Know-how for Horticulture™

Review of potato research & development program

Jeff Peterson
Horticulture Australia Limited

Project Number: PT02033

PT02033

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the potato industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the potato industry.

ISBN 0 7341 0629 7

Published and distributed by:
Horticultural Australia Ltd
Level 1
50 Carrington Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

SHAREHOLDER VALUE FROM AUSTRALIAN LEVY-FUNDED POTATO RESEARCH AND DEVELOPMENT

A report to Horticulture Australia Ltd and the levy-paying members of the Australian potato industry

AGRICULTURAL
SUPPLY
CHAIN
SERVICES Pty Ltd

Australian Potato Industry Council

Horticulture Australia

J R Peterson
R L Batterham

Project number: PT02033

March, 2003

1 Project Title:	Shareholder value from Australian levy-funded potato research and development	
HAL reference:	PT02033	

2 Organisation:	Agricultural Supply Chain Services	
Postal address:	32 Bannister Head Rd MOLLYMOOK NSW 2539	

Admin. contact:	Jeff Peterson	Phone: 02 4455 1130 Email: jeff.Peterson@bigpond.com

3 Project Team		
	Mr Jeff Peterson	Phone: 02 4455 1130 Email: jeff.Peterson@bigpond.com
	Asoc. Prof. R Batterham	Phone 02 9351 2677 Email: r.batterham@agec.usyd.edu.au

4 Objective of project:

To ascertain and report the cost-effectivenes of levy-funded research and development in the Australian Potato Industry.

5 Key dates:	Commencement date:	1st July, 2002
	Completion date:	1st April, 2003
	Report date:	1st April, 2003

6 Project cost	HAL contribution	$30 000
	Industry contribution	$30 000
	Total	$60 000

Acknowledgements

This project was only possible with the co-operation and assistance of many people, far too many to list by name. They include the numerous researchers, extension officers and R&D administrators who participated in these programs, in the NSW, Victorian, Queensland, South Australian and Tasmanian Departments of Agriculture, various divisions of the CSIRO, several universities and in private employment as consultants or researchers. In addition, members of the potato processing industry provided valuable assistance and guidance, as did representatives of the Potato Industry R&D Committee, the Australian Potato Processors' Association, VicSpa and the Crookwell Certified Seedgrowers Association. The information in the QA chapter was supplied by members of the processing, wholesale and retail industry. The assistance of the many growers and seedgrowers who provided assistance is also acknowledged, as is that of Horticulture Australia who supported the project by the provision of research records and reports.

Disclaimer

The views expressed and the conclusions reached in this report are those of the authors and not necessarily those of persons consulted. The authors shall not be responsible in any way whatsoever to any person who relies in whole or in part, on the contents of this report unless authorised in writing by the corresponding author.

CONTENTS

INDUSTRY SUMMARY

The Australian potato industry has invested over $15 million in research and development activities since the beginning of the levy funding arrangements in 1991. This project was commissioned to analyse the success of this investment, by quantifying the benefits that have accrued from research in eleven program areas, and that will accrue over a twenty year timeframe, and comparing these with the costs of the original R&D. All comparisons were based on net present value, derived using a standard 8% discount rate.

Not all projects were susceptible to this form of economic analysis and in some instances it was found necessary to use a qualitative analytical framework.

Where economic analyses were applied, the R&D costings included only the contributions of industry and matching government funds. In-kind or financial contributions of the research providers or of industry were not quantified and were not considered here. Neither were benefits that accrued to anyone other than direct industry participants, such as members of other horticultural industries (who sometimes shared the funding arrangements), downstream industries such as chemical or agricultural machinery manufacturers or retailers, or regional communities who benefit from the presence of successful and profitable potato enterprises in their economies. Likewise, the potentially important economic benefits to consumers of potatoes were ignored. To this extent these are partial economic analyses designed to record whether the projects have returned a positive economic return to the levy-paying industry investors, rather that to precisely quantify that benefit.

The results of the analyses are presented on a program basis as follows:

1 Cadmium. The projects produced the scientific evidence for a necessary change in the regulatory standards for potatoes, and which allowed the industry to continue more or less unaltered. The analysis was strongly positive, indicating that the research represented a useful investment, though it was also noted that further work is required to manage possible future problems with cadmium in potatoes. This project also produced a useful environmental outcome due to the widespread adoption of low-cadmium fertilisers.

2 Genetic improvement. The program includes breeding and evaluation of crisping, french fry and fresh market potatoes, as well as gene technology for virus resistance in a limited varietal range. Neither of the processing breeding (and evaluation) components of the program has produced varieties that have been widely adopted by industry and the analyses indicated a negative return on these investments. Analyses of an emerging scenario in which the companies individually contract with the breeder (within the current funding arrangements) indicate the availability of potentially large benefits, which will vary with the extent to which beneficial varietal attributes can be identified and achieved, and newer competitive varieties adopted by the companies. This approach should provide a basis for commercial competitive advantage that is presently unavailable.

The fresh market breeding program has released some attractive varieties, though again, the rate of adoption has been poor. The reviewers believe that without appropriate commercial arrangements (including varietal ownership and strong chain leadership) this part of the program is unlikely to return a positive net present value on the investment.

The outcomes of the gene technology program are likely to be limited to one variety (in the timeframes of this analysis), but may include a valuable addition to the industry's pest and disease management objectives. The reviewers were conscious that community concerns at the use of GMO's in fresh produce, and corporate rejection of the technology, would delay, if not prevent, the adoption of GM varieties.

Subject to the ability to use GM fresh market potatoes by around 2006, the project is assessed as being moderately beneficial to the industry, and to the environment.

3 Integrated pest management (IPM). IPM for foliar insect pests (including tuber moth) has been highly successful, both economically and environmentally. The rate of adoption, which was facilitated by a series of funded projects, was enhanced by the activities of processors and R&D levy-funded regional development activities. The economic analysis indicated that investment in this research has already produced a high positive net present value, which is likely to increase in the future.

Work in Western Australia has added significantly to the knowledge of soil borne insects, but attempts to develop biological control methods have so far been unsuccessful. Biofumigation using brassica rotations was not successful in potatoes, but has become a valued part of the disease management program in some vegetable crops. It was not possible to value this research outcome within the terms of reference for this review. Research into the vectors of virus diseases in WA has also contributed to an ability to reduce disease infection rates through the identification and choice of low risk areas, but again it was not possible to value the outcome of this research.

4 Potato cyst nematode (PCN). Potato cyst nematode is a recent arrival in Australia which has the potential to cause considerable economic, social, and environmental harm to the industry. The R&D responses to this incursion were rapid, well planned and effective and resulted in the production of a pest management strategy that will effectively allow the industry to continue with minimal disruption. While there are a number of ways in which the economic value of the R&D program could be assessed, the reviewers chose to base their analysis on a worst case scenario in which growers in high risk areas would need to fumigate their land as in parts of Europe. The economic analysis indicated a highly positive net present value for the research. Alternative strategies which rely on genetic resistance in Australian and imported varieties and avoidance of infested areas were not considered.

5 Tuber borne diseases (rhizoctonia and common scab). Research on these two diseases has represented a significant draw on the R&D investment funds. They are difficult research subjects and progress has been slow, but nevertheless positive. A full-scale economic analysis was not undertaken on the outcome of this research. However, on current indications, research in Tasmania may result in a positive economic outcome. This work has already produced plantlets of two french fry varieties which were selected, *in vitro,* for resistance to common scab. Other research has provided some important research tools, expanded the knowledge of the organism and its relationship with its environment, screened and selected chemical control measures, identified the (limited) potential for biofumigation (using brassicas) and developed codes of practice to limit disease spread within the industry. Current research, which builds on the results of previous studies, is exploring the potential for integrated disease management through the use of crop rotations. This research requires the long-term commitment of the industry and funding bodies, is unlikely to produce spectacular breakthroughs, but is nevertheless deserving of ongoing funding support, but within a comprehensive industry/HALR&D plan.

6 Resource management and protection. This relates to the industry's objectives for environmental sustainability. The program includes a number of projects that were assessed separately for economic benefit (eg, cadmium, IPM etc), and some which had not been previously considered (soil and water management). The outcomes of this part of the program were difficult to assess in the absence of clear industry objectives for soil, water, chemical and community sustainability. While each project has made a contribution towards achieving sustainable production, the reviewers recommended that future progress, and an ability to claim sustainability credentials, would depend on industry's willingness to develop and implement a focused, outcome oriented sustainable production systems R&D strategy.

7 Quality assurance/HACCP. The Australian potato industry ranks high in the adoption of food safety practices, largely as a result of the work undertaken in a single levy funded project. While not subjected to economic analysis due to data limitations, this research area was clearly and strongly beneficial, through its impact on grower (and industry) knowledge and acceptance of QA and HACCP principles and practices, and through its impact on the more pragmatic and user-friendly Freshcare program. It is assessed as a highly effective R&D investment.

8 Regional industry development project – Southern and Northern Highlands. Like other regional industry development projects this one was strongly focused on important economic and environmental outcomes. The project was small in scope but proved highly effective when viewed from either an economic or an environmental perspective, and represented a valuable industry investment.

9 Regional industry development project – Atherton Tablelands. The major industry outcome from this project was an increased awareness and adoption of IPM by non-contracted growers, and possibly a heightened knowledge and awareness of improved production practices by participating growers. The benefits were not quantified or recorded, so no economic analysis was possible. The project is assessed as being "marginally beneficial" on purely qualitative considerations.

10 Industry development – Crisping Group. These projects involved the dedicated efforts of an industry development officer to the crisping potato industry in Southern Australia. Over a limited time, the project resulted in improvements in yield, reductions in input costs and increases in processing efficiency. It also produced some significant, though unquantified environmental outcomes. The success of the work was largely due to the partnership that was developed between the researcher, the crisping growers and the processors. Because of this, one third of the benefits are accredited to the project, and two thirds to the processors themselves. The benefits due to the levy investment were significant, and the project assessed as highly effective.

11 Export market development. Two projects were considered under this category, and within a qualitative framework. The first analysed the potential for Australian potato exports into Asia, and provided an important, if disappointing, assessment of market opportunity. This was a valuable result which has tempered attitudes to both R&D and export activity in the industry ever since. This project represented a sound R&D investment. The second project, which was falsely predicated on a large potential for the industry in Asia produced new shipping technologies that have so far not been adopted, and that failed to drive further expansion in the market. Because of the inaccuracy of the assumptions that underpinned the project, it is judged to have been a poor R&D investment.

Relative effectiveness of R&D investments

An exact ranking of projects on the basis of their economic value to the industry, or on their return on investment was not possible; some projects were evaluated qualitatively, some outcomes are primarily environmental, and some of the outcomes are prospective, and their realisation will depend upon the successful adoption of new approaches to research planning and technology transfer. The projects were therefore grouped into the following categories:

Highly effective investments

- Integrated pest management
- Cadmium
- Potato cyst nematode
- Industry development (crisping)
- Quality assurance
- Aspects of the resource management (sustainable production systems) program

Ineffective investments

- Export market development
- Breeding (of public varieties)

Potentially effective investments

- Breeding for French fry and crisp processing, subject to the adoption of processor-led, individual chain programs leading to unique proprietary varieties and effective competitive advantage for each of the processors.
- Breeding for fresh market potatoes, subject to the development of similar partnership arrangements to those that are currently being agreed with the processors.
- Tuber borne diseases (rhizoctonia and common scab).
- Resource management (subject to identification of industry objectives and development of R&D strategic plan).

- Industry development (Atherton)

The role of economic analysis in research planning

While acknowledging the importance of using economic tools in the planning and evaluation of R&D the authors recommend that this is most effectively applied during the strategic stages of planning, as an aid to selecting the most beneficial R&D investment strategies. Achievement of significant industry outcomes usually result from a combination of activities, including one or more research projects, a communications and adoption strategy and sometimes other non R&D activities such as structural or regulatory change. There may be significant costs to the industry. Traditional BCA's on individual projects seldom take these additional costs into account, often attributing the total benefit to a single research activity, leading to distortion in the project's value, and in the expectations of the industry for its investment.

The suggested approach is to:

- Develop a sharply focused industry strategic plan, with priorities based on economic evaluation of the nature of the problems/opportunities, and of the long term social, environmental and economic goals of the industry.
- Calculate the potential net present value and benefit cost ratios for each program area
- Develop an implementation plan, that includes all of the activities needed to achieve the strategic objectives, including R&D.
- Evaluate the total costs of implementation, ie to the stage of an agreed level of industry adoption.
- Commission the required R&D in accordance with these measures.

Who benefits from the R&D investment?

Under the current arrangements levies are contributed by growers, processors and seed growers. Argument is presented to suggest that the major economic benefits of R&D tend to migrate "up the chain". Thus processors and wholesalers/retailers (and consumers) eventually benefit most through reducing grower prices, more or less in accordance with their ability to reduce production costs and to stay in business as prices decline. While it probably doesn't matter who pays the levy, the distribution of benefits of research depend on the underlying economic structure of the industry. When many "small" growers sell to one or a few "large" buyers (in a marketing environment with less than perfect competition) the benefits of research tend to move towards the buyers, who are able to exercise some "market" power.

Recommendations

Throughout the course of this project the reviewers identified a number of issues and practices that might assist in more efficient and/or effective R&D planning, evaluation and management. They are:

The current potato industry strategic plan is very broad and unfocused, and provides limited assistance to planners and researchers in the identification of new project opportunities. As in any industry there will be a range of issues which are limiting productivity or market opportunity but with the help of the most basic economic analysis it should be possible to rank these in accordance with their economic (and environmental and social) values to the industry. These then become the key strategic objectives for industry change, which set the industry and R&D agendas and direct the selection of research programs around identified industry outcomes. This is the appropriate role for economic analysis in the R&D planning and management process.

Recommendation 1 *The R&D planning process would benefit from an industry strategic plan whose strategic objectives are quantified and prioritised on the basis of economic evaluation of their contribution to the industry.*

Recommendation 2 *There should be a potato industry "implementation plan" that identifies all of the activities required to achieve each key strategic objective, including R&D, and which is the basis for program and project selection and management.*

The management and evaluation of some program areas would also be facilitated by the availability of specific plans that identify outcomes and pathways. For example, there is no potato industry plan for sustainable production and the environment; without such guidelines previous work in this area has targeted specific issues and problems without necessarily contributing in any structured or prioritised way to the attainment of an industry objective for sustainability, or of environmental responsibility.

In the case of the complex and expensive area of soil-borne diseases it appears that individual researchers and institutions have developed their own R&D strategies. Funding for this work is highly competitive and potentially useful work is sometimes put at risk because of variable commitment to the particular research approach by funding decision makers. Again, the project planning process would be well served by having a research strategy for each of these program areas, whose technical merit is agreed between researchers (and reviewers), and which is signed off by the R&D Committee and HAL. Subject to regular reviews of project outcomes and costs this plan should set the direction for future funding and projects, and coincidentally provide a degree of security to the program that currently doesn't exist.

Recommendation 3 *The Potato Industry R&D Committee should develop and publish research plans for soil- and tuber-borne diseases.*

Recommendation 4 *The Potato Industry should identify and publish its objectives for sustainable production and the environment, and develop its R&D strategy for these in accordance with identified priorities*

MEDIA SUMMARY

The Australian potato industry has invested over $15 million in research and development activities since the beginning of the levy funding arrangements in 1991. This project was commissioned to analyse the success of this investment, by quantifying the benefits that have accrued from research in eleven program areas, and that will accrue over a twenty year timeframe, and comparing these with the costs of the original R&D. All comparisons were based on net present value derived using a standard 8% discount rate.

Under the current arrangements levies are contributed by growers, processors and seed growers. Argument is presented to suggest that the real economic benefits of R&D tend to migrate "up the chain", ie that processors and wholesalers/retailers eventually benefit most through reducing grower prices, more or less in accordance with growers' ability to reduce production costs and to stay in business as prices decline. While it probably doesn't matter who pays the levy, it is clear that growers' customers are the principal beneficiaries.

Not all programs could be analysed using the conventional economic measures of Net Present Value (NPV), Benefit:Cost Ratio (BCR) and Internal Rate of Return (IRR). Some, including elements of the environmental program could only be assessed qualitatively, while others that were considered to be potentially valuable were assessed prospectively. Examples include the two processing potato breeding initiatives in which programs are to be tailored to the specific needs of each of the processing companies.

On these bases, the eleven program areas that were considered in this analysis were categorised as follows:

Highly effective investments

- Integrated pest management
- Cadmium
- Potato cyst nematode
- Industry development (crisping)
- Quality assurance
- Aspects of the resource management (sustainable production systems) program

Ineffective investments

- Export market development
- Breeding (of public varieties

Potentially effective investments

- Breeding for French fry and crisp processing, subject to the adoption of processor-led, individual chain programs leading to unique proprietary varieties and effective competitive advantage for each of the processors.

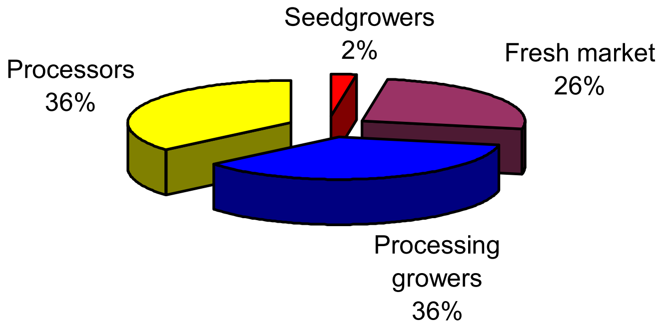
- Breeding for fresh market potatoes, subject to the development of similar partnership arrangements to those that are currently being agreed with the processors.
- Tuber borne diseases (rhizoctonia and common scab).
- Resource management (subject to identification of industry objectives and development of R&D strategic plan).
- Industry development (Atherton)

The R&D program has been an effective investment for the potato industry. With better selection of programs and projects, based on economic analysis of total program costs to the point of industry adoption, and realistic estimates of industry benefits the economic returns on the investment could be enhanced even further. This approach must include consideration of the most effective drivers to adoption, and a willingness to consider new and innovative approaches to ensuring that industry achieves the potential set by the research. This will require a more focused and analytical approach to both industry- and R&D planning.

CHAPTER 1 - INTRODUCTION

Since the introduction of the industry levy funding arrangements for potato R&D in 1991, some $15 million of grower, seed grower and processor contributions have been applied to a range of projects, collectively designed to improve the industry's competitive position, and its environmental sustainability. The project range is comprehensive, and includes activities in the areas of genetic improvement, pest and disease management, crop agronomy, and production efficiency, and generally speaking reflects the industry's strategic and R&D plans. Some projects have explored opportunities for increasing market performance, and more recently, ways of better meeting customer needs through the development and application of through-chain quality systems.

The funds are contributed by three industry sectors, the seed growers who pay 50 cents per tonne of seed, fresh market growers, who also pay 50 cents, and processors and their growers who **each** pay a levy of 50 cents per tonne. For an industry of about 1 million tonnes, based on a certified seed base of 50,000 tonnes, this means that the sectors contribute in approximately the following proportions:



These funds are then matched by the Australian Government on a dollar-for-dollar basis.

This project was commissioned by Horticulture Australia Ltd (HAL) on behalf of the Australian potato industry to evaluate the commercial, environmental and social effectiveness of the R&D investment over the life of the program.

The funding arrangements have been in place now for more than ten years and many of the projects have been completed and the results made available to the industry. In some cases these have been widely adopted and incorporated into routine industry practice. Many projects have no immediate commercial or practical outputs in their own right. They contribute indirectly (or perhaps later) to commercial outputs. As an example, the early work on potato cyst nematode was necessary to provide the knowledge base that was later used to construct the industry's PCN management plan, which became available in late 2002, and more than 10 years after PCN was first discovered in the country. Similarly, cadmium became an issue for the industry in the early 90's, and all of the investment to date has been to provide the data that has enabled the development of an industry management plan and regulatory change for cadmium, which is the only output that matters to the growers and their customers. Focusing on individual projects is therefore of little use when trying to identify their value to industry, each must be considered in the context of the overall industry problem, and its contribution to the final commercial or environmental benefit. Some projects, such as those on soil borne diseases are at an early stage in this cycle and it may be many years before their full impact on the industry can be realised.

This project responds to industry questions concerning value for money, and the relative effectiveness of alternative R&D investment strategies. It identifies the outcomes of a range of R&D activities and their costs, and presents its findings in terms of the benefit received in relation to the costs incurred. The approach follows industry's request for a project by project analysis, although for the reasons given above, concentrates on whole program areas rather than individual projects. The programs selected for the study include:

- Programs designed to overcome a specific problem or impediment to industry development. These projects are focused, discrete and typically inexpensive (in relative terms). Two examples are PCN and cadmium.
- Programs of special interest to various industry sectors. These include projects related to seed quality and production, projects related to the development of the crisping or french fry industries, and projects designed to improve grower efficiency, such as the regional industry development projects at Atherton or in the NSW Southern Highlands.
- Major and financially demanding strategic programs whose full benefits may yet be unrealised, eg soil borne diseases and genetic improvement.

It is seldom possible to objectively measure the impact of a particular research activity, and it is usually necessary to work from a set of (often arbitrary) assumptions regarding what might have happened had the research not been conducted. For example, in looking at the impact of a management practice on the spread of a pest or disease, the usual approach is to compare the measured or expected effects against an assumed rate of spread and industry impact (ie. in the absence of the practice). Different scenarios can be developed to provide a sense of the potential value of the practice in each of these circumstances, which can be varied and made more precise if and as better data becomes available. Individual readers may wish to substitute different assumptions to suit their own circumstances; those used here were selected on the best available information, but seldom represent the only available options, even within the immediate timeframe.

Finally, the study was undertaken with a national perspective. This differs from some previous studies that evaluated the benefits of a particular research activity to an individual state or area. While these studies might indicate a positive benefit to that state or region, it does not necessarily indicate a net benefit to the national industry, nor a useful deployment of national levies. A research or extension activity that simply shifts benefits between regions, or between individuals within the industry has a zero net benefit, and is of no national value.

1.1 Project outputs

The terms of reference for the project, and the specific deliverables agreed by the project management committee were as follows:

1.2 Terms of reference

1 To analyse and report the benefit: cost ratios for research and development projects undertaken on behalf of the levy-paying Australian potato industry since the beginning of the levy arrangements in 1991.

2 To report the benefits received by the various industry sectors, crisping, french fry, fresh market and seed.

1.3 Project deliverables

The project management committee has requested the following outputs. Not all forms of analysis or all outputs are appropriate in all of the project areas to be studied, so some discretion will be necessary on behalf of the project team in analysing the data, and preparing the report. The requested deliverables are:

1. Benefit:cost ratio (BCR) expressed in NPV terms, over a twenty year period.
2. Breakeven point for each program area studied
3. Sensitivity analyses indicating breakeven points in terms of the rate of industry adoption of the research outputs.
4. A comprehensive economic analysis
5. Reporting of economic, environmental and social benefits.
6. A ranking of program areas on the basis of their relative returns on investment
7. An economic model for use in ranking and selecting future R&D programs and projects,
8. An analysis of processor benefits from R&D.
9. Where possible, reports to be presented on a sectoral basis, ie, processing, fresh, and seed.

In subsequent discussions with the management committee, it was agreed that IRR's (internal rate of return) should also be generated during each analysis, and that the BCA's and IRR's should be presented for both the full twenty year period, and for the shorter period ending in the selected "base" year, 2000.

The agreed program areas to be included in the analysis are:

1 Cadmium

2 Genetic improvement
3 Integrated pest management
4 Potato cyst nemetode
5 Tuber-borne diseases (R*hizoctonia* and common scab)
6 Resource management and protection
7 Quality assurance/HACCP
8 Regional industry development project – Southern and Northern Highlands
9 Regional industry development project-Atherton
10 Regional industry development project – Crisping group
12 Export market development

CHAPTER 2 - PROJECT METHODOLOGY

2.1 Introduction

The general approach to most economic evaluations of rural research, which is outlined in Appendix A, is to estimate the value of that research in terms of its contribution to the "net social welfare" of a society (e.g. a state or a country). The measure of net social welfare is made by adding up the net benefits to various groups (e.g. producers, processors and consumers) in the society.

In this study, the authors were asked to estimate the net benefits of a series of research projects to potato growers and, in some cases, to potato processors. We were specifically asked not to attempt to estimate the benefits of the research to consumers. For this reason, we have not used the full cost benefit analysis normally used to evaluate rural research (see Alston, Norton and Pardy 1998). Instead the cost-savings approach, discussed by Johnston, Healy, L'ons and McGregor (1992) and also briefly outlined in Appendix A, is used.

2.2 Implementation of the cost saving approach

The calculation of the cost savings is based on gross margins budgeting. This budgeting technique is widely used in farm management. Standard gross margin budgets are available from state departments of agriculture for most important agricultural industries. Gross margins budgets for potatoes under Australian conditions are available on the World Wide Web[1], for example NSW Agriculture (2001) Potato Fresh, Summer Crop, Spray Irrigated; Potato Processing, Summer Crop, Spray Irrigated; Potato Fresh, Winter Crop, Spray Irrigated and Department of Primary Industries, Water and Environment (2002) Cash Crop Enterprise Budget - Low Rainfall and Cash Crop Enterprise Budget - High Rainfall.

In calculating cost savings the gross margins budgets are modified to reflect the changes in technology resulting from the research. Any change in fixed farm costs that results from the change in technology is also considered. The process implies considerable knowledge of the technology of the industry in question and also implies knowledge of the size of the industry i.e. the number of current and potential producers. The other important factor to consider is the adoption rate and adoption ceiling of new technology.

---

[1] The two major sources of gross margins budgets used in this report are from NSW Agriculture and Deparment of Primary Industry and Energy in Tasmania. For the NSW data, http://www.agric.nsw.gov.au/reader/ then follow the links Farm Business and Trade, then Vegetable Gross Margins to the various potato gross margins. The Tasmanian data is in the form of downloadable Excel spreadsheets http://www.service.tas.gov.au/av/Topic.asp?Topic=Primary+industry+and+energy/, then follow the link Farm Management, then Agricultural Economics and Management, then download the spreadsheets Cash Crop Enterprise Budget - High Rainfall and Low Rainfall.

In several cases in this study, partial budgeting techniques were combined with gross margins budgets. This was done where the outcome of the research project under consideration led to changes in some components of the gross margins budget, but not in other components. The costs and benefits associated with the outcome of the research were then calculated from the changes in the gross margins budget.

2.3 Costs and benefits over time

When costs and benefits accrue through time a method is needed to value them at a common point in time to allow valid comparison of the various models. In this case, the costs and benefits are associated with various research projects that accrued costs and delivered benefits at different times in the period under consideration.

There are several discounted cash flow methods for making these comparisons. Of these, **net present value (NPV)** is the most generally accepted (see Levy and Sarnat 1994) chapters 3 and 4). Net present value can be thought of as a measure of "profitability" though time. It is the amount the project has or will return, in excess of "breakeven". The greater the net present value, the more desirable is the project economically.

The net present value is calculated by first budgeting cash flows on a yearly basis. The cash flows are multiplied by a present value factor, which is in turn based on a given discount rate (similar to an interest rate). The resulting discounted cash flows are summed to produce an estimated net present value.

In this particular case, the net present values are calculated as at the year 2000. All (nominal) cash flows prior to this year are first converted to real year 2000 values by multiplying by the consumer price index with a base year 2000 = 100.[2] The CPI data was sourced from Australian Bureau of Statistics (2000). These real values are compounded forward to the year 2000. The nominal cash flows on which these calculations are based are the actual cash flows that have occurred and have been recorded by institutions such as the Australian Bureau of Statistics[3], the Horticultural Research and Development Corporation (Annual Report) and more recently Horticulture Australia (Annual Report). The cash flows occurring after 2000 are generally estimates based on year 2000 data. They are assumed to be real money values. No annual growth rate in the money values is assumed and no CPI future estimates are used as such conversions would contain elements of double counting. Estimated post 2000 cash flows are discounted back to year 2000 values. The benchmark discount rate is 8 percent (recommended by Department of Finance 1991) but sensitivity analysis using 5 percent and 11 percent is included.

The other discounted cash flow methods used in this study are the internal rate of return (IRR) and the benefit cost ratio (BCR). The **internal rate of return** is the rate of discount that equates the present value of benefits with the present value of costs

---

[2] CPI data from http://www.abs.gov.au/Ausstats/abs%40.nsf/c08c69053a26f3e2ca2568b5007b861a/6606103a4fc05737ca25699000802e4c!OpenDocument

[3] Potato production and value data from Australian Bureau of Statistics various dates, Agriculture Australia 7113., Australian Bureau of Statistics, Canberra.

associated with an investment project. The **benefit cost ratio** is the discounted value of benefits divided by the discounted value of costs.

Net present value and the benefit cost ratio give consistent results. However, net present value measures the magnitude of the net benefits whereas the benefit cost ratio is purely a ratio. Benefit cost might, for example, indicate a value of 2 for a project where the discounted costs are $1 and the discounted returns are $2, and the same value of 2 where the discounted costs are $1,000,000 and the discounted returns are $2,000,000. In this example case, net present value would give a value of $1 for the first example and $1,000,000 for the second. A project with a net present value of $1,000,000 is obviously preferable to one with a net present value of $1. Projects can be ranked on the basis of the net present value.

The results derived from the internal rate of return are usually consistent with net present value and benefit cost ratio. However there are circumstances under which internal rate of return will give results that are not consistent with the other measures, or gives multiple solutions, or cannot be calculated. This occurs when there are alternating positive and negative cash flows. Internal rate of return has also been criticized using the same argument as above for the benefit cost ratio, that is, it does not provide a measure of the magnitude of the net benefits of a project. However, many people prefer internal rate of return over the other measures because it gives a result that (superficially at least) is like a simple accounting return on capital invested. However internal rate of return is more complex that a simple accounting return in that it does consider the timing of the costs and benefits of a research project.

