to one group), as it provided training in IPM. Personal contact with growers by Jean Bentley helped make this project a success. The project certainly had a positive influence on adoption of IPM. However some growers were concerned that the availability of training programs was not well publicised among growers on some occasions.

TM97001 (Powdery Mildew control):

- Powdery mildew project was regarded as potentially useful but has been inconclusive to date. Some queries about where this project is going; others would like to see on-going work.

TM97007 (National Strategy for Western Flower Thrips):

- Training course on Western Flower Thrips was rated as good.

4.1.2 Fresh sector

Comments on the value of HRDC-funded IPM projects were sought from the growers who attended each of the three grower meetings that were held at various district centres in February 1999, using the approach outlined above for the processing sector.

The collated views of the growers on the IPM projects for the fresh tomato industry in Queensland funded by the HRDC to date are summarised below.

General comments:

- The present approach is too disjointed and tends to reflect the preferences of the influential researchers at the time, rather than the industry needs. Also, the knowledge generated under the various projects is not integrated.
- Projects are too pest-specific; need to have a broad view of the pest spectrum.
- Bundaberg growers valued the IPM projects carried out by Crop Tech, including the information provided in radio broadcasts and field walks.
- The Bundaberg growers were aware of the strategic spraying project (VG412) and had changed sprayers as a result.

4.2 Researchers' views on the value of HRDC-funded IPM projects

4.2.1 Processing sector

Comments were sought from the key field production researchers on the value of HRDC-funded IPM projects. Comment was solicited during an open-ended, largely unstructured discussion with the researchers on an individual basis. As the emphasis was on 'first recall', the comments tend to reflect those projects that have had made the greatest impression – good or bad – on the researchers. Researchers consulted were:

- Jane Moran, DNRE IHD Knoxfield;
- Sze Flett and Roger Ashburner, DNRE ISIA Tatura ; and
- Sandra McDougall, NSW Agriculture, Yanco.

The collated views of these researchers on the IPM projects for the processing tomato industry funded by the HRDC to date are summarised below.

> **Note.** Comments are included where available for several HRDC projects of relevance to but not central to HRDC's IPM research program. These projects are TM137, TM405, VG409, VG415 and VG511.

General comments:

- Current/recent HRDC projects tend to be too narrowly focussed.
- HRDC has shown little direction in the area of weed control and herbicides (particularly in terms of recognition of IPM principles).

TM041 (Phytophthora root rot):

- Phytophthora no longer a problem, but not sure that the actual project played a pivotal role in arriving at a solution.

TM137 (Soil fumigation with Metham sodium):

- A lot of growers use Metham sodium, but this is essentially a soil sterilant and hence, in the eyes of one researcher, its use may not be consistent with IPM principles. The rationale for this view is that the organisms colonising sterile soil most quickly are invariably pests, resulting in more frequent use of chemicals. It was also suggested that the treatment selects resistant organisms and some soil bacteria can break Metham sodium down. However, some points to counter this view included:
  i. Metham sodium fumigation is applied as a strip along the plant line. Microbes quickly recolonise from the adjacent untreated soil. Some of the beneficial effects of Metham sodium fumigation can include re-colonisation by saprophytic fungi and bacteria, some of which may help to prevent invasion by pathogens. However, a comparable situation may not apply in the case of insect pests.
  ii. Serious problems with resistance to this fumigant have not been observed.
  iii. Metham sodium breaks down fairly quickly in moist soil, releasing compounds that also have a fumigant effect - this is in fact the way it works.

TM201/95001/98009 (dedicated IPM projects):

- These projects have had a heavy extension orientation and consequently have had a big impact in the field.
- Growers need confidence in IPM and this project helped to provide growers with the necessary technology to give them that confidence.

TM208 (Evaluation of Thimet for control of wireworm and other insects):

- Good adoption in Victoria, but less relevant in NSW.
- Use of Thimet has increased - a good outcome.

HG319 (Use of petroleum oils):

- Tomatoes were only a small part of that project.

TM301 (Study trip to US on mechanical weed control):

- Limited adoption of findings by growers (other techniques for weed control are used as required).

TM405 (Evaluation of Titus for weed control):

- Product now available commercially and it seems to be very successful.

TM602 (Selection of Trichogramma):

- Work is still in progress at the laboratory level and has not been translated to the field as yet. Some delays due to problems with commercial production of Trichogramma.

TM97004 (IPM in tomatoes - research into practice):

- The project included training of scouts. Some of the trained commercial scouts have since left for greener pastures, eg cotton. However, some DIY scouts (growers) were trained.

TM97001 (Powdery Mildew control):

- The project has shown that it is necessary to put more sprays (sulfur) on earlier in the season than was the standard industry practice, but of course this has increased production costs. Two alternative chemicals have shown promise, but one leaves residues in the fruit; the other has application problems. The pathogen causing Powdery Mildew is unique to Australia; hence it is not possible to directly adopt the results of overseas research.

TM97007 (National Strategy for Western Flower Thrips):

- Western Flower Thrips are endemic in some nursery areas for tomato seedlings, but not at this stage in those areas used by the processing industry. As yet, there are no Western Flower Thrips in the field in processing growing areas (they are confined to fresh tomato growing areas in the Sydney basin). However, if they do get established in processing tomato-growing areas, the industry will have a spotted wilt problem, as these thrips are vectors for this disease. For this reason, the processing tomato industry has supported the national Western Flower Thrips Strategy. This potential problem also highlights the need for the tomato seed and nursery people to be included within the scope of the IPM program (HACCP approach).

4.2.2 Fresh sector

Comments were sought from the key field production researchers (QDPI and private) and QDPI extension officers on the value of HRDC-funded IPM projects, using an approach similar to that outlined above for the processing sector. The people consulted were:

- Iain Kay, Geoff Barnes and John Maltby, QDPI, Bundaberg
- Des McGrath and Phil Anning QDPI, Bowen
- Graham Stirling, Nematologist, Biological Crop Protection, Brisbane

General comments:

- Despite 10 years of IPM, the Queensland industry is still very dependent on a heavy spraying program for Heliothis. IPM has enabled the reduction of spraying frequency at the beginning and end of the season, but not in the middle section of the season where 2-3 sprays per week are still required. IPM has reduced the total number of sprays in the season by 5-6 (Bundaberg area).

- IPM calls for a coordinated district-wide approach but this is difficult to achieve, as all growers are independent operators. However, Bowen growers have agreed that there will be no plantings before 15 February.
- Not close enough to HRDC's tomato IPM projects to make specific comments on their outcomes and impact, but certainly has gained the impression that IPM is performing better in the field now compared with 10 years ago.
- There is no evidence of build-up in resistance by soil pests to chemicals. Part of the reason for this is that soil chemicals are only used once per year.
- A change in varieties has had a major impact on pest management.
- Lag phase to get projects going (12-18 months) is too long.

4.3 Consultants' views on the value of HRDC-funded IPM projects

4.3.1 Processing sector

Comments were sought from all of the commercial scouts/consultants currently operating in the processing growing sector on the value of HRDC-funded IPM projects. Comment was solicited during an open-ended, largely unstructured discussion with the consultants on an individual basis. As the emphasis was on 'first recall', the comments will tend to reflect those projects that made the greatest impression – good or bad – on the consultants. Scouts/consultants consulted were:

- Brian Walker, Griffith area (scouting and consulting)
- Michael Hind, Boort area (scouting and consulting)
- David Webb, Jerilderie/Griffith areas (scouting and consulting)
- Anne Ginter, Rochester area (scouting only)
- Adrian Lees, Rochester area (consulting only)

The collated views of the scouts/consultants on the IPM projects for the processing tomato industry funded by the HRDC to date are summarised below.

General comments:

- Most of the projects have been extended to the growers, but not all have been adopted.
- The DNRE Sustainable Agriculture project out of Tatura was widely regarded as ineffective R&D by growers

TM041 (Phytophthora root rot):

- A cause of the problem was found and practices to avoid the problem have been adopted.
- Project provided useful information to consultants.

TM043 (Residue analysis):

- Project was successful and the testing program has been adopted by the industry on a collective basis.

TM137 (Soil fumigation with Metham sodium):

- Growers in NSW districts are not happy with banded Metham sodium, as the local soils are not suitable. Hence there is high interest in Titus in these districts.

TM201/95001/98009 (dedicated IPM projects):

- All of the HRDC projects related to IPM on processing tomatoes generally regarded as useful. The US Study Tour for growers was very successful.
- Initial work on thresholds under these projects critical to the success of the IPM program.
- The TOMCAST model does not cover Bacterial Speck or Powdery Mildew.
- Weather patterns are very variable around Rochester and it is considered that just one weather station is insufficient to provide the TOMCAST model with data.

TM208 (Evaluation of Thimet for control of wireworm and other insects):

- Use of Thimet has been widely adopted and is proving to be very useful.

TM405 (Evaluation of Titus for weed control):

- A useful project, well known to growers. Product only recently released commercially. A query on its effectiveness on Bathurst Burr.

TM602 (Selection of Trichogramma):

- The concept behind this project is good in theory, but there are numerous practical problems with it, eg commercial production of Trichogramma, method of release.

TM97001 (Powdery Mildew control):

- Powdery Mildew is clearly a major issue and was frequently mentioned as needing attention. However also mentioned that little real progress on this project has been made to date. Industry is nevertheless hopeful that the work on alternative treatments for Powdery Mildew will prove to be successful, as it is estimated that this disease is costing growers 10-50% of their yield.
- Some expressed the view that there is a need to get away from aeroplanes for application of fungicides. They claim it is impossible to achieve adequate coverage of the plant for control of all diseases.

4.3.2 Fresh sector

Comments were sought from all of the commercial IPM consultants currently operating in the fresh growing sector in Queensland on the value of HRDC-funded IPM projects, using an approach similar to that outlined above for the processing sector. The following consultants provided comments:

- John and Penny Hall and Gary Artlett, Bundaberg
- Dale and Sally Abbott and Chris Monsour, Bowen
- Julian Winch, Lockyer/Stanthorpe

The collated views of the scouts/consultants on the IPM projects for the fresh tomato industry in Queensland funded by the HRDC to date are summarised below.

- The two 'original IPM consultants' in the Queensland tomato industry (John Hall and Dale Abbott) showed a high level of awareness of HRDC's IPM projects and in fact have been involved in some of the projects. They have assisted with the important

matter of transmission of information about IPM projects to growers. This was done by various means including radio broadcasts and field walks. They and their staff have participated in grower training sessions on spraying and top spraying in particular. These sessions were conducted by John Harden and other UQ Gatton staff.

- However, the third of the recognised tomato IPM consultants in Queensland (Julian Winch) indicated that he was only vaguely aware of HRDC's IPM research program. He was not receiving information about HRDC projects, but relied on the occasional informal contact with the other consultants. This situation was probably exacerbated by the fact that QDPI no longer provided tomato research and extension in the Lockyer and Stanthorpe areas.
- Development of IPM has enabled the risk of periodic crop failure to be avoided, as it is the only way of handling pests in the heavy load years (at least 1-2 years in 10).
- The research program has resulted in the development of an IPM system with the main element being strategic spraying based on monitoring and the presence of beneficials, eg mites, lacewings.

4.4 Processors' views on the value of HRDC-funded IPM projects

Most of the five major processors felt that they were not in a position to provide knowledgeable comment on HRDC's past research program on IPM in tomatoes. Hence this matter was not pursued in any depth and specific comments were not recorded.