Most authorities regard net present value as being at least as good as the benefit cost ratio and internal rate of return under all circumstances, and superior to benefit cost ratio and internal rate of return in the circumstances outlined above. All three measures of discounted cash flow as a means of evaluating the economic performance of a research project are reported here, so that readers may choose the measure with which they are most comfortable.

2.4 Limitations of the economic analysis

A major limitation of any economic analysis is the availability of reliable data. Broadly, the data used in this analysis is aggregate production and value statistics published by the Australian Bureau of Statistics and gross margins data gathered from a variety of sources. It is very difficult to gather reliable information on the production of different varieties, in different regions of the various producing states, and used for different purposes (eg. seed, fresh market, and various forms of processing). A case could be made for the collection (or collation) of more of these data by either the Australian Bureau of Statistics or Horticulture Australia Limited.

For horticultural products in general in Australia, and potatoes in particular, there is little recent research reported on the economics of the structure, conduct and performance of the markets through which these products pass. Knowledge of the structure, conduct and performance of an industry is important in accessing the competitiveness of the various links in the marketing chain in the industry. If, for example, many small producers with no market power sell to a single processor who is prepared to exercise market power, the distribution of returns to research in the industry will be different to the situation were there are many small producers and many small processors. There has been research on the structure, conduct and performance of horticultural industries in the USA, Canada, the UK and other European countries but little recent research of this type in Australia in recent years. Exceptions are Industry Commission (1993) and Stanford, Van Hilst and Connell (1995). Again, a case could be made for the funding more of this type of research.

A detailed analysis of the consequences of the potato research projects in terms of net social welfare, which is the usual way in which the benefits and costs of research are evaluated, requires additional data on the nature of the supply of, and demand for, the various potato products.

2.5 Previous studies

In most studies, the returns from investment in agricultural research have been shown to be well above generally accepted measures of 'a social discount rate' or 'social opportunity cost of capital'. This work has been extensively reviewed (see, for example, Alston, Norton and Pardy 1998).

Unfortunately there have been few studies of the returns from investment in research into potatoes. An exception is Araji, White and Guenthner (1995) who found the internal rate of return to research into potatoes in the US to be about 80%. In Australia, a limited number of economic studies on various aspects of research in the potato industry have been conducted. Strange and Morison (1996) considered the cost and benefits of integrated pest management research, but did not conduct a full scale cost benefit analysis. Black (1996) estimated the net present value of the South Australian potato variety improvement program at about $8.6 million for the period 1982 to 1995. EconSearch Pty Ltd (1998) conducted a benefit cost analysis of the research done by the CRC for Soil and Land Management on cadmium in potatoes. This study estimated the net benefits of the research at about $9 million. ACIL (1999) estimated the returns to potato breeding and concluded that '(t)he breeding program has the potential to deliver economic benefits to the industry if, and only if, it is well targeted, completed in a faster time frame that has previously been the case and at lower cost.'

2.6 References

ACIL (1999), Potato breeding: returns from future investments. Report to the Potato Industry Committee of HRDC.

Alston, J.M., Norton, G.W. and Pardy P.G. (1998), *Science under scarcity: principles and practice for agricultural research evaluation and priory setting*, CAB International, Wallingford.

Araji, A.A., White, F.C. and Guenthner, J.F. (1995), Spillovers and the returns to agricultural research for potatoes. *Journal of Agricultural and Resource Economics*. 20(2) 263-76.

Australian Bureau of Statistics (various dates), Agriculture Australia 7113, Australian Bureau of Statistics, Canberra.

Australian Bureau of Statistics (2000), Consumer Price Index, Australia 1900-1, Australian Bureau of Statistics, Canberra.

Black, I.D. (1996), *A benefit-cost analysis of the South Australian Potato Variety Improvement Program 1982-95*, South Australian Research and Development Institute, Adelaide.

Department of Finance (1991), *Handbook of cost-benefit analysis*, AGPS, Canberra.

Department of Primary Industries, Water and Environment (2002), Crop gross margins budgets, http://www.service.tas.gov.au/av/Topic.asp?Topic=Primary+industry+and+energy/

EconSearch Pty Ltd., Agtrans Research and McColl Consulting (1998), Final report impact assessment for CRC for Soil and Land Management, Cooperative Research Centre for Soil and Land Management (CRCSLM), Adelaide.

Horticulture Australia (2001), *Annual Report*, Horticulture Australia, Sydney.

Horticultural Research and Development Corporation (various dates), Annual Report, Horticultural Research and Development Corporation, Sydney

Industry Commission (1993), *Horticulture*, Report No 29, Australian Government Printing Service, Canberra.

Johnston, B., Healy, T., L'ons, J. and McGregor, M. (1992), *Rural Research—The Pay-Off*, CSIRO Occasional Paper No 7, Canberra.

Levy, H. and Sarnat, M. (1994), *Capital Investment and Financial Decisions*, Fifth Edition, Prentice Hall, New York.

NSW Agriculture (2001), Crop gross margins budgets, http://www.agric.nsw.gov.au/reader/

Stanford, L., Van Hilst, R. and Connell, P. (1995), *Vegetables for human consumption: an overview of the Australian industry*, Australian Bureau of Agricultural and Resource Economics, Canberra.

Strange, P. C. and Morison, J. (1996), Comparative benefit cost of IPM and conventional pest management in potatoes, Horticultural Research and Development Corporation.

CHAPTER 3 – INFORMATION SOURCES

The analyses contained in this report relied on the availability of industry statistics and program information. While much of this data was available from HAL, the industry itself or from various R&D providers, the lack of reliable and detailed production statistics, particularly for fresh market production, was a difficulty that the reviewers found hard to overcome, and which ultimately limited the accuracy of some of their conclusions. The following data sets were used in the analyses, and where appropriate are included in the appendices:

3.1 The projects

The study reviewed the costs and benefits of eleven areas of the levy-funded potato R&D program. The projects which were agreed to represent those program areas, and the actual costs (not in NPV terms) are listed at Appendix F. Where economic analyses were conducted, the costs were converted to year 2000 values for comparison with similarly standardised assessments of the program, or project benefits. Those figures are not included in the appendix.

3.2 Potato production, national and regional (by area)

Appendix G

3.3 Potato production, by end use

Appendix H

3.4 Levy collections for potato R&D

Appendix I

3.5 Gross margins (of production)

Gross margins of production which were used in these analyses were obtained from several sources, and used in accordance with the particular requirement of each analysis. That is, wherever possible the Queensland gross margins were used in evaluating program impacts in that state, and in NSW, local data were also used. The following gross margins were available to the authors:

NSW Agriculture Farm Enterprise Budget Series, gross margins for Potato – Processing, -Fresh, and –Winter fresh (all 2001)

Queensland Horticultural Institute Potato Information Kit, Annual Update 1998. Agrilink series, Department of Primary Industries, Queensland.

Department of Primary Industries, Water and Environment (2002), Crop gross margins budgets, http://www.service.tas.gov.au/av/Topic.asp?Topic=Primary+industry+and+energy/

CHAPTER 4 - CADMIUM

Cadmium is a heavy metal that is known to cause kidney failure when present in sufficient quantities in the body. In general, the amount of cadmium ingested by Australian consumers is low by world standards, though, in 1994 potatoes provided the largest single source of cadmium in the Australian diet (Evans *et al* 1997).

Cadmium is poorly excreted and accumulates in certain organs in the body so even a small daily intake over many years may result in harmful effects on human health (though in reality, evidence of disease from dietary cadmium uptake is rare). The three principal sources of cadmium in humans are smoking, industrial pollution, and dietary intake.

The way in which plants uptake the metal from the soil, the patterns of accumulation in various organs and the environmental and genetic influences that determine the levels in the edible plant parts are poorly understood and have only recently been studied in any detail. Superphosphate is the main source of soil cadmium,; different forms of superphosphate vary in their content depending on the source of rock phosphate used in manufacture.

As for all heavy metals, Australian food legislation prescribes maximum cadmium tolerances in many foods. Moluscs and animal offal are the most concentrated sources of dietary cadmium, so were allocated specific MPC's (maximum permissible concentrations) based on known consumption patterns and medical evidence in the earliest editions of the Food Standards Code of the Australian and New Zealand Food Authority (ANZFA). In the absence of supporting evidence, "all other foods" were treated homogeneously with an MPC of 5ppm, which was expressed in potatoes as 5mg Cd/kg of tuber weight **as eaten**. This was an unsatisfactory situation for the potato industry for several reasons:

- Because potatoes represent a large part of the diet they were identified, by many in the industry, as an obvious target for regulators.
- Even the best of the low-cadmium forms of superphosphate supply cadmium to the soil at a higher rate than it is being exported in the commodity.
- Processing, especially crisping concentrates the metal even further in the finished product.
- Some local media campaigns had disadvantageously highlighted these issues in the public arena
- There was no supporting evidence to indicate that 5ppm was an appropriate standard anyway.

While the standard had not been administered prior to the project it became increasingly apparent from the profile the subject was receiving in the press from about 1991 that this situation could not continue indefinitely. On the basis of analytical information that had been collected within the industry it was clear that some important potato districts were at considerable threat because of the high proportion of samples that were either at, or above the MPC, so industry needed to act to avoid potentially serious impacts on both its production base, and its marketing capability.

4.1 The program

The industry response to the threat posed by out-of-tolerance cadmium levels in potatoes occurred in two parts, the first in 1990 in Tasmania where the industry participated in a program to reduce cadmium contamination in vegetables and poppies (VG011, VG99042), and later a more focused program of activities specifically targeting cadmium in potatoes. These were conducted by CSIRO Division of Land and Water, under the leadership of Dr Mike McLaughlin, in collaboration with departments of agriculture in each of the States, and in response to the national potato cadmium strategy by APIC (Australian Potato Industry Council). This program of work which commenced in 1992:

- Concluded that Australian soils are generally low in cadmium
- Found that the potato varieties grown in Australia are highly susceptible to cadmium accumulation
- Identified the regional differences in cadmium uptake by potatoes, and regions with higher risk of excessive cadmium accumulation,
- Established that cadmium was a problem for all states,
- Established that about 25% of potatoes exceeded the MPC nationally,
- Linked high tuber cadmium to high soil salinity
- Identified that historically, phosphatic fertilisers used in Australia are high in cadmium, due to the source/s of rock phosphate and the manufacturing process used. These fertilisers are the main source of the cadmium problem in potatoes.
- Found that cadmium uptake is increased where
    - soils are sandy and low in organic matter. Cadmium attaches to clay particles and organic matter making it less available to the plant.
    - pH is low. Cadmium is less available to plants as pH increase.
    - zinc levels are low. Cadmium and zinc substitute for each other, thus with more available zinc in the soil, less cadmium is absorbed.
    - chlorine is available either from saline water or saline soil. Chlorine appears to mobilise cadmium.

This work clearly confirmed that the continued development of the industry was under threat, and that if the standard was to be observed there would need to be a significant restructuring of the industry to less risky areas where a higher level of compliance could be assured. On the other hand, the standard itself had not been established on the basis of any scientific evaluation of the industry or of the threat posed by cadmium in potatoes.

Using the data collected in these projects industry successfully sought a review of the standard with the result that it was:

- raised from 0.05 to 0.10 mg/kg,
- as measured in the raw tuber.

Nationally this reduced the non-compliance level from 25.6% to less than 5%.

Subsequent to this the program has produced best-practice guides for reducing cadmium in potatoes that have been widely distributed amongst growers and industry advisers. Examples are Bourne and Seelinger (1999), CRC for Soil and Land Management (1999), McPharlin (2001), McLaughlin (undated) and Williams, Jackson and Maier (2000). Some of these guides are available as downloadable pdf files on the internet[4].

In addition the research has contributed to changes to the manufacture and use of fertilisers with lower cadmium analyses, though the main driving force behind these changes was the increasing concern over the build up of cadmium in pasture and cropping soils.

While the program has had a significantly beneficial impact on the industry's ability to continue, the problem of cadmium hasn't been solved; the work to date has provided some important breathing space but not a solution. Even with the best fertilisers cadmium is being applied to soils at a faster rate than it is being removed by the tubers so it is only a matter of time before the problem re-emerges as a critical issue for the Australian potato industry. Next time, changing the Standard won't be an option. The research project PT96020 (*Mechanisms of cadmium accumulation by potato tubers*) is an important (if lonely) contribution to a more permanent result; its longer term goal is to pave the way to preventing cadmium reaching the tubers. Unfortunately this work is not to be continued within the current funding program.

4.2 Options for industry

Had the regulatory change not been achieved, growers would have had the following response options:

- Move out of potato production into the next best production alternative; or relocate potato production to a more favourable site (both expensive) In this analysis it was assumed that the alternative is beef cattle weaner production with gross margin of $30 per cow. The gross margin per hectare depends on the stocking rate but is insignificant when compared to the gross margin for potatoes of about $5000 per hectare. The base (and very conservative) assumption is that no land is removed from potato production, with sensitivity analysis up to 10% of affected area being removed from production. Relocation costs were not considered.
- Adopt management practices as identified in the Strategy to minimise uptake. They include a combination of water quality, improved soil management practices, low cadmium fertilisers etc. It is conservatively estimated that the additional cost associated with these practices is $100/ha, annually.

4

http://www.affa.gov.au/corporate_docs/publications/pdf/oper_env/armcanz/cadmium.pdf
http://www.clw.csiro.au/publications/general2002/Cd-in-Potatoes-Managing-risk-brochure.pdf
http://www.agric.wa.gov.au/agency/Pubns/farmnote/2001/f10701.pdf

4.3 Economic analysis of the research program

As indicated above, if the research had not been successful and the MPC had not been increased, potato growers in the affected areas would have faced increased management costs, estimated using simple gross margin budgets at $100 per hectare. A sensitivity analysis was conducted for costs of $50 and $200 per hectare.

4.3.1 Assumptions

1) In terms of national production, it was assumed that 25% of production would not have met the “old” MPC of 5mg/kg in raw potatoes. This is a conservative assumption given the reported values for non-compliance of 25-50% (Evans *et al*, 1997; McLaughlin, *et al* 1997). The likely impact of the higher estimate is tested in this analysis by means of the sensitivity analysis.
2) The proportion of potato production in each state that could not comply with the “old” MPC was as follows:

NSW	Vic	Qld	SA	WA	Tas
25%	30%	0%	50%	33%	0%

3) It was assumed (as a base, conservative assumption) that all growers, in each state, would have been able to comply with the “old” MPC by adopting a recommended “package” of management practices, at an increased cost of production.
4) However, it is clear that some growers, in situations where cadmium uptake by potatoes is high, could not have complied with the “old” MPC regardless of the management practices used. In a sensitivity analysis, it was therefore assumed that 10% of the above production in each state would be in this situation (for example, 10% of 25% = 2.5% of production in NSW). In this case it is assumed that potato production would cease and be replaced by beef cattle production, with a low gross margin per ha, when compared to potatoes. An obvious alternative assumption is that growers would have to relocate, but costing such a possibility was beyond the scope of this study.
5) If the “old” MPC had not been changed, it was assumed that it would have been enforced in 1997. Thus, the adoption of the management changes, or the switch to beef cattle, under the “old” MPC was assumed to be sudden and complete in 1997.

4.3.2 Results

The breakeven point for this program came very early as the benefits of the research were effectively realised on the assumed date of enforcement of the old standard, in 1997. The present value of benefits and cost stream arising from the research program are illustrated in Figure 4.1.

The sensitivity of the discount rate (5 and 11%), the variable costs (of adopting recommended agronomic practices) ($50 and $200/ha) and the affected proportion of

production (from zero to 10%, or from 25 to 30%) in determining the NPV were also tested, and the results summarised in table 4.2. These illustrate firstly the beneficial nature of the research, almost regardless of the assumptions, but also how a minor shift in the assumptions, for example in relation to the proportion of industry assumed to be unable to comply with the legislation, might increase the economic outcomes of the research even further, perhaps to as much as $33 million over the twenty years.
In the sensitivity analysis only the net present values are reported in Table 4.2.

4.3.3 Discussion

This has been an effective piece of research that has allowed the industry to continue without major disruption, and at significant saving, conservatively estimated at around $5.768 million over a twenty year time frame (table 4.1), and extending well into the future (figure 4.1). As the altered MPC will continue to benefit the industry indefinitely, the overall economic benefit will extend beyond this amount as long as potatoes comply with the standard, and as long the standard remains unaltered. It is noteworthy that a previous economic analysis of this research identified $9 million in benefits over a similar timeframe (EconSearch, 1998). This is further confirmation of the conservative nature of the current approach, and also of the tactical importance of the research program itself.

The benefit cost analysis further indicates the value of the research; it is unusual to record such a strongly positive value within so few years after the completion of a research project, or such a high value (as 24%) over the lifetime of the analysis. The IRR values are also exceptionally high and indicative of a well targeted and implemented research subject.

Table 4.1 Economic value of the cadmium research program using the 'base' assumptions

Performance measure and time period	8% discount rate for NPV and BC
NPV 1992-2020	$5,768,000
NPV 1992-2000	$1,290,000
BC 1992-2020	24
BC 1992-2021	6
IRR 1992-2020	73%
IRR 1992-2000	66%

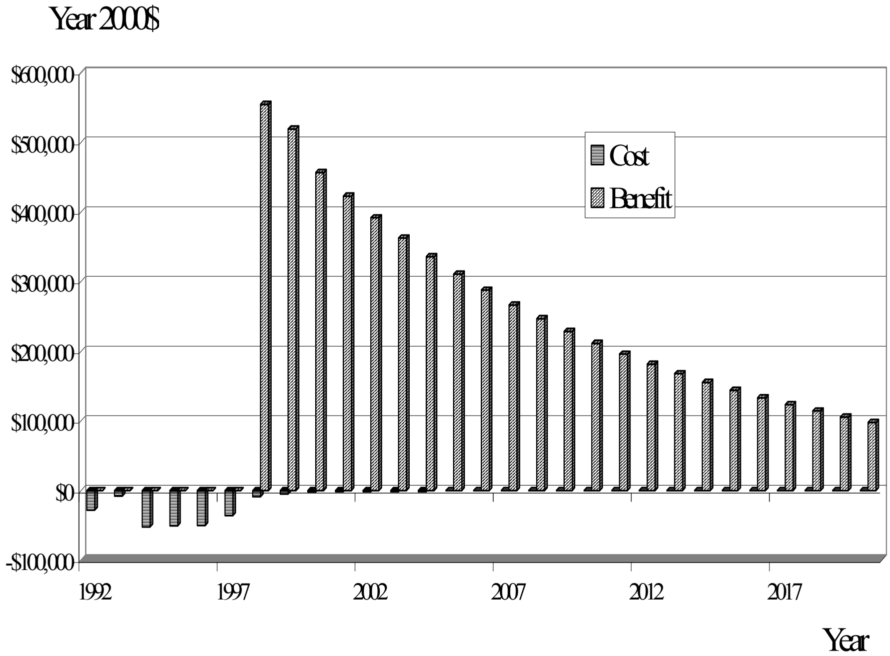
4.3.4 Environmental and social benefits

The main social outcome of this research was an increase in the MPC for cadmium. It was argued that the "old" MPC applied to potatoes was too restrictive and that, based on a review of public health considerations, the change in the MPC was reasonable. However, cadmium is toxic and in human health terms "less is better than more". It is possible that future research on the effects of cadmium on human health may suggest a more restrictive MPC than that currently imposed.

The environmental benefits of the research come from the improved knowledge of the major source of accidental application of cadmium via phosphatic fertiliser and of the agricultural management possibilities for reducing cadmium in potatoes.

There is a spillover effect (externality) of the improved knowledge of fertiliser to other agricultural industries. Lower cadmium fertilisers would also benefit the livestock industries, especially fat lambs, and also perhaps the broad-acre cropping and vegetable industries which are also subject to prescribed cadmium standards.

Figure 4.1 Present value of benefits and cost stream arising from the cadmium research program



4.4 Conclusion

Using conservative assumptions the present value of the research program was clearly and massively positive. The change in the MPC to 0.1 mg/kg fresh weight was the most influential factor resulting from the program.

The soil-plant-water research which was conducted within this program has identified risk factors and management responses to reduce tuber cadmium concentrations and which have underpinned the industry's cadmium strategy.

Most importantly for future research planning is the observation that the cadmium content of even the best of the "low cad" fertilisers is such that cadmium inputs in the potato cycle exceed the exports, leading inescapably to the conclusion that the current research has only bought time, and that without serious attention to alternative management strategies in the short to medium term, the next generation of growers and researchers will be faced with the same problem that was addressed by these projects, but without the option of changing the regulatory standard. Now is clearly the time to start thinking about new approaches to growing potatoes under such regimes.

Table 4.2 Changes in net present value depending on changes in assumptions

Item	Value	Time period	Net present value
Change discount rate	5%	1992-2000	$1,644,000
Change discount rate	5%	1992-2020	$8,970,000
Change discount rate	11%	1992-2000	$1,017,000
Change discount rate	11%	1992-2020	$3,855,000
Increased variable cost that did not occur as a result of the research	$50/ha	1992-2000	$525,000
Increased variable cost	$50/ha	1992-2020	$2,761,000
Increased variable cost	$200/ha	1992-2000	$2,821,000
Increased variable cost	$200/ha	1992-2020	$11,783,000
Percentage of affected area unable to meet MPC increased from 0% to	10%	1992-2000	$8,324,000
Percentage of affected area unable to meet MPC increased from 0% to	10%	1992-2020	$33,382,000
Affected area increased from about 25% to	30%	1992-2000	$1,700,000
Affected area increased from about 25% to	30%	1992-2020	$7,395,000

4.5 References

Bourne, J. and Seelinger, M. 1999, *Cadmium in potatoes; managing the risk from saline irrigation water*. CRC for Soil and Land Management, Adelaide.

CRC for Soil and Land Management. 1999, *Managing cadmium in potatoes for quality produce*, second edition. CRC for Soil and Land Management, Adelaide.

EconSearch Pty Ltd., Agtrans Research and McColl Consulting 1998, *Final report impact assessment for CRC for Soil and Land Management*, Cooperative Research Centre for Soil and Land Management (CRCSLM), Adelaide.

Evans, G. *et al* 1997, *Managing cadmium in agriculture and food; issues for government*. Bureau of Rural Sciences, Canberra.

McLaughlin, M.J. *et al*. 1997, Cadmium in Australian potato tubers and soils, *Journal of Environmental Quality*, 26, 1644-1649

McLaughlin, M.J. undated, *Australian agriculture acts to reduce cadmium levels*, CSIRO Land and Water, Glen Osmond.

McPharlin, I. 2001, *Phosphorus fertiliser management of potatoes on sands*, Department of Agriculture, Perth.

Williams, C., Jackson, K. and Maier, N. 2000, *Agronomy overview - best management practices and future directions*, Australian Potato Research, Development and Technology Transfer Conference 31 July to 2 August, 2000. Adelaide.

CHAPTER 5 - GENETIC IMPROVEMENT

The Australian potato industry has long recognised the value of genetic improvement, for its contribution to grower productivity, and to the quality and value of potatoes in the retail market or at the processing plant. While there have been several Government improvement programs in the country for many years (now only one, at Toolangi in Victoria), their principal contributions (before the levy) were through the importation of outstanding varieties from overseas programs. The benchmarks for the processing and fresh market industries were set by the importation and successful adaptation of three varieties, Sebago for the fresh market, Atlantic for crisping and Russet Burbank for french fries. The Australian-bred Coliban that was released in the 1970's created a market for fresh washed potatoes and until recently has been unchallenged for that purpose. These varieties set a high standard for further improvement, and are the benchmarks for the levy-funded improvement program at Toolangi in Victoria, and for that matter, for any other public or private improvement initiatives.

Throughout the levy period the program has released a number of varieties for the three industry sectors. They are categorised in table 5.1 below.

Genetic improvement includes more than breeding and extends to germplasm collection and conservation, varietal evaluation, gene technology and any supporting genetic or other program designed to release and foster genetic improvement in the industry.

Since the inception of the levy scheme, varietal evaluation has also been largely funded from levies. The initial stages of evaluation have been conducted in Victoria under the control of the breeder; their purpose is to characterise genotypes, to provide important data back into the program. Additionally, they identify candidate varieties for further testing and possible commercialisation in the states. Each producing state has traditionally sought funding from the levies for this purpose, either independently or via the National Potato Improvement and Evaluation Scheme (NaPIES). This funding has become increasingly difficult to win in competition with other programs and in 2002 HAL has indicated that it can no longer support this form of activity from the levies, but only by matching voluntary contributions collected on a state basis, by industry.

The gene technology component of the program is under the joint control of the Victorian Department of Primary Industry (DPI) and CSIRO, and aims to introduce virus resistance genes into the new varieties through the initial transformation of key parental lines, initially Sebago, Crystal and 80-90-5, but now including Shine and two other numbered lines. This work is still at an early stage and at this point in time, has not selected lines for use in breeding. The researchers believe that "double resistance" genotypes could become available from the current round of glasshouse and field trials for use in the breeding program from (say) 2005 or 2007. These benefits are factored into the analysis.

Table 5.1 Potato varieties emerging from the Australian levy-funded research and evaluation program

Australian			Imported		
Fresh	**Crisping**	**French fry**	**Fresh**	**Crisping**	**French fry**
Shine	Crispa	Riverina Russet	Trent	Simcoe	Ranger Russet
Ruby Lou	Dalmore	MacRusset	Nadine		Umatilla Russet
Snow gem	Evans		Nicola		
Winter gem	Wilwash		Kipfler		
Otway red	Wilstore		Red Norland		
Lustre	Wontscab				
Brakelight	Sonic				
	Catani				
	Dawmor				

Toolangi is also important for its genetic conservation and preservation activities, which have both national and international significance.

The Toolangi program has traditionally focused on three industry sectors, fresh market, french fry and crisping. In accordance with industry wishes, levy-funded fresh market potatoes have been traditionally released as public varieties, and without the option for exclusive proprietary ownership. The same is true of the processing varieties, although it is likely that new arrangements that will allow each of the industries to pursue their individual breeding objectives within a levy funded arrangement will shortly be agreed. This will have the effect of introducing chain leadership to those programs and should lead to a better matching of varieties to commercial need, a higher level of varietal penetration and economic benefit to both growers and processors.

5.1 The fresh market program

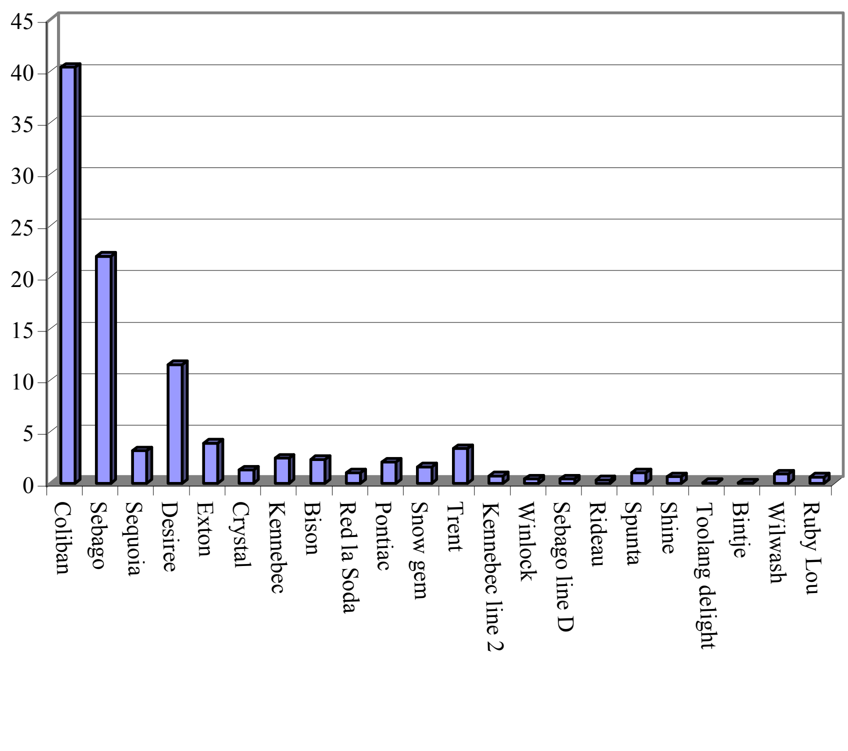
The introduction of a new fresh market variety can have economic impact through increasing grower efficiency (i.e. by reduced input costs), by increasing price, or by increasing the size of the market. On the basis of observed industry behaviour, there appears little evidence that despite their claimed consumer appeal the Australian-bred varieties that have been released from the program (since 1991) have improved grower profitability or retail performance, or prompted any significant interest from seed or ware growers (figures 5.1 – 5.3).

An analysis of the various sectors of the fresh market industry is enlightening, e.g.

- The fastest growing section of the industry is the "washed, white skin" trade that has long been dominated by the (Australian bred) variety Coliban. While several new varieties have emerged from the levy-funded program, the significant development in this part of the industry has been the variety Nadine, a proprietary variety that has the potential to provide additional rewards to growers, wholesalers and retailers. Access to Nadine is limited to a few large growers. It has been well marketed by packaging seed and technical services and its success is a classic case of well-developed marketing chains, strong chain leadership and industry partnership. It would be difficult for any other public washing variety to compete, at least in those areas where Nadine dominates.