4.5 Growers' views on future directions for HRDC-funded research on IPM in tomatoes

4.5.1 Processing sector

Comments were sought from the growers who attended each of the five grower meetings that were held at various district centres in January 1999 on the future direction of the HRDC-funded IPM research program. Comment was solicited during an open-ended, largely unstructured discussion with the groups of growers.

The collated views of the growers on the future direction of HRDC's IPM research program for the processing tomato industry are summarised below. These views should be regarded as indicative only as they are not the result of a rigorous research needs analysis.

- Conduct more research on bio-control for Heliothis, including use of viral pathogens such as nuclear polyhedrosis virus.
- Develop control measures for Powdery Mildew that are compatible with Trichogramma.
- Develop an alternative to sulfur for control of Powdery Mildew.
- Develop protocols for the prediction of a fungal outbreak, similar to what can be done with insects (based on egg counts etc).
- Conduct more research on existing and new chemicals for control of blackberry nightshade.
- Future research on weed control needs to take better account of different soil types.
- Evaluate efficacy of injecting Metham sodium into the soil through trickle tape.

- Monitor the impacts of growing drip-irrigated crops, with the aid of Metham sodium, on the same block for 3 or 4 years in succession.
- Identify alternative crops that are compatible with tomatoes and which could be grown as a rotation with tomatoes in the fields set up for drip irrigation.
- Any future field research on tomatoes should be conducted on a grower's property to ensure commercial conditions apply.

4.5.2 Fresh sector

Comments on the future direction of the HRDC -funded IPM research program were also sought from the growers who attended each of the three grower meetings. The approach used was similar to that outlined above for the processing sector.

The collated views of the fresh tomato growers on this topic are summarised below. These views should be regarded as indicative only; they are not the result of a comprehensive needs analysis.

- The R&D program needs to be better integrated with a clear focus on some long-term objectives.
- Adaption/adoption of research findings into commercial practice is an issue that needs continual attention.
- IPM in tomatoes is still in its very early days in terms of understanding and managing the complex biological system that is centred on a paddock of tomato plants. The science behind IPM needs to be moved to a new level in order to gain this understanding. Also, a drastic shift in the approach to the management of insect pests and plant diseases is required, away from 'hard chemicals' towards 'biological chemistry'. However, it is recognised that the latter approach may not be without its critics, especially from the vocal 'anti-genetic engineering of foods' lobby.
- A problem for IPM in tomatoes is the short growing period of the crop. Under these circumstances, stabilisation of the paddock ecology is an issue that needs to be addressed.
- IPM needs to be viewed as just one component of Integrated Crop Management (ICM), ie the fully integrated 'environmental' approach. If developments in the UK are a guide, the supermarket chains will drive things in this direction. They are emphasising ICM.
- Farmers need more direct involvement in the formulation and conduct of projects; this will ensure that projects are relevant and are conducted under commercial conditions and that the results of the projects are adopted into commercial practice.
- There is a role for future research in developing pest resistant varieties, finding more beneficials and implementing host crops for harbouring beneficials.
- All crops need to be monitored and a system developed for recording where pests are building up in a district and making this information public (to support those using IPM and to stop unnecessary pest build up). HRDC could assist in this area by establishing a comprehensive network of crop monitoring professionals.
- Growers themselves need to be able to identify the major pests and beneficials.
- Industry needs to define and implement a host-free period to reduce carry over of pests season to season.
- The growers need to have available and use a range of practices under a cooperative district-wide approach.

- Monitoring can revitalise IPM tools that are failing and put them back at the right time and the right place.
- Further training sessions are required on setting up, calibrating and using pesticide application systems.

4.6. Researchers' views on future directions for HRDC-funded research on IPM in tomatoes

4.6.1. Processing sector

Comments were sought from the key field production researchers on the future direction of the HRDC-funded IPM research program. Comment was solicited during an open-ended, largely unstructured discussion with the researchers on an individual basis. Researchers consulted were:

- Jane Moran, DNRE IHD Knoxfield;
- Sze Flett and Roger Ashburner, DNRE ISIA Tatura ; and
- Sandra McDougall, NSW Agriculture, Yanco.

The collated views of these researchers on the future direction of HRDC's IPM research program for the processing tomato industry are summarised below. These views should be regarded as indicative only; they are not the result of a rigorous research needs analysis.

- IPM needs to be looked at in a holistic sense. All people in the industry need to be trained to look at the whole ecological landscape, of which the crop is just a part. In other words, it is a matter of how people look at a crop. For example, we need to make sure that secondary pests do not inadvertently become a problem.
- If the latest 'industry emergency' (1998-99 season), ie bacterial canker, is considered, quarantine both at the national and property levels will become an issue.
- The decision-making framework for application of IPM in the field needs to be kept current.
- IPM is likely to be an area that will need continuing research.
- Ecology of the tomato patch is finely balanced.
- Preparation of extension material on IPM in modular format so that it can be easily adapted to various uses.
- Development of protocols for management of resistance to chemicals.
- Basic research on application protocols for biologicals.
- Powdery Mildew control.
- Convincing growers to use advice from the TOMCAST model for control of fruit rots and other diseases.
- Improving insect parasitism early in the season through timed releases and possibly in conjunction with use of specific chemicals.
- Nightshade is still a big problem. Better control of nightshade may contribute to better control of Powdery Mildew and other diseases. Nightshade is related botanically to tomatoes, so it may act as an alternative host for them.
- Training program for DIY scouts so that the industry is not so reliant on commercial consultants. Growers have not been encouraged to do training courses; rather, the focus has been on commercial scouts/resellers. While there is an ethical concern

about resellers providing a scouting/advisory service, they can nevertheless provide some cross-subsidisation to financially support the scouting service. Processors may have to add to IPM consultant's fees if an effective and professional service is to be maintained.

- GIS as a tool for management of pests and diseases at the district level.

4.6.2. Fresh sector

Comments were sought from the key field production researchers (QDPI and private) and QDPI extension officers on the future direction of the HRDC-funded IPM research program. Comment was solicited during an open-ended, largely unstructured discussion with the researchers on an individual basis. The people consulted were:

- Iain Kay, Geoff Barnes and John Maltby, QDPI, Bundaberg
- Des McGrath and Phil Anning, QDPI, Bowen
- Graham Stirling, Nematologist, Biological Crop Protection, Brisbane

The collated views of these researchers/extension officers on the future direction of HRDC's IPM research program for the fresh (Queensland) tomato sector is summarised below. These views should be regarded as indicative only; they are not the result of a rigorous research needs analysis.

- An expensive though undoubtedly effective option for dissemination of information generally (including on IPM) would be the appointment of an industry development officer for the Queensland tomato industry (ie the equivalent of Lauren Thompson in the processing industry). QDPI is not sufficiently resourced to provide a comprehensive and dedicated information and liaison service for the tomato industry.
- Heliothis should remain the focus of tomato IPM research. Changes in varieties mean that thresholds will have to be re-worked. Management of resistance to chemicals is also an on-going issue.
- Need to understand biology and ecology of pests and beneficials.
- Finding/breeding more beneficials.
- Identification of host crops for beneficials and integrating them into the production system.
- Breeding of tomato varieties resistant to key pests and diseases.
- Major need for on-going research on IPM strategies generally and their adjustment.
- In the case of soil-borne pests and diseases, it is largely a case of 'out-of-sight out-of-mind' for both farmers and IPM consultants. Farmers do not know what they are targeting when they treat their paddocks with a fumigant, yet they still use them. Yield increase in response to methyl bromide treatments has never been demonstrated (G Stirling, pers. comm.) Farmers also do not understand the role of plastic mulch in the control of pests, plant diseases and weeds. Consultants generally just ignore soil pests and diseases. Hence a basic education program for both growers and consultants on soil-borne pests and diseases and their management is required.
- Soil-borne diseases and nematology is a very complex field that requires years of continuous experience to gain the necessary experience. Indeed this area may be beyond the technical capability of the 'average IPM consultant'. Hence the HRDC needs to consider whether it has a strategic role in fostering and training people to enter and stay in this field. After the thresholds for soil nematodes are defined and a field protocol for nematodes developed, people with the necessary experience to do the diagnosis and make the recommendations on treatment will still be required

- Soil pests are a generic problem across all vegetables, not just tomatoes.
- Management of soil-borne pests and diseases requires a whole systems approach, eg crop rotation, time of planting, resistant varieties. In contrast to pests like Heliothis, soil-borne pests are paddock-specific and the history of the paddock is important. A decision-making framework for management of soil-borne pests and diseases needs to be developed.
- Resistance of plants to nematodes is an established phenomenon. The genes for this trait may be able to be inserted into the tomato plant.
- Pesticide withholding periods a problem when crops picked three times a week.

4.7 Consultants' views on future directions for HRDC-funded research on IPM in tomatoes

4.7.1 Processing sector

Comments were sought from all of the commercial scouts/consultants currently operating in the processing growing sector on the future direction of the HRDC-funded IPM research program. Comment was solicited during an open-ended, largely unstructured discussion with the scouts/consultants on an individual basis. Scouts/consultants consulted were:

- Brian Walker, Griffith area (scouting and consulting)
- Michael Hind, Boort area (scouting and consulting)
- David Webb, Jerilderie/Griffith areas (scouting and consulting)
- Anne Ginter, Rochester area (scouting only)
- Adrian Lees, Rochester area (consulting only)

The collated views of these scouts/consultants on the future direction of HRDC's IPM research program for the processing tomato industry are summarised below. These views should be regarded as indicative only; they are not the result of a rigorous research needs analysis.

- Need a focus on diseases, especially bacterial speck (*Pseudomonas syringae pv. tomato*).
- Application techniques are a major barrier to disease control. Aeroplanes and some ground rigs are unsatisfactory. Aeroplanes and overhead booms are suitable for insects but not for two spotted mite, russet mite or diseases.
- Research into more effective disease control chemicals, both for fungi and bacteria, especially powdery mildew and bacterial speck.
- Development of a predictive model for Powdery Mildew.
- Production of a field handbook on tomato diseases (similar to that used in Queensland?).
- Some thought that the current thresholds for Heliothis are satisfactory, but were not sure that this situation applied to other pests. Most thought all thresholds, including those for Heliothis, might need some fine-tuning down the track. However, one thought that thresholds for larvae should be reviewed now, as they needed to be more flexible to cover all field situations.
- Improved methods for control of insect pests and plant diseases, as cheap as possible and using softer chemicals, are required across the board. This may involve development of 'new generation' insecticides, eg biologicals.

- Development of commercial field tests for big bud virus in leafhoppers, spotted wilt virus in thrips.
- Development of a SMART software package as a decision-making tool to handle groups of chemicals (would need to be updated regularly).
- Education of growers and all of the industry on pesticides and their use. Need to cover the basics: what they are, what they do, residues, etc. Growers generally need a lot more education on pesticide usage.
- Soil sustainability is a big issue. Some growers rotate tomatoes with maize and winter cereals. Others lease land for a season and then move on like nomads. The Processing Tomato Research Council is looking to other industries to share the cost of research on this topic.
- Plant nutrition, as a factor in IPM strategies and a component of Integrated Crop Management (ICM), needs refinement.
- Production of high solids fruit with drip irrigation. At present, good drip irrigators are obtaining huge yields with low solids fruit. Removing the extra water from the fruit increases the cost of evaporation during processing. We need to learn much more about controlling the flow of irrigation water under this system. (**Note.** This is more of an ICM, rather than an IPM, issue.)

A general comment was that a thorough research needs analysis of the processing growing sector may be warranted.