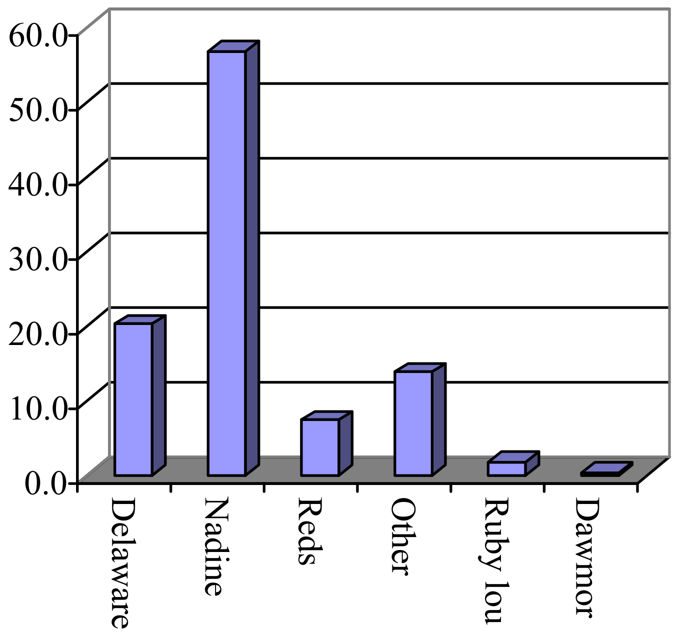
- The "red-skin" market is currently supplied by two varieties, Pontiac (which has some significant disadvantages), and the cream fleshed Desiree. Red skinned varieties represent a small part of the market (figures 5.1-5.3), which is also targeted by a number of new Toolangi releases including Ruby Red and Breaklight. While it is still too early to judge the likely penetration of these varieties in Australia, the indications are that unless they receive strong commercial support from wholesalers and consumers (which is not currently evident), they are unlikely to become major new players in the retail trade. The success of these varieties in funding terms will not only depend on the extent of customer demand, but also on the premiums they generate to the levy payers (growers) via price or productivity benefits. On current knowledge there is no evidence of a price premium, nor is there any basis to anticipate reductions in the cost of production through either yield advantage or reduced input costs.
- The "brushed" potato market is dominated by the variety Sebago. It remains a firm favourite with both growers and consumers (at least in the eastern states), and there are no new or "near market" varieties in the program that are poised to displace Sebago from this position.

Figure 5.1 Certified seed production of fresh market potatoes in 2001/02(percent of total) Source VicSpa



Overall, while it is accepted that these are relatively young varieties, and some have yet to reach the market, the reviewers concluded that in the absence of evidence for market failure in this part of the industry, or of appropriate commercial arrangements and clear economic advantage for the new varieties it is unlikely that they will gain a significantly greater share of the market. Judged purely on the basis of its commercial outcomes, the fresh market breeding program has been unsuccessful in supporting the interests of its levy paying constituency. However, it was also concluded that there are unexplored opportunities available to levy payers by partnering the program with significant wholesale interests to develop commercial chains which are competitive to Nadine and Coliban for example, and which are capable of generating real economic benefit for industry. Without such arrangements it will become increasingly difficult to justify on economic grounds, the continuing public breeding activity for fresh market potatoes in this country.

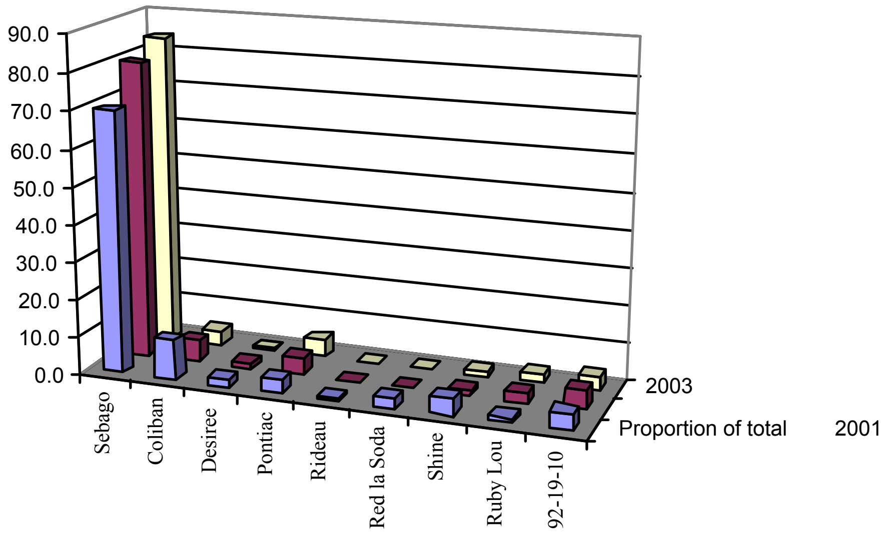
Figure 5.2 Production of commercial potatoes in Western Australia in 2000/01 (percent of total) Source Western Potatoes (2001)



5.2 The crisping program.

Crisping growers are paid on the basis of a set price plus a bonus for compliance to quality standards. Benefits to the crisping industry could occur as a result of reduced input costs (to growers), improved prices due to better quality performance, or (to processors), increased conversion efficiency (via higher dry matters and reduced wastage). The principal elements of the pricing models include dry matter content, compliance to a size standard, freedom from tuber damage and low tuber reducing sugar levels.

Figure 5.3 Minitubers used in the production of certified seed at Crookwell, NSW 2001 (front) to 2003 (percent of total) Source D Carter, pers comm.



No variety that has been produced with levy funds has been widely adopted by the crisping industry thus far. Several are still under trial and it is possible that they may remain in the company programs at a low level, so have been included in this analysis. The reasons for this are not clear. Certainly no variety has comprehensively out-performed the industry standard Atlantic, or provided major support to the companies' year-round fresh supply objectives, for example in winter fresh vs. storage. Notwithstanding this, it is probably also true that the program has failed to provide companies with competitive advantage and it was for this reason that one company contracted separately with the program to supply varieties that are uniquely suited its own particular raw material supply strategy. In recognition of these failings the crisping companies are now negotiating a new arrangement with the program within the levy arrangements that will produce unique proprietary varieties for each manufacturer. The following analysis assumes that this process is successful, and that companies achieve significant quality advantages that reflect in improvements in their own productivity and in grower rewards, as a result of breeding and selection for specific raw material requirements.

5.2.1 Economic analysis of the crisping research program

5.2.1.1 Assumptions

This analysis assumes that by taking control of their individual genetic improvement initiatives, each company receives proprietary varieties that enhance their own particular combination of raw material supply needs of storage, fresh supply from traditional districts and winter-fresh potatoes. The development of these varieties will not commence from a standing start, the program is well developed with respect to these attributes and should be capable of producing potentially valuable genotypes almost immediately, but certainly within the next round of crosses. This process will be further enhanced by the contracted breeding experience with the Smith's

Snackfood Company in which similar attributes were successfully achieved, albeit over a longer time frame. With a greater focus on specific breeding objectives and well managed evaluation processes, it should be possible to have promising new lines entering Company supply programs by 2006, for gradual increase over succeeding years.

This analysis is based on the underlying assumptions that:

- As judged by industry adoption, the levy-funded crisping breeding program to date has produced little of direct benefit to the industry,
- Significant benefits will be achieved as a result of the new contractual arrangements, and
- The program has generated a number of indirect benefits (germplasm assembly and characterisation, breeding knowledge and experience, advanced breeding lines) that will enhance the outcomes of future company programs.

For the purposes of this analysis it is assumed that potatoes are priced at $200 per tonne with a further $100 available for quality compliance. It is also assumed that further benefits will be achieved as a result of company owned proprietary varieties, which result in potatoes that routinely reach the following standards:

- Dry matter, increased by 1%
- Size compliance increased by 5 percent
- Colour compliance increased by 5 percent
- Bruising reduced by 2 percent

The economic benefits which would be generated by these improvements to growers and processors are indicated in table 5.2. These ignore the additional benefits of reduced transport costs and reduced waste disposal costs at the factories, or any economic benefit that might result from improved pest or disease resistance, yield, or any other driver of variable production costs.

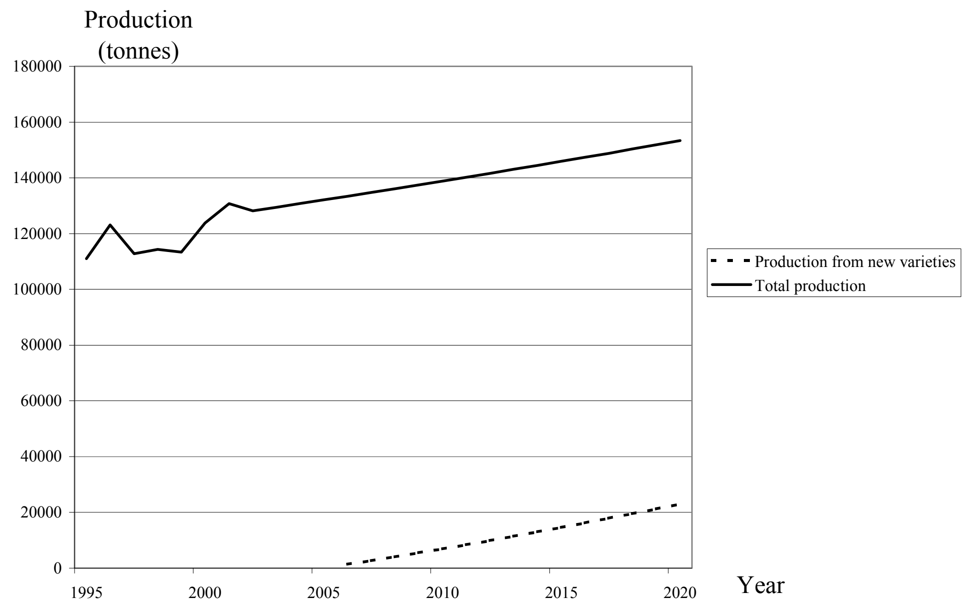
Based on this information, it is assumed that the gross margin to growers and processors increases by $30 and $28.70 per tonne of each new variety grown within the supply plans respectively (table 5.2). As these are subject to change as contractual conditions are reviewed, the sensitivity of their impact on the economic outcomes of the breeding initiatives will be assessed within the analysis.

Table 5.2 Benefits to growers and processors of improved proprietary crisping potato varieties

Attribute	Benefit to grower per tonne	Benefit to processor per tonne
Dry matter increased by 1%	$16.00	$13.70
Bruising red. By 2%	$5.00	$10.00
Size compliance increased by 5%	$5.00	$10.00
Colour compliance increased by 5%	$4.00	$25.00
Less grower premium		($30.00)
Total	**$30.00**	**$28.70**

The volume of new varieties grown is assumed to increase from around 1,330 tonnes in 2006 (including existing public Australian bred varieties) to about 23,000 tonnes in 2020, predominantly of proprietary varieties (figure 5.4). This is a deliberately conservative assumption: the level of adoption of varieties that produce the types of benefits identified in table 5.2 would almost certainly increase to well above this volume, so adoption rate is also subjected to a sensitivity analysis.

Figure 5.4 Assumed adoption rate of purpose-bred crisping varieties from the levy-funded program



5.2.1.2 Results

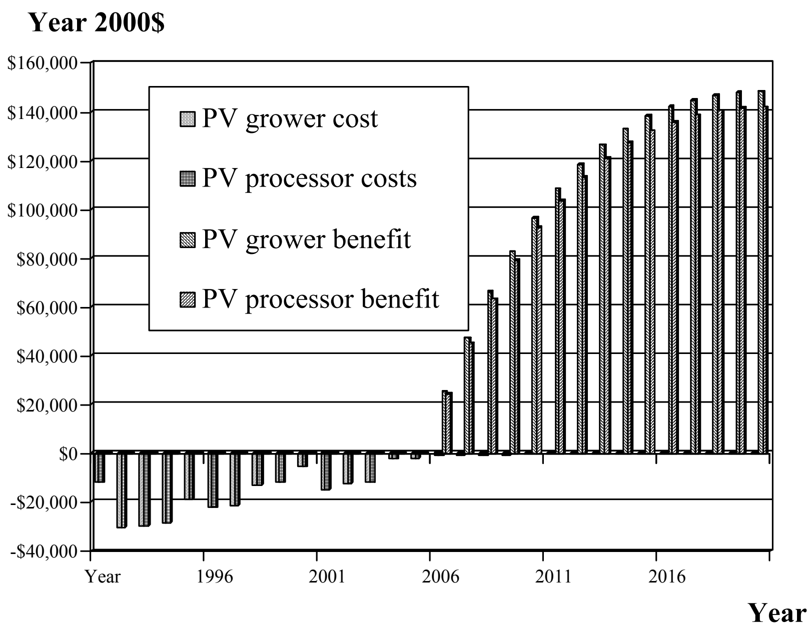
As predicted the project has produced few benefits to the growers or processors to date (see NPV values for 1991-2000 in table 5.3, figure 5.5), resulting in a negative NPV for the research, zero benefit: cost ratios and undefined IRR values. It would be difficult to argue the case for continuation of the program under its present guise, but by assuming modestly successful outcomes and conservative levels of adoption of new varieties under the new, company-specific arrangements the potential economic benefits are significant, to both the processors and to the growers at around $2.8 million over the 20 year period of analysis. This figure may well under-represent the real level of potential benefit, for example if the level of adoption increased from 23 000 to 46 000 tonnes per annum over the life of the program, the net benefit would increase to about $6 million to growers and processors combined (table 5.4), which would increase even further if the rate of increase between 2006 and 2020 were further accelerated.

As indicated earlier these benefits would be further enhanced by any additional breeding outcomes in terms of yield or pest and disease resistance. For example, a 5% yield increase would equate to 8 000 “free” tonnes to growers in 2020 alone (i.e. $1.6-2.4 million), and at an average cartage cost of $20/tonne, a further annual saving of $160 000 in current values.

Table 5.3 Value of the crisping breeding initiative using conservative "base" assumptions of varietal benefit and adoption rates.

Performance measure and time period	8% discount rate for NPV and BC
NPV growers 1991-2020	$1,429,000
NPV processors 1991-2020	$1,356,600
NPV growers 1991-2000	-$193,500
NPV processors 1991-2000	-$193,500
BC growers 1991-2020	6.92
BC processors 1991-2020	6.62
BC growers 1991-2000	0.00
BC processors 1991-2000	0.00
IRR growers 1991-2020	20%
IRR processors 1991-2020	20%
IRR growers 1991-2000	Undefined
IRR processors 1991-2000	Undefined

Figure 5.5 Present value of benefits and cost stream arising from the crisping research program



5.2.1.3 Discussion

A couple of points should be emphasised as a result of the above economic analysis. First, a significant amount of money, compared to the other research projects, has been expended with no measurable economic outcome to date. Despite this, there is a significant <u>potential</u> payoff to this research, depending on the rate of adoption of the new varieties which will depend on strong marketing chain leadership being exercised by the processing companies.

Second, the present value of the benefits of this research have been evenly distributed between growers and processors. The present value of costs to growers and processors are the same as each group contributes the same levy amount per tonne. Exactly how the net benefits might be distributed between growers and processors in the future largely depends on competitive forces operating within the industry.

Table 5.4 Sensitivity analysis for crisping potato breeding: Changes in net present value depending on changes in assumptions

Item	Change from base assumptions	Time period	Net present value
NPV growers	5% discount rate	1991-2020	$2,301,100
NPV processors		1991-2020	$2,191,900
NPV growers		1991-2000	-$167,400
NPV processors		1991-2000	-$167,400
NPV growers	11% discount rate	1991-2020	$863,900
NPV processors		1991-2020	$814,800
NPV growers		1991-2000	-$223,900
NPV processors		1991-2000	-$223,900
NPV growers	Grower GM $20 (base $30)	1991-2020	$872,300
NPV growers	Grower GM $40 (base $30)	1991-2020	$1,985,800
NPV processors	Processor GM $30 (base $28.70)	1991-2020	$872,300
NPV processors	Processor GM $70 (base $28.70)	1991-2020	$1,985,800
NPV growers	Halve adoption rate	1991-2020	$593,900
NPV processors		1991-2020	$557,700
NPV growers	Double adoption rate	1991-2020	$3,099,300
NPV processors		1991-2020	$2,954,500

5.3 The french fry program

Some new varieties released from the breeding program have been adopted, albeit as a small proportion of the company supply programs, and two new numbered lines which are well regarded appear to have some future promise, and are expected to play a more significant part in future contracts.

There are similarities between the crisping and french fry situations, in the relatively low level of adoption of new varieties from the levy funded program, the desire for competitive advantage, the importance of tuber quality in driving conversion efficiency and product quality (and competitiveness), the need to reduce production costs in competition with both Australian and international competitors, and the need to exploit new production environments and strategies with innovative and adapted genotypes.

Also like the crisping industry, french fry processors are negotiating a new approach to funding and driving genetic improvement by entering into individual agreements with the breeder for varieties that meet their specific needs. The analysis assumes success with these arrangements, and that new varieties with the following attributes are delivered to each of the two processors in time for a first commercial production in 2006. The attributes are:

- Increased bruise resistance
- Better compliance to shape and size specifications
- Yield increase
- Reduced storage losses
- Waste reduction (through increased conversion rates)

5.3.1 Economic analysis of the research program

5.3.1.1 Assumptions

The approximate price of potatoes for french fries is $200 per tonne with up to a further $30 available for quality compliance, although this varies between companies and factories.

It is assumed that, as a result of the research, growers will gain:

- an extra $7.50 per tonne in quality bonuses as a result of increased dry matter, tuber size compliance and reduced damage and bruising
- and that production costs will be reduced by a further $7.50 per tonne as a result of yield increases of approximately 4%

Thus the overall increase in gross margin for growers is assumed to be $15 per tonne.

Similarly, processors are likely to benefit as a consequence of:

- 2% increase in conversion yield due to dry matter and shape, $4.20 per tonne
- 2% reduction in storage losses, $4.20 per tonne
- 2% reduction in waste due to bruising, disease and insect damage and handling damage, also $4.20 per tonne.

Thus the overall increase in gross margin for the processor is $12.60 per tonne, minus the $7.50 paid to growers for a net increase of $5.10 per tonne

This represents a conservative view of likely benefits, which could be much greater, and which would include some additional factors such as reduced freight and factory wastage. The 2% increase in conversion efficiency would result from an average tuber dry matter increase of only 0.2-0.3%. The assumed increases are considered to be easily achievable, and by no means the ultimate end point in the breeding initiative.

The production assumptions are likewise conservative, beginning with about 1,200 tonnes of Australian bred varieties in 1997 (existing and new varieties) and increasing as indicated by figure 5.5. In the analysis it is assumed that production of these will increase to about 167,000 tonnes in 2020, about 18% of the projected total french fry crop. This figure is also conservative and difficult to predict and will be driven almost totally by the success of the program in meeting the commercial needs of the processors, so the effects of higher (and lower) levels of adoption are examined in the sensitivity analysis.

5.3.1.2 Results

Relatively minor improvements in such a large industry will produce large benefits, as illustrated in table 5.5 and figure 5.6. Over the twenty-year time frame for this analysis, the benefits to growers and processors combined, as a result of very conservative increases in grower performance and conversion efficiencies will exceed $10 million. The sensitivity analysis (table 5.6) illustrates the effect of a more realistic adoption rate of 30%, in increasing net benefits to over $18 million. Regardless of the assumptions tested in this table, the potential outcomes of a well directed breeding approach, coupled with strong leadership by the companies will be significant, and well in excess of the costs of the research itself.

It should be remembered that (as for crisping) this is a partial analysis; it ignores a number of potentially significant additional benefits such as freight and storage costs that would arise from higher dry matters, and reduced waste disposal from factories. In addition to the benefits quantified above, increasing the dry matter content of potatoes results in a reduced demand and therefore a reduced freight bill. Growers would benefit from higher yielding potatoes through their reduced input and overhead costs.

Figure 5.6 Assumed adoption rate of French fry varieties from the Australian levy funded breeding program

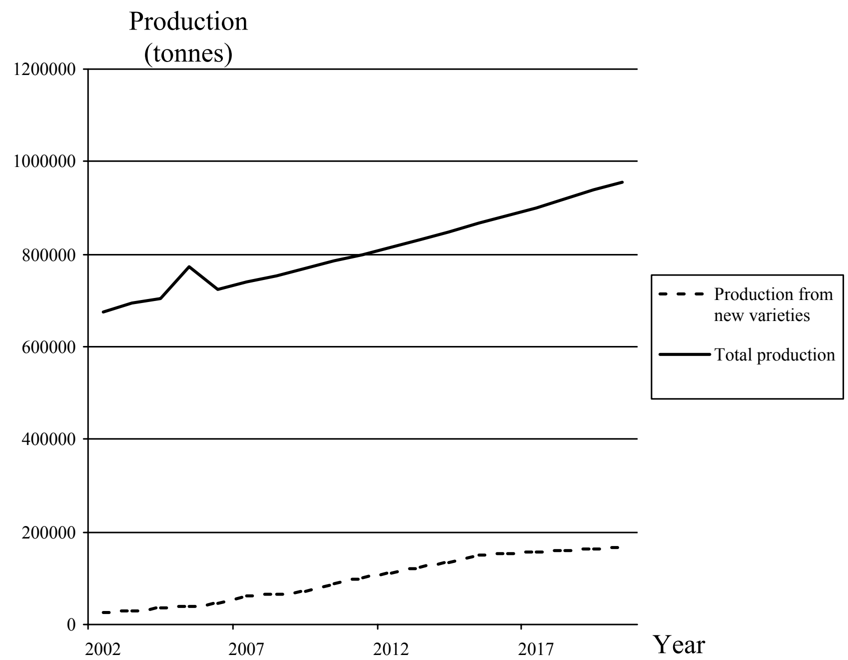


Table 5.5 Value of the French fry breeding initiative using conservative "base" assumptions of varietal benefit and adoption rates.

Performance measure and time period	8% discount rate for NPV and BC
NPV growers 1992-2020	$10,713,500
NPV processors 1992-2020	$3,406,200
NPV growers 1992-2000	-$159,200
NPV processors 1992-2000	-$290,500
BC growers 1992-2020	30.91
BC processors 1992-2020	10.51
BC growers 1992-2000	0.56
BC processors 1992-2000	0.19
IRR growers 1992-2020	40%
IRR processors 1992-2020	27%
IRR growers 1992-2000	-6%
IRR processors 1992-2000	Undefined

5.3.1.3 Discussion

While the economic analysis of french fry breeding reveals generally similar results to those of the crisping program, there are some important differences. Varieties from the french fry program have already been adopted, albeit on a small scale, and as a result of strong marketing chain leadership by the processing companies. However the adoption of existing varieties was insufficient to generate positive NPV's for the research program for the period up to the year 2000, and as for crisping it is concluded that the realisation of the major benefits of the research will depend on the new commercial arrangements between the companies and the program. The continuation of the french fry program in its current form would have greater chance of success than the crisping program given the apparent attractiveness of existing Toolangi varieties to processors, and the changing attitudes of their major customers to new genotypes in their products.

Based on this analysis growers generally gain more than processors. However, this is heavily dependent on the structure of the payment and rewards system and can vary to shift the balance in either direction. On the basis of previous history it is unlikely that growers will retain these benefits for long, they will eventually be eroded in favour of the processors (and consumers) as growers come under increasing pressure to increase production efficiency and product quality, and to respond to customer demands for lower raw material costs.

Figure 5.6 Present value of the benefit and cost streams for french fry potato breeding, using "base" assumptions of varietal benefit and adoption rates

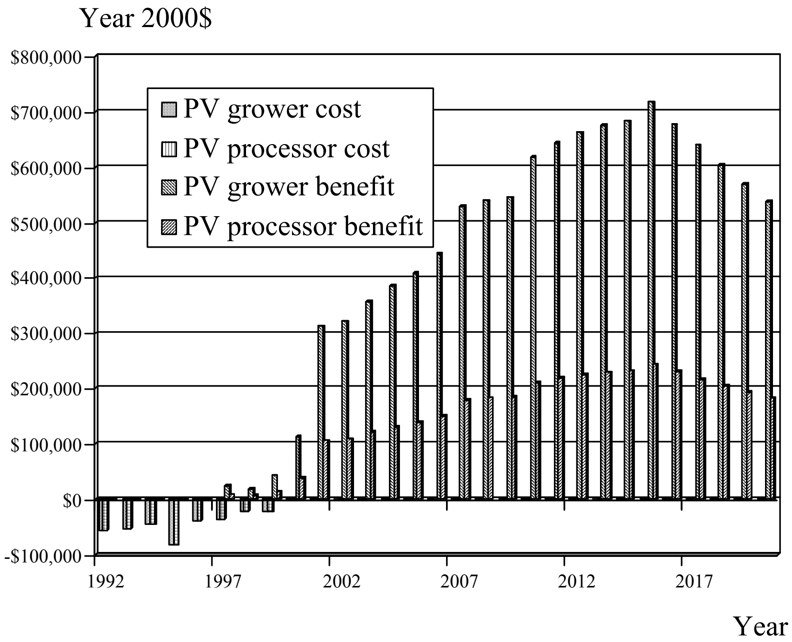


Table 5.6 Sensitivity analysis for french fry potato breeding: Changes in net present value depending on changes in assumptions

Item	Change from base assumptions	Time period	Net present value
NPV growers	5% discount rate	1991-2020	$15,110,500
NPV processors		1991-2020	$4,932,600
NPV growers		1991-2000	-$115,900
NPV processors		1991-2000	-$244,400
NPV growers	11% discount rate	1991-2020	$7,797,000
NPV processors		1991-2020	$2,378,500
NPV growers		1991-2000	-$209,400
NPV processors		1991-2000	-$343,600
NPV growers	Grower GM $10 (base $15)	1991-2020	$7,022,900
NPV growers		1991-2000	-$225,500
NPV growers	Grower GM $20 (base $15)	1991-2020	$14,404,000
NPV growers		1991-2000	-$92,800
NPV processors	Processor GM $0.10 (base $5.10)	1991-2020	-$284,400
NPV processors		1991-2000	-$356,900
NPV processors	Processor GM $10.10 (base $5.10)	1991-2020	$7,096,700
NPV processors		1991-2000	-$224,200
NPV growers	Decrease adoption rate to 10% (base 17.5%)	1991-2020	$6,325,500
NPV processors		1991-2020	$1,914,300
NPV growers	Increase adoption rate to 30% (base 17.5%)	1991-2020	$18,026,800
NPV processors		1991-2020	$5,892,700

5.4 The gene technology program

The principal thrust of this element of the genetic improvement program has been towards the development of potato leafroll virus (PLRV) and potato virus Y (PVY) resistance in a limited range of imported and locally-bred varieties, including Sebago, Crystal and Shine and a number of parental lines. Researchers believe that clones with resistance to both viruses will be available in two years. Thus commercial release to the seed industry should occur in 2006. Commercial quantities should be available in 2008 following the use of a rapid multiplication program.

The transformed varieties will only be of value if they are acceptable to the consuming public, and they conform to the requirements of the gene regulators. While reviewers are generally pessimistic that these hurdles will be overcome in the short term, the following analysis assumes otherwise.

Without additional funding (the project concludes in June 2004) it is unlikely that processing varieties will be transformed. Instead virus resistance will need to be introduced using transformed parental lines and normal crossing techniques. Depending on the success of the current project, the eventual acceptability of GMO potatoes to consumers and processors, and the breeding priorities of the processors, as well as the success of the crossing program itself it is almost inconceivable that the processing industries will benefit from this work within the time frame of this study. In any event, the assumptions are too arbitrary to allow any reasonable estimate of likely benefit to the processing industry.

The most likely contribution of the project to the industry over the period will be through the reduction in seed production costs and increased commercial production in the fresh market potato industry, principally in the variety Sebago.

5.4.1 Economic analysis of the gene technology program

This analysis is based on the impact of the gene technology program on fresh market production. For this analysis, fresh market production was calculated from total production, less quantities used for processing for various purposes and seed production. Data derived using this method is likely to contain errors. Based on the data, current fresh market production represents about 25 percent of the industry, trending down over time.

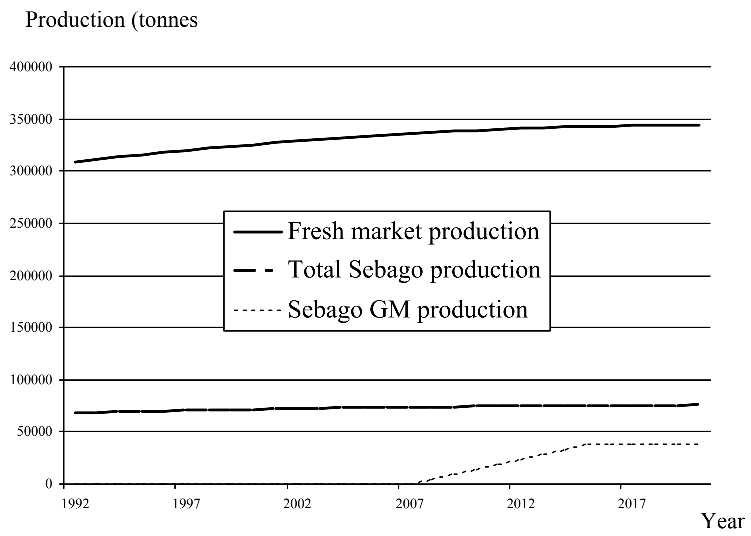
5.4.1.2 Assumptions

1. The fresh market production trend will continue to at least 2020 with fresh market production then being about 20 percent of total production (fig 5.7).
2. Sebago will continue to be about 22 percent of fresh market production.
3. The first genetically modified Sebago seed will be available in 2008. Adoption of the modified variety will be linear from 2008 to 2015 and plateau at half of the total Sebago production in 2015.
4. The benefits to seed producers are in the form of cost savings. These would result from a reduction of two aphid sprays ($40 per ha) and a 1 percent

reduction in seed rejections, which would decrease the area planted for seed and hence save the variable cost of seed production.

5. The benefits for fresh market production are due to yield increases and associated cost savings. A 1% national saving is assumed for the main analysis, though the impacts of up to 4% savings were tested in the sensitivity analysis. The benefit is a proportional saving of the variable cost of $5000 per ha of production.

Figure 5.7 Assumed fresh market production and adoption for the gene technology program



5.4.1.3 Results

The economic outcomes for this project, based on the above assumptions, (including a 1% yield increase) are negative, with an estimated NPV over the full timeframe of negative $385 100 and a zero benefit: cost ratio (table 5.7, figure 5.8). The analyses in table 5.8 indicate that unless a yield advantage of around 3% could be achieved as a result of the new technology, the NPV would remain negative over the full life of the analysis. A 4% yield advantage would produce a positive NPV of $287 300 by 2020. These results were not significantly enhanced by increasing the rate of adoption of GM technology in the sebago crop, or by assuming more favourable discount rates (table 5.8).