4.7.2 Fresh sector

Comments were sought from all of the commercial IPM consultants currently operating in the fresh growing sector in Queensland on the future direction of the HRDC-funded IPM research program, using an approach similar to that outlined above for the processing sector. The following consultants provided comments:

- John and Penny Hall and Gary Artlett, Bundaberg
- Dale and Sally Abbott and Chris Monsour, Bowen
- Julian Winch, Lockyer/Stanthorpe

The collated views of the scouts/consultants on the future direction of HRDC's IPM research program for the fresh Queensland sector are summarised below:

- Develop a system for keeping all stakeholders (especially consultants, who have a key role) informed on a regular basis of the implementation, progress and outcomes of all HRDC-funded projects on IPM (and probably on other subjects as well). A newsletter is one option.
- Development of control measures for Silver Leaf White Fly (serious pest in the Bundaberg region).
- Identification and registration of 'soft 'chemicals that will allow beneficials to survive.
- Foster IPM as a long-term solution to insect pest and plant disease problems.
- Identification of new control options for two-spotted and russet mites, eg any form of biological control, alternative chemical treatments. (These mites are a very significant pest in the Lockyer. There are no known biological control agents for them and only one of the registered chemicals is effective.)

- Development of control measures for bacterial leaf diseases of tomatoes (a major problem in the Lockyer).
- Recognition of regional research as a legitimate approach, as problems vary from region to region.
- Some consultants not interested in carrying out further HRDC projects; application, administration, reporting, etc considered too complicated and time consuming.
- Training/updating programs need to be run for IPM consultants, but targeted at potential/ current consultants who have the right professional background (degree with a plant protection major or similar essential). The reality is that growers need a consultant on the ground to write the IPM protocol for each grower and to then supervise its implementation.

4.8 Processors' views on future directions for HRDC-funded research on IPM in tomatoes

Most of the five major processors felt they were not in a position to provide knowledgeable comment on the future directions of HRDC's future research programs. However, some comments were forthcoming, as follows:

- More trained IPM scouts/consultants are needed in the industry. However, the financial situation of scouts needs attention. For this reason, it may be necessary to foster a linkage between scouts and re-sellers, even though there can be perceptions of a conflict of interest. It may also be possible to send scouts to California to work in the off-season - for experience and money.
- Development of new varieties for the processing sector is dominated by H J Heinz, where the focus is mainly on yield.

4.9 Evaluation of HRDC's research program on IPM in tomatoes by the project team and recommendations on its future direction

Each of HRDC's nominated IPM projects was evaluated on a systematic basis by a panel comprised of three members of the project team: Associate Professor John Harden, School of Land and Food, University of Queensland Gatton (convenor of the evaluation panel), Dr Peter Taylor, TS Agricultural Consultants, Melbourne (and part-time Lecturer in Plant Pathology at the University of Melbourne) and Mr Dan Papacek, Director, Integrated Pest Management Pty Ltd, Mundubbera.

A checklist for each project, covering reporting, relevance of the work to IPM, outcomes and adoption, was completed for each project. A set of completed checklists is included in the Report at Attachment 4.

A simple 'overall success' rating was assigned to each project by Professor Harden. The rating was based on the information provided in the checklists at Attachment 4 and the comments made by growers and consultants. The ratings plus comments are listed in Table 4.1 for processing tomato projects and Table for 4.2 for fresh tomato projects.

From the information summarised in Tables 4.1 and 4.2 and the detail provided elsewhere in this Report, the following observations can be made about HRDC's R&D program on IPM in tomatoes to date:

- The most successful projects have been those that have had a direct involvement or strong links with the consultants who are working with growers in the implementation of IPM programs.
- Harmonising the use of pesticides and biological control is an essential part of IPM and few projects have addressed this area.
- The project reports generally don't provide clear statements of the outcomes and how they relate to the implementation of IPM. Those rated '5' in Tables 4.1 and 4.2 did provide this information.
- Many of the projects have a specific pest focus and don't relate to an overall IPM outcome or objective.
- There appears to be little or no coordination between projects in relation to IPM.

In addition, there was little evidence of any formal integration of projects across the processing and Queensland fresh sectors, or of proactive interaction between the key stakeholders (eg researchers and consultants) from the two sectors.

With regard to HRDC's future R&D program on IPM in tomatoes, it is recommended that:

a. Research projects be coordinated within an IPM context and have a clear IPM focus and outcomes.
b. Proposed research projects be carefully assessed to ensure they have a real IPM focus, as researchers are inclined to 'tag' projects with the IPM label to improve chances of funding.
c. All reports of projects provide clear statements as to the outcomes in producer and IPM implementation terms.
d. Consultants providing grower services in relation to pest management be provided with both the milestone reports for projects as they are achieved and the industry and technical summaries at the conclusion of projects.
e. Projects be reviewed/inspected each six months by a small team that includes a leading grower, the relevant consultant and an independent person interested in the implementation of IPM strategies.
f. Grower organisations in particular districts be introduced to an operational definition of IPM and be invited to participate in the development of a points system to assess compliance with IPM.
g. HRDC further the adoption of IPM by providing funding to establish a national IPM certification scheme. Growers who qualify would be able to use an IPM logo. This has considerable consumer ramifications and would provide real choice in the market place.
h. IPM be promoted as the only sustainable option in both the fresh fruit and processing tomato industries. The present approach adopted by many growers, which is dependent upon a continual stream of new chemical pesticides becoming available, does nothing to reduce the problem of resistance development in serious pests such as Heliothis or new pests such as white fly.

Table 4.1. Overall rating of the success of HRDC-funded IPM projects in the processing tomato sector.

Note. The overall success of the projects has been rated on a scale of 1-5 where 1 is the poorest rating. It takes into account project reporting, relevance of the work to IPM, outcomes and adoption. The ratings were based on a technical evaluation of the project by the project team, with comments from growers and consultants also taken into account.

HRDC No.	Project Title	Organisation	Success Rating	Projects Comments
TM041	Studies of Phytophthora root rot of processing tomatoes and the evaluation of control measures	IHD Knoxfield	4	A useful project that provides particular information on the pest including monitoring techniques.
TM043	Chemical residue analysis of processing tomatoes	ISA Kyabram	3	A marginal project in relation to IPM techniques and strategies.
TM201	Development of IPM strategies for processing tomatoes	IHD Knoxfield	5	A very relevant and important project for the development of IPM in processing tomatoes.
TM208	Evaluation of the role of Thimet in IPM for processing tomatoes	Crop Sciences, Univ of Sydney	1	No useful reports or information available.
HG319	Evaluation of petroleum spray oils (multi crop project including processing tomatoes; originally put up as TM300)	NSW Agriculture, Rydalmere	2	Results indicated spray coverage can be improved using air assisted sprayers however use of oils not conclusive.
TM301	Study tour to USA: non-chemical weed control systems for processing tomatoes	NSW Agriculture, Trangie	1	No information of particular relevance to IPM in tomatoes.
TM95001 (TM501)	Advanced IPM in processing tomatoes	IHD Knoxfield	5	An important project developing information and techniques important for the implementation of IPM in production situations.
TM96002 (TM602)	Selection of Trichogramma for control of Heliothis in tomatoes (TM602 cont'd)	La Trobe University	4	A relevant project provided Trichogramma becomes commercially available as a result of the project work.
TM97001	Improved Control of Powdery Mildew on Processing Tomatoes	IHD Knoxfield	1	A useful project area, unfortunately no compounds tested provided control of the pathogen.
TM97004	IPM in tomatoes – from research to practice	IHD Knoxfield	4	An important project focused on developing useful information and the training of personnel to implement IPM.
TM97007	National strategy for the management of western flower thrips and spotted wilt virus	Agriculture WA	Too early to assess	A relevant project area as this pest has a wide host range
TM 98009	IPM Tomatoes 2001	IHD Knoxfield	Too early to assess	A logical and appropriate project to build on TM95001 and TM201.

Other projects of relevance to IPM

TM137	Soil fumigation with Metham sodium to control blackberry nightshade & soil pathogens	ISIA Tatura	4	A focused project providing useful information on the management of soil-borne pests.
TM405	Evaluation of DuPont Titus for post emergent control of nightshade and other weeds in processing tomatoes	DuPont (Aust) Pty Ltd, North Sydney	4	The development and registration of Titus for management of nightshade was important to support pest management activities in processing tomato production.

Table 4.2. Overall rating of the success of HRDC-funded IPM projects in the fresh (Queensland) tomato sector.

Note. The overall success of the projects has been rated on a scale of 1-5 where 1 is the poorest rating. It takes into account project reporting, relevance of the work to IPM, outcomes and adoption. The ratings were based on a technical evaluation of the project by the project team, with comments from growers and consultants also taken into account.

HRDC No.	Project Title	Organisation	Success Rating	Projects Comments
VG201	Introduction of IPM programs for fruit & vegetable crops in Bowen	Bowen Crop Monitoring Services	5	A highly relevant project providing a real impetus to IPM in the dry tropics.
VG206	IPM – phase II	Crop Tech Research	5	A continuation of the foundation project which established the basis for IPM in fresh market tomatoes in the sub-tropics.
VG412	Strategic use of pesticides as part of IPM programs for vegetables	UQ Gatton	5	A relevant project building on both VG201 and VG206 resulting in further development of IPM strategies, particularly targeted use of pesticides.
VG502	A production-break strategy for tomato leafminer in Queensland	CRC for Tropical Pest Management	2	A useful research area, however project doesn't provide a particular outcome
VG95006 (506)	Monitoring, management and reduction of tomato leafminer in Bowen (VG506 contd)	Bowen Crop Monitoring Services	5	A focused project providing very useful IPM information of use in production strategies for the dry tropics.
VG95009 (509)	Pest and beneficial ecology in tomatoes (VG 509 cont'd)	QDPI Bundaberg	3	A basic project providing information on particular pests and beneficials, but without a particular set of applied outcomes.
VG97040	Trichogramma wasps in IPM programs for vegetable crops	BioResources, Toowoomba	2	A potentially useful area of research, but the focus was not tomato IPM, however Trichogramma may be a useful beneficial.
VG98006	IPM strategy to reduce Tomato Spotted Wilt Virus (TSWV) in the dry tropics	Bowen Crop Monitoring Services	N/A	Too early in the project for any particular comment.

i. HRDC fund a project to gather data on current grower practices and on levels of pest resistance to pesticides. Consultants could be the major source of information, with validation of the information by growers.

j. Information be gathered on the nutrient and moisture status (water) of crop plants, as they affect the activities and importance of pests, and combined with pest management data to support inclusion of IPM into integrated crop management (ICM) programs.

k. A program of accrediting and supporting professional IPM consultants and their activities, as distinct from crop scouts who simply gather data, be established. The implementation of IPM has been impeded by a lack of real professional services. Producers need to be encouraged to pay a professional fee for professional IPM services. (Also see Section 5.2.)

l. More attention be given to solving IPM-limiting problems such as the adverse effects of sulfur (used as a Powdery Mildew fungicide) on beneficials such as Trichogramma. There should also be more research on the biology of the Powdery Mildew fungus as a basis for developing more cultural control measures.

It is also recommended that links between the research programs conducted within the fresh and processing sectors be strengthened. Measures in this regard could include:

- an on-going series of joint workshops, involving researchers, consultants and growers from the two sectors, on topics of common interest;
- reciprocal attendance by researchers and consultants at sector conferences; and
- conduct of some HRDC research projects on a joint basis where there is a common interest.