5.4. Discussion

Under the generally conservative assumptions of this analysis it appears that investment in the gene technology program will be marginally profitable, at best. This assessment is made before any consideration of the possible problems associated with consumer acceptance of GM technology. A successful technology program that results in the use of genetically engineered virus resistance in other varieties, and especially in processing varieties will result in a more positive investment result.

Table 5.7 Value of the gene technology program using "base" assumptions of cost savings, including 1% yield increase, and adoption rates.

Performance measure and time period	8% discount rate for NPV and BC
NPV growers 1992-2020	-$385,100
NPV growers 1992-2000	-$637,500
BC growers 1992-2020	0.40
BC growers 1992-2000	0.00
IRR growers 1992-2020	3%
IRR growers 1992-2000	Can not be calculated

5.4.1.5 Environmental and social benefits of the potato improvement program

The wider adoption of disease resistant varieties will produce a desirable environmental outcome, due to the more restricted use of chemical sprays. However, many still view GM varieties as "environmentally negative" and the judgment regarding the environmental benefits of gene technologies must await the conclusion of the community debate.

5.5 Discussion and conclusions – genetic improvement

The Australian potato improvement program has made important contributions to the Australian industry, through the importation of key varieties, through its own breeding efforts (Coliban), and through its special position as repository of germplasm, and of potato breeding and genetics expertise. It has made additional contributions through its contracted arrangements with individual members of the industry, notably with one major crisping processor who now routinely uses a number of varieties which were developed within their contracted breeding program.

Through its earlier activities the program set high standards of performance, particularly through the importation of Atlantic, Russet Burbank and Sebago, and through its own washing variety Coliban. Since the introduction of the levy arrangements in 1991 the program has struggled to exceed these standards, and no public variety produced during that time has become widely accepted throughout the industry. The likelihood of this happening is diminishing as privately owned varieties such as Nadine gather pace, and as other breeders (such as New Zealand Crop and Food) exploit partnership opportunities with Australian fresh market and processing interests. Not only are these developments providing important new genotypes and services into the industry, but they are also clear evidence of the absence of market failure, which provides the normal justification for government funded research, and particularly for the involvement of the R&D corporations such as Horticulture Australia. The current analysis concludes that with new arrangements between major "chain captains", such as individual processors or wholesalers, very significant benefits might be possible, but that in the absence of these it is unlikely that the research could be justified on economic, nor in fact market failure grounds. This clearly applies to both processors and the fresh market sector.

Figure 5.8 Present value of the benefit and cost streams for the gene technology program.

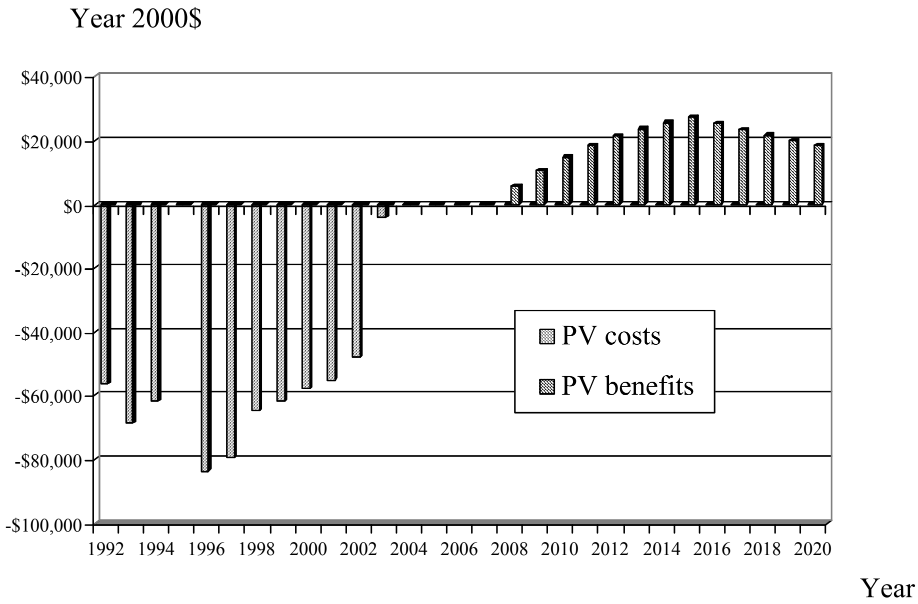


Table 5.8 Sensitivity analysis: Changes in net present value depending on changes in assumptions

Item	Change from base assumptions	Time period	Net present value
NPV growers	5 % discount rate	1992-2020	-$202,800
NPV growers		1992-2000	-$588,000
NPV growers	11 % discount rate	1992-2020	-$526,200
NPV growers		1992-2000	-$694,600
NPV growers	100% of Sebago is GM variety	1992-2020	-$128,700
NPV growers	after 2015	1992-2000	-$637,500
NPV growers	2% increase in yield=2%	1992-2020	-$161,000
NPV growers	saving in area grown	1992-2000	-$637,500
NPV growers	3% increase in yield=3%	1992-2020	$63,100
NPV growers	saving in area grown	1992-2000	-$637,500
NPV growers	4% increase in yield=4%	1992-2020	$287,300
NPV growers	saving in area grown	1992-2000	-$637,500

The seed industry has received little attention during this analysis; it is a minor contributor but a potentially significant beneficiary of the program. Discussions with seed growers revealed a level of scepticism and concern at the failure of its members to benefit from the research; under the present arrangements seed growers accept a high level of risk in agreeing to grow any new variety that is not linked into a defined, and preferably contracted supply chain. This is especially true of the fresh market where contracts are uncommon, and where the industry has traditionally supported a free market approach, meaning the absence of managed chains and varietal protection. Until this situation alters we conclude that benefits of the new varieties will continue to elude seed growers, and the industry generally.

That said, a program that responds more directly to individual processor or fresh market needs, which facilitates real advantage to competitive chains within an appropriately constructed commercial and legal framework offers major opportunities for commercial benefit, and coincidentally, meets the requirements of Australian Competition Policy and provides justification for the continuation of the breeding initiative.

Finally, the gene technology program offers new approaches to hastening the availability of specific disease resistances to the Australian industry. While admittedly this analysis has been based on conservative assumptions concerning its likely impact and value, there is little evidence for a softening of consumer attitudes towards genetic modification in fresh products such as potatoes, nor especially of corporate interest in making the move from conventional to GM products. The case for adoption of GM varieties (for virus resistance) is not compelling on economic or environmental grounds and it is difficult to imagine an industry based on GM varieties within the timeframe of this project.

CHAPTER 6 INTEGRATED PEST AND DISEASE MANAGEMENT

The program has funded three main areas of activity that were designed to increase the science and adoption of alternative pest and disease management practices, and to reduce the usage of chemicals in potato production. They are:

1. Integrated disease management
2. Increasing the adoption of IPM for potato tuber moth and foliar insect pests, and
3. IPM for soil borne insects.

The disease project (PT341) developed a useful approach to disease forecasting for early and late blight, though with the introduction of very efficient and effective fungicides the line of enquiry was subsequently discontinued. The project was well conceived at the time, but of no benefit in the new disease management environment, and will not be considered further within this analysis.

Prior to 1991 research in Agriculture Victoria (now DPI) had defined many of the principles to be used in the IPM programs for insect pests that are now so widely used by potato growers. Dr Paul Horne was prominent in this research for his efforts with the potato tuber moth, for which he identified an IPM control approach using both biological (parasitoid) and physical (soil and water management) approaches. Much of the subsequent work in IPM in the eastern states built on these foundations, either to improve the strategies for tuber moth, to provide a more integrative management program for the full range of destructive insect pests, or to increase the rate of adoption of IPM by potato growers.

Dr Horne's work spanned five major projects, four of which were funded from growers' levies:

1. PT216 *Development of a commercial assessment method to detect parasitoids of the potato moth* (1992-1994), which identified new techniques for assessing the extent of parasitism in caterpillars as a practical aid for the further development of IPM for tuber moth.
2. PT336 *Implementation of an IPM strategy for potato moth* (1991-1994). This project was specifically targeted at increasing grower awareness and adoption of IPM approaches to potato tuber moth monitoring and management. Importantly, it also quantified the level of adoption of these practices amongst growers in Victoria. It was the subject of an internal benefit cost analysis by Agriculture Victoria in 1996 (Dept of Agriculture, Energy and Minerals, 1996). This analysis demonstrated clear benefit of IPM over chemical controls for tuber moth.
3. PT 437 *IPM strategies for potato moth*. This project extended the activities commenced in the previous project (1995-1997), but was still focused on the single pest insect.

4. PT 656 *National IPM program for potato pests*, which extended the concepts from tuber moth to the full array of significant pest insects in Victorian, and Australian potato crops (except soil insects). For the first time the management practices for all potato insect pests were integrated into a single management program.
5. PT98403 *Preparation of field guide and reference books for pests, beneficials and diseases of potato crops,* in which practical reference guides were prepared to assist growers in the identification of pest and beneficial insects, and diseases.

In summary, this project series developed and promulgated the principles of advanced integrated pest management to the stage where growers could adopt this efficient alternative technology with confidence, and at considerable economic and environmental advantage.

The adoption of IPM in Australian potato production is the result of the combined efforts of many industry stakeholders. It has been founded on a knowledge base that was developed both within Australia and overseas and it is difficult to fairly apportion the contributions of each to the overall outcomes. The four regional and industry development projects (NSW, SA, Atherton, Crisping industry), and the project by Spooner-Hart (PT306) played a valuable role in increasing grower awareness and adoption of IPM, and the contributions of three of these projects are evaluated elsewhere in this report. It is considered that these projects (by Horne) played a defining role in the adoption of these technologies by the Australian industry. Without them it is unlikely that IPM would be as widely used by the industry as is currently the case and it is reasonable in this analysis to ascribe the majority of useful commercial and environmental outcomes to these projects.

6.1 Grower adoption of IPM in the Eastern states

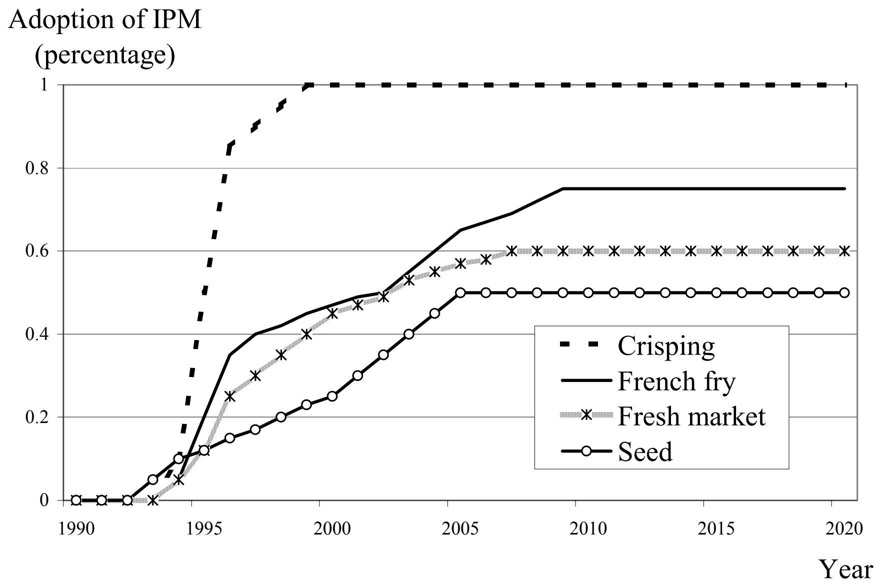
The rate of awareness and adoption of IPM to 1996 amongst Australian growers was quantified by Horne et al (1999). From a standing start in 1990, they reported adoption rates of 80–86% by crisping growers in 1996, 23–33% by french fry growers, 23–29% by fresh market growers, and 5–25% amongst seed growers. The assumed rates of adoption by eastern state growers for the period of the analysis, which take into account Horne's findings, and known attitudes to IPM by the various industry sectors are depicted in figure 6.1. The growth rates for the fresh market sector are probably conservative, given the increasing trend towards large-scale production by professionally resourced operations.

6.2 The benefits of IPM

IPM offers both economic and environmental advantages to the industry. The economic benefits arise primarily from the very significant reduction in the number of insecticidal sprays, as indicated by Strange and Morrison in their 1996 benefit cost analysis of IPM in the crisping potato industry. Crisping growers throughout the country have been progressive in their adoption of IPM, and by 1996 most, if not all growers in this group were routinely monitoring their crops as part of their integrated pest management programs. The savings to growers were substantial, based on the reduced insecticidal spray applications (from 4–5 sprays per crop to around 1–1.5), at a net saving of $200–$300 per hectare per annum. The costs of monitoring are insignificant against this, at about $10-20 per hectare per annum[5]. Many growers have completely eliminated the need for spraying insects, leading to even larger savings.

Chemical management of insects is no longer considered to be sustainable; instances of insecticide resistance are now common and non-chemical approaches offer the only long-term option for pest control.

Figure 6.1 Assumed rate of adoption of IPM for tuber moth and foliar insects in Eastern states



6.3 Economic analysis of IPM for tuber moth and foliar pests

6.3.1 Assumptions

1) There are cost savings of $200 to $300 per hectare (Strange and Morison 1996). This assumption is explored in the sensitivity analysis.
2) Adoption of IPM by the various parts of the industry are as in figure 6.1, with changes in adoption rates considered in the sensitivity analysis.
3) The adoption of IPM was restricted to Queensland, New South Wales, Victoria and Tasmania.
4) The cost savings were apportioned to the various sectors of the industry according to the proportions in Appendix H.

[5] This equates to between $1 and 1.5 million annually for the crisping industry alone, in 1995 dollars.

6.3.2 Results

On a consideration of the base assumptions, the IPM program has already generated savings of $16 million to the industry, and will generate net benefits of over $65 million over the full period of the analysis, and with high and positive benefit:cost ratios and outstanding returns on the R&D investment (IRR) (table 6.1). The processing industries are already enjoying much of that benefit, but it can be expected that as adoption increases in the fresh and seed industries they will also maximise their benefits well within the period (figure 6.2).

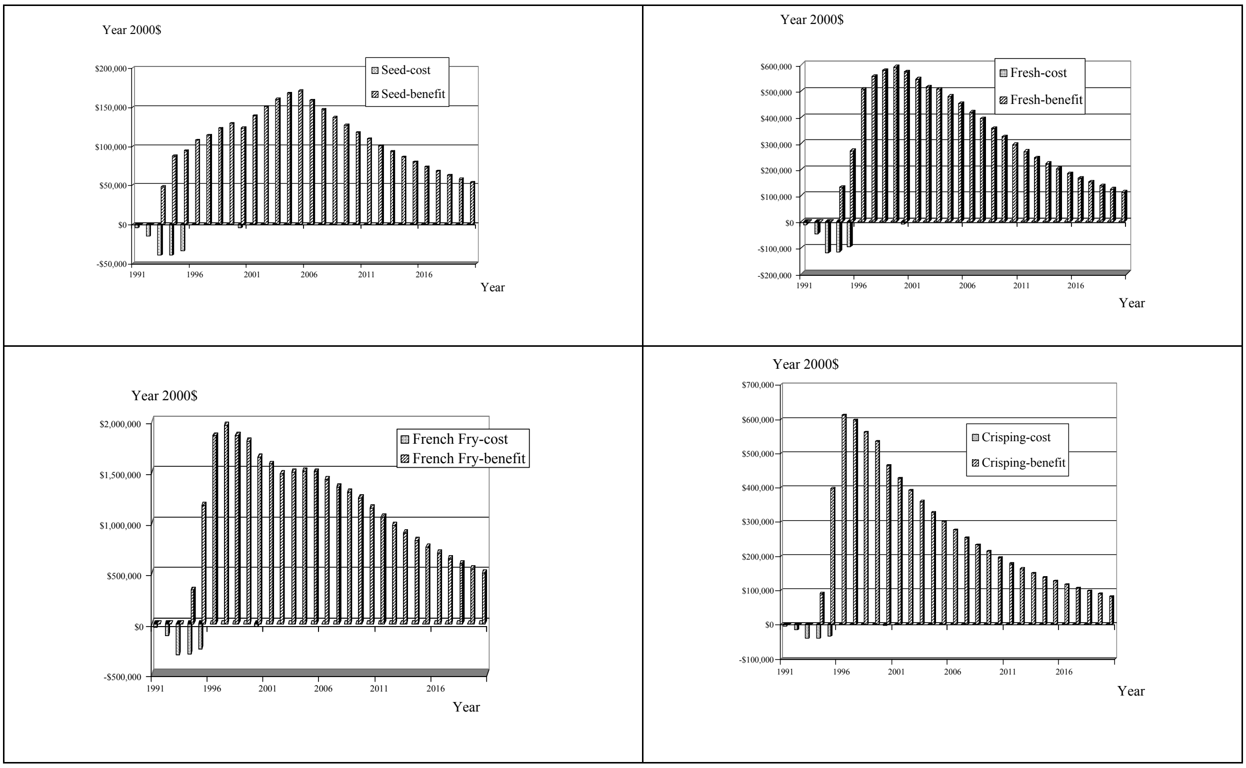
Table 6.1 Economic value of the IPM research using the 'base' assumptions

Performance measure and time period	8% discount rate for NPV and BC
NPV Crisping 1991-2020	$10,458,200
NPV French Fry 1991-2020	$40,778,500
NPV Fresh 1991-2020	$11,686,500
NPV Seed 1991-2020	$3,642,800
NPV Crisping 1991-2000	$3,116,600
NPV French Fry 1991-2000	$9,614,500
NPV Fresh 1991-2000	$2,800,600
NPV Seed 1991-2000	$691,100
BC Crisping 1991-2020	53
BC French Fry 1991-2020	31
BC Fresh 1991-2020	23
BC Seed 1991-2020	23
BC Crisping 1991-2000	23
BC French Fry 1991-2000	10
BC Fresh 1991-2000	8
BC Seed 1991-2000	6
IRR Crisping 1991-2020	191%
IRR French Fry 1991-2020	120%
IRR Fresh 1991-2020	98%
IRR Seed 1991-2020	150%
IRR Crisping 1991-2000	191%
IRR French Fry 1991-2000	119%
IRR Fresh 1991-2000	97%
IRR Seed 1991-2000	150%

The analysis was not highly sensitive to discount rate (Table 6.2), but was significantly varied by assumptions about cost savings.

The apportionment of benefits between sectors reflected the size of the individual sector; french fries received much greater benefit than the smaller sectors. While the seed industry received the smaller share of benefits, they were nevertheless positive, and significant.

Figure 6.2 Present value of the benefit and cost streams of IPM for tuber moth and foliar pests*



* **Note**: While the horizontal axes in the above graphs are more of less drawn to the same scale, the **scale on the vertical axes are different.** Thus the present value of the benefits is much greater for the french fry sector of the industry than for the seed potato sector, as an exampl

6.3.3 Discussion

The returns to industry for their investment in this technology have been outstanding. The economic results would have been slightly different had all of the underpinning research also been funded from Australian industry levies, had the costs of the contributions by Australian processing companies, Government extension officers and private consultants been included in the analysis, or had the contributions of the regional development projects been taken into account. Nevertheless, the projects that were funded under this part of the program were clearly effective in making IPM available to the industry and justifiably receive the lion's share of the honour for this achievement.

Added to the economic dimensions of the analysis is the very significant environmental benefit which arises from the reduced spray usage in the Australian potato crop, and the overall contribution of the technology to the sustainability of the Australian potato industry.

Table 6.2 Changes in net present value depending on changes in assumptions

Item	Value	Time period	Net present value
Crisping—change discount rate	5%	1991-2020	$11,144,800
French Fry—change discount rate	5%	1991-2020	$45,885,100
Fresh—change discount rate	5%	1991-2000	$13,002,800
Seed—change discount rate	5%	1991-2020	$4,210,100
Crisping—change discount rate	11%	1991-2020	$10,119,600
French Fry—change discount rate	11%	1991-2020	$37,604,100
Fresh—change discount rate	11%	1991-2020	$10,843,800
Seed—change discount rate	11%	1991-2020	$3,280,000
Crisping—change discount rate	5%	1991-2000	$2,913,600
French Fry—change discount rate	5%	1991-2000	$9,064,100
Fresh—change discount rate	5%	1991-2000	$2,662,500
Seed—change discount rate	5%	1991-2000	$647,000
Crisping—change discount rate	11%	1991-2000	$3,333,300
French Fry—change discount rate	11%	1991-2000	$10,192,400
Fresh—change discount rate	11%	1991-2000	$2,943,300
Seed—change discount rate	11%	1991-2000	$738,400
Crisping—change cost saving	$150	1991-2000	$7,773,200
French Fry—change cost saving	$150	1991-2000	$30,066,600
Fresh—change cost saving	$150	1991-2000	$8,562,600
Seed—change cost saving	$150	1991-2000	$2,664,300
Crisping—change cost saving	$250	1991-2000	$13,143,200
French Fry—change cost saving	$250	1991-2000	$51,490,600
Fresh—change cost saving	$250	1991-2000	$14,810,400
Seed—change cost saving	$250	1991-2000	$4,621,400
Crisping—change cost saving	$300	1991-2000	$15,828,200
French Fry—change cost saving	$300	1991-2000	$62,202,600
Fresh—change cost saving	$300	1991-2000	$17,934,400
Seed—change cost saving	$300	1991-2000	$5,600,100

6.4 IPM research in Western Australia

6.4.1 Soil borne insects, biofumigation and biodegredation

Two researchers in Western Australia have also made important contributions to IPM approaches to pest management in potatoes using levy funding. They are Dr John Matthiessen and Dr Stewart Learmonth. The targets of their work were/are:

- Biological and IPM approaches to the management of White Fringed Weevil (WFW) and African Black Beetle (ABB)

- Reducing virus diseases (mainly in seed crops) through IPM approaches to viral vector management.

Funding assistance for much of this work also came from the Western Australian Potato Growing Industry Research Trust Fund.

These researchers identified WFW, ABB and wireworm as the most destructive soil borne insect pests of potatoes in the State. The only control measure available prior to their research was the use of large doses of powerful, broad-spectrum pesticides, particularly metham sodium at a cost of around $700 per hectare. This fumigant was/is favoured over alternatives such as methyl bromide for environmental and operator safety reasons. However, at the time that its use was increasing most rapidly in Australia, it was being phased out in other parts of the world. It is not widely used in potatoes in the Eastern states.

The work commenced with a joint project (PT021) that lay the foundation for future studies of soil borne pests and their management strategies; it described the biology of the two principal pests and their *modus operandi* in damaging potato crops and took the first steps towards bio-control through the identification of techniques to control adult insects, and through the testing of fungal, viral, bacterial and nematode pathogens. The researchers concluded that these were not viable options for the management of these important pests and attention turned to alternative approaches, notably the use of crops with natural soil fumigant properties ('biofumigation').

This approach was explored in the following project (PT447) by Dr Matthiessen using various Brassica species and varieties, both as a means of reducing treatment costs, and to reduce industry's reliance on chemical fumigants. This work was continued in VG97050, which:

- characterised a wide range of Brassica genotypes for their biofumigation potential,
- developed bioassay techniques to test the effects of Brassica tissue on pathogens and insects,
- investigated alternative ('smarter') ways of applying metham sodium, and
- explored alternative chemical control strategies for ABB, which use reduced applications of the fumigant.

The principal outcomes of these projects, at least for the potato industry were somewhat disappointing. Biofumigation was not found to be an effective control measure for the soil borne insects WFW or ABB, and despite early indications that the technique might offer advantage in controlling soil borne pathogens, subsequent work at Knoxfield by Dr Dolf de Boer (PT632, PT96032) has so far been unable to demonstrate significant disease suppression benefits in potatoes in the field. A benefit cost calculation on this research project gives a negative net present value (to potatoes) and it appears that the project is unlikely to deliver economic benefits to the potato industry. For this reason, a full-scale benefit cost analysis using several economic measures and sensitivity analysis was not conducted.

Notwithstanding this, the outcomes of the projects have been highly successful for some other vegetable industries where biofumigant disease control is now widely used, and with great success. This provides a good example of the spillover effects of research where the outcome benefits other industries; no attempt has been made here to evaluate these in economic terms. Further, the negative results for the potato industry should not be viewed as an indication of failure, the project was well justified on the basis of existing knowledge and offered a reasonable prospect for the industry which deserved investigation. This was good research that simply didn't produce the hoped-for outcomes, at least for the potato industry

IPM approaches for soil-borne insects have been difficult to identify, but the search is continuing through project PT 01008 that is attempting to improve the reliability of control through the provision of monitoring techniques to define populations as the basis for designing pre-planting pesticide applications.

During the course of this work Dr Matthiessen realised that the efficiency of metham sodium fumigation might be reduced somewhat through the processes of 'enhanced biodegradation', in which soil borne bacteria which metabolise the chemical evolve to the point of diminishing the effectiveness of treatments. These effects, which were potentially concerning to an industry that was heavily reliant (in some regions) on the effective availability of metham sodium were the subject of two further projects, PT618 and PT619 to investigate the extent and nature of the condition. The outcomes of the research are yet to be reported (to HAL), though it is understood that they confirm its existence and that its severity in potatoes is probably cause for less concern than for other vegetable industries. The problem was most acute in a particular location in WA, and was associated with a particular combination of soil type and intensive chemical usage in vegetable production. The principal outcome for the potato industry will be its ongoing ability to use metham sodium into the indefinite future, provided that rotation cycles do not shorten such that the frequency of application becomes too great, thereby inducing enhanced biodegredation. This has been a positive research outcome for the potato industry.

6.4.2 Aphid research in WA

Seed production in Western Australia is an important industry, as the basis for the commercial potato industry, and as a source of export earnings. Seed production systems used in the State are evolving rapidly, but are constrained by the presence of aphid-vectored virus disease. Levy funds have been directed towards this issue through several projects which have produced a communications package to help seed growers monitor their crops (PT00034), explored potentially new seed production districts (PT018), monitored existing areas for the presence and nature of vectors (PT96054), and commenced commercial crop monitoring (PT01040). The research will not necessarily lead to the adoption of IPM approaches as in the eastern states, at least in the shorter term, the identification of districts where aphids are less likely to occur represents an important and valuable contribution to the industry's objective of viral disease reduction.

The important outcome of this work will be a reduced level of virus infection in seed for the WA commercial potato industry with subsequent benefits in increased commercial yields and quality, and to the export industry. However, it is still too early to quantify these benefits, or to attempt any meaningful economic analysis.

6.5 Conclusions

Measured in terms of economic benefit the IPM program has been a highly effective research investment. In reducing the amount of pesticide usage throughout the industry it has also had important, though unquantified environmental benefits.

References

Horne, P.A., Rae, J.E. Henderson, A.P and Spooner-Hart, R. (1999), Awareness and adoption of IPM by Australian potato growers. *Plant Protection Quarterly* 14 (4), 139-142

Strange, PC, and J Morrison (1996), *Comparative benefit cost of IPM and conventional pest management in potatoes* Final report to HRDC, project PT538.

CHAPTER 7 - POTATO CYST NEMATODE (PCN)

This serious pest of potatoes was first discovered in a crop at Munster in the southern suburbs of Perth in 1986, and later at Wandin in Victoria in 1991. PCN is a soil borne nematode that is widely spread in other potato producing regions of the world where it causes very significant economic loss through its direct impact on crop performance and management costs, and on industry development through constraints on market access. Its detection in Australia came as something of a shock, particularly given the realisation that the infestations were well advanced when recognised.

The initial responses, which followed the identification in Western Australia, were largely by quarantine authorities, who imposed a number of restrictions on the movement and treatment of potatoes, and on the management of the infested areas (see Gwynne, 1991). For example, further production of non-resistant varieties was disallowed at Munster, and protocols were developed by the state quarantine authorities for the movement of potatoes from the infested area. These were further developed with the detections in Victoria, particularly as they related to the production and movement of seed, and the interstate movement of potatoes. Internationally, once it became known that PCN had been detected in Australia the opportunities for exporting potatoes from both Victoria and South Australia were reduced, specifically to South Korea (which banned potatoes from the two states), Mauritius and Vanuatu (which required as a whole on the basis of PCN.

The outbreaks were viewed with the utmost seriousness by both industry and officialdom because of the potential impacts on:

- reduced cropping productivity,
- reduced profitability through increased pest management and compliance costs, and
- reduced market opportunity, both domestically and in the export arena.

Subsequently, in 1993 Horticultural Policy Council commissioned an important review of the pest, to include a strategy for its future containment and management. The recommendations produced by this report (Horticultural Policy Council, 1993) formed the basis for the future policy, management and research activities on PCN to this day. In summary it recommended:

- the adoption of a code of practice for all sectors of the potato industry,
- uniform guidelines for the control and detection of an outbreak,
- the development of a focused research program, and
- an education and awareness program for all sections of the industry and the community.

It also recommended that the future control of the strategy be taken over by the Australian Potato Industry Council (APIC).

As an immediate outcome of this process, the states developed and agreed on standardised sampling and testing procedures. Unfortunately the recommended national sampling strategy was never completed so that the extent of the nematode's spread throughout the country is still not fully understood. Consequently, there is no standard basis for the interstate trade in potatoes (all Victorian potatoes are banned by Tasmania while the trade into other states is governed by a range of State-specific protocols), and the scientific basis for negotiating international protocols is incomplete. The commercial result is reduced market opportunity for some production areas (and increased opportunities for others), and increased compliance cost.

Arising from the HPC review, HRDC/HAL funded a group of projects that were designed to:

- specifically identify the biological nature of the infestation,
- develop techniques which would detect the organism more efficiently and at an earlier stage of its development in an area,
- increase the efficiency of incorporation of PCN resistance in the breeding program, and
- develop a national strategy for managing PCN.

Some of this work was conducted in association with Dr John Marshall of New Zealand Crop and Food.

The earlier work by Jill Hinch and John Marshall (PT 346) reported in Hinch et al, 1998 established that:

- only the golden nematode *Globodera rostochiensis* was present in the country. Fortunately the sister species *G pallida* or pale nematode was not detected, and has still not been detected to this day, and that,
- only one biotype of *G Rostochiensis*, known as Ro1 was detected.

These findings had great strategic significance, given the relative difficulty in achieving genetic resistance to *G pallida*, and the widespread availability of Ro1 resistance throughout the world's potato varieties and breeding lines. The principal crisping variety Atlantic has resistance to this strain of the nematode (and was the one variety that could be grown in the infested area in Western Australia). This work laid the foundations for the subsequent management and research program.

The second project (PT0131) by a group of Victorian scientists at Knoxfield, and also in cooperation with Dr Marshall will be completed in 2004. It was commissioned as a result of the known deficiencies in the existing soil testing and detection methods. It was known that conventional methods could only detect the organism well after the original infestation, and then, only at significant expense, which was estimated on the basis of Tasmanian experience in the HPC review at $65.83/ha for fork testing, and $35.64/ha for soil testing. In 2002 terms, this equates to at least $100 for sampling. The Victorian diagnostic laboratory now charges $84 to test each sample.

While it is still early days, the researchers believe that the project is on target to produce:

- a test that can more sensitively detect the presence of PCN, at any stage of its development and in extremely minute amounts. This will improve their ability to detect outbreaks at an earlier stage, and at any time in the nematode life cycle. This will be an important tool in the management plan for PCN in Australia, and

- a cheaper test, estimated at around $30/sample in contrast to the current figure of $84.

.

The third project by Gumley et al (PT436 and 520) sought to develop molecular markers to increase the efficiency of breeding for PCN resistance through an ability to select for resistance at the seedling stage. This was particularly important because of the inability to screen for resistance in Australia using conventional methodologies, and the probable need to screen progeny under quarantine in New Zealand. This approach would have been expensive and probably unachievable within the constraints of reasonable funding expectations. Regrettably at the conclusion of the project the scientists involved were unable to demonstrate a clear pathway for the use of this technology in the Australian breeding program. As a consequence it must be concluded that the research has had no positive impact on the industry, and offers no potential future benefits for increased PCN resistance in Australian varieties.

Related to this, the early recommendation by the PHC review for greater attention to PCN resistance as a breeding objective has now largely been abandoned because of the technical difficulties involved, the costs of screening under quarantine in New Zealand, and probably also due to the flagging interest in genetic resistance as an urgent element of the management strategy.

The final HAL-funded element of the PCN R&D strategy is project PT 99055 (PCN Management Strategy by Dr Gordon Burg at Knoxfield). This project has the important objective of developing a national PCN management plan, working from the knowledge that was gained in the previous study. While the final report is as yet unavailable, it is understood that the adoption of the Plan will provide a logical, science-based framework within which the trades of growing and marketing of potatoes can proceed with least unnecessary cost and inconvenience. It will also provide a basis for the development of protocols and possible future access to those international markets from which some parts of the industry are currently excluded because of PCN.

7.1 The benefits of the PCN research program

The principal outcome of the program will be a soundly based PCN management plan which will:

- facilitate the processes leading to the resumption of interstate and international trade in potatoes.
- identify the spread of the pest nationally, and
- reduce further spread.

7.1.1 Trade benefits

The impact of PCN on both interstate and international trade has been regional rather than national. For example, South Korea has imposed a ban on the importation of potato imports from Victoria and Western Australia, but is happy to receive shipments from NSW, SA, Queensland and Tasmania. While the research program will presumably allow Victoria to rejoin that trade on the basis of a negotiated pest free area protocol, there is no evidence to suggest that the national trade has suffered as a result of the ban and therefore, from a national perspective, the trade benefits arising from the research will also be zero. Similarly, it must be assumed that the Western Australian decision to ban Victorian potatoes simply resulted in a shift in production profile within the Australian potato industry with no overall change in the net value of the industry at a national level. While the research outcomes will have the potential to change the proportion of potatoes destined for the Western Australian market as Victorian growers achieve quarantine approval, there is no reason to conclude that the market will increase in size or value as a result, or that the research has had any significant overall economic benefit at the national level. On the contrary, the ability to demonstrate compliance to quarantine protocols will require a level of testing for the organism, and compliance to some form of "certification" scheme. For the purposes of this analysis it is assumed that 100 growers, each with 5 crops, representing 100,000 tonnes of potatoes (say 10 000 ha) wish to become eligible for these trades, and that the conditions of eligibility are:

- Demonstrated area freedom, based on intensive testing of each crop in the area for three years, costing $150 per crop per year, or 100 x 5 x 185 x 3, or $277,500
- One quarter of the area being tested each year (25 x 5 x 150, or $23,125
- Administrative compliance costs, say $10/ha/year, or $100,000

then, the costs of reaccessing the lost markets are around $277,500 in the first year and $123,125 each year thereafter.

It is unlikely that the trade considerations will have any impact on the processing industry, or the seed industry.

The research was conducted to provide the Australian industry with the capability to respond to quarantine restrictions placed on Australian potatoes. Should the pest spread to other states, or should any importer take a stronger view on the risks of importing potatoes from this country the effect would be to reduce the trade.

7.1.2 Productivity benefits

So far PCN has only been detected at a few sites in Western Australia and Victoria. The Wandin site is no longer a potato production area and the only known infested site in Victoria which is still actively and significantly involved in potato production is Gembrook. Unfortunately, the possibility of other infestations in the State (and in other states cannot be discounted because of the failure to complete a comprehensive national screening program, as proposed by HPC. Industry and researchers take very seriously the possibility of further spread, and the impact that that could have in restricting trade even further, and on the productivity of potatoes where nematodes are endemic. Thus, the value of the research can be assessed in terms of its ability to prevent further spread, and to allow production to continue without any special costs of PCN management or control beyond those mentioned above. Assessing the likely spread of nematodes in the absence of an effective management plan, and their impact on potato productivity is difficult, especially in the diverse environments in which potatoes are grown in Australia, and in the absence of a comprehensive knowledge of the organism's performance here.

In the following analysis the economic impact of the pest in commercial potato production is estimated for three scenarios. In the absence of a coordinated control program (as will be proposed in PT99055), it is likely that the organism will spread from existing infested areas into "clean" production districts and areas. There is little information to help predict the likely rate of spread, so for the purposes of the analysis three rates are used, varying from a conservative 1percent per year to an aggressive 10%.

7.2 Economic analysis of the PCN research program

The impact of the spread of PCN, and hence the benefits that will be achieved as a result of having a well designed and managed detection and treatment program can be calculated as the savings in the control costs. In the absence of the management plan it is assumed that the pest would continue to spread (at the nominated rates) and that the only available control measure would be soil fumigation with granular nematicides at a cost of $775/ha/year (Evans and Haycock, 2000). In reality of course, at least during the earlier stages of infestation growers would quarantine infested sites for potato growing purposes and the industry would simply shift to new and clean production districts. This would not be without financial penalty to the grower, nor social and economic penalty to their families and communities in which they operate. Notwithstanding this, industry is acutely conscious of how European growers deal with PCN, and their reliance on expensive chemical remedies and has agreed that the nematicides treatment is an appropriate basis of costing these hypothetical infestations. While plant breeding will provide an important tool for living with PCN in the longer term, the likely availability of resistant varieties that are suitable for Australian growing conditions is uncertain within the time frames of this project, and are not further considered in this analysis

At present the overall export market for Australian potatoes is not affected by the presence of PCN, although there are constraints on some states in some markets. If the pest was to spread into the other states the impact on exports (as well as on the interstate trade) could be severe, and although the threat is real, it is difficult to identify any "most likely" scenarios for analysis, which is therefore restricted to the direct effects of treatment costs on growers.

7.2.1 Assumptions

The following analysis assumes that 100 ha of potato producing land is currently affected by PCN, and that without the management plan, the uncontrolled spread occurs at one of three rates, 10%/year, 3% or 1%. These are conservative estimates given that the detection of infestation in an area will have an impact over a greater area than that in which the organism is identified, and if found in intensive potato producing districts, or on large production units, could impact tens or hundreds of hectares at a single stroke. They are also within the response range described by Phillips et al (1998).

The cost of treatment is $775/ha/year.

7.2.2 Results

The net present value and the benefit cost ratios for the various rate of spread assumptions are shown in table 7.1. The internal rate of return could not be calculated for any of the alternatives. The present value of the benefit and cost streams is illustrated in figure 7.1. The benefits would be proportionately higher if more rapid rates of spread or larger areas of initial infestation are assumed.

On the basis of these very conservative assumptions it is clear that this has been an effective research area, which will potentially yield benefits of $1.6 to $5.2 million over the life of the project and very positive and satisfactory benefit:cost ratios.

In the sensitivity analysis on the discount rate, only the net present values for the period 1992 to 2020 are reported in table 7.2.

Table 7.1 The net present value and benefit cost ratio for the research program

	Rate of spread of nematode	8% discount rate
NPV 1992-2020	10%	$5,211,700
	3%	$2,061,800
	1%	$1,637,600
NPV 1992-2000	10%	$1,265,300
	3%	$927,700
	1%	$848,400
BC 1992-2020	10%	15
	3%	6
	1%	5
BC 1992-2000	10%	6
	3%	4
	1%	4

7.2.3 Seed industry

Assuming that the current required sampling rate for seed production areas is maintained, the principal benefit to the seed industry would be in the lower costs of testing that would result, from about 2004 onwards, as a result of project PT1031. The Knoxfield diagnostic laboratory conducted 750 PCN analyses last season at a cost of

$84 per sample. Researchers believe that DNA probe methodologies that are being developed would reduce this cost to approximately $30 per sample, a saving of $40,500 per year. At a sample collection cost of $100, the current total cost of PCN testing is $138,000 in Victoria alone so the potential benefits for the industry is between $40,500 and $138,000 annually.

Figure 7.1 Present value of the benefit and cost streams for PCN research

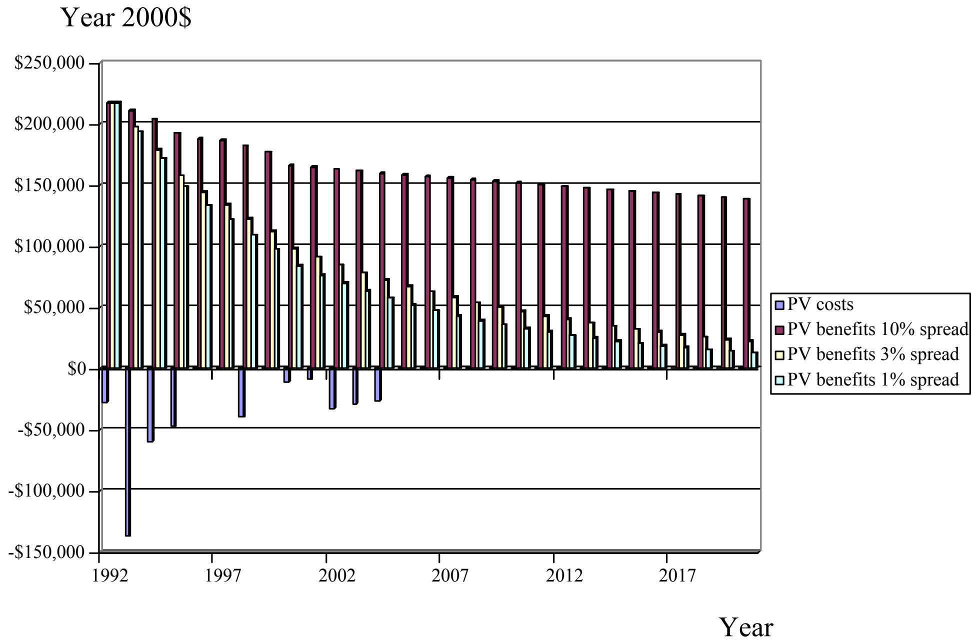


Table 7.2 Sensitivity of net present values to changes in the discount rate

Item	Discount rate	Rate of spread of nematode	Net present value
Change discount rate	5%	10%	$6,642,700
Change discount rate	5%	3%	$2,329,700
Change discount rate	5%	1%	$1,786,100
Change discount rate	11%	10%	$4,330,900
Change discount rate	11%	3%	$1,924,600
Change discount rate	11%	1%	$1,577,600

7.3 Environmental and social benefits

The ability to detect outbreaks at an earlier stage than is currently possible will increase confidence in the PCN-free status of growing areas, and in association with the Management Plan, reduce the need for nematicidal chemicals in potato production. These chemicals are widely used in Europe (though increasing availability of resistant varieties is helping) and it would be damaging to the

Australian industry's objectives for food safety and reduced chemical usage if the industry were to become reliant on chemical soil treatment.

The more widespread adoption of PCN would increase production costs, reduce profitability and eventually result in some growers shifting their operations to "clean" areas, at least in the earlier stages of spread. The Plan will slow the rate of spread and help overcome these social impacts.

7.4 Discussion and conclusions

While this analysis has required a number of rather arbitrary assumptions, the lessons available from Europe are also instructive. There the pest is widely distributed and gives rise to important and significant costs of participating in the potato industry. It has had important environmental, social and economic impacts on the industries.

The current analysis takes a relatively short term view of the problem, the risk is that over a much longer time frame the impacts could be very much greater than discussed here, both on production economics and on our ability to expand the export opportunities in Korea and other Asian and Pacific countries. In commissioning these research projects, the R&D Committee was conscious of the longer term potential for PCN to impact the Australian industry and in this context, the benefits of the research are almost certainly many times greater than the very conservative figures used here.

7.5 References

Evans, K. and Haycock P. (2000) Potato cyst nematode management-present and future, *Aspects of Applied Biology* 59, pp 91-97

Gwynne, R.T. (1991) Potato cyst nematode (*Globodera rostochiensis*) in Western Australia – a brief history of quarantine action. Contribution to 6th National Potato Research Conference, Healesville.

Hinch, J., F Alberdi, S.C. Smith, J.R. Woodward and Evans K. (1998), Discrimination of European and Australian *Globodera rostochiensis* and *G Pallida* pathotypes by high performance capillary electrophoresis. Fundamentals of Applied Nematology, 1164-5571

Horticultural Policy Council (1993), *Potato cyst nematode – Impact on Australian Horticulture and a proposed national strategy*. Report to the Minister for Primary Industries, Industry Report no 6.

Phillips, M.S. and D.L. Trudgill (1998), Population modeling and integrated control options for potato cyst nematodes in Marks, R.J. and Brodie, B.B. (eds) *Potato cyst nematodes : biology, distribution, and control*, CAB International, Wallingford.

CHAPTER 8 - TUBER-BORNE DISEASES, RHIZOCTONIA AND COMMON SCAB

Rhizoctonia (*R. solani*) and common scab (*Streptomyces scabies*) are two common members of a soil borne disease complex affecting potatoes in Australia. These are also important diseases internationally whose impacts are felt through their effects on tuber appearance, processing yield and productivity. Appearance is an important issue for the fresh market, and symptoms of the disease have an important bearing on the acceptability of potatoes for processing. Like most of the soil borne diseases, rhizoctonia and common scab are both soil and tuber borne, so the need for disease free seed is an important part of the disease management strategy.

Because of their international significance these diseases are also studied around the world, and measures of success of Australian research will relate to its effective integration into the world program, and the way it tackles uniquely Australian issues such as adaptation to our climate, ecology and soils. The diseases have proven difficult to manage and research progress has been difficult and slow. There have been few "breakthrough" projects, and progress towards effective management strategies will be achieved by building a knowledge base on the biology and pathology of the organisms from which new strategies can be developed and tested.

Not all Australian research on these two diseases has been funded from the levy, significant and important projects have been conducted and funded within the university system, by processing companies, and by other research providers. This analysis is therefore incomplete as a study of the research status for these diseases, restricted as it is to those projects which were funded from levy sources.

As in some other program areas included in this study, the analysis was hampered by the absence of a clear research strategy for the diseases, or clearly articulated research objectives. Of course the long term objectives of disease freedom is the "light on the hill" that attracts and motivates both researchers and funding committees, but the issues are more complex than that; there are many possible means of achieving disease freedom (chemical, genetic, biological), and it is unlikely that any one strategy will provide the solution anyway. There are also many shorter term and intermediate targets for research, including the closure of the knowledge gaps, and building the knowledge base from which future scientists can provide effective and resilient management strategies. One project (PT537) funded a workshop to review progress and to develop a coordinated approach to research in these (and other) tuber borne diseases. Whilst this was undoubtedly an important networking opportunity for the scientists and industry leaders involved, it did not produce a research plan beyond noting the need for management strategies for the complex, such as rotations and farm hygiene. These two issues are evident in the research program since that date.

In reviewing the program it became obvious that the elements of the current and past levy-funded research fall into the following strategic areas (table 8.1):

Table 8.1 Rhizoctonia and common scab research, strategic areas and project range

Strategic area	Project range
1 Understanding the biology and ecology of the causal organisms and developing biological and ecological approaches to their management and control.	Rapid identification technologies (PT006, PT01019)
2 Identifying and developing chemical control measures	Testing and developing new chemical control measures (PT610, PT96010), PT97015 "Natural" control measures (VG98076)
3 Identifying and developing resistance mechanisms in potatoes	Identification and development of resistant clones (PT01020, PT98015))
4 The role of rotations and biofumigation in management and control	Understanding the role of pastures (PT01017) Rotation effects and biofumigation (PT632, PT96032)
5 Integrated approaches to disease management	Antagonistic organisms (PT 315) Disease detection and monitoring (PT205) See also strategy 1 above
6 Farm hygiene and codes of practice	Disinfestation practices (PT 98918) Codes of hygiene practices (PT505)
7 Resource development, workshops, and conferences.	PT 02013, PT537

While the economic losses caused by these diseases can be quantified, the contributions made by each project could not. Few of the projects have or are likely to produce clear economic outcome in their own right (despite expectations), but will contribute knowledge and technologies that will have measurable impact at some future time. (The possible exception is PT 01020 *Evaluation and commercialisation of common scab resistant clones).* They are steps on the pathway to the ultimate goal and are therefore not suited or eligible for economic analysis and have been evaluated here within a qualitative framework.

8.1 Analysis of the rhizoctonia and common scab research

The projects were evaluated qualitatively against researcher-defined objectives, in table 8.2. Current projects are included in this table to illustrate the full extent of the research, and the directions for the next few years.

Overall the reviewers formed a positive view of the research, the outcomes of which are summarised below.

- The common scab resistance project has produced apparently resistant plantlets of two french fry varieties, which may translate into one or possibly two disease resistant clones. Resistant clones of crisping and fresh market varieties are also possible within the scope of the project.

- It has also produced a methodology which, if proven, can be used to produce common scab resistance in other varieties.
- The relationship between seed tuber infection with common scab and crop infection has been explained, at least in part.
- The potential (and limitations) for chemical disease control through seed tuber treatment has been demonstrated for common scab.
- The potential of biological control, using antagonistic micro-organisms hads been confirmed, though commercial treatments of this nature remain to be developed.
- The (lack of) potential for disease control by biofumigation with brassicas has been established.
- The knowledge base, especially concerning the biology of some organisms and their relationship with the environment has been expanded to form an important stepping stone for future research into integrated disease management.
- Soil disease assay tests have been developed.
- Codes of practice have been developed, to reduce the spread of soil borne diseases throughout the industry.
- Current research will produce advanced diagnostic tools, and (possibly) lead to integrated management strategies through crop and pasture rotation.

8.2 Conclusions

Soil borne disease research is notoriously difficult and slow, and requires trust and faith on behalf of R&D Committees in the search for practical and economically valuable outcomes. Equally, the Committee needs to take a world perspective with this research to ensure a close “fit” with the international program, and that it is clearly targeted at the specific problems and issues of the Australian industry. This is particularly true for example in the case of the rotation and pasture research, where the knowledge that will eventually result in useful industry outcomes can only be gained by painstaking adherence to the longer term vision, a clear and carefully conceived strategy, and a willingness to commit the necessary funds. This said however, the reviewers were impressed with the progress, agreed with the directions indicated by the current projects, and concluded that with the qualifications outlined in table 8.2 the research investment has been generally well targeted.

Table 8.2 Evaluation of levy funded rhizoctonia and common scab research.

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
1 Understanding the biology and ecology of the causal organisms and developing biological and ecological approaches to their management and control.	PT 02016 Common scab thresh-hold on tuber seeds for processing potato crops	Identification of meaningful common scab threshold levels for adoption in certified seed scheme, and for processing potatoes. Arises from PT96010, which identified a relationship between the severity and nature of seed-borne infection and infection in the subsequent crop.	Current	A new project.	
	PT 01019 Prediction and molecular detection of soil borne pathogens of potato	Develop diagnostic tests using DNA approaches that can accurately predict the presence and numbers of soil borne pathogens. Validate the predictive value of the probes to provide tool for assessing disease risk in potato soils.	Current	As above	
	See also strategic areas 4 and 5.				
2 Identifying and developing chemical control measures	PT 610/96010 Investigation on common scab, and development of control methods	Improve awareness and understanding of common scab in seed tubers of Russet burbank Determine relationship	Complet ed	There were two important outcomes of this project: 1 It confirmed that low levels of CS could be treated (in seed tubers) with chemicals.	This project made an important contribution to the knowledge of common scab. It identified the

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
		between seed and commercial tuber infection Develop control strategies Evaluating chemicals for effectiveness on other soil borne diseases		Mancozeb was identified as a low cost alternative to mercury based chemicals. It also identified appropriate application protocols. 2 It established a relationship between disease severity (on seed tubers)and infection in the subsequent crop. This has important implications for certified seed schemes, and led directly to a current project, PT02016 which investigates the relationships between CS thresholds in seed lines and disease transmission.	relationship between the severity and nature of seed infection and infection in the commercial crop, identified some practical control measures (including their limitations), led to the reduction in the use of mercury based fungicides, and provided important insights into the status of seed infection in certified seed potatoes Research arising from this project is clearly focused on a key issue for certification managers, ie the appropriateness of current arbitrary standards of disease in certified seed.
	PT 97015 New chemical treatments for fungal diseases of seed potatoes	Evaluate new chemicals against soil borne fungal pathogens, (silver scurf, black dot, rhizoctonia, powdery scab, common scab) as replacement for thiabendazole	Complet ed	Evaluated and quantified the efficacy of new sanitisers against rhizoctonia, and common scab, and several other diseases growing on seed tubers.	This research contributed important knowledge on the potential of several new chemicals, relative to existing (though unregistered for the

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
		in seed potatoes. Reduced risk of disease spread by seed. (Follows PT405 Integrated control of silver scurf and black dot of potato tubers in which preliminary studies of new candidate chemical controls were evaluated)		Indicated alternative treatment for rhizoctonia (to formaldehyde), and ranked new chemicals against Monceren (which was the most effective treatment) Identified more efficacious chemical treatment for black dot Unable to study disinfectant treatments on common scab, due to low and variable infection levels in treated tuber. Provided important information on chemical toxicity on new sprouts, which contributes to the knowledge and practice of seed treatment.	purpose) products, and on the toxic effects of the chemicals on seed tubers.
	VG 98076 Screening potato and vegetable soil borne disease that may be controlled by Eucalyptus mulch.	Test the efficacy of Eucalyptus leaf mulch (which had been previously shown to completely control onion white rot) against a range of potato soil borne diseases, including rhizoctonia and common scab.	Complet ed	The results were inconclusive due to the poor expression of disease in the experimental sites. Researchers recognised the practical difficulties of using this type of mulch, but recommended further research to test for efficacy in vitro, and to identify the	While the observed effect on onion white rot deserved to be pursued, the failure to ensure an adequate level of infection compromised this project. In the absence of this level of experimental quality control it is difficult to

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
				specific biocidal compounds involved.	be positive about this project.
3 Identifying and developing resistance mechanisms in potatoes	PT98015 Development of extreme reistance (immunity) to common scab within current cultivars	Clones of Russet Burbank and Shepody with "extreme and durable" resistance to common scab, (not using genetic engineering technologies).	Complet ed	The project successfully developed a process for in vitro selection of tissue cultured plantlets for resistance to the *Streptomyces* toxin, thaxtomin. The technique was used to produce 4 thaxtomin resistant plantlets of Russet Burbank and 12 of Shepody, which have clear potential for development as resistant commercial strains. The project contributed significantly to the knowledge of this organism in Australia, by identifying the presence of at least four pathogenic strains, including two novel ones, and confirming that all pathogenic strains produce thaxtomin. Finally, it also confirmed the presence of clonal variation in resistance to this disease in at least Russet Burbank, indicating another potentially	The project has successfully achieved its objectives in the production of resistant plantlets, to undergo glasshouse and field evaluation in a new project (PT01020) In addition to this, it has made a significant contribution to the knowledge of this disease, and identified potentially important avenues for further investigation of long term control strategies. If the field evaluations confirm the availability of resistant clones suitable for use in the processing industry it will achieve well deserved recognition for its contribution to both the Australian and international industries. If the field trials fail to

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
				valuable avenue for further study.	produce these commercial outcomes the technology is available for future reuse. In any event, the risk of the research was justified by the potential rewards, and the high likelihood of success.
	PT 01020 Evaluation and commercialisation of common scab resistant clones	Commercial clones, protected under PBR legislation and fully commercialised Enhanced knowledge of the mechanism of disease resistance. Alternative disease control strategies for cultivars other than the Russet Burbank and Shepody.	Current	Clones of Russet Burbank, which were selected on the basis of their *in vitro* thaxtomin resistance are currently being evaluated for tuber resistance to *Streptomyces* in the glasshouse. The project also allows for the selection of crisping and fresh market varieties.	If this project achieves its stated aims of commercially acceptable common scab resistant french fry varieties, the economic benefit will be large. The costs of common scab in the Tasmanian industry alone are variously estimated at $1 to $3 million annually, indicating a BC ratio over the twenty year period of the review of many hundreds to 1.
4 The role of rotations and biofumigation in management and control	PT632/96032 Influence of rotation and biofumigation	An understanding of the effects of different crop rotation strategies, including	Current	The project provided important new information on the pathogenic nature of a	Research into other control strategies for rhizoctonia have been

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
		biofumigation with Brassica spp on soil borne diseases, including rhizoctonia and common scab, and with the ultimate objective of providing additional integrated management strategies for soil borne diseases.		range of *Rhizoctonia* species, and their host ranges, and formed the intellectual basis for further research in the use of rotations as management tools for this, and other soil borne diseases. It also confirmed the inability of brassica rotations to control these diseases.	only partially successful and the use of rotations, which offers a potentially valuable approach to managing this disease has been strongly encouraged by the R&D Committee. The knowledge base which is required to underpin and direct this research has been provided, at least in part, by this project. While providing no directly applicable outcomes (ie, control strategies) the knowledge provided by this project will eventually contribute to the goal of improved disease management through the use of rotations, and should be continued
	PT01017 Understanding the implications of pastures on the management of soil	Understanding the role of pastures in the disease cycle of soil borne diseases (rhizoctonia, common scab, etc), and a knowledge base for	Current	This project is relatively new, and it is too early to judge its progress as yet.	

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
	borne diseases of seed potatoes	the development of pasture management strategies to assist in the management of diseases. Specific objectives are: 1 Determine relative abundance of pathogens associated with different pasture regimes. 2 Identify which pasture species support or suppress pathogens. 3 Identify pasture management strategies that minimise carryover of disease into later potato crop. 4 Evaluate the overall impact of the pasture phase on potato production.			
5 Integrated approaches to disease management	PT 205 Integrated management of potato common scab	An integrated disease management plan based on controlled irrigation practices, seed hygiene and treatment, foliar and soil treatment, and cultivar evaluation for disease resistance, as well as a diagnostic soil testing and evaluation mechanism.	Complet ed	The project confirmed the need to develop control strategies in the local environment, and with locally adapted pathovars. While not able to produce a clear (integrated) disease management strategy for the disease, it did provide some important directions and indications for future	The project failed to provide a simplistic "magic bullet" for the control and management of common scab. Given the complexity of the organism, and of the disease this is not surprising. However it has significantly advanced our knowledge

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
				research and management. For example, it confirmed the ability of the soil assay test to detect and distinguish pathogenic and non pathogenic strains of the organism and indicated the way forward for soil pathogen population monitoring. It indicated a number of factors that might predispose crops to infection (ie, directions for further research), and identified that soil moisture management alone cannot be relied on as a control measure. The project provided encouraging results to chemical treatments, and cultivar trials indicated variable resistance, which suggest the possibility of clonal variation within the target variety (Russet Burbank), again a subject for future research.	of the disease, provided some useful contributions to the emerging views on management strategies, and produced some clear directions for future research. Overall, it is assessed as having served a useful role in the understanding of the disease, and made useful contributions to its current and future management.
	PT 315 Rhizoctonia control in fresh market potatoes	Biological control of soil borne inoculum of rhizoctonia using antagonistic fungi and bacteria.	Complet ed	The project confirmed the potential of the micro parasite *Verticillium biguttatum,* for the control of	Like many pathology projects, this work was conceived and carried out outside any industry

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
		Elimination of tuber borne inoculum using fungicide dips. Chemical control of soil borne inoculum by furrow application.		rhizoctonia, which was a positive outcome which may produce future dividends. However, the organism has not been commercially developed, and the research was not continued due to lack of funding.	plan for rhizoctonia management. While it may have been a "good bet" at the time, the absence of a commercial product prevents the research from having any useful industry outcome, at least in the medium term. This project highlights the need for a sound scientific plan for R&D for each of the major diseases.
	PT006 Rapid identification of *Streptomyces spp* on potato, the key to integrated management	Develop a test to identify the presence of *S scabies* in the soil, to enable monitoring of the levels of the organism in potato soils, and as a means of quantifying the value of rotation crops in Russet Burbank.	Complet ed	Developed an ELISA methodology, which was not evaluated against soil samples from a range of infection levels to produce a predictive test. Recommends additional research to develop DNA probes (see PT01019), and predictive capability.	A valuable contribution to many aspects of disease management and control, eg in seed production and site selection.
	PT98018 Cleaning and disinfestation practices	Practical disinfestation practices for seed and ware growers (to eliminate the risk of infection due to spread by spores on machinery, bins,			

Strategic area	Project	Objectives	Status	Project outcomes	Evaluation
		bags, and in sheds.			
7 Resource development, workshops, conferences and visiting scientists.	PT537 Review of potato tuber borne diseases	Coordinated research program for all soil borne diseases in potatoes		Workshop minutes	Failed to develop a research plan for key diseases.
	PT 02013 Attendance at international workshop on common scab	Strengthen strategic linkages between Australian and international researchers and programs.		The Conference will be held in November 2003.	