5 THE ADOPTION PROCESS FOR IPM IN THE TOMATO INDUSTRIES

5.1 Factors influencing adoption of IPM by growers

To gain an insight into why some growers adopt IPM and some don't, or only partially adopt it (to varying degrees), growers who attended the grower meetings were directly asked to respond to the following questions:

- *'Why growers take up IPM?'* and
- *'Why growers don't take up IPM?'*.

Researchers, consultants and processors were asked similar questions during their interviews.

Responses to these questions are summarised below on a sector basis.

5.1.1 Processing sector

Growers. The main themes of the responses by growers to the question *'Why growers take up IPM?'* are summarised below. It was evident, however, that an overriding theme in the minds of many growers was that IPM is synonymous with employment of a scout; hence the responses below need to be interpreted accordingly.

Note that the responses listed below should be interpreted essentially as quotes; no valued judgements are made at this point as to whether the assertions made by the growers are valid. However, regardless of whether they are valid or not, they still represent opinions of growers about IPM and as such form part of the intellectual environment in which IPM has to survive and prosper.

- Crop areas are getting bigger, so can't do the scouting yourself.
- A push by a consultant to use his/her IPM services.
- Consultants are able to focus on pests and diseases and are more skilled in detecting pests and diseases than are growers.
- There is a need for a greater awareness of what is happening with pests and diseases in your crop. IPM provides this awareness.
- Pressure for reduced use of chemicals can be expected in the future, so the industry needs to be prepared. Chemicals need to be used more effectively.
- IPM is one step towards a goal of an improved life style.
- Better quality fruit is produced with IPM.
- IPM reduces the risk of insects building up resistance to chemicals. Monitoring allows you to spray before large insect populations build up, reducing the probability of selecting a resistant strain.
- Expertise is available, so why not use it?
- IPM is used in the expectation that it will give good results. It is like an insurance policy; it provides security and reduces the risk of crop failure.

- There is a chance that IPM may save 1 or 2 sprays per year. However, the real issue is not the chemicals saved, but rather that the chemicals are used more effectively.
- The real financial benefit from IPM is not in the chemicals saved, but in the value of the crop over the weighbridge. Savings in chemicals will fluctuate from year to year, but even in a 'bad' year (like 1998-99, when the insect pressure was very heavy), a grower stated he is still in front financially, all things considered. For this reason, the grower would pursue IPM even if it resulted in only a marginal benefit (ie cost of scouting *vs.* chemicals saved).
- Tomatoes are a high value, high risk crop and the margin between profit and loss is narrow. For this reason the industry has generally been quick to take on new technologies to survive. IPM is one of these new technologies.
- It is good to be seen to be doing the right thing by the environmental lobby. Some pride was expressed in the fact that a 'European expert' has rated Australia as one of the 'top five IPM countries in the world'.
- IPM is saving me, ie the grower, money.
- Occupational safety must be a consideration. Any reduction in spraying can only reduce the risk to the operator of exposure to chemicals.

A more cynical response was that adoption of IPM was very straightforward: all you have to do is employ someone to walk through the crop looking for pests and diseases (rather than do the walking yourself) and you can then say you have adopted IPM.

Similarly, the main themes of the responses by growers to the question *'Why growers don't take up IPM?'* are summarised below:

- Growers are comfortable with what they are doing now and are reluctant to move to new technologies.
- The loss of an IPM consultant from a district, as happened in the Jerilderie area prior to the 1998-99 season, can cause temporary abandonment of IPM until other arrangements can be made, eg training in DIY scouting.
- There is concern that if just one mistake is made in the IPM program, there is risk of serious product loss or damage.
- The perceived benefits of IPM vary with the season and the district. In a year of heavy pest pressure, a 'bad' year, IPM can cost me, the grower, money. Under IPM, chemical costs this year (a 'bad' year) were twice what they were last year (a 'good' year).
- Doubts whether a consultant is really more experienced at walking through a paddock than the grower.
- Risk of a scout giving bad advice.
- Risk of a scout spreading diseases. This is not regarded as a major issue, but there is still a need to be careful in some cases, eg powdery mildew, bacterial canker.
- A grower needs time to build trust in a consultant (especially if connected to a chemical re-seller; some growers make a point of <u>not</u> buying chemicals from such a person, due to perceived conflict of interest.)

- IPM is too expensive for a small grower.
- Processors should be paying for monitoring.
- IPM is only another cost without any benefit.

Researchers. The main themes of the responses by researchers to the question *'Why growers take up IPM?'* are summarised below:

- Confidence in having an expert to do the scouting (applies to both commercial and DIY scouting).
- Economy of sprays.
- A feeling of doing the right thing by the environment.
- Concern about resistance build-up due to chemical usage.
- Experts (ie trained scouts) are needed to identify and track pests and diseases accurately.
- Simply following the trend set by other growers (ie peer pressure). Similarly, a status symbol.
- Reduced use of chemicals, but as an initial attraction only. Any savings are offset by the cost of a scout and IPM may in fact cost more in the long run.
- Personalities of the main stakeholders (could be a negative factor in some cases).
- Respect for Lauren Thompson in her position as Industry Development Officer with the APTRC.
- Continuity of service provided by commercial scouts on a year to year basis. (It was suggested that private scouts generally tend to provide a relatively stable service from year to year {though there have been exceptions}, whereas DNRE staff have historically changed roles/locations at fairly regular intervals.)
- Pressure from export markets. This can come at three levels: attention to incidence of chemical residues, a stated preference for product grown under an IPM regime, or a stated preference for product produced under 'total' environmental management.

The main themes of the responses by researchers to the question *'Why growers don't take up IPM?'* are summarised below:

- Perceptions of increased costs under IPM.
- A fear that the quality of fruit will be lowered.
- Reluctance of having other persons coming onto the property resulting in possible loss of 'trade secrets' and spreading diseases (but generally an isolated issue).
- Avoiding any risk that pest damage might increase with IPM.
- A poor understanding by growers of IPM.
- Growers not clearly convinced of the benefits of IPM.
- Over-insuring by spraying more than necessary/ a fear of not spraying (*cf.* taking aspirin in case you might get a headache).

- Lack of confidence in the scout.

A 'territorial' issue that was not helpful to the development of IPM as an integrated, multi-disciplinary practice in its early days was that IPM was perceived by entomologists to be an 'insect thing' and therefore the sole province of entomologists. As a consequence, some entomologists strongly resisted the 'intrusion' of plant pathologists into the IPM arena.

Consultants. The main themes of the responses by consultants to the question *'Why growers take up IPM?'* are summarised below:

- Response to consumer pressure for fewer chemicals on fruit and in the environment.
- Anticipation of a cost saving on chemicals.
- Availability of a dedicated consultant
- Seeing it proven to be successful elsewhere.
- Farmers haven't got time to do it.
- A consultant gives a farmer an additional pair of eyes.
- Filling the vacuum left by withdrawal of DDT and other 'heavy' chemicals.
- Grower - consultant contact and interaction.
- Greater security of getting a crop (more important in the final analysis than any savings on sprays).

The main themes of the responses by consultants to the question *'Why growers don't take up IPM?'* are summarised below:

- Perceived risk of fruit quality problems and losses.
- Lack of confidence in scouts.
- Resistance to change.
- Lack of access to a consultant.
- Unwilling to meet the cost of a consultant.
- Concern about transport of insects and diseases between farms.
- Some growers think they know it all.

Processors. The main themes of the responses by processors to the question *'Why growers take up IPM?'* are summarised below:

- Cost of chemicals (though savings on chemicals vary with the season).
- To reduce pest damage (and hence avoid price penalties).
- Minimise environmental damage.
- Peer pressure - from other growers.
- As a backup system. Some growers may not take 100% notice of the consultant's recommendations, but most do.

The main themes of the responses by processors to the question *'Why growers don't take up IPM?'* are summarised below:

- The fact that for most people a consultant is a pre-requisite to IPM.
- Availability of consultants.
- Lack of awareness/understanding/education of the system and its benefits (includes literacy problems).
- The generation factor: younger growers are generally more receptive to IPM than the older ones.
- A perception that savings in chemicals may not be sufficient to offset the cost of a scout.
- Cost of IPM services can be a critical issue for some growers. The price/cost margins for tomatoes are small and some growers simply cannot afford to hire a scout in the present economic climate.
- Claims by growers (often overstated) that IPM will result in greater grub damage if growers strike a few days of wet weather, which can delay spray applications.
- A perception that scouts might spread disease from one block to another.

5.1.2 Fresh (Queensland) sector

Growers. Limited information was obtained from Queensland growers on this issue. However, some responses to the question *'Why growers take up IPM?'* were:

- IPM is used because it works - when you use a consultant to get the information.
- Crops need to be monitored.

One response by a growers' meeting to the question *'Why growers don't (fully) take up IPM?'* was:

- Principles of IPM are difficult to implement fully in fresh tomato production because of the pressure of Heliothis.

Consultants. The main themes of the responses by consultants to the question *'Why growers take up IPM?'* are summarised below:

- For crop security. Growers look for help when their existing system starts to fail.
- Growers lack the ability to identify insect pests and plant diseases.
- A grower's lack of time to make decisions about a crop's condition.
- Awareness of the threat to efficacy of chemicals for control of pests in the long term.
- Growers like the idea of optimal chemical usage (ie minimal cost at little risk to fruit quality).
- A grower can usually save some sprays per season by using monitoring and spray action thresholds.

The main themes of the responses by consultants to the question *'Why growers don't take up IPM?'* are summarised below:

- A lack of understanding of the IPM concept, especially the long-term implications for effective pest management.
- Grower has limited contact with other growers or no technical support base, because they are either small growers, geographically isolated or in a low priority area for Government extension services.
- Many growers find it difficult to switch from conventional management practices to a new system. Their current procedures have been fine-tuned over many years and they cannot see any benefit in changing to a new system.
- IPM has to compete with cheap chemicals (often sold on a door to door basis) and the 'bargain chemical + quick fix' mentality.
- To save on costs.
- Grower has been let down in the past by an 'IPM' consultant.
- A range of social factors including local personalities, politics, lack of interest, stubbornness and resistance to change.

5.2 Role and situation of private IPM consultants

Consultants have clearly played a pivotal role in the development, promotion and implementation of IPM as an effective management tool in both the processing and the Queensland fresh tomato sectors. However, to develop a commercial scouting and consultancy business focussed on the application of IPM in tomatoes is quite a challenge.

One of the first points to consider is that the tomato IPM business is very specialised and the market is relatively small. Effectively, there are four scouting/consultancy businesses operating in each of the sectors under consideration at the present time. It has taken/will take several years for these businesses to become viable. Even then, they can only survive because of diversification of their IPM work into other crops to give them year-round work, or by linking the IPM with other business operations such as rural produce/chemical reselling, laboratory services or more broadly-based crop management services.

While there are opportunities for some of the consultancies to diversify into other crops, opportunities for this in some districts seem to be limited. If working in tomatoes only, what does a scout do for the other six months of year?

As pointed out elsewhere in this report, it can take at least two seasons for a grower to gain confidence in the scout. During this period, the scouts may be forced to discount their rates in order to 'get a foot in the door'. Expenses can be high, with a lot of travelling involved. Scouting can also involve long hours in the field, often under trying physical conditions, eg hot days and wet, muddy soils.

Most of the consultants indicated that they could not make a living out of tomatoes only. Benchmark consultancy rates in the processing industry are $60 per hectare for one visit per week and $100 per hectare for two visits per week. Some consultants indicated that they were making only a modest income from IPM even with diversification into other crops.