CHAPTER 9 - RESOURCE MANAGEMENT AND PROTECTION

Not all of the potato program has been strictly concerned with economic outcomes, at least in the short term, and some projects have been conducted for the purposes of improving the environmental sustainability of the industry. The key resource protection issues for the industry include:

- pesticide usage, soil and product residues,
- heavy metals in the soil, and product,
- the sustainability of soil management practices, particularly as they relate to erosion, eg in sand hill production areas, but also as they affect soil structure, biological and chemical health, and salinisation,
- sustainable water usage, as it affects soil health, as well as long term access to water, compliance with community and government standards for water use efficiency, and issues of regional and off-site drainage and effects,
- sustainable crop nutrition practices, especially in relation to the soil and water effects,
- community and social issues, especially but not exclusively at the urban interface, and
- the management of exotic and/or industry-threatening pest and disease incursions.

While these issues have obvious and important relevance to the economic and physical sustainability of the industry, they have higher-level importance, for example on industry's ability to comply to food safety and (emerging) environmental standards which are being sought by increasing numbers of consumers.

The program, and the industry, has made deep inroads into some areas of environmental importance, which have been dealt with elsewhere in this report. They are summarised in table 9.1.

9.1 Additional programs in resource management and protection

In addition to those areas referred to in table 9.1, and not analysed for their economic impact elsewhere in this report, the program includes completed and ongoing projects in other areas. These are listed and assessed alongside the wider resource management program in table 9.3.

9.2 Analysis of the resource management and protection program

This chapter aims to provide an evaluation of the environmental benefit of the resource protection projects. Some of these have already been reported from an economic perspective, but in this section we evaluate the environmental outcomes using a qualitative evaluation framework.

Table 9.1 R&D programs which have been analysed elsewhere in this report with significant environmental outcomes

Resource issue	Comment
Cadmium	This major program area secured a way for potato production to continue, more or less unaltered through developing and negotiating a science-based argument for regulatory change. The funded program will have little impact on the cadmium levels in Australian potatoes though the increasing use of "low cadmium" fertilisers slows the rate of accumulation in potato growing soils. The problem of cadmium accumulation has not been solved, merely deferred.
Reducing pesticide usage	The IPM projects, coupled with regional development and similar activities have significantly reduced the industry' reliance on agricultural chemicals. The adoption of these technologies is incomplete and further progress is achievable from well targeted extension activities. No IPM approach has been devised for the soil borne pests white fringe weevil and black beetle, for potato diseases, nor any method to reduce the use of soil fumigants where they occur.
Food safety	The QA research has had an important impact on the adoption of "food safe" practices throughout the industry, especially in safe chemical storage and use, compliance with registered use patterns (for pesticides), and compliance with regulatory standards for heavy metals. The Australian potato industry is a leader in the adoption of safe food production systems.
Improving pest and disease resistance by crop genetics	The gene technology component of the genetic improvement program will (if acceptable) offer a limited chemical-free alternative to the management of virus diseases. Many imported varieties have specific resistance (eg, Atlantic to PCN Ro1), but significant sources of disease resistance in European and American genotypes have not been fully exploited.
Exotic pest incursions	The PCN research has identified a strategy for the management of this destructive nematode which avoids the use of chemical fumigants.
Reducing the impact of growing potatoes in the Sydney Water Catchment	The industry development project in the NSW Southern Highlands was specifically targeted at securing the future of the potato industry in the Sydney water catchment. The primary issues, which were largely overcome in the project included soil, pesticide and nutrient accession to the city's water supply.
Increased adoption of "sustainable" management practices	Regional programs (Atherton, Southern Highlands, Crisping industry) have increased the adoption of improved pest management, irrigation and soil management practices.

This process has been made more difficult by the absence of clear industry environmental objectives (other than "to be environmentally sustainable"), or a timeframe within which specific industry targets are to be achieved. There is no satisfactory yardstick or benchmark by which to judge the program. Table 9.2

suggests a notional higher-level framework for a potato industry resource protection (environmental sustainability) plan, which has been used in the construction of the analytical framework in table 9.3.

Table 9.2 A notional (though incomplete) framework for a potato industry sustainable production strategy

Sustainability issue	Outcomes	Project range (example)
Sustainable soil management systems	Soil management practices that are compatible with long-term objectives for sustainability with respect to: ❑ Soil physical structure ❑ Soil chemistry ❑ Soil biology ❑ Salinity ❑ Heavy metal and chemical residues	❑ Benchmarks of sustainability for various growing environments ❑ Nutrition studies to ensure applications are in balance with soils' capacity. ❑ Rotation studies to maintain soil physical characteristics ❑ Production systems to minimise impact of soil borne heavy metals and chemical residues
Sustainable chemical use	Chemical use patterns that accord with community, soil and biological standards and capacities.	❑ Non-chemical pest and disease management technologies ❑ Efficient chemical application procedures ❑ Selection of "softer", more acceptable chemicals ❑ Studies of pathogens to improve chemical control options ❑ Systems (such as improved supplier) to ensure compliance with regulatory standards. ❑ Weed studies to minimise the impact of herbicide usage.
Sustainable water use	Recycled water use	❑ Studies of potato agronomy and physiology to increase water use efficiency ❑ Engineering and soil studies to increase water use efficiency, reduce salinity effects and reduce off-site impacts of potato production
Industry impacts	An industry that accords with community impact standards	❑ Waste management and disposal ❑ Farming at the community interface

These problems of lack of clarity on R&D needs and strategies are recognised in the current Potato Industry R&D Plan, where a key action is to "develop a mechanism to identify the environmental and sustainability concerns". When this planning research is undertaken it would be advantageous from a research planning perspective to set both clear objectives for improvement (eg, "reduction in pesticide usage by 30% by 2005"), and considered strategies for achieving these outcomes, along with measures (benchmarks and KPI's) and review and management processes designed to achieve industry outcomes (rather than project outputs).

In summary, our inability to critically and comprehensively evaluate the resource protection program has been caused by:

- the lack of a clear and systematic approach to the identification and quantification of sustainability issues in the potato industry,
- the incomplete and *ad hoc* nature of the sustainability component of the R&D Strategic Plan,
- the absence of clear industry objectives for sustainability,
- the absence of any management processes or mechanisms to relate sustainability R&D activities to measured industry outcomes, and
- the absence of any R&D prioritisation in the sustainability "program"

Notwithstanding these deficiencies, the program has made some significant inroads into aspects of resource protection. For example it has:

- reduced cadmium inputs into Australian potato soils,
- reduced pesticide usage through the adoption of IPM for foliar insect pests,
- improved grower nutrient management practices, presumably contributing to reduced losses to the water table and off-site impacts on rivers and streams,
- improved grower practices in the management and storage of chemicals through the quality systems initiative,
- increased the rate of grower adoption of "sustainable" practices through focused regional programs,
- explored and quantified options for reducing potato wastes,
- contributed to reduced soil erosion in specific circumstances (eg, Southern Highlands Regional Development project in the Sydney Water Catchment Area), and
- developed weed control strategies for at least one difficult to control weed species.

Overall however, the program has been inadequate in its attention to major sustainability issues of water and soil management, and to aspects of the chemical usage program.

The reviewers were unable to provide a satisfactory report on the economic benefits of this area of the R&D program. Some of the programs such as IPM have been highly successful economically, and will coincidentally have contributed significant environmental benefits. Their contributions to an overall objective (of reduced or eliminated chemical usage in the industry) have not been quantified against planned industry outcomes so that, even in the more obvious cases it has been difficult to draw any conclusions about the overall impact of the program on the sustainability of the production systems, or of the various resources involved in producing potatoes.

Other R&D activities appear to have been *ad hoc* and at times incomplete. The lack of attention to water use and drainage appears to be out of proportion to the size and nature of the issue, and (intuitively) it would appear that the program fails to address important issues of soil erosion and soil and nutrient loss from potato lands.

While the authors have generally avoided giving recommendations in this review, they believe that this is warranted in this particular area of the program. They believe that environmental sustainability should be an area of key concern for any industry, that deserves to be addressed both comprehensively and analytically. This is especially true where industries are moving to new production areas and systems, where they are potentially significant targets for community concern with respect to their impact on the soil and water resources of the nation, or where they are believed to represent human health risks in terms of chemical residues or off-site spray impacts. The potato industry is a candidate for criticism in all of these areas, and should have a R&D response which comprehensively addresses each of them. This must be clearly and meaningfully articulated in industry strategy documents, and planned and driven to achieve real industry change, to an acceptable level. Only when such a planning and management and review process has been implemented can the impact of R&D activity be objectively assessed.

Table 9.3 Evaluation of the Australian potato resource management program

Program area		Projects	Project outcomes	Evaluation
Sustainable soil management systems		Cadmium (Chapter 4)	Amended regulatory standards and cadmium management strategy	The project will have a limited effect on soil cadmium levels, further work will be required as cadmium inputs to the soil continue to exceed losses in harvested crop.
		Integrated approaches to crop management (Chapters 12, 13, 14)	Improved grower soil management practices, reduced erosion and off-site impacts, better matching of nutrients to plant needs and soil capability.	These projects have had positive impacts on the sustainability of soil physical and chemical (and presumably biological) health, with significant on- and off-site benefits.
	PT428, PT94028	Information packages and decision support software for improved nutrient management of potato crops	Decision support software and knowledge base to improve grower practices in matching fertiliser use to plant needs and soil capability.	The software has had a limited acceptance (about 60 packages sold), though this appears to underestimate the impact of the program outcomes. There is little doubt that potato growers are more conscious of the need for correct fertilising practices and of the potential for off-site impacts, and that the project has positively influenced these changes.

Program area		Projects	Project outcomes	Evaluation
	PT107	Development of crop management strategies for improved productivity & quality of potatoes grown on highly acid soils	A demonstration of the effects of liming in reducing cadmium uptake by potatoes (in a limited range of soils)	The project failed to produce any transportable principles concerning acid amelioration in (selected) potato growing soils.
	PT97026	Developing soil and water management systems for potato production on sandy soils in Australia	Management practices to improve water penetration and storage in repellant sandy soils.	This project provided useful management information regarding production from sandy soils at the time the industry was expanding into these newer production regions. While the project had useful production outcomes, its contribution to sustainable soil management practices (eg erosion and off-site impacts of irrigation) were minor.
	PT97003	More economic and environmentally responsible use of phosphorus fertiliser in potato cropping on krasnozem soils in Australia	High phosphorus applications in Tasmanian krasnozems, (which supply 85% more P than required by the crop) could not be replaced by alternative, more P efficient fertiliser regimes.	Over-fertilising with P is a potentially serious environmental issues, as well as an economic one. This project failed to offer an alternative approach to fertilising in these soils, and was probably an incomplete attempt to do so.
	PT02014	Sustainable agronomy packages	A new project designed to improve the	This project will develop production

Program area	Projects	Project outcomes	Evaluation
	for export potatoes	potato export industry in WA	systems for new, export varieties (such as Dawmor), using "sustainable" practices. While (like the regional development projects) it may have an important impact on the adoption of better agronomic practices, it will produce no new principles of sustainable potato production.
Sustainable chemical use	IPM (Chapter 6)	Non chemical management practices for a (incomplete) range of insect pests.	The projects have had major economic impact, and significant environmental benefit due to reduction in chemical usage. On the supposition that pesticide usage per se is unsustainable in the longer term, it must be concluded that additional work is justified to find non-chemical approaches to soil borne insects, diseases, and possibly nematodes, and to increase the overall adoption of defined sustainable practices.
	HACCP and safe chemical use (Chapter 10)	An important contribution to the development and adoption of QA systems, leading to improved storage and management.	This project has had an important and beneficial impact on the industry and contributed in a significant way to its agricultural chemical usage and management.

Program area		Projects	Project outcomes	Evaluation
		Genetic pest and disease resistance (Chapter 5)	Virus resistant clones of Sebago, in or after 2004.	Community and consumer attitudes to GM whole foods will probably delay the realisation of potential sustainability benefits from this project for at least another decade.
		Integrated approaches to crop management (Chapters 12, 13, 14)	Improved grower adoption of IPM, reduced chemical usage.	Apart from their positive economic outcomes these projects have contributed to the sustainability of the industry through the replacement of chemicals by durable IPM approaches. Further regional projects of this nature are justifiable in the drive towards increased adoption of sustainable practices.
	PT96047	Control of black nightshade and other weeds in potatoes	A registered chemical for the control of black nightshade in potatoes.	The project identified a useful chemical approach to controlling a problematic weed in potatoes (a positive result). However, an expansion of the work could probably be justified to explore alternative management practices.
Sustainable water use				
Industry impacts	VX01006	Developing cost effective UV protection of biological pesticides	This project is still incomplete, but if effective will increase the efficacy of biological pesticides through reduced breakdown due to UV.	A positive approach to supporting the adoption of biological pesticides in potatoes.

Program area	Projects		Project outcomes	Evaluation
	VX99002	Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry	An economic analysis of the availability and potential usefulness of organic waste in Tasmania, of which the vegetable (and potato) industries form a small part.	This was a useful contribution by the Tasmanian potato industry in the search for improved utilisation of organic wastes. The project was a "first step" towards a systematic approach to a difficult problem, and the project is assessed as positive.
	PT304	Review of potato waste utilisation in Australia	An understanding of the quantum of waste generated by the Australian potato industry, and of the logistical issues involved in attempting to utilise this resource.	Another useful project in defining the problem, but one which offers little assistance in addressing the issues and opportunities.
	PT409	Evaluation of the economic opportunities for potato by-product industries in Australia	An evaluation of potential uses for waste products from Australian potato processors and farms (following a review of waste utilisation practices in the USA and Holland). The highest ranked opportunity was for stockfeed. The project offered little support for fuel or potato flour industries in Australia.	While the project offered little direction for improved utilisation of potato waste, it did underscore the economic difficulties of using theses products in a small and geographically dispersed industry, such as Australia's. This was an important contribution to the debate about waste disposal.

CHAPTER 10 - QUALITY ASSURANCE/HACCP

This has been an important but perhaps under-resourced area of R&D activity. Funds have been applied to only two projects in potatoes, and only one of these (by the QDPI) has been concerned with the development of a system for the potato industry, and activities to increase grower awareness and adoption. This project was conducted at a time of intense food safety activity in the industry and many growers, especially those which were aligned with any of the large processors or marketing chains were being actively encouraged or trained to comply with one or other of the many quality systems that were already in the market place. These include the Woolworths Quality Standard, The Smiths Snackfood Quality Standard, SQF 2000, ISO9002, and more recently, FreshCare. The second project (*Developing a product description language for potatoes*) was commissioned in support of all of the quality programs throughout the industry.

The need for food safety QA in potatoes has emerged as a consequence of the increasing community awareness of food safety issues generally, and of the demands of most major processors for quality assured, safe food and raw material supplies. Different parts of the industry responded in different ways. Some chain leaders instituted relatively simple "approved supplier" requirements while others required their growers to adapt to sophisticated, and demanding HACCP-based programs. In any case, the purpose of the scheme was to ensure compliance to rigid standards of safety, which is defined in the following terms:

- compliance to Food Standards requirements (especially cadmium),
- compliance to pesticide residue standards,
- freedom from potentially damaging physical objects (glass, stones etc),
- freedom from foreign chemicals (rat baits, oil etc), and
- adoption of "best management practices"), for example in the use and storage of farm chemicals.

To satisfy these requirements growers must:

- maintain chemical use diaries,
- demonstrate that their equipment is functioning properly, especially with respect to calibration of chemical applicators, and maintenance of harvesters, pilers and trailers etc,
- demonstrate a routine ability to produce potatoes that comply to the Food Standards, and
- adopt "good farming practices".

At the higher level, growers need to be accredited to the standard, and audited by a third party, though the more generic approach, which resulted in part as a result of this project, produced the more "user friendly" Freshcare program.

The project PT96014 *Development of a quality assured production and marketing system for the fresh potato industry* which was conducted by the Queensland

Department of Primary Industries at Gatton takes a wider view of quality management, which encompasses both food safety and physical product quality. The objectives were to:

- develop a model for potato production, handling and marketing systems,
- improve profitability of fresh market production,
- develop a greater market focus for a pilot group of growers,
- employ the techniques used in quality management to present a better quality product to the market, and
- identify producer-customer relationships to optimize best returns for both parties.

As noted, the project involved the researcher working with a small group of growers, who both learned and "directed" the project throughout its life. The outputs can be divided into two classes, those which directly benefited the individuals in the group, and those which had wider and more sustainable impact across the industry. At the completion of the project, and as a result of the project most or all of the growers in the pilot group had:

- adopted approved chemical storage practices,
- commenced a basic record keeping system that was consistent with the requirements of most QA systems,
- commenced recording chemical usage in a standard spray diary, and
- become accredited with Freshcare

In addition, two had acquired AQIS export accreditation.

While the economic benefits to these growers were never measured or recorded, it is apparent that they received additional and special benefit from their participation in the study that in itself might well have justified the R&D expenditure. The researcher believes that a number of these growers, who have now progressed to more profitable enterprises did so as a direct result of their participation, though of course this cannot be measured.

The latter group of outputs included:

- an on-farm QA guide (*Quality Assurance Guide for Potato Farmers),*
- a chemical storage guide (*Farm Chemical Storage Guide),*
- a potato defect poster, and
- a model record-keeping system for recording quality and food safety activities during growing, harvesting, storage and transport of potatoes.

10.1 Assessing the benefits

This project does not lend itself to quantitative analysis. The benefits occur as a result of:

- the educative and informative role played by the researcher during his participation in many industry meetings around the Australian potato industry,
- the effectiveness of the major published outputs in assisting the development and adoption of quality systems and practices (such as chemical storage), and

- the impact of the researcher and the publications on quality systems and practices in non-target industries

In assessing the impact of the project contact was made with key personnel in various processing and retailing operations, and industry and government field staff whose comment provided the substance for this report. In summary, their comments are highly supportive of an effective project outcome; particularly they agree that the researcher had a major impact on the understanding by growers of the nature of and need for quality systems in the Australian potato industry, and that this influence extended widely across the industry. Its impact was also felt in many other horticultural industries. For example, one quality manager with a major wholesaler believes that most of her 1200 suppliers (across all commodities) were favourably impacted by the researcher, and the project.

There was also strongly supportive comment regarding his influence on the Freshcare program. Prior to Freshcare, growers were being encouraged to adopt more sophisticated and expensive systems, mostly requiring third party auditing. Freshcare offered a more pragmatic approach which concentrates on real industry issues, and which does not require the same level of training, knowledge, documentation or audit. It is a practical and user-friendly approach to quality management in the fresh produce industry which has now been widely accepted and adopted. The researcher, and the project were important influences in both the definition and development of the Freshcare model, and in its acceptance by Australian potato growers. His influence clearly went well beyond the potato industry.

10.2 Conclusions

While the benefits of the project could not be quantified it is clear that it has been highly effective in its impact on the drive towards industry-wide adoption of food safety quality systems in the potato, and other horticultural industries. The project has had some parallels with some of the industry development projects which have been assessed within the current analysis in that it has been highly focused and outcome driven, and also highly effective in achieving industry change.

Previous to this project the QA debate was dominated by the highly developed and sophisticated systems, such as ISO, SQF or the Woolworths Quality System. These are demanding on growers' time and skills, costly to conduct, and realistically, excessive solutions to somewhat simple problems. This project offered a simpler approach to QA that has had wide impact, both through its effects on the Freshcare program, and more generally. This has been a major contribution from a successful piece of research, and industry investment, and an area of activity that the R&D Committee may review for possible continuing investment.

CHAPTER 11 - REGIONAL INDUSTRY DEVELOPMENT PROJECT – SOUTHERN AND NORTHERN HIGHLANDS

This series of projects was designed to increase the level of awareness, and adoption, of sustainable production practices amongst potato growers in the highland potato growing regions of NSW, initially the Southern Highlands around Robertson, but towards the latter stages also at Dorrigo and Guyra. Robertson growers produce potatoes within the highly sensitive and protected catchment area for the Sydney water supply, and in a social environment which is particularly sensitised to many of the sustainability and environmental issues related to pest and soil management.

The project was conducted by Sandra Lanz of Lanz Agricultural Consulting in association with the Robertson District Potato Advancement and Landcare Association, Sydney Water, the Wingecarribee Shire Council and the Departments of Agriculture and Land and Water Conservation. The project was initiated to overcome the environmental problems created by soil erosion from potato farms in the Robertson area, but was expanded to include a range of soil and crop management issues which contribute to industry sustainability. They were:

- **Irrigation**. Growers had a limited knowledge of the principles of irrigated crop production, or of the efficiency of their irrigation practices.
- **Integrated pest management**. The principal pests at the commencement of the project were tuber moth and aphids, and the two significant diseases were target spot and (occasionally but significantly) potato leafroll virus. Research that was current at that time had developed IPM approaches to the management of these diseases that were less reliant on chemicals, and more compatible with principles of sustainability. Soil insect pests white fringe weevil (WFF) and African black beetle (ABB) were an issue at Robertson, but more so in the northern districts.
- **Crop nutrition**. Conventional approaches were not based on established principles of crop nutrition and were thought to be wasteful in terms of inputs and the environment, and inefficient in terms of optimising crop productivity.
- **Soil phosphorus**. Potato soils were high in unavailable phosphorus.

The first stage of the project concentrated on grower education and improving soil management and irrigation practices.

The final stage in 1997–1999 concentrated on two areas of concern, the high levels of phosphorus that had developed as a result of a long history of fertiliser usage, and the implementation of integrated pest management. The objectives of the second stage were to:

- implement biological control for potato tuber moth at Robertson,
- develop management practices for white fringe weevil and African black beetle at Guyra and Dorrigo,
- develop and implement phosphorus management strategies for the krasnozem soils at Robertson (to utilize the high levels of fixed P in the soils, and,
- reduce input costs of potato production by 10%

The project team included:

- R Spoonerhart, University of Western Sydney (IPM)
- L Tessoriero NSW Agriculture (Pathology)
- M Robbins, NSW Agriculture (Irrigation management)
- S Little and R Greene Dept of Geography, ANU (Soil phosphorus management)
- P Hocking CSIRO Division of Plant Industry (Soil phosphorus management)

11.1 Outcomes of the research program

11.1.1 Irrigation management

Growers contribute the larger share of their improved productivity to their enhanced understanding of irrigation principles as they relate to the potato crop. During the course of the project growers adopted soil monitoring techniques and strategic irrigation practices which they believe made the most significant contribution to the 14-18% yield increases that were achieved.

11.1.2 Integrated pest management

Stages 1 and 2 of the project were designed to increase grower knowledge and awareness of the principles and practices of IPM, for example through their ability to identify pests and beneficial insects, their newly developed crop monitoring skills, and their better understanding of the role of different approaches to pest management. Growers completed the National Farm Chemical Users Course, and a growers' Handbook of Best Practice was produced.

During this stage of the project the potential for using the parasitic wasp *Orgilus lepidus* for the biological control of the tuber moth, and as a strategy for reducing chemical usage in the Robertson area was realised, and the widespread adoption of this form of control became a central objective of the final stage of the project, at Robertson and in the northern areas. Growers also adopted non chemical approaches to managing soil borne grubs.

The researchers reported positive outcomes of the program at Robertson, with a high level of control of the tuber moth, and encouragingly large counts of predatory insects in the field following the reduction in broad-spectrum pesticide applications. This encouraged growers to maintain their interest in crop monitoring and IPM. Growers now purchase and release predatory insects in preference to using chemical sprays, with resulting financial and environmental benefit.

White fringed weevil (WFW) was identified by growers as the major soil pest at Guyra, and both WFW and African black beetle (ABB) at Dorrigo. While there was some minor monitoring of these pests within the project there were no significant outcomes there in terms of control or management practices.

11.1.3 Crop nutrition

At the beginning of the project crops were fertilised according to traditional practice. Growers learned to use soil analysis as the basis for strategic fertilising practices, which improved crop response and detracted from losses (particularly of nitrogen) to the catchment. The costs of their nutrition programs were not affected to a great extent, though the environmental benefits were significant.

11.1.4 Soil phosphorus management

The earlier work (stages 1 and 2) indicated that soils at Robertson contained high levels of phosphorus that were unavailable to the potato plant. The soil phosphorus team studied the effects of selected cover crops on the availability of the phosphorus to succeeding potato crops. The experimental crop was a combination of brassicas (with biofumigation benefits?) and white lupins. White lupin was chosen because of its physiological ability to “mine” the bound phosphorus, later releasing it in an organic form that would be available to the potatoes. The environmental benefits through reduced phosphorus run-off would also be significant.

The results of this work were encouraging, though inconclusive. The cover crops had benefits through their effects on soil structure and carbon level and the contribution of the lupins to soil nitrogen supply. Eight weeks after planting the available phosphorus levels were also increased as a result of the cover crops.

11.2 Economic analysis of the Southern Highlands industry development project

11.2.1 Assumptions

At the beginning of the project some 18 growers, growing 300 ha of fresh market potatoes for the Sydney market were involved in the Robertson district and the project. The numbers and production areas in the Northern Tablelands was unrecorded, but thought to be about the same. At the completion of the project, twelve growers continue to produce 200 ha of potatoes at Robertson, but 80 percent of production comes from two families, both of whom have embraced the outcomes of the project. The Northern growers showed little interest in the project, which therefore had little impact beyond the Southern Highlands.

The claimed outcome of the project was an average 15% yield increase, resulting from the adoption of improved agronomic, water management and nutritional practices, and the adoption of IPM by the growers. The average yield at the beginning of the project was 25t/ha, and the variable input costs typically $5 000/ha

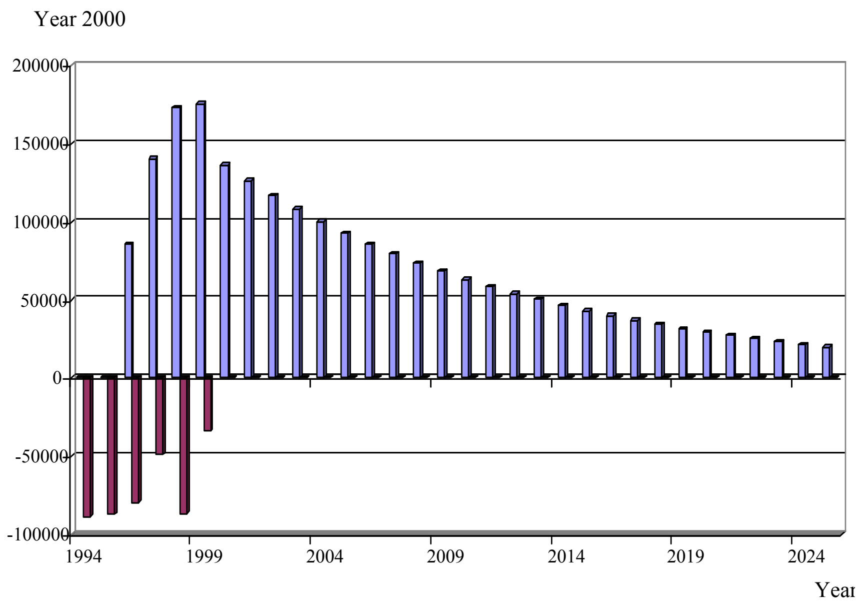
11.2.2 Results

Small but positive NPV's were recorded as a result of grower adoption of the new technologies which were introduced by this project (table 11.1, figure 11.1). The Benefit:cost ratios were also small and positive. Given the high rate of adoption amongst the participants the sensitivity analysis was restricted to varying input costs and discount rate (table 11.2). The principal benefits sought by this project were environmental, mainly reduced soil and nutrient loss to the catchment, reduced pesticide use (and run-off) and more efficient use of irrigation water. These objectives were also achieved.

Table 11.1 Economic value of the Regional Development (Southern and Northern Highlands) research

	8% discount rate
NPV 1994-2025	$1,743,300
NPV 1994-2000	$286,800
B/C 1994-2025	5
B/C 1994-2000	2
IRR 1994-2025	49%
IRR 1994-2000	37%

Figure 11.1 Present value of benefit and cost streams



11.3 Environmental and Social benefits

This project was different to most rural research and development projects in that the primary aim of the work was to improve environmental and social amenity. In a sense, the economic benefits to the industry measured here are the spillover effects. While we have no measure of the environmental benefit, it is understood that soil spills that were previously common after heavy rain no longer occur and the adoption of IPM has reduced agricultural chemical usage drastically, in some cases to almost zero. The nutrition program has improved the matching of fertiliser inputs to soil and plant capability and also contributed to an important environmental outcome.

Table 11.2 Sensitivity analysis: effects of changing variable costs and discount rate on NPV of Southern Highlands industry development project

Item	Value	Time period	Net present value
Change variable costs	$4000	1994-2025	$1,309,800
Change variable costs	$4000	1994-2000	$144,600
Change variable costs	$6000	1994-2025	$2,176,800
Change variable costs	$6000	1994-2000	$429,000
Change discount rate	5%	1994-2025	$2,218,300
Change discount rate	5%	1994-2000	$295,300
Change discount rate	11%	1994-2025	$1,424,700
Change discount rate	11%	1994-2000	$275,600

11.4 Discussion and conclusions

This was a small project with modest outcomes when viewed from the perspective of the national levy funds. The outcomes however were significant for the growers concerned, and especially to the Sydney Water Catchment because of the reduced runoff of soil, nutrients and pesticides into the city's water supply. These benefits would probably be sufficient on their own to justify the expenditure on this project, which demonstrates what can be achieved by combining clear project objectives with dedicated resources, and provides a useful model for further development within the industry.

CHAPTER 12 - REGIONAL INDUSTRY DEVELOPMENT PROJECT-ATHERTON

According to the researcher, prior to this project potato growers in the Atherton Tablelands appeared to have had a record of indifference to the activities of Government advisors, resulting in low adoption rates of newer technologies. A preliminary project (PT012) clearly established that traditional fertiliser use practices were wasteful of inputs, and presumably also damaging to the environment but traditional extension approaches were ineffective in altering grower fertilising practices. The objective of this project was to explore novel approaches to improving grower awareness and adoption of preferred sustainable practices, through participatory group activity designed to give growers “greater ownership of the processes”.

As in the other industry and regional development projects the key objectives were to increase the sustainability and productivity of the industry on the Atherton through “better” management practices. The focus areas were defined by the two groups that were formed during the project as:

- seed quality, management and planting practices,
- pest and disease control,
- irrigation management, to increase water use efficiency,
- crop nutrition to improve profitability and sustainability, and
- quality assurance

Throughout the project growers were introduced to a wide range of new concepts, including crop monitoring for pest management, the use of introduced and naturalised predators, soil monitoring and irrigation scheduling, and the use of soil and foliar analyses as a basis for fertiliser planning. The project had many similarities to the regional development project in the NSW Southern Highlands project (PT97010), and in fact was conducted in close cooperation with that group and its coordinator, Sandra Lanz. Visits between the two groups were identified as major learning opportunities by members of each.

The outcomes of the project were not quantitatively analysed, although the value of participation by the thirteen growers involved is obvious from the qualitative survey that was conducted, and from discussions with the researcher. The principal benefit that growers received from their participation was their training in, and subsequent adoption of IPM for tuber moth and other foliar pests, which was assisted by visits from Dr Paul Horne, the principal researcher in potato IPM.

12.1 Evaluation of benefits

The project commenced in 1994, and formally concluded in 1997. It involved thirteen growers, who at that time produced an average of about 30ha of potatoes each. In 2002, the same group produces nearly 1900 ha, and is still using the concepts and technologies they gained during this project.

Four of the growers in one of the groups were contractors to the Smith's Snackfood Company, and as a condition of their contract were well advanced in their (independent) training in IPM principles.

While there were many potential benefits from the program it is clear that the most significant economic benefit was from the IPM activity, which has been separately analysed in Chapter 6, and is not included in this analysis. Other benefits claimed include:

- an understanding of the principles of QA, which facilitated entry into formal QA programs such as FreshCare,
- greater quality consciousness and improved quality performance,
- better understanding of seed, seed management and planting strategies,
- improved fertiliser use strategies, with resultant crop improvements and environmental benefit from reduced wastage,
- improved water use efficiency through crop water monitoring and irrigation scheduling,
- an ongoing, but new capacity by growers to learn and adopt new production technologies.

As was the case in other industry development projects, especially the Crisping Group in Victoria (Chapter 13), it is doubtful that the improvements that were recorded during the life of the project could be attributed solely to the existence of the project. At least four of the Atherton growers were contracted to the Crisping industry, and were being separately encouraged and trained in the principles and practices of integrated pest management, and commercial IPM consultants were also active in the area at the time of the project. Nevertheless the project played a role in introducing some of the growers to the technologies, and in creating an awareness and knowledge of improved agronomic practices resulting from the other parts of the exercise.

Unfortunately, the economic benefits of the project were neither measured, nor recorded, and the data is too limited and unreliable to attempt any form of economic analysis. From discussions with the researcher, the primary outcome was the heightened awareness and adoption of IPM amongst the fresh market growers, which has been previously factored into the analysis of IPM in chapter 6. While other benefits, especially in terms of grower awareness of improved production practices were probably achieved it is not clear that they have improved the economic or environmental performance of the industry, or that apart from its impact on the adoption of IPM, the project has been an effective industry investment.

12.2 Discussion and conclusions

The failure to include any form of economic assessment or to provide any realistic and objective assessment of project outcomes was a serious limitation to this analysis. While it is believed by the researcher and accepted by the reviewers, that the project achieved some useful changes in grower attitudes and some (limited) adoption of improved production practices, its full and ongoing value to the industry could not be measured.

CHAPTER 13 - REGIONAL INDUSTRY DEVELOPMENT PROJECT – CRISPING GROUP

In 1990 when this project was commenced the crisping industry was very different to its current structure. Only a few years previously the industry was dependent on two varieties, Kennebec (about 80% of production), and Sebago (10%). These varieties have significant disadvantages to both growers and processors, they have low dry matter contents (and therefore low conversion rates), are poorly shaped, and are subject to Maillard browning and hence a high level of factory wastage. Kennebec has reasonable storage qualities, certainly better than Sebago. Table 13.1, extracted from the project report (PT014, PT542 *Technology transfer to improve the productivity and quality of crisping potatoes in Victoria and Southern New South Wales)* illustrates the industry's reliance on a small base of (now mostly discarded) varieties, and the complexity of the varietal program that resulted from the improvement program throughout the 90's:

Table 13.1 Changes in Crisping Varieties 1980-1998
(Figures represent percentage of crisping potato production)

Variety	1980	1990	1991	1992	1993	1994	1996	1998
Kennebec	80	33	28	20	18	8	1	1
Sebago	10	15	6	2	1	0	0	0
Snowchip	0	4	6	6	5	0.5	0	0
Tarago	0	10	8	10	11	2	0	0
Norchip	0	9	7	5	3	0	0	0
Atlantic	0	26	40	49	45	65	70	75
Denali	0	2	5	9	14	18	24	15
Wilstore	0	0	0	0	5	2	2	1
Trent	0	0	0	1	1	2	2	6
Simcoe	0	0	0	0.1	1	1	1	2

Source: Project report

The crisping industry (at that time) was centred in Southern Victoria, mainly on or around the Koo Wee Rup Swamp and East Gippsland. Factories located in Melbourne and Sydney were supplied with fresh potatoes during the summer and autumn months, and stored potatoes for the remainder of the year. About 55 000 tonnes of crisping potatoes were produced in Victoria against a national total of 125 000 tonnes.

At about the time of the project's initiation the variety Atlantic was "discovered" and introduced into the Australian crisping program. Atlantic was purpose-bred for the crisping industry (in the USA), and had superior dry matter, shape and size to the existing varieties. A range of other varieties was also released throughout the project, including Denali, Norchip, Simcoe, Trent, Wontscab and Wilstore. Also the Victorian (later to become national) potato breeding initiative at Toolangi began releasing lines with crisping and storage potential for field and processing evaluation.

The introduction of Atlantic heralded a number of changes for the industry. Processors began to explore options for year-round fresh potato supply from a wider range of production districts and their expectations for increased efficiencies in production, supply and conversion increased dramatically.

The Potato Crisping Research Group (PCRG) was established to facilitate these improvements at the agronomic level. Funded from processor and grower sources, the PCRG was the initial customer of the breeding program, and was therefore the source of new publicly bred varieties for the Australian crisping industry. The role of this group expanded to fill a real need, i.e. to develop the agronomic practices that were needed to optimise the productivity and performance of crisping varieties, including Atlantic and other imported genotypes. The project PT 014 (and later PT542 and PT 95042) was/were commissioned for this purpose.

The project (*Technology transfer to improve productivity and quality of crisping potatoes in Victoria and Southern NSW*) was funded under the voluntary contribution arrangements, on the basis of its regional focus. Funds were used to provide:

- a graduate officer for agronomic research,
- technical assistance to rapidly multiply new varieties,
- capital equipment for tissue culture, a neutron probe for irrigation research and polyhouses for mini tuber production,
- a vehicle for field trial work throughout Victoria,
- a new cooking laboratory and equipment at Toolangi,
- funding for field trials with new varieties at twelve sites,
- funding for crop agronomy trials,
- better communication with growers through an industry newsletter "Peelings", or publications such as "Cultivar Reports", and
- industry seminars of interest to growers.

Mr. Tony Myers was appointed to the industry development position. Towards its end the project took a more national role.

The objectives of the project were to:

- implement new varieties in the crisping industry in the defined production areas, and
- achieve rapid adoption of new technologies, particularly to optimise the performance of new cultivars.

At the later stages it expanded to include “coordinate continued improvement in the quality and productivity of crisp potatoes throughout Australia”.

Specific targets for improvement included:

- improved grower (and processor) performance through new and improved genotypes,
- increased productivity through improved agronomic practices, especially water use, nutrition, seed management and pest and disease management.
- improved approaches to farm chemical use and storage, and

- reduced wastage, on-farm and in-factory, through improved handling and storage practices

The approaches used by Mr Myers included:

- publication of a crisping industry newsletter, *Peelings*, which was discontinued with the introduction of the national newsletter *Eyes on Potatoes,*
- major annual industry workshops, originally with a regional, but later national, focus,
- on-site demonstrations, farm walks and visits and attendance at other industry occasions,
- visiting scientists, and reciprocal industry visits to major crisping industries in the USA and Europe, and
- providing a forum for researchers to demonstrate and discuss relevant research findings.

In 2002, Victoria is no longer the center of the industry; one of the two processors has relocated its factories to Adelaide, Brisbane and Perth, and both are actively pursuing year-round fresh supply strategies. Storage is now a relatively small component of the program, used mainly as security during the wet winter months for southern factories. While the project originally reached about 55 000 tonnes of storage and fresh production from traditional (autumn harvest) production systems, the effects can still be felt in about 60 000 tonnes of storage and year-round fresh supply in Victoria and Southern NSW. While Atlantic is still the dominant variety, one company is increasing the proportion of “in house” proprietary varieties which it produced within its Australian and US genetic improvement programs. Neither publicly-bred Australian varieties, nor varieties from unaligned international programs have been accepted to any significant extent.

13.1 Project achievements

The project report claims significant improvement in both grower and processor benefits as a result of the investment:

- both benefited from the improved genetic base, as a result of improved yields, tuber dry matter, improved compliance to shape and size standards and reduced tuber damage, as well as improved storage performance,
- tuber dry matter increased as a result of the varietal changes detailed in table 13.2,
- yield increases as a result of the project, from 20-25t/ha when Atlantic was first introduced, to 37t/ha in 1998. Some growers now regularly budget for 40-50t/ha,
- widespread adoption of IPM. Many growers regularly use no insecticides for pest control,
- disease forecasting systems reduce the usage of fungicidal sprays, e.g. for late and early blight,

Table13.2 Changes in Specific Gravity in crisping potatoes 1980 -1998 **

Variety	1980	1990	1991	1992	1993	1994	1996	1998
Kennebec	1.076	1.070	1.075	1.076	1.072	1.074		1.078
Sebago	1.065	1.066						
Snowchip	1.075	1.074						
Tarago	1.085	1.083	1.088	1.080	1.081			
Norchip	1.073	1.080	1.079	1.071	1.074	1.069		
Atlantic	1.083	1.084	1.086	1.082	1.086	1.084	1.082	
Denali	1.083	1.092	1.088	1.084	1.081	1.089	1.084	
Wilstore				1.078	1.080	1.076	1.082	1.084
Trent				1.094	1.091	1.090	1.091	1.089
Simcoe				1.086	1.085	1.084	1.087	1.088

** An increase of 0.005 specific gravity units equates to 1% difference in tuber dry matter and is a major benefit to growers who receive a bonus payment, and processors who achieve increased manufacturing efficiencies.
Source: Project report

- improved seed management and planting practices; 80% of growers now routinely assess their seed piece size, and seek information on seed physiological age as a result of the project,
- fertiliser use patterns have improved; 95% of growers use soil or petiole analysis as the basis of their nutritional decisions,
- improved irrigation practices; 25% of growers now use irrigation scheduling systems of one kind or another,
- reduced losses due to physical damage, as a result of an awareness program conducted within the project, and
- improved potato storage as a result of the sabbatical of Dr S Johnson, which occurred as a result of this project.

13.1.1 Sharing the credit

While the project had an important influence in achieving these changes in grower and industry performance, it was not the only one. The adoption of IPM was largely driven by the companies' pesticide use policies, and their payment and award policies drove the shift towards higher dry matters and tuber quality. Company field staff were active in promoting the new technologies, working both independently, and in association with Mr. Myers and Department of Agriculture researchers and field staff and commercial consultants also played a part. Consequently it is difficult, if not impossible to apportion the credit precisely to any one source, so for the purpose of this analysis, the project is accredited with one third of the changes that occurred during the period.

It is also clear that in the absence of the project growers would have eventually adopted the changes, as a result of the demands of the crisping companies, and with the assistance of departmental resources and private consultants. The term of influence for the purposes of the analysis of the project is therefore limited to 2003, or 5 years after its completion.

Finally, one of the major outcomes of the project was the acceptance by growers of the principles of IPM, and the adoption of chemical-free (or at least reduced) pest and disease management practices. As this has been separately treated elsewhere in this report, these benefits are not included in this analysis.

13.2 Economic analysis of the research project

13.2.1 Assumptions

The analysis assumes the following improvements, as a result of the project and all other influences, during the period:

1. yield increase of 25 percent on a 25 tonne/ha base (8.33 percent due to project). This increase in yield occurred over time and is illustrated in Figure 13.1 below,
2. the increase in yield resulted in a reduction of the area grown, as total production was fixed by contract. This saved $5000 per ha in variable costs, with the area 'saved' increasing to 280ha by the year 2000. This saving flows to the growers.,
3. dry matter increase, 2 percent (0.66 percent due to project). This increase in dry matter also occurred over time and is also illustrated in Figure 13.1,
4. the dry matter increase benefits growers and processors. It is valued in Table 13.3, with the benefits 'coming on stream' from 1992 to 1998,
5. reduced losses due to high reducing sugars, 2 percent (0.66 percent due to project). It is assumed that this increase occurred at about the same time and rate as the increase in yield,
6. reduced wastage due to insect and disease, and mishandling, 2 percent (0.66 percent due to project). A similar assumption concerning timing and rate is made to the above,
7. size compliance increased by 5 percent. A similar assumption concerning timing and rate is made to the above,
8. from 2004 onwards all benefits are valued at zero. (It was assumed that from 2004 onwards the benefits that have been achieved from this project would have been achieved as a result of other research and extension efforts), and
9. the grower and processor costs of the research project are shared equally.

13.2.2 Results

This project generated between $6 and $8 million (NPV) to 2000, and anticipating between 8 and $11 million to 2003, and with B:C ratios between 25 and 47 (table 13.4, figure 13.2). The results are relatively insensitive to discount rate changes because all the costs and benefits associated with the project occur in the early years (table 13.5).

Table 13.3 Economic impact of the crisping industry development project

Improvement	Grower benefit $/tonne	Processor benefit $/tonne
Dry matter increase	10.55	4.80
Reduced losses due reducing sugars	1.00	3.30
Reduced losses due wastage	3.30	6.60
Improved size compliance	5.00	10.00

Figure 13.1 Increase in yield and dry matter due to the project

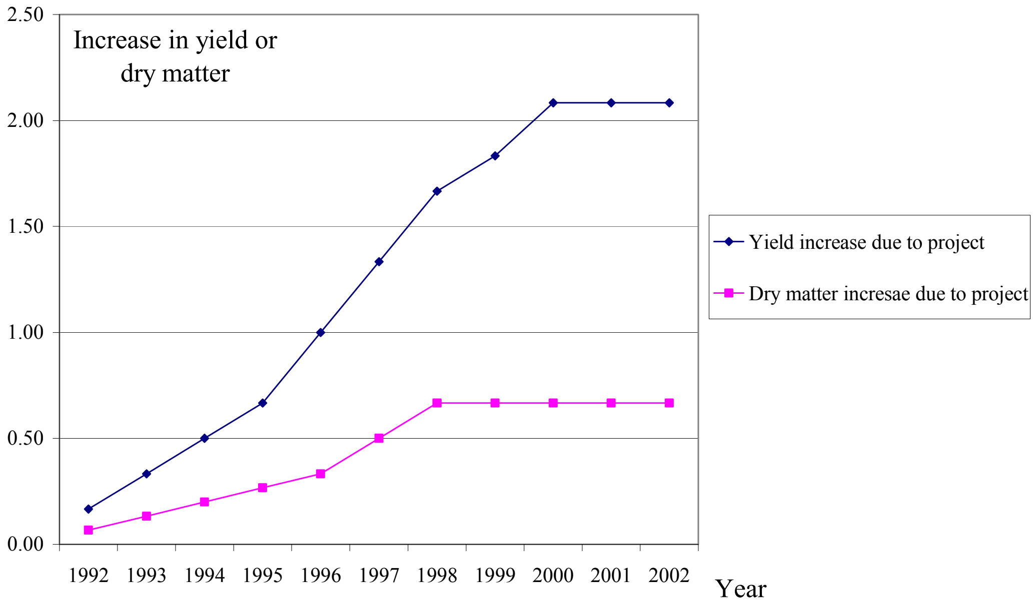


Table 13.4 Economic value of the regional crisping industry development project

Performance measure and time period	8% discount rate for NPV and BC
NPV growers 1992-2020	$8,844,700
NPV processors 1992-2020	$11,681,300
NPV growers 1992-2000	$6,198,900
NPV processors 1992-2000	$8,109,400
BC growers 1992-2020	35.88
BC processors 1992-2020	47.07
BC growers 1992-2000	25.45
BC processors 1992-2000	32.98

13.3 Environmental and social benefits

Significantly, this project has contributed to the environmental sustainability of the industry through reduced pesticide usage, improved water use practices and the use of nutrition practices that are in balance with the plants' needs and the soils' capabilities. While meaningful economic values are difficult to derive for these effects it is clear that the project has had a desirable and positive environmental outcome.

Figure 13.2 Present value of benefit and cost streams, Regional crisping industry development project

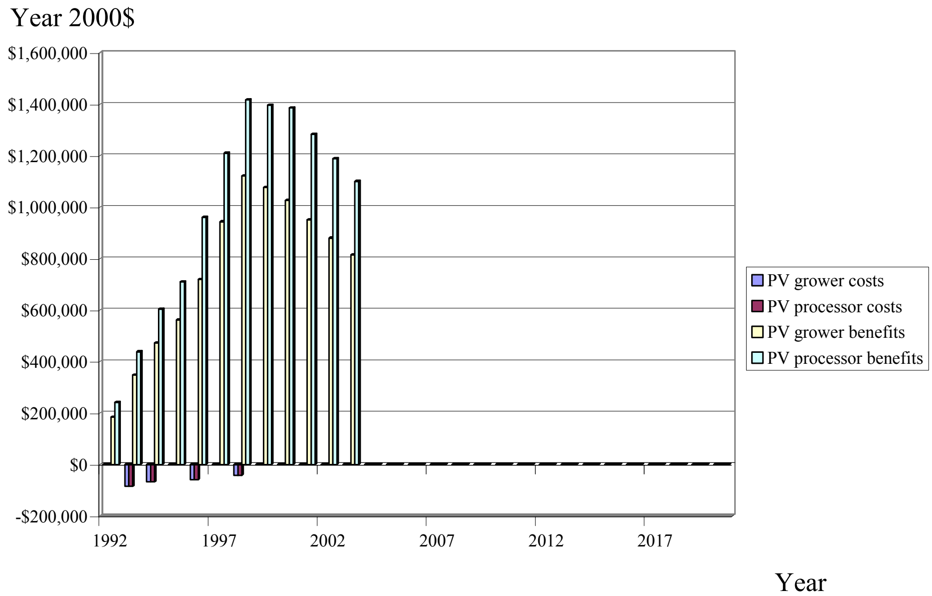


Table 13.5 Sensitivity analysis, Regional crisping industry development project . Changes in net present value depending on changes in assumptions

Item	Value	Group and time period	Net present value
Change discount rate	5%	Growers 1992-2020	$8,538,100
Change discount rate	5%	Processors 1992-2020	$11,287,100
Change discount rate	5%	Growers 1992-2000	$5,742,300
Change discount rate	5%	Processors 1992-2000	$7,512,600
Change discount rate	11%	Growers 1992-2020	$9,211,100
Change discount rate	11%	Processors 1992-2020	$12,154,500
Change discount rate	11%	Growers 1992-2000	$6,702,200
Change discount rate	11%	Processors 1992-2000	$8,767,500

13.4 Discussion and conclusions

The economic returns from this project are impressive by any standard. Admittedly they occurred at a time of rapid industry change, as processors increased their demands for improved efficiency and quality, and as new technologies (varieties, nutrition and IPM) became available to the industry. In this analysis we have allocated one third of the improvement, over a limited time span to the project. In reality the impact of the project would extend beyond that allowed here; once a grower has adopted a new technology the benefits last a lifetime and beyond, and it would not be unreasonable to project the project benefits for the 20 year period used to assess other programs and projects within this report. Thus, if the "one third" rule that has been adopted for apportioning the project outcomes seems high (and we don't think it is), the impact is more than offset by the conservative approach to limiting the benefits to 2003.

Also, the analysis has ignored the wider impact of the project, on growers in other areas, or in other industries such as seed or fresh market production. There can be little doubt that these flow-on effects were significant, and that a fuller analysis would have revealed even greater economic return on the somewhat modest R&D investment.

These results are not atypical of the industry development series of projects, and serve to illustrate the (very significant) benefits that are available by focusing resources on a desired industry outcome, within a finite target audience. It has been an effective R&D strategy for the potato industry that should be continued as a key means of technology transfer of new and existing production technology.

CHAPTER 14 - EXPORT MARKET DEVELOPMENT

The development and growth of export market opportunities has not been a major focus of the program, despite the widely held belief that exports are potentially large and lucrative, and that they hold the key to the longer term security of the Australian fresh, seed and processing potato industries. Only two projects that were funded by the levy were directly concerned with exports, PT 98022 *(Potato export market development*, by Sully and McKinna, and PT 97031 *Innovative transport and disease control systems: Potato exports to Asia* by Sharp. The first (PT98022) provided an important analysis of market opportunities in Asia, while the second sought technical solutions to some of the transportation issues that were constraining Australia's ability to successfully market fresh potatoes into Asian destinations. While the research effort in this program area is limited, it has produced some significant outcomes that deserve some analysis and consideration. They will be dealt with separately in the following sections.

14.1 PT 98022 Potato export market development

This project was initiated by Ag Victoria for the purpose of defining and expanding national potato exports. It commenced with the belief that a large potential market existed throughout Asia for Australian producers, and that the major impediment to success in the export industry was the relative inefficiency of Australian producers *vis a vis* their main competitors in the USA, Netherlands, China and Indonesia. At the outset of the project the potential target markets were thought to be throughout Asia generally, with the exception of China. In addition to the fresh market trade, there was also identified a growing opportunity for exporting fresh potatoes for processing in Asia, mainly for crisping, and for Australian-grown seed because of the inefficiencies in seed production in the disease infected soils of Asia.

The growth would be fuelled by a number of drivers, including the changing dietary tastes and habits amongst Asians, an expanding processing industry, improved technology, especially in storage and transportation, and an increasing competitiveness of Australian producers due to an expected improvement in productivity due to scale and supply chain refinement.

The project outcomes were less positive about Australia's opportunities as indicated for the various industry sectors. Overall it concluded that the only long term markets of any substance were for premium product in Hong Kong, Malaysia and Singapore, and that the upper limit to the trade is around 14 500 tonnes annually, only part of which was available to Australia. Australia cannot compete in the non-premium end of the market against the more cost competitive USA and Holland, nor can it hope to achieve the kind of production efficiencies that will allow it to compete against industries that enjoy the economies of scale found in those countries.

The conclusions for the various industry sectors were:

Ware potatoes

- Apart from the premium niche market in Hong Kong, Singapore and Malaysia the opportunities for Australian producers are limited due to their lack of cost competitiveness.
- Dutch and American industries will generally outperform Australia.
- Expanding Chinese and Indonesian production will eventually squeeze out even the Dutch and American suppliers.
- There will continue to be limited, *ad hoc*, short term and spot marketing opportunities for Australian exporters.

Seed potatoes

- Seed represents Australia's best export prospects.
- Australia has a seasonal advantage over its most formidable competitors in the seed trade, Holland and the USA.
- The seed trade is moving to high technology production systems, thereby providing opportunities for in-country production (based on proprietary technology?)

Processing potatoes

- Australian processors will have difficulty competing with larger and more cost efficient processors in the USA, Canada and Europe.
- It will never be profitable to ship unprocessed raw potatoes for French fry production to Asia on a routine basis.
- The production of French fry processing potatoes (and processing) is now expanding in China, Thailand and Indonesia, and it is likely that these sources will ultimately displace imports from the USA and Europe, and place a final bar to any Australian opportunity.
- There will remain a small opportunity for exporting crisping varieties to Asian manufacturers in the short to medium term.

One of the major impediments to an increasing Australian participation in the Asian markets is the relatively high production costs for potatoes in this country, driven by a lower scale of production than in the USA or Europe, and by our relatively high freight costs. Some market-driving opportunities exist, for example by targeting niche opportunities with differentiated products in the premium ware markets, supported by innovative branding, but realistically Australia is unlikely to achieve the cost efficiencies, or the coordination, to become a significant participant in the Asian markets for ware and processing potatoes.

Seed and seed production technology is different and there remain significant opportunities for Australian growers and companies to service this industry.

14.1.1 Economic analysis of PT 98022 Potato export market development

The project benefits are reviewed qualitatively in table 14.1. The original intent of the project was to improve Australia's export performance through developing more efficient supply chains, but it became apparent to the researchers at an early stage that this could only be achieved by working with individual large production/marketing units, who were independently addressing the issues of scale-related costs and supply efficiency. The project offered little benefit to the "average" levy paying grower, and none to the processors. The major benefit of the project was that it laid to rest the belief in the "limitless" export potential for ware potatoes in Asia, and helped refocus the industry, and its resources on the domestic market and its associated activities.

Table 14.1 Analysis of the Export development project

Beneficiary	Benefit	Outcome
Exporters	Understand export market and better positioned to focus attention on sustainable markets	The projects identified the true potential of the export market for ware potatoes in concluding that the market was more limited than commonly believed. It highlighted the better opportunities for market development for seed, and for crisping potatoes.
Growers (ware potatoes)	Corrects balance in domestic and export prospects	Reassured growers of the pre-eminence of the domestic market for fresh potatoes and of the limitations on export opportunity. Also highlighted that the export market would retain its *ad hoc* nature, severely limiting the opportunities for targeted production (for export).
Growers (Seed)	Affirms potential for seed and seed technology exports	Tropical Asia has difficulty producing potato seed, and imports large volumes from Europe and North America. There are good opportunities for the Australian seed industry to challenge these sources, particularly by taking advantage of its seasonal and freight situation. Australia is also well positioned to export technology and services in support of its seed program.
Processors	Confirms limited opportunity for exporting surplus potatoes	No opportunities for processors.

14.1.2 Conclusion, Export development project

While the project failed to achieve its primary objectives of increased exports of Australian potatoes it provided a valuable analysis of the market that was previously unavailable. Its benefits accrue to the industry generally for its ability to focus investment on more productive pursuits, and on the levy program itself, again for increasing the focus on more productive areas of R&D investment.

14.2 PT97031 Innovative transport and disease control systems: Potato exports to Asia

This project was also predicated on a belief in a potentially significant export market for Australian fresh and seed potatoes into Asia, perhaps as high as 4 million tonnes annually, to be driven (according to the authors) by technologically superior freight and transport capabilities which would be developed within the project. The key output of the project would be increased market expansion.

Potato exports at the time of the project were normally conducted in standard refrigerated containers. This technology has a major disadvantage in its inability to ensure tuber surface dryness, and hence in typically poor outturns due to various wet rots. The project followed the successful development of a fan-forced ventilated non-refrigerated container system for the Australian export onion industry, but differed from that because of the need to regulate atmospheric humidity more closely to maintain tuber quality and integrity.

The project produced two major outcomes:

- a protocol for through-chain handling and quality management, from production to out-turn, and
- a container design to achieve the disease and quality specifications.

Table 14.2 Analysis of project PT97031

Beneficiary	Benefit	Outcomes
Exporters	Demonstrated improved shipping technology	The results of the project have been rejected (or ignored) by the export industry.
Growers	Potentially expanded export markets	The technology-driven market expansion which was anticipated by the researchers failed to eventuate. The markets simply didn't exist, regardless of the newer shipping technologies.
Potato industry and consumers	Improved quality management by through-chain protocols	Failure to adopt the technology has denied these benefits to exporters, and to the market generally.

The technology was widely demonstrated to industry, who were able to view it in operation during a number of trial consignments to Asia. While further work was indicated by these trials the potential of the technology was clearly demonstrated, although not convincingly enough to convert exporters away from existing approaches to containerised shipping. The technology remains available, but unused. No sector of the industry benefited from the research (table 14.2)

14.2.1 Conclusions Potato containerisation project

Given the failure to achieve adoption, and the absence of the projected growth in exports, it is concluded that the project represented an ineffective R&D investment, based (it can now be said) on an inaccurate perception of its likely benefits.

A more positive prognosis remains possible, subject to a later adoption, or to the sale or licensing of the technology to an overseas partner.

14.3 Conclusion

This series of projects produced mixed results for the industry. The importance of having a realistic understanding of the potential for export development for potatoes cannot be overstated, and though the first project produced no positive commercial outcomes (in the way of increased exports), it did provide an important basis for consideration of future export R&D and activity. It is assessed as having been a sound R&D investment. The second project (containerisation) was ill conceived given the unlikelihood of Asian export expansion, and is accordingly assessed as having been an inadvisable and poor investment.

CHAPTER 15 – OBSERVATIONS ON THE PROGRAM, AND ON THE USE OF ECONOMIC ANALYSIS FOR EVALUATING RESEARCH OUTCOMES AND PROJECT PLANNING

15.1 The relative effectiveness of programs

The reviewers were requested to rank the various programs in order of their economic success. This is not simply achieved, because:

1. Three of the programs were not suited to economic analysis, and were treated within a qualitative framework. It is difficult to compare the value of (say) the environmental outcomes of the resource management program with the economic benefits of a breeding activity that produces a more efficient processing cultivar. While it is possible to estimate economic values for environmental benefits, the resources required to make these estimates are well beyond these available in this project.