One established consultant in the processing sector indicated that he was grossing about $40,000 per season from tomatoes, with expenses of about $10,000 for the season. Another consultant in the processing sector (a chemical reseller who employs a scout) claimed that 'he had lost about $250,000 over the last four years on his IPM consultancy venture, taking into account the training period for the IPM scout and the loss of chemical sales to tomato growers who adopt IPM'. Regardless of any consideration of the accuracy of the stated loss, his statement does serve to highlight some of the commercial realities of the IPM business. This consultant also faced a further dilemma: he had too much work for one scout, but not enough for two, so what does he do?

The grower-consultant relationship seems to operate on a basis of trust, with the final decisions on spraying etc left to the grower. Formal contracts are not the industry norm.

Consultants indicated that they do not want to bear all the risks associated with implementation of 'IPM solutions' that are not yet fully proven under commercial conditions, and fail to meet growers' expectations. This risk needs to be shared collectively by all of the stakeholders in the industry, including growers, researchers and consultants in a partnership arrangement.

Under present arrangements, there is a strong tendency for consultants to play it safe and to stick with strategies that rely heavily on chemicals. This risk-averse behaviour by consultants acts as a barrier to the adoption of more innovative IPM practices.

The issue of legal liability for the consultant is ever present. Consultants have already been sued by growers for giving 'bad advice', and undoubtedly there will be further court action in this area in the future. Hence there is a need for consultants to carry professional indemnity insurance, another expense.

The question of how a person becomes an IPM consultant is very pertinent. At this stage, there are no formal requirements to become an IPM consultant. In the processing industry, there is an informal mentoring system in place. Under this system, a person with appropriate base qualifications, eg a University Degree in Agricultural Science, undertakes some short training courses and works under the supervision of an experienced consultant for two years. The issue of how the trainee is supported financially during this period is a real one, and one that needs to be addressed at an industry level.

In the fresh sector, the 'training' system seems to be more of a matter of establishing your credentials in the field. In all cases, the market will be the final determinant, ie if a consultant performs to growers' expectations, then they will stay in business.

A system for formal accreditation of IPM scouts and consultants is currently under development by the Institute for Horticultural Development, DNRE Knoxfield. Consultation with the relevant stakeholders in the Queensland industry has been encouraged to ensure that the proposed system is acceptable to all parties and has national application.

Consultants generally saw consulting to the horticultural industry as a good career (interesting, challenging, whole farm approach, opportunity to influence outcomes). However, they would like to see more recognition of their efforts from the growers. In this regard, it was noted that some of the processing growers displayed a rather mean-spirited attitude towards consultants at the grower meetings. Some of the growers were even amazed to discover that their consultant had a university degree.

Most tomato growing districts are serviced by just one IPM consultant. A consequence of this is that the consultant's clients, and in fact the whole IPM effort, are very vulnerable if the consultant suddenly ceases to offer a service. One outcome of this is that an 'IPM grower' can quickly become a 'non-IPM grower', a reality experienced by some growers in a processing district last year.

The scenario of 'what happens to a grower's IPM program if their consultant withdrew their services tomorrow' was put to the processing growers who attended their meetings. Most growers had no contingency plans for such an eventuality; a few growers indicated that they had sent their wives to an IPM training course as an emergency backup measure.

Consultants are in the unique position of being in direct contact with their grower clients once or twice per week during the tomato season. They thus have the opportunity to play a very useful role in disseminating information and extending new technologies to growers. Needless to say the consultants themselves need to be well informed on all matters pertinent to IPM. Unfortunately, discussions with one Queensland consultant highlighted the fact that support mechanisms for consultants on an industry-wide basis were, at the best, haphazard and, at the worst, poor.

The processing sector has a distinct advantage relative to the Queensland industry in the area of organised information dissemination: it has a dedicated industry development officer supported by the APTRC. While the Queensland industry has the QFVG and Local Producer Associations (which vary in their staffing levels), the tomato growers have to compete with other commodities for attention. In any event, the primary role of the Queensland grower organisations is not technical support.

Hence the HRDC and/or the tomato industries need to give consideration to the development of a system for providing technical support to all tomato IPM consultants on a regular, on-going and national basis. A regular 'tomato IPM' newsletter sponsored by the HRDC could be a good starting point.

5.3 Overcoming the barriers to adoption of IPM

Growers have to develop an attitude that they need IPM before they will use it. Development of this attitude is driven by a range of factors, eg a desire for crop security, concerns about resistance of insects to chemicals, identification with the 'clean green' marketing image and a concern about the environment. However, for some of the more reluctant growers, a market driven approach may be the only way, ie pressure from supermarkets and other major buyers for production of tomatoes

under a minimum IPM protocol. (Supermarkets in the UK have already embraced quality systems that extend back to farm production systems.)

Cheap chemicals and aggressive marketing of chemical are presently one of the barriers to adoption of IPM.

One of the tomato industry's pioneering IPM consultants is of the opinion that IPM is 'a very applied and doing, experiencing, growing sort of technology.' To gain and maintain acceptance of IPM by growers, the consultant advocates following approach:

1. Conduct open learning demonstrations and farm walks.
2. Develop protocols for introducing IPM to the individual grower. There are now so few serious tomato growers that introduction of IPM to growers on a one-to-one basis is possible. IPM skills can be generic but the thresholds and management have to be region specific.
3. Develop an active network of crop monitoring professionals to facilitate open exchange of ideas and experiences.
4. Use 'case histories' as a powerful tool to demonstrate effectiveness of the system. The success of IPM as an industry program is dependent on grower confidence in the IPM system, as it involves an amount of faith, risk management and collaboration on the part of both the growers and the crop consultants.
5. Coopt the young growers and consultants and develop them as IPM proteges.

In relation to point (4) above, it is worth noting that tomatoes are a high-cost, high-risk crop. Hence, before growers will change from their established field production practices in which they have confidence, they must be satisfied that any variation in their practices will not increase this risk, and preferably will reduce the risk. Thus for IPM, or a component of it, to be accepted as a practice, it must be demonstrated up-front that it is a low risk option. Doing the research behind IPM is just the first step; the real challenge is translating that research into field practice that growers will accept, confident in the fact that it will result in a positive outcome for them. Clearly some growers and in fact some consultants are yet to be convinced that IPM is a low risk option for tomatoes.

In relation to point (5) above, there is concern however that potential recruits for IPM consultancy work are no longer being trained by the academic institutions in adequate numbers to meet the growing demand.

However, it is encouraging that at least in some districts there are significant numbers of younger growers entering/second generation family members staying in the industry. Younger people are generally regarded as more receptive to IPM than are their older peers. They also see IPM as underpinning their formal quality assurance programs where these have been adopted.

Apart from pest crises (which proved very effective in stimulating the development and adoption of IPM practices in the Queensland industry earlier this decade), the entry of IPM consultants into the industry has been the best way of getting growers to switch to IPM. However, for people to enter and stay in the industry as IPM consultants, they need to be trained, adequately remunerated, recognised as

professionals, given adequate technical support and provided with an operating environment that is legally less risky for them than is presently the case (see Section 5.2 above).

Adoption of IPM on an industry-wide basis also takes time. For example, it has taken 20 years in the Central Queensland citrus industry to achieve 95% adoption of IPM. Furthermore, some citrus growers still have occasional difficulties adhering to the IPM protocols.

Both of the sectors of the tomato industry under study have set goals of achieving full adoption of IPM in the next year or so (refer Section 1.1). However, it is recommended that both sectors review their strategic objectives for adoption of IPM. This review needs to take into account both the current levels and the recent rates of IPM adoption in the tomato industries as measured in this study. It also needs to take into account the degree to which IPM is used, ie 'full' or 'partial'.

6. CONCLUSIONS

This study has centred on adoption of IPM in the fresh and processing sectors of the Australian tomato industry. Aspects of IPM adoption considered in detail were:

- the extent of IPM adoption among tomato growers;
- the barriers to further adoption of IPM;
- the economic returns over the past 10 years due to investment in tomato IPM research, development and extension; and
- the effectiveness of HRDC's research projects on IPM.

The study found that growers in both sectors of the tomato industry are highly aware of the IPM concept and many believe they have adopted IPM. It was apparent, however, that few growers have pushed IPM to the limits of its potential. Indeed some growers are unconvinced about the technology's applicability to tomatoes while others could be best described as 'partial' adopters. The barriers to full adoption of IPM lie to some extent in the complexity of the concept.

The definition of IPM is an issue in itself. It became obvious during the study that many growers do not have a clear understanding of the totality of IPM. To some growers, IPM is no more than scouting their crop for pests. One reason for the 'flexibility' in interpreting 'use' versus 'non-use' is that IPM is essentially a set of principles that must be translated into a set of practices and procedures on the farm. The list of possible IPM practices and procedures is long. In this study, for example, tomato growers, consultants and researchers were presented with a list of 33 separate and identifiable field practices that 'IPM experts' regard as being integral to the use of IPM.

Even to categorise a particular grower as an "IPM user' or a 'non-user' can be misleading. For example, a case was encountered in this study where the grower classed himself as a 'non-IPM' user (because he did not employ a professional scout) but careful examination of his management practices convinced us that the grower was in fact using IPM principles to a substantial degree. Further, there are growers who resent the IPM tag (presumably because they see the IPM extension effort as a form of 'external manipulation').

In the final analysis, the term 'IPM' should not be the primary focus of attention. Rather the emphasis should be on achieving the adoption of crop management practices that are consistent with sustainable and profitable crop production. To this extent IPM is a holistic, dynamic and evolving technology. Thus the practice of IPM must be continually adapted to keep the technology useful and relevant. In this regard, consideration should be given to the application of the HACCP (Hazard Analysis and Critical Control Points) principles to tomato production. This would help to define the pest management problems that IPM can be used to mitigate. The introduction of HACCP would also help to define what is beyond the scope of IPM and thereby lend perspective to the rather open-ended expectations presently surrounding IPM.

Briefly stated, the key findings of this study were:

1) There has been a high level of adoption of IPM practices among tomato growers, although there exists much variation in the extent to which the potential of IPM has been and is being utilised.

2) Formidable barriers to universal and full adoption of IPM remain. These barriers are tied, for example, to the complexity of the IPM concept, the perseverance required in its proper application, the efficacy of the IPM 'tools' in the case of tomatoes and the need to convince some growers (and consultants) that IPM is a low-risk strategy in tomatoes.
3) The returns to IPM R&D have differed markedly between the fresh and processing sectors. Relative to the fresh sector, the economic returns to IPM R&D in the processing sector, over the past decade, appear to have been poor. There are several reasons for this including the higher value of the fresh sector and greater scope for IPM to save yield in the fresh sector. However this does not mean there should be any slackening in efforts to develop IPM technologies in both sectors and bring them into practice.

Key issues for the HRDC include:

- where to focus the R&D necessary to underpin the successful application of IPM in the future;
- what data collection and management systems need to be put in place to support the future evaluation of IPM; and
- how to progress adoption of IPM by tomato growers towards the industry's goal of 100% adoption within the next few years.

The results of this study, supported by a series of recommendations and observations throughout the report, will provide the HRDC with a focus on the issues that we believe need to be addressed.

Attachment 1

Administrative details for HRDC Project VG98135:
'Evaluating Effects of R&D on Integrated Pest Management in the Processing and Fresh Tomato Industries"

1. Terms of reference and expected outcomes

The specific terms of reference for the study, as stated in the project brief, were:

1. Investigate the impact of outcomes from R&D projects, sponsored by HRDC-industry, on pest and disease practices in fresh (Queensland only) and processing tomatoes.
2. Objectively measure the rate of adoption of IPM practices by growers and key factors leading to adoption since the beginning of the HRDC-industry R&D programs in tomatoes.
3. Evaluate the public benefit, in terms of social, environmental and financial factors, of R&D outcomes.
4. Evaluate the benefit-cost of investment on IPM R&D by HRDC-industry and agencies.
5. Identify the financial, social and other barriers to adoption and opportunities to increase adoption of IPM.

Expected outputs from the study, as stated in the project brief, were:

1. Description of changed practices and objective measures of adoption of IPM resulting from R&D in the tomato industries.
2. Public benefit and benefit-cost evaluation of R&D IPM projects sponsored by HRDC-industry in the tomato industries.
3. Examples of success from R&D on IPM in the tomato industries.
4. Definition of the barriers-opportunities to adoption of IPM in the tomato industries.
5. Recommendations on the future investment for IPM R&D in the fresh and processing tomato industries.
6. Full written report.
7. Oral presentations to the Industry Reference Group and HRDC Board.

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Attachment 2

PROFORMA FOR CONFIDENTIAL GROWER QUESTIONNAIRE

INTEGRATED PEST MANAGEMENT IN TOMATOES

The purpose of this questionnaire is to determine the extent to which IPM has been adopted, the net benefits to the industry from IPM adoption and the barriers that are preventing adoption of IPM throughout the entire tomato growing industry. The findings will assist the Horticultural Research & Development Corporation to better direct future investments in IPM.

As the study is only interested in "whole of industry" results, individual responses to this questionnaire will be kept strictly confidential. Once you have completed the questionnaire, mail it promptly to Alliance Resource Economics using the reply paid envelope provided. Your assistance in this matter will benefit the industry and is greatly appreciated.

If you have any queries about this questionnaire, please contact _____ at _____, on telephone _____.

1. Your Name and Contact Details (for use only if follow-up is required)
Name:
Address:
Telephone number:

2. Production indicators for the last full season (1998)	
Area of tomatoes (ha)	
Volume (tonnes)	
Average yield (tonnes per ha)	

3. Have you ever used IPM either partially or fully?	**Yes**	**No**
If 'yes' what year did you start?		
If 'yes' have you continued using IPM?		
If 'no' why not? Please comment:		

4. Problems for Management in Tomato Production

The following pests and diseases can be the target of an IPM program in tomatoes. Consider each of the three categories separately and **in each category tick up to three** of the pests or diseases or weeds you consider to be the most important for tomato production on your farm.

Common Insect & Mite Pests	Tick	Common Diseases	Tick	Weed Pests	Tick
Heliothis		Bacterial speck		Blackberry nightshade	
Aphids		Bacterial spot		Wild cape gooseberry	
Russet mites		Bacterial canker		Wireweed	
Spider mites / Two-spotted mite		Powdery mildew		Bathurst burr	
		Target spot (Alternaria sp)		Oxtongue	
Thrips		Fulvia leaf mould		Heliotrope	
White fly		Botrytis (grey mould)		Nutgrass	
Rutherglen bug		Fusarium wilt		Johnson grass	
Cluster caterpillar		Verticillium wilt		**Others:**	
Cutworms		Bacterial wilt			
Wire worms		Spotted wilt (Bronze wilt)			
Leaf hoppers		Sclerotinia rot			
Others:		Pythium			
		Rhizoctonia rot			
		Arboviruses			
		Big Bud			
		Root-knot nematode			

5. Important Beneficials

Please tick any you believe are important to production of tomatoes on your farm

Name	Tick	Comment
*Trichogramma spp. (parasitic wasp)		
Spiders (general predators)		
Copidosoma spp. (parasite of tomato leaf miner)		
*Orgilus lepidus (parasite of tomato leaf miner)		
*Phytoseiulus persimilis (Chilean predatory mite)		
Aphidius colemani (parasite of aphids)		
Coccinella transversalis (a ladybird; predator of aphids)		
Hover flies (predator of aphids)		
Assassin bugs (predator of caterpillars and plant sucking bugs)		
Diaeretiella rapae (parasite of aphids)		
Big-eyed bugs (predator of thrips and mites)		
*Lacewings (predator of aphids and mites)		

*These are available commercially for release; the others only occur naturally.

6. Checklist of IPM practices

Place a tick in the columns beside each of the practices you have used or will use to a significant degree on your farm during the current, previous and/or future seasons or a cross if you did not or will not use the practice.

A. Pre-season treatments:	**Current Season**	**Past Seasons**	**Future Seasons**
1) Land selected for tomato production (including leased land) has a history of cropping with non-solanaceous plants, ie plants other than tomatoes, potatoes, capsicum, eggplant and similar.			
2) Irrigation system designed to avoid poor drainage and long periods of soil saturation.			
3) A crop rotation that includes non-solanaceous plants used.			
4) Organic matter build-up of the soil, eg rotary hoe in a non-solanaceous off-season crop.			
5) Use of methyl bromide avoided.			
6) If metham sodium is used, application band is narrow.			
7) Use of pre-plant insecticides minimised.			
8) Sequentially planted blocks separated (eg later plantings up wind of earlier plantings).			
9) Whole farm planning used.			
9) Surrounding vegetation included in management program for pest and diseases, eg pre-planting release of beneficial insects.			
(This row for office use only)			

B. Seedlings:	**Current Season**	**Past Seasons**	**Future Seasons**
1) Choose most disease resistant variety(ies).			
2) Purchase seedlings from accredited supplier (QA product) or produce pest-free seedlings in own Nursery. Consider and use plant quarantine.			
(This row for office use only)			

C. Crop production:	**Current Season**	**Past Seasons**	**Future Seasons**
1) Keep detailed records of production procedures (fertiliser type & use, date of growth stages, and max. & min. temperatures).			
2) Conduct regular (min. fortnightly) foliage analysis to determine and implement nutritional management program.			
3) Base nutrient program on soil analysis and foliage analysis reports.			
(This row for office use only)			

D. General Pest Management:	**Current Season**	**Past Seasons**	**Future Seasons**
1) Remove old crops immediately following last harvest.			
2) Sow inter-row plants that favour beneficials.			
3) Monitor at least weekly for insects, plant diseases and weeds.			

D. General Pest Management (continued):	Current Season	Past Seasons	Future Seasons
4) Maintain monitoring and spray records. (To include levels of pests & beneficials)			
5) Calibrate spray machinery at start of each growing season.			
6) Keep records of release / application of beneficials.			
(This row for office use only)			

E. Disease Management	Current Season	Past Seasons	Future Seasons
1) Select varieties with disease resistance and with open canopy.			
2) Choose fungicides with least impact on beneficial species.			
3) Apply fungicides only if weather data and monitoring indicates it is necessary.			
4) Use weather data, crop growth stage and thresholds for deciding when to apply curative fungicides.			
(This row for office use only)			

F. Insect Management:	Current Season	Past Seasons	Future Seasons
1) Monitor insects by counts and with yellow sticky cards or pheromone traps. Check weekly. Change monitoring devices when needed.			
2) Release appropriate natural enemies at recommended rates and intervals at the first sign of insect activity.			
3) Use insecticides only for those pests for which effective natural enemies are not available or pest/beneficial ratios indicate action required.			
4) Monitoring includes assessment and recording of beneficial activity.			
5) Treatment decisions based on perceived impact of beneficials and the effect of insecticide sprays.			
(This row for office use only)			

G. Weed Management:	Current Season	Past Seasons	Future Seasons
1) Use plastic mulch to reduce weed competition.			
2) Apply herbicides only if indicated by monitoring and previous paddock history.			
3) Select herbicides with minimal impact on beneficial organisms and the environment.			
(This row for office use only)			

1.1.1 Any other comments about management of pests and diseases on your farm

7. Long term or average impact of IPM on amount and cost of inputs

The purpose of this question is to establish the difference in the average level of inputs required for production of tomatoes using IPM relative to conventional crop management. If you believe you use IPM, please indicate how your inputs and costs are different (on average) compared to conventional management (ie, program spraying and no scouting). If it is not possible for you to express any of the changes in actual terms, use proportional (%) terms.

Item	Quantity per Season (eg. number; man hours)	Cost ($/ha)
Increase (+) in crop monitoring if using an IPM scouting service (Note. If you switched from a scouting service to 'do-it-yourself' scouting or *vice versa*, please explain at Question 9)		
Increase (+) in crop monitoring if family labour is used for this activity (See note in box above)		
Increase (+) or decrease (-) in chemical applications with IPM (average season)		
Increase (+) or decrease (-) in labour for pest, disease and weed control with IPM (average season)		
Other increases or decreases (specify)		

8. Approximately, how has the cost of chemicals and their application moved in past years?

1.1.1.1 Time period	Cost of chemicals used ($/ha/application)	Cost of applying chemicals ($/ha/application)	
		Aerial	Ground
Now			
5 years ago			
10 years ago			

9. Did any of the increases/decreases due to adoption of IPM continue beyond the first year that you used it? (circle) YES / NO Please comment:

10. Do the figures given in Question 7 apply to the whole of your tomato production area as indicated in Question 2? If not, please indicate the proportion (%) of area on which IPM was used.

11. Quality Impacts
Has adoption of IPM caused your quality grades to improve/deteriorate? Have there been implications for price? Please comment.

12. Do you believe your adoption of IPM has had any desirable social impacts such as a healthier environment or green image for agriculture? Please comment.

Attachment 3

PROFORMAS FOR:

1. Interview proforma for industry stakeholders other than growers

2. Supplementary questionnaire for consultants and researchers

CONFIDENTIAL

HRDC PROJECT: EVALUATION OF THE EFFECTIVENESS OF R&D ON INTEGRATED PEST MANAGEMENT IN TOMATOES

INTERVIEW PROFORMA FOR INDUSTRY STAKEHOLDERS OTHER THAN GROWERS

1. Name, Contact Details and Stake in the Industry
Name:
Address:
Telephone:
Stake in the industry (in relation to IPM):

2. Statistical Summary of Local Tomato Growers /Suppliers	
Name and extent of your district/ supply area	
Number of growers	
Total area (ha)	
Total volume (tonnes)	
Average yield and range in district/ supply area(tonnes per ha)	
Market outlet for product (eg fresh, paste, whole peeled canned)	
Number and % of 'your' growers practising some form of IPM	

3. Long term or average impact of IPM on amount and cost of inputs

The purpose of this question is to establish the difference in the average level of inputs required for production of tomatoes using IPM relative to conventional crop management. Please indicate how inputs and costs under IPM differ (on average) in comparison to conventional management (ie, program spraying and no scouting). If it is not possible for you to express any of the changes in actual terms, use proportional (%) terms.

Item	Quantity per Season (eg. number; man hours)	Cost ($/ha)
Increase (+) in crop monitoring if using an IPM scouting service		
Increase (+) in crop monitoring if family labour is used for this activity		
Increase (+) or decrease (-) in chemical applications with IPM (average season)		
Increase (+) or decrease (-) in labour for pest, disease and weed control with IPM (average season)		
Other increases or decreases (specify)		

4. To what proportion of your district do the above savings or cost increases apply?

In terms of area:	In terms of volume:

5. Approximately, how has the cost of chemicals and their application moved in past years?

1.1.1.2 Time period	Cost of chemicals used ($/ha/application)	Cost of applying chemicals ($/ha/application)	
		Aerial	Ground
Now			
5 years ago			
10 years ago			

6. Do any of the increases/decreases due to adoption of IPM continue beyond the first year that it is used? (circle) **YES / NO Please comment:**

7. Are there any quality impacts due to IPM relative to conventional management?

Gradings (eg level of grub damage)

Price

Is any assistance given through price or other arrangements to encourage the adoption of IPM by growers?

7. What are the factors that either attract particular growers to Adopt IPM or influence others Not to Adopt IPM?	
Factors that Attract Growers to IPM	**Factors that Cause Growers Not to Adopt IPM**

8. Is IPM generating beneficial effects beyond the farm gate such as a healthier environment or product marketing? Please comment.

9. What impact has IPM had on your own role/business in the district?

10. Comments on value/outcomes/impact of HRDC's tomato IPM projects

11. Suggestions on future directions/priorities for of the HRDC's R&D program on IPM in tomatoes

12. Other comments

SUPPLEMENTARY QUESTIONNAIRE FOR CONSULTANTS AND RESEARCHERS

HRDC PROJECT: REVIEW OF IPM IN TOMATOES

The purpose of this questionnaire is to give you the opportunity to provide some additional input into the above project. This was foreshadowed during the interview that _____ Taylor and _____ conducted with you earlier in the year.

The questions attached formed part of the questionnaire that growers were asked to complete, but have been modified to allow you to give 'the complete picture' for your district/region. Your views will also help us to interpret the grower responses; eg whether or not a particular pest or practice is relevant to IPM in each district.

Also, we have now changed the format of the question about increase/decrease in costs associated with IPM. Therefore, could you also complete this question, based on your experience with all the growers that you work with, ie provide what you think is a typical response.

Please return the completed questionnaire to us in the reply paid envelope provided.

If you have any general queries about this questionnaire, contact _____ . If you have a query specifically about the increase/decrease in costs associated with IPM, contact _____. .

1. Your Name and Contact Details
Name:
Address:
Telephone number:
Role in IPM:
Your qualifications and training if practising as an IPM consultant/scout:

2. Problems for Management in Tomato Production

The following pests and diseases can be the target of an IPM program in tomatoes.

Consider each of the three categories separately. **In each category, rank all of the pests or diseases in order of importance that, in your opinion, applies in your district or region.** In each column, place the number '1' in the box beside the pest or disease of highest importance and continue the numbering to indicate decreasing order of importance.

If a particular pest or disease is not relevant in your district or region, write 'NR' in the box beside it.

If you wish to add 'Others', include these in the rankings.

Common Insect & Mite Pests	Rank	Common Diseases	Rank	Weed Pests	Rank
Heliothis		Bacterial speck		Blackberry nightshade	
Aphids		Bacterial spot		Wild cape gooseberry	
Russet mites		Bacterial canker		Wireweed	
Spider mites / Two-Spotted mite		Powdery mildew		Bathurst burr	
		Target spot (Alternaria sp)		Oxtongue	
Thrips		Fulvia leaf mould		Heliotrope	
White fly		Botrytis (grey mould)		Nutgrass	
Rutherglen bug		Fusarium wilt		Johnson grass	
Cluster caterpillar		Verticillium wilt		**Others:**	
Cutworms		Bacterial wilt			
Wire worms		Spotted wilt (Bronze wilt)			
Leaf hoppers		Sclerotinia rot			
Others:		Pythium			
		Rhizoctonia rot			
		Arboviruses			
		Big Bud			
		Root-knot nematode			
		Others:			

3. Important Beneficials

Rank the beneficials listed below in order of importance that, in your opinion, applies in your district or region. Place the number '1' in the box beside the beneficial of highest importance and continue the numbering to indicate decreasing order of importance.

If a particular pest or disease is not relevant in your district or region, write 'NR' in the box beside it.

If you wish to add 'Others', include these in the rankings.

Name	Rank	Indicate if introduced via release from a commercial source
*Trichogramma spp. (parasitic wasp)		
Spiders (general predators)		
Copidosoma spp. (parasite of tomato leaf miner)		
*Orgilus lepidus (parasite of tomato leaf miner)		
*Phytoseiulus persimilis (Chilean predatory mite)		
Aphidius colemani (parasite of aphids)		
Coccinella transversalis (a ladybird; predator of aphids)		
Hover flies (predator of aphids)		
Assassin bugs (predator of caterpillars and plant sucking bugs)		
Diaeretiella rapae (parasite of aphids)		
Big-eyed bugs (predator of thrips and mites)		
*Lacewings (predator of aphids and mites)		

*These are available commercially for release; the others only occur naturally.

4. Checklist of IPM practices In the first column, rank the importance of the listed practice to IPM in your district or region, as follows: 1 = very important; 2 = moderate importance; 3 = ; low importance; NR = not relevant.

In the second column, rank the extent to which you think the practice is used by your clients/all growers you consider to be using IPM, as follows: 1 = used in the majority of cases (75% or growers or more); 2 = used by about half the growers; 3 = used but only to a limited degree (less than 25% of growers); 4 = not used at all.

In third column, use similar rankings for use of the practice by non-IPM growers.

If you don't have sufficient local knowledge to make a judgement, indicate with a '?' in the appropriate column.

A. Pre-season treatments:	**Import-ance to IPM**	**Use by IPM growers**	**Use by non-IPM growers**
1) Land selected for tomato production (including leased land) has a history of cropping with non-solanaceous plants, ie plants other than tomatoes, potatoes, capsicum, eggplant and similar.			
2) Irrigation system designed to avoid poor drainage and long periods of soil saturation.			
3) A crop rotation that includes non-solanaceous plants used.			
4) Organic matter build-up of the soil, eg rotary hoe in a non-solanaceous off-season crop.			
5) Use of methyl bromide avoided.			
6) If metham sodium is used, application band is narrow.			
7) Use of pre-plant insecticides minimised.			
8) Sequentially planted blocks separated (eg later plantings up wind of earlier plantings).			
9) Whole farm planning used.			
9) Surrounding vegetation included in management program for pest and diseases, eg pre-planting release of beneficial insects.			
(This row for office use only)			

B. Seedlings:	**Import-ance to IPM**	**Use by IPM growers**	**Use by non-IPM growers**
1) Choose most disease resistant variety(ies).			
2) Purchase seedlings from accredited supplier (QA product) or produce pest-free seedlings in own Nursery. Consider and use plant quarantine.			
(This row for office use only)			

C. Crop production:	**Import-ance to IPM**	**Use by IPM growers**	**Use by non-IPM growers**
1) Keep detailed records of production procedures (fertiliser type & use, date of growth stages, and max. & min. temperatures).			
2) Conduct regular (min. fortnightly) foliage analysis to determine and implement nutritional management program.			
3) Base nutrient program on soil analysis and foliage analysis reports.			
(This row for office use only)			

D. General Pest Management:	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
1) Remove old crops immediately following last harvest.			
2) Sow inter-row plants that favour beneficials.			
3) Monitor at least weekly for insects, plant diseases and weeds.			
4) Maintain monitoring and spray records. (To include levels of pests & beneficials)			
5) Calibrate spray machinery at start of each growing season.			
6) Keep records of release / application of beneficials.			
(This row for office use only)			

E. Disease Management	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
1) Select varieties with disease resistance and with open canopy.			
2) Choose fungicides with least impact on beneficial species.			
3) Apply fungicides only if weather data and monitoring indicates it is necessary.			
4) Use weather data, crop growth stage and thresholds for deciding when to apply curative fungicides.			
(This row for office use only)			

F. Insect Management:	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
1) Monitor insects by counts and with yellow sticky cards or pheromone traps. Check weekly. Change monitoring devices when needed.			
2) Release appropriate natural enemies at recommended rates and intervals at the first sign of insect activity.			
3) Use insecticides only for those pests for which effective natural enemies are not available or pest/beneficial ratios indicate action required.			
4) Monitoring includes assessment and recording of beneficial activity.			
5) Treatment decisions based on perceived impact of beneficials and the effect of insecticide sprays.			
(This row for office use only)			

G. Weed Management:	Import-ance to IPM	Use by IPM growers	Use by non-IPM growers
1) Use plastic mulch to reduce weed competition.			
2) Apply herbicides only if indicated by monitoring and previous paddock history.			
3) Select herbicides with minimal impact on beneficial organisms and the environment.			
(This row for office use only)			

5. Long term or average impact of IPM on amount and cost of inputs

The purpose of this question is to establish the difference in the average level of inputs required for production of tomatoes using IPM relative to conventional crop management. Based on your experience and knowledge, please indicate how the inputs and costs to growers using IPM differ (on average over several seasons) from those using conventional management (ie, program spraying and no scouting). If it is not possible for you to express any of the changes in actual terms, use proportional (%) terms. If you don't know, indicate with a '?'.

Item	Quantity per Season (eg. number; man hours)	Cost ($/ha)
Increase (+) or decrease (-) in crop monitoring if using an IPM scouting service		
Increase (+) or decrease (-) in crop monitoring with family labour if used		
Increase (+) or decrease (-) in chemical applications with IPM		
Increase (+) or decrease (-) in labour for pest, disease and weed control with IPM		
Other increases or decreases (specify)		

6. Approximately, how have chemical costs and applications costs moved over the past 10 years?

1.1.1.3 Time period	Cost of chemicals used ($/ha/application)	Cost of applying chemicals ($/ha/application)	
		Aerial	Ground
Now			
5 years ago			
10 years ago			

7. Do the increases/decreases in grower costs that are apparent in the first year in which IPM was adopted continue in subsequent years? (circle) **YES / NO Please comment:**

Attachment 4

HRDC Project VG98135
'Evaluation of R&D on IPM in Tomatoes'

Project evaluation checklists completed by the project team for each of the HRDC projects on IPM in tomatoes.

Note. Checklists are also included for projects TM137 and TM405. These projects were not on the core list of IPM projects but are relevant to IPM

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM041** Name: **Studies of Phytophthora root rot of processing tomatoes and the evaluation of control measures.**

1. Final/progress reports available commensurate with time frame for project:

   Final Report available

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Tending to marginal because a major focus of the project was on chemical control. However, information on longevity of fungus was valuable for timing of crop rotations. The eventual solution to the problem (change in irrigation management) was postulated during the project but not subject to any field experimentation.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   OK.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Some adoption of crop rotations with long breaks. Changes in irrigation practice and possibly in varieties have had positive effects independently of the project.

6. Other comments?

   Resistant tomato varieties were selected but these are no longer in commercial use for other reasons.

   The basic work that could have lead to registration of two fungicides for tomatoes was carried out by the project.

   In summary, despite criticism from some growers, it was an appropriate project at the time.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM043** Name: **Chemical Residue analysis of processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   HRDC database report only

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | **Marginal relevance** | Reasonably relevant | Highly relevant

   Brief comment on reason for ranking:

   Project was on quality assurance aspects of tomato production and not on pest management. However, it did indicate that chemical residues were not a problem in processing tomatoes at that time.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Does not fit into a mainstream IPM program. Nevertheless it would have provided a valuable reference point for those involved in the formulation of the IPM programs. (The approach to IPM may have been rather different if chemical residues had been identified as a significant issue.) Subsequent work on residues has been taken over by the processing industry.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   The industry has taken on the task of regular monitoring for pesticide residues.

6. Other comments?

   The project showed that the management of chemical residues was not a primary reason for promoting/adopting IPM.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM137** Name: **Soil fumigation with Metham sodium to control blackberry nightshade & soil pathogens**

1. Final/progress reports available commensurate with time frame for project:

   Final Report available.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Although the prime reason for banded application was cost, the application system has spin-off benefits for IPM.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Marginal for the processing industry. (However, very relevant in the fresh industry as Metham sodium will serve as a replacement for methyl bromide after it has been phased out. Its use will be an integral part of IPM strategies.)

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes, this was a very successful project.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Yes, the system has been adopted where the soil type is suitable.

6. Other comments?

   A useful project with a successful outcome.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM201** Name: **Development of IPM strategies for processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   HRDC database report, plus final report available

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant Marginal relevance Reasonably relevant **Highly relevant**

   Brief comment on reason for ranking:

   Project involved development and extension of IPM strategies for control of Heliothis, utilising egg-sampling and spray thresholds. Also developed preliminary systems for cutworms and thrips.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   OK.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Yes, project involved three commercial scouts - scout training and promotion of IPM.

6. Other comments?

   Nil.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM208** Name: **Evaluation of the role of Thimet in IPM for processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   Interim HRDC database milestone report only.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Main consideration was chemical control of wireworms. IPM was a secondary issue, although Thimet, because it is systemic in plants and is taken up from soil-applied granules, is much softer on beneficials than insecticides applied to foliage.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Reasonably well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Not at the time of report. Bad weather and low pest numbers were blamed.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   No. Wireworm is not on label for tomatoes. No NRA permits for tomatoes/ wireworms either.

6. Other comments?

   This project was poorly reported.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **HG 319** (originally submitted as TM300 but tomato work subsequently integrated with work on other crops)

Name: **Evaluation of petroleum spray oils for processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   Available.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | **Marginal relevance** | Reasonably relevant | Highly relevant

   Brief comment on reason for ranking:

   Oils are thought to be 'softer' on beneficials than most insecticides. However the relevance of this work was reduced by a complete failure of the researchers to monitor population levels of any beneficials in their experiments.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   In theory, fits well, subject to the limitation mentioned above. In practice, has proven to be of marginal relevance.

4. Were/are the stated outcomes for the project achieved/being achieved?

   The research showed that oils are effective insecticides for control of Heliothis, two-spotted mite, leafhoppers and greenhouse white fly. However, the results were rather general and not specific for use with tomatoes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   No. Report states that registration submissions were made in 1997. No registrations on tomato are as yet listed on NRA database.

6. Other comments?

   It is surprising that no monitoring of any beneficial predator or parasitoid was carried out to support the supposition that the use of these oils is any more appropriate in IPM programs than other insecticides.

   However it did show that spray coverage in processing tomatoes could be improved by use of fan-assisted sprays.

   Pest incidence was variable in the tomato experiments.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM301** Name: **Study tour to the USA: non-chemical weed control systems for processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   Final report is available.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant Marginal relevance Reasonably relevant Highly relevant

   Brief comment on reason for ranking:

   Emphasis was on machinery and mechanical weed control.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Does not fit.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   No. 'Vision cultivator' not used in the processing industry to our knowledge.

6. Other comments?

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM405**

Name: **Evaluation of DuPont Titus for post emergent control of nightshade & other weeds in processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   HRDC database report. NB. Product is now registered and available

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Direct IPM benefits through reduction in Nightshade population and weed management strategies.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Marginal.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes. Project was successful.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Yes. Product is being sold commercially and is used extensively.

6. Other comments?

   Even though this involved the development of a commercial pesticide it was important as part of management strategies for an important weed pest.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM501/95001**

Name: **Advanced integrated pest management in processing tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   Incomplete draft of Final Report available, plus Progress Report to 1996.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant Marginal relevance Reasonably relevant **Highly relevant**

   Brief comment on reason for ranking:

   Refinement of IPM for pests, including investigation of disease forecasting model (TOMCAST), development of refined strategies for bacterial speck control & improved methods for monitoring insect pests and plant diseases in crops.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Very well - builds on previous projects and extends scope.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes. Established fundamental elements of IPM for disease management, insecticide resistance management and scouting methodologies and evaluated effect of IPM on pesticide use in 1996-97. Also, in the evaluation of the disease forecasting model TOMCAST, it was found that few fungicides were in fact required for control of most diseases except Bacterial Speck and Powdery Mildew (not covered by the TOMCAST model).

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Yes - project involved extensive use of professional scouts, who have adopted the results of the research. Area of tomatoes monitored by professional scouts has increased in recent years.

6. Other comments?

   Comparison of pesticide usage for 1996-97 indicated IPM growers used 2.4 fewer insecticide and 2.7 fewer fungicide applications than non-IPM growers. Comparisons were not made for earlier years because data sets are incomplete.

   In summary - an appropriate project with several major outcomes.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes
Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM602/96002** Name: **Selection of Trichogramma for control of Heliothis in tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   HRDC application database milestone reports.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Trichogramma is potentially a key component in control of Heliothis.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Fits well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program (if known - refer to feedback from growers and consultants etc)?

   A commercial company has accepted a shipment of selected strain for propagation.

6. Other comments?

   It was unclear to the project team whether the technical production problems had been resolved.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM97001** Name: **Improved control of Powdery Mildew on Processing Tomatoes**

1. Final/progress reports available commensurate with time frame for project:

   HRDC application database progress report only.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Highly relevant because the main fungicide currently available (sulphur) has adverse effects on the Trichogramma parasitoid and management of Powdery Mildew continues to be a significant production issue.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Fits well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   To some extent - none of the test compounds gave good control of mildew.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   No, as no recommendations on products to replace sulphur have yet been made.

6. Other comments?

   Nil.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM97004** Name: **IPM in tomatoes – from research into practice**

1. Final/progress reports available commensurate with time frame for project:

   Progress reports in HRDC application database are available

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Focuses on issues surrounding IPM implementation, grower and consultant education, production of IPM manuals etc.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Very well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Appear to have, at least in some cases. No evidence of training outcomes, the training criteria or whether or not the trainees were assessed.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Partial industry adoption (refer to information gathered during this project, ie VG98135).

6. Other comments?

   It would have been more appropriate to refer to Pest Management Methods rather than Control Methods.

   Who formed the training team?

   How were the potential consultants chosen for training?

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **HG97007** Name: **National strategy for the management of western flower thrips & tomato spotted wilt virus**

1. Final/progress reports available commensurate with time frame for project:

   HRDC progress reports available for 1997/98.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Although only some of the research is directly on tomatoes, studies on mechanisms of resistance to pesticides and in particular on development of predators as potential biocontrol agents are very relevant.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   OK.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Some delays due to delayed funding, otherwise yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Too soon to tell. Commercial partnerships to develop phytosieiid predators are being sought.

6. Other comments?

   Only 1-2% of total funds of this project are being provided by tomato sources.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes
Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **TM98009** Name: **IPM Tomatoes 2001**

1. Final/progress reports available commensurate with time frame for project:

   No progress reports available.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant Marginal relevance Reasonably relevant **Highly relevant**

   Brief comment on reason for ranking:

   Broadly based project, but focusing on problems important to success of IPM, eg biological insect control, soft pesticides, disease forecasting and compatibility of disease control with insect pest management.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Fits well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   No information.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Too early to tell.

6. Other comments?

   Nil.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG201** Name: **Introduction of IPM programs for fruit & vegetable crops in Bowen**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Practical and aimed particularly at increasing grower awareness of IPM and best management practices.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Highly relevant and followed a very successful initial project..

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Adoption of field hygiene strategies. Some growers reluctant to adhere to limitation on growing periods (especially for silverleaf whitefly).

6. Other comments?

   Nil.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG206** Name: **IPM Phase II**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Practically oriented at a range of strategies with the potential to improve prospects for IPM in tomatoes.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Highly relevant and follows a very successful initial project.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Yes, included a lot of extension to growers and appropriate small-scale field trials to establish operation of IPM. (Top spraying now used commercially.)

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Acceptance of certain outcomes by industry has been quite good. Producers still regard this work as very useful.

6. Other comments?

   This was one of the important foundation IPM projects.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG412** Name: **Strategic Use of Pesticides as Part of IPM Programs for Vegetables**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Practical with potential for significant impact on tomato IPM.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Highly relevant and builds on IPM Phase II project (VG206).

4. Were/are the stated outcomes for the project achieved/being achieved?

   They were achieved, with spraying equipment modified and careful selection and targeting of pesticides as a result.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program (if known - refer to feedback from growers and consultants etc)?

   There is evidence of acceptance and adoption by growers including requests for field days and training.

6. Other comments?

   Changes to spraying systems, monitoring and use of beneficials as a result.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG502** Name: **A production-break strategy for tomato leafminer in Queensland**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   May have potential.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Reasonably logical.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Unsure

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Unsure, no evidence provided.

6. Other comments?

   Project staffing problems an issue.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG95006/506**

Name: **Monitoring, management and reduction of tomato leafminer in Bowen (VG 506 continued as VG95006)**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | Reasonably relevant | **Highly relevant**

   Brief comment on reason for ranking:

   Potential to impact significantly on existing pest management practices for the better, support for production break.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Highly relevant and appropriate.

4. Were/are the stated outcomes for the project achieved/being achieved?

   The outcomes are being achieved.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Growers now more conscious of need for improved hygiene as part of an IPM approach and implementation of a production break.

6. Other comments?

   Nil.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG95009/509** Name: **Pest and beneficial ecology in tomatoes (cont'd as VG95009)**

1. Final/progress reports available commensurate with time frame for project:

   Yes.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant Marginal relevance **Reasonably relevant** Highly relevant

   Brief comment on reason for ranking:

   Basic research is important for improving understanding of biological systems as part of IPM or any pest management approach.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Reasonably well.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Unsure, and not clear from reports available.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Unsure, and no real evidence of use of results in IPM strategies.

6. Other comments?

   Need clear milestone reports or final report focused on practical outcomes.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG97040** Name: **Trichogramma wasps in IPM programs for vegetable crops**

1. Final/progress reports available commensurate with time frame for project:

   Only report provided was the Progress Report for Milestone 3.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Potential for significant improvement in vegetable pest management practices favouring higher biocontrol component.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Work focused on brassicas and not tomatoes.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Possibly but not specifically related to tomatoes.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   In corn there is a strong interest and partial adoption. Little adoption in tomatoes to date.

6. Other comments?

   Trichogramma has potential for use in fresh tomato IPM program.

HRDC Project VG98135: Evaluation of R&D on IPM in Tomatoes

Checklist for evaluation of HRDC projects on IPM in tomatoes

Number of project: **VG98006** Name: **IPM strategy to reduce Tomato Spotted Wilt Virus (TSWV) in the dry tropics**

1. Final/progress reports available commensurate with time frame for project:

   Not appropriate – very early in the project.

2. How relevant is the project to the IPM concept? Please rank as follows (note that a project might be highly relevant to the production of tomatoes, but not necessarily in the context of IPM):

   Not relevant | Marginal relevance | **Reasonably relevant** | Highly relevant

   Brief comment on reason for ranking:

   Probably a specific pest management project rather than broader 'IPM' project. However, all pest management options make up the broader picture of 'IPM'.

3. How well does the project fit into a logical sequence of R&D projects on IPM in tomatoes?

   Reasonably.

4. Were/are the stated outcomes for the project achieved/being achieved?

   Unsure, as it is early in the project.

5. Is there evidence that the results of the project have been adopted by industry and what has been the impact on the IPM program?

   Not yet.

6. Other comments?

   Probably a very useful project provided results communicated to producers and built into IPM strategies.