2. While the assumptions used to quantify the benefits were selected on the basis of best available information, it is acknowledged that many are arbitrary, and deliberately conservative. For example, the choice of 1%,3% and 10% for the annual spread of PCN is not based on any science or experience; these figures were selected to provide an indication of the value of the research under this limited range of (hypothetical) circumstances. Industry may opt for an alternative strategy in the event of future detections, for example forcibly avoiding the use of infected lands. In that case, the economic outcomes would be different.

3. Readers may disagree with some of the assumptions and decide to replace them with different information of their own. For example, processors may have a different view of the benefits available from breeding, or different knowledge concerning current or future aspects of quality measurement and pricing. They may arrive at quite different results to those reported here, which are based on the best information available to the reviewers.

The outcomes of the analyses are summarised in table 15.1. While this table should be read in conjunction with the assumptions reported in the individual analyses, it does provide an indication of the relative effectiveness of the various investments. The reviewers' summary of this table is as follows:

Highly effective investments

- Integrated pest management
- Cadmium
- Potato cyst nematode
- Industry development (crisping)

- Quality assurance
- Aspects of the resource management (sustainable production systems) program

Ineffective investments

- Export market development
- Breeding (of public varieties)

Potentially effective investments

- Breeding for French fry and crisp processing, subject to the adoption of processor-led, individual chain programs leading to unique proprietary varieties and effective competitive advantage for each of the processors.
- Breeding for fresh market potatoes, subject to the development of similar partnership arrangements to those that are currently being agreed with the processors.
- Tuber borne diseases (rhizoctonia and common scab).
- Resource management (subject to identification of industry objectives and development of R&D strategic plan).
- Industry development (Atherton)

15.2 Benefits to industry sectors

The potato R&D program is funded from several sources, the levy paying growers (fresh, crisping, french fry), the crisping and french fry processors, and seed growers. These contributions are matched by Commonwealth Government funds. Research providers also make a significant contribution through the provision of research infrastructure and staff. The benefits that accrue to each of the sectors have been identified wherever possible throughout this report, and are summarised in table 15.2.

This analysis indicates that all sectors of the industry benefit from the research investment, at least initially. Seedgrowers appear to benefit least (though their levy investment is also modest). However, it is likely that with the introduction of new partnership arrangements, their relationships with their customers will strengthen and the degree of risk that they traditionally bear will decline. Ultimately it is unlikely that seedgrowers will be able to maintain the economic benefits of this investment.

A similar note of caution applies in the longer-term assessment of grower benefits. History shows that producers seldom retain the economic benefits of new technologies for long; eventually they are transferred to their customers through reduced contract prices or increasingly difficult to achieve quality standards. This has certainly occurred throughout the industry over the past decade, and is likely to continue to do so into the future (see Appendix D). Conceivably most (or all) of the grower-identified benefits will eventually be transferred to their customers. This raises interesting issues regarding the equitability of the current funding arrangements, both with respect to the growers themselves, and to the failure to collect levies from the marketers who benefit from the fresh market R&D investment. Importantly, the transfer of benefits should be considered in the planning of research that is initially targeted at grower practices. There is a need to differentiate projects that offer sustainable grower benefit from those that simply initiate another round of price reduction.

15.3 Economic analysis in R&D planning

Research planning is a complex and imprecise process. The object of the planners should be to maximise the return on the research investment over the longest possible time. This implies a process that:

1. Identifies the most economically important industry outcomes. This is normally achieved through the industry strategic planning process, and is independent, at least in the first instance from considerations of R&D. The outcome of this process is a priority listing of key objectives to achieve significant industry progress, or to overcome important impediments to the continued growth of the industry.

2. Produces an action plan that integrates the various activities that are needed to achieve the strategic objectives. These may include wide ranging activities at the corporate, community, research, communications and regulatory levels; R&D is an important part of this plan, but only a part, and

3. Defines and evaluates a R&D process that will produce the required research outcomes.

In undertaking this project the reviewers were asked to consider and advise on the use of economic tools, and especially investment analyses (often called benefit cost analysis) in the research planning process. Their comments can are summarised below:

1. Economic tools can be used to assist in the evaluation of research projects from the initial stages of development, through research design evaluation, then monitoring of the research process and finally in the impact evaluation of the long term economic, environmental and social outcomes of the project (see Templeton 2003). Investment analysis, using net present value calculations, is essential in the industry strategic planning process, in the initial screening of projects, and in the impact evaluation of completed projects. The analysis can be done in spreadsheets, as used in this project. Alternatively it can be done using specialized project evaluation software such as that developed by Alston, Norton and Pardey (1998).

2. The outcomes of some projects are more amenable to economic analysis than others. As an example, it is often difficult (although not impossible) to evaluate environmental and social outcomes of research projects in economic terms. In some cases, environmental and social outcomes may be more important than economic outcomes and the evaluation process needs to be flexible enough to deal with such issues.

3. Projects that contribute to an eventual economic outcome may not in themselves be able to demonstrate a positive net present value. For example, the identification of a potential new parasitic insect may be an important

contribution to an emerging new approach to IPM, and prove to be cost effective in hindsight.

There are several possible ways of overcoming this problem. One, and probably the most desirable, alternative is to conduct more detailed economic evaluations of the possible outcomes of proposed research projects. This involves following the possible outcomes of the research to logical conclusions, and attempting to attach probabilities to the various outcomes. This approach could, at least, establish the upper and lower bounds on investment returns to the project. Another possibility is to consider individual research projects within a 'portfolio' of research programs, using a logical process similar to the above. A third possibility is to earmark a given (small) percentage of the research budget to "pure research" projects that are not expected to provide direct economic benefit.

4. The preferred target for economic analysis as a research planning tool lies somewhere closer to the strategic planning level where choices are made concerning the value of alternative industry strategies. Here sound economic analysis of the likely economic merit of various competing strategies will provide an objective basis for program design and project selection. There is little point in undertaking such analyses on projects that are likely to produce mediocre outcomes.

The reviewers recommend using specialised research evaluation software, such as that developed by Alston, Norton and Pardey (1998) in conducting industry strategic planning, in the initial screening of research projects and in the impact evaluation of completed projects. Their approach includes estimation of consumer as well as producer and processor net benefits, using a net social welfare approach. However, these tools require considerable knowledge of research evaluation and good economic data to support their use. Thus the reviewers also recommend that Horticulture Australia Limited initiate the collection of more detailed economic data (perhaps by ABS or ABARE) that would assist, especially in industry strategic planning and the evaluation of completed projects.

In the research monitoring and evaluation phase, project planning and evaluation software, for example, Microsoft Project, is a useful addition to standard budgeting and spreadsheet analysis. It is relatively easy to use these tools.

Also, the authors are aware of a BCA tool that has recently been produced for the Australian macadamia industry in association with HAL project MC 01027, and which is currently being evaluated by Horticulture Australia for wider use. The project manager responsible for potato R&D will participate in this evaluation, and if necessary will assist in its adaptation to the special needs of industry R&D planners.

Table 15.1 Relative benefits of R&D outcomes for all program areas

Program area	Benefits	Assumptions	NPV to 2000 Yr 2000 dollars (x1000)	NPV to 2020 Yr 2000 dollars (x1000)	Additional benefits
Programs that were analysed for economic benefit					
Cadmium	Ability to continue producing potatoes	Comparison against cattle production	1, 292	5,768	Reduced cadmium inputs to potato production through increased use of low-cadmium fertilisers
Breeding crisping potatoes	Increased yield and quality, increased processing efficiency	Public varieties	Negative	Negative	A breeding infrastructure that is capable of rapidly responding to individual company specifications.
		Processors as chain leaders, proprietary varieties	-387	2,785	
Breeding French fry	As above	Public varieties	Negative	Negative	As above
		Processors as chain leaders, proprietary varieties	Negative	14,120	
Breeding fresh market		Public varieties	Negative?		

Gene technology	Increased grower yields and reduced production costs, reduced chemical inputs	Research becomes cost effective if yield advantage is 3% or greater	Negative		Reduced pesticide usage because of virus resistance.
IPM	Reduced pest management costs	Control costs, adoption rates	12,270	68,577	Major reductions in chemical usage
PCN	Avoid chemical fumigation	Rate of spread 10%, 3% or 1% per annum	848 – 1,265	1,638 – 5,212	Avoids the use of fumigants. Also avoids significant social disruption that accompanied early outbreaks.
Regional industry development – Southern Tablelands	More efficient and environmentally acceptable production practices	Comparison with pre-existing practices	286,800	1,743	Environmental benefits through better soil management, water management and reduced reliance on chemical pest and disease management. The environmental benefits were at least as important as the economic benefits.
Regional industry development - Atherton	More efficient and environmentally acceptable production practices	Comparison with pre-existing practices	Not measured, but limited	ditto	Grower awareness and adaptability to new technologies..
Industry development – crisping group	Yield and quality benefits (and bonus payments) to growers, increased production efficiency (processors)	Grower benefits limited to one third of all improvements achieved to 2003.	14,308	19,525	Environmental benefits due to improved pest, soil and water management, reduced processing waste and increased processing efficiency.

Export market development	Increased export opportunity and performance.	Nil	Nil	Economic evaluation of export market potential. Specialised potato container system for exports. Technology with offshore sales potential?

Programs that were analysed qualitatively

Tuber borne diseases (Rhizoctonia and common scab)	The projects relating to these diseases are a "work in progress" and need to be continued if the major outcomes, of effective and efficient disease management are to be achieved. The projects have contributed, importantly and significantly to the knowledge base on the two diseases, and may result in genetic resistance in at least two varieties. The value of the work can only be assessed in hindsight, and depending on the disease management outcomes. Its continuation is an act of faith by the industry, which would be greatly supported by the presence of a R&D plan for current and future research.
Resource management	The absence of a R&D plan to direct the sustainable development and environment programs makes it difficult to critically evaluate this suite of projects. When assessed against the individual project aims they are generally effective. In the absence of industry-agreed objectives and strategies it was difficult to assess the value of the work, other than to observe that it appears to have made positive contributions to the sustainability of the industry, and to its environmental credentials.
Quality assurance	These projects made a significant contribution to the adoption of quality management systems in the industry, as well as to other horticultural industries. While it was not possible to measure its economic outcomes, its benefits in terms of food safety and market access are unquestioned. It has been a highly successful investment on the part of industry.

Table 15.2 Benefits of potato R&D programs to industry sectors (8% discount rate)

Program	Growers	Seedgrowers	Crisping processors	French fry processors	Comment
Cadmium	5,768				Benefits to various sectors were not individually quantified. However, as it could be expected that processors would continue to source from alternative areas, at no necessary disadvantage, it is assumed that the growers are the principal beneficiaries of this research.
Breeding – crisping (under new program management)	1,429		1,357		The maintenance of this benefit split depends on the continuation of current payment and bonus schemes. Past experience indicates (as in Appendix D) that grower benefits will eventually be transferred to processors.
Breeding – french fry (under new program management)	10,173			3,406	As above.
Gene technology					In the event of a positive economic benefit (ie, if yield advantages above 3% are realised due to the new technology), growers will receive a minor benefit, while processors and wholesalers/retailers will enjoy the additional benefits of reduced pesticide usage.
IPM	12,831 *	4,006	11, 462	38,277	While growers will benefit from these technologies in the first instance, the benefits will ultimately flow up the chain to processors and retailers and in the form of reduced prices. (appendix D). This analysis did not distinguish between growers and processors for this reason (apart from seed growers, whose enjoyment of the benefits may also be ephemeral).

Program	Growers	Seedgrowers	Crisping processors	French fry processors	Comment
PCN	1,638 – 5,212				Economic benefit depends on assumptions regarding the likely rate of spread of the pest. The benefit split will vary with the area of first outbreak, but at least in the first instance, will favour the grower.
Regional industry development – Sthn Tablelands	1,743				The environmental benefits probably outweigh the economic advantages from this work, so some of the benefit must be apportioned to the community. Nevertheless, the program has allowed potato production to continue in the area, which represents a major grower benefit.
Regional industry development – Atherton					The significant outcome of this project was probably the improved awareness and adaptability of growers to new technologies, a positive though unquantifiable benefit.
Industry development - crisping	8,845		11,681		The maintenance of this split depends on the continuation of existing pricing policies. Reduced proices over the period since the research probably indicate that the economic benefits are shifting from the growers to the processors.
Export development					No measurable benefits.
Tuber borne diseases (rhizoctonia and common scab)					The benefits of these programs are as yet largely unrealised. Environmental benefits are a community asset, but also

Program	**Growers**	**Seedgrowers**	**Crisping processors**	**French fry processors**	**Comment**
Resource management					benefit both growers and processors in their ability to continue the sourcing of potatoes from tried districts. Benefit splits are difficult to ascertain.
Quality assurance					These unquantified benefits are apportioned between the grower (who can meet customer demands for QA food safety), and processors and wholesalers/retailers who can meet the demands of their consumers.

* fresh market growers and wholesalers/retailers

15.4 References

Alston, J M, Norton, G W and Pardy P G 1998, *Science under scarcity: principles and practice for agricultural research evaluation and priory setting*, CAB International, Wallingford.

Levy, H. and Sarnat, M. (1994), *Capital Investment and Financial Decisions*, Fifth Edition, Prentice Hall, New York.

Templeton, D.J. (2003), Research Evaluation to Increase Impact, Paper presented to the 47th Annual AARES Conference, Freemantle 11-14 February.

Appendix A—THE ECONOMIC EVALUATION OF RURAL RESEARCH

A.1 Introduction

The economic evaluation of research was introduced by Griliches (1958) in a paper on the costs and benefits associated with the introduction of hybrid corn in the Midwest of the USA. While this study was *ex post* in character, it has become common practice to use cost benefit analysis as a guide in the selection of research projects by funding institutions such as the rural research and development corporations.

A.2 The cost benefit approach

The basic approach is to attempt to measure *ex post* or estimate *ex anti* the net social benefit accruing from a research project or program. It stems from questioning the desirability of, and payoff from, publicly funded research and development. The approach is analysed in considerable detail in Alston, Norton and Pardy (1998). A good explanation of the approach, accessible to non-economists, is in Johnston, Healy, L'ons and McGregor (1992). The following draws heavily on that work.

A.3 Costs

The costs include 'the research and development, adoption and research maintenance costs. Research and development costs are the costs of undertaking the initial research, including administrative costs and the costs of subsequently developing it into a workable technology. These costs are usually incurred by other organizations…' Johnston, Healy, L'ons and McGregor (1992), p. 10.

There are usually problems associated with accurately costing individual projects, especially in partitioning overhead costs to projects. This cost estimation usually involves detailed discussion (usually including a detailed questionnaire) with the researchers associated with a project and administrative staff of the institution who have knowledge of the allocation of the overheads.

The timing of the costs (and benefits) is also important in the economic evaluation. A length of time (project horizon) over which the evaluation is made must be given. Likewise a decision must be made concerning the 'appropriate' discount rate to use in any analysis. The discount rate represents 'the time value of money' or the opportunity cost of using funds to invest in alternative public investments. The Department of Finance (1991) recommends discount rates within a given range for the economic evaluation of public investments. It is technically easy to conduct an analysis using several different discount rate.

A.3 Benefits

A.3.1 Non-Market benefits

These are benefits such as environmental or public health benefits. They are difficult to value and are usually ignored in cost benefit analysis. If they are considered to be particularly significant, techniques such as contingent valuation can be used to estimate these non-market benefits. Contingent valuation uses interview techniques involving the use of detailed questionnaires and considerable skill is required in the design and implementation of the interviews.

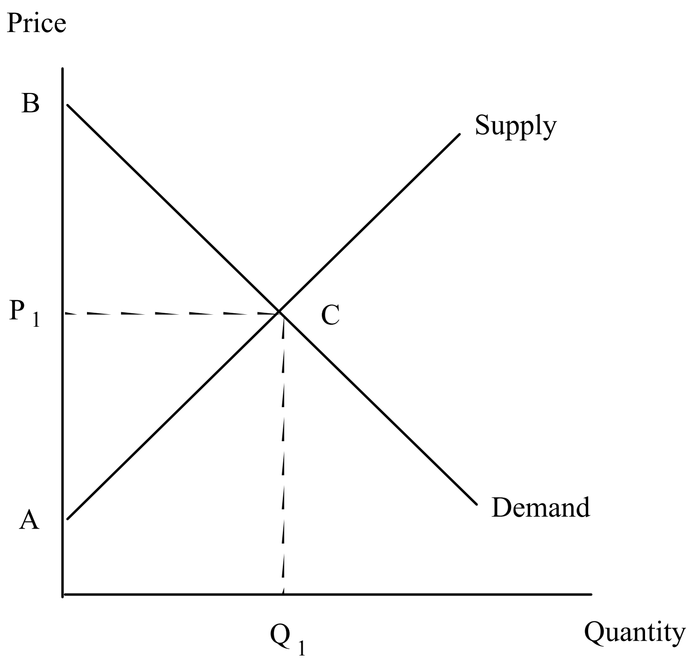
A.3.2 Market benefits

In general, benefits are much more difficult to measure, or estimate, than costs. Benefits can be divided into market and non-market. 'Market benefits are those that improve the performance of good and services traded in the market place. For example, a new technology that improves the productivity of a farming system will result in lower costs of production of farm products. New technologies of this type are known as process innovations. Alternatively, research and development may lead to products that better suit consumer needs. For example, plant breeding may be able to remove some undesirable trait from a plant product. New technologies of this type are known as product innovations. The net result of the adoption of a process or product innovation is to generate economic benefits to producers and consumers' Johnston, Healy, L'ons and McGregor (1992), p. 7.

A.4 Economic evaluation of the benefits—net social welfare

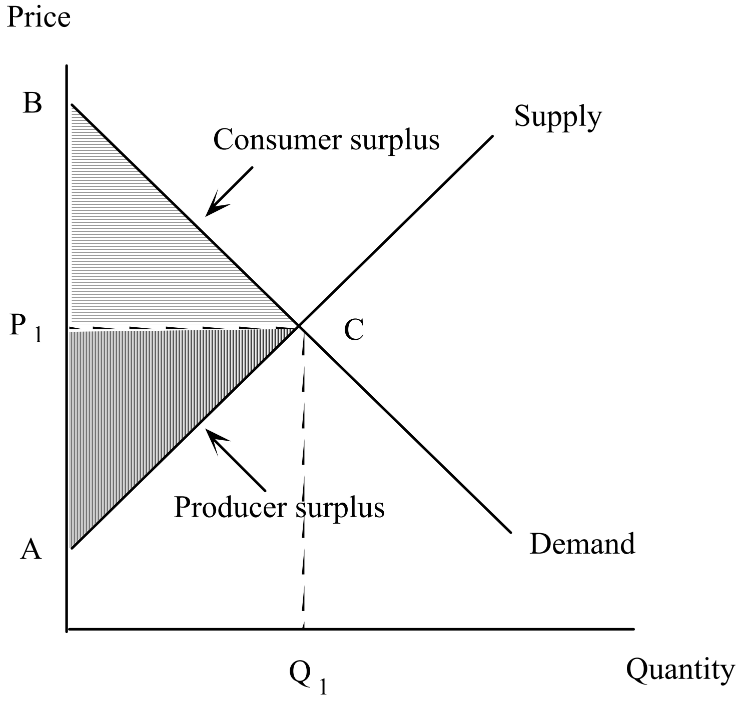
Take the case of a commodity before an innovation resulting from research. Price and quantity are determined in a market based on the market clearing intersection of a supply curve and a demand curve.

Figure A.1 Intersection of the supply and demand curves determines the market price and quantity



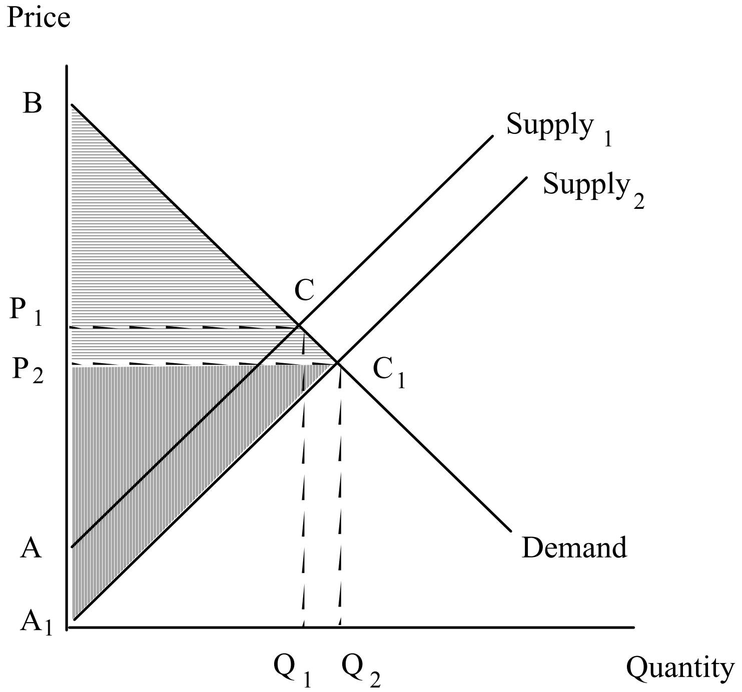
The area AP_1C (vertical stripes below) is producer surplus and is a rough measure of the 'wellbeing' of producers. The area BP_1C (horizontal stripes below) is consumer surplus and again is a rough measure of the 'wellbeing' of consumers. The combined area is 'net social welfare'.

Figure A.2 Net social welfare is the sum of producer and consumer surplus



If producers adopt a new technology that enables them to produce more at the same cost, or the same amount at a lower cost the supply curve shifts out to the right. Normally, producers, as a group, become 'better off' in producer surplus terms. Consumers, as a group, always become 'better off' in consumer surplus terms (this is one justification for public [that is, taxpayers w□□are alsoconsumers] funding of research). Net social benefits (the area of both triangles) increase. The size of the increase is the area ACC_1A_1. This is illustrated below in Figure A.3.

Figure A.3 Increase in net social welfare caused by adoption of new technology



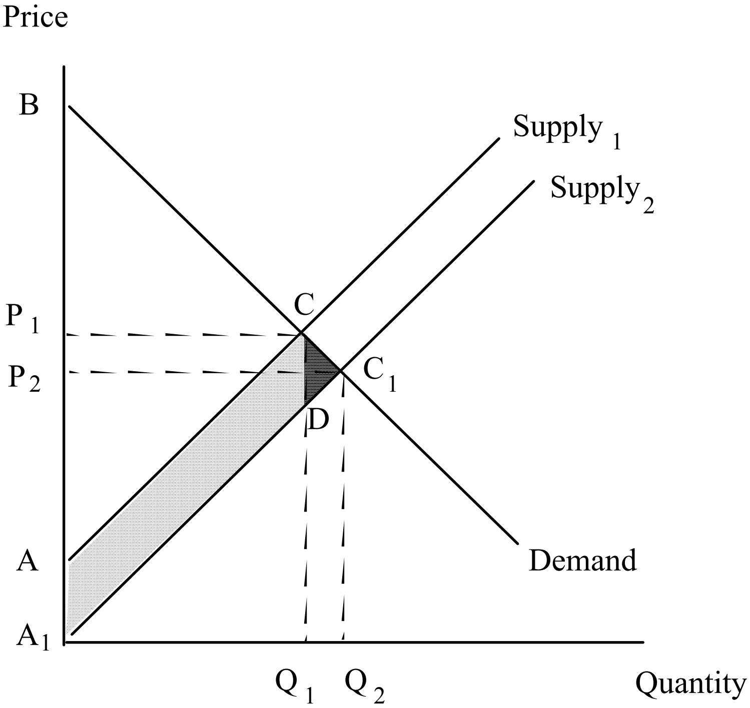
The situation becomes a little more complex if there are multiple markets eg. export markets. In this case, some of the benefits of research flow to consumers (and also producers if there is technology transfer) in overseas countries. It is possible to show the general flow of benefits in multiple markets using a series of diagrams.

Unfortunately, the estimation of the net social benefits of research requires knowledge of the elasticity of supply and demand. For some agricultural industries reasonable estimates of these elasticities are available. For many other industries, the best that can be done is to use a series of assumptions concerning the elasticities and then calculate the net social benefits of research.

A.5 The cost saving approach

As an alternative the cost saving to the agricultural industry resulting from the research can be estimated. In Figure A.4 below the cost saving to producers is illustrated by the shaded area $ACDC_1$. The smaller 'wave filled' triangle CC_1D is ignored; thus the benefits of research are under-estimated. The extent of this under-estimate depends on the size of the cost saving relative to the original market price and on the elasticity of supply and demand.

Figure A.4 Under-estimation of the benefits of research



A.6 References

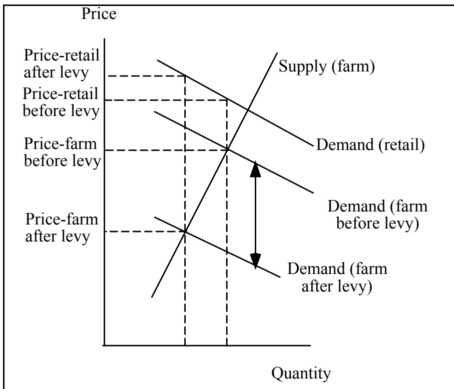
Alston, J M, Norton, G W and Pardy P G 1998, *Science under scarcity: principles and practice for agricultural research evaluation and priory setting*, CAB International, Wallingford.

Department of Finance 1991, *Handbook of cost-benefit analysis*, AGPS, Canberra.

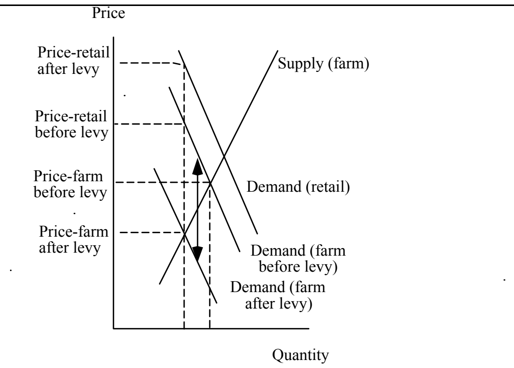
Griliches, Z. 1958, Research costs and social returns: hybrid corn and related innovations. *Journal of Political Economy* 66, 419-432

Johnston, B., Healy, T., L'ons, J. and McGregor, M. 1992, *Rural Research—The Pay-Off*, CSIRO Occasional Paper No 7, Canberra.

APPENDIX B – ILLUSTRATION OF WHO GAINS AND WHO LOSES FOLLOWING A CHANGE IN A RESEARCH LEVY, DEPENDING ON ELASTICITY OF DEMAND.



In this case, demand is relatively elastic—there is a relatively large change in price at farm level compared to the price change at the retail level

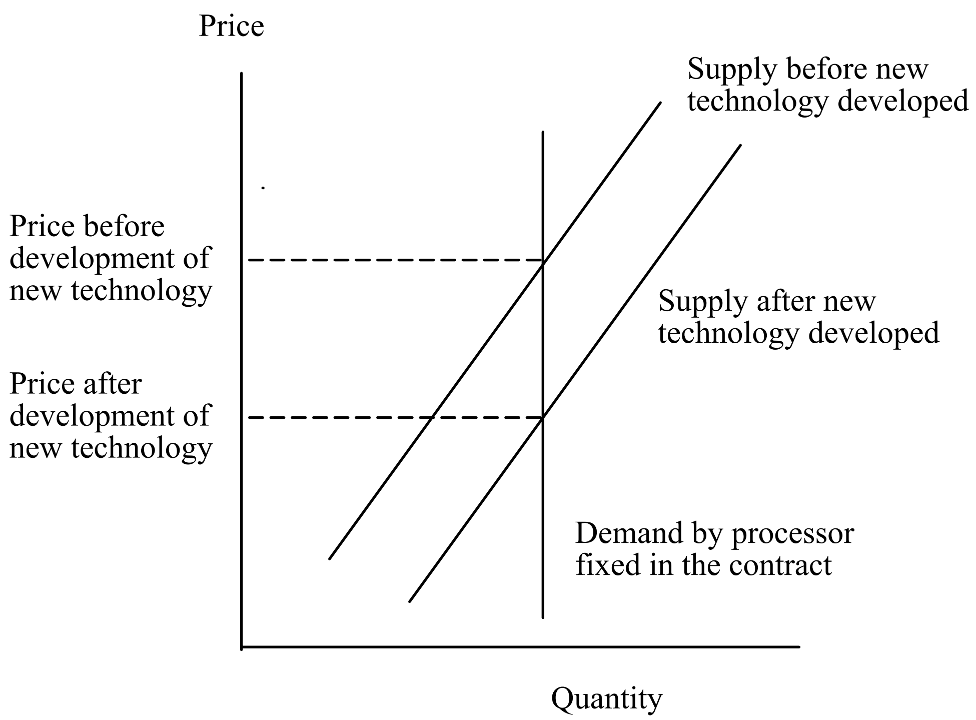


In this case, demand is relatively inelastic—there is a relatively large change in price at retail compared to the price change at the farm—proportion of the levy consumers pay increases

APPENDIX C – ILLUSTRATION OF THE SHIFT IN BENEFITS OF A COST SAVING TECHNOLOGY FROM CONTRACTED GROWERS TO CONTRACTING PROCESSORS.

Contracted growers face demand functions that are fixed in the contractual agreement. When a new technology is developed as a result of research, the processors tend to appropriate the benefit of the research by their use of market power. This is illustrated below where it is assumed that a cost-saving technology is developed,

The cost-saving technology shifts the aggregate supply function of the contracted growers outwards. The demand function is fixed by the contract and the price paid to farmers falls. In reality the price fall is not instantaneous. It is more usual for the nominal price paid to growers to remain constant, but gradually fall in real terms over time as inflation reduces the value of the nominal price.



APPENDIX D - WHO FUNDS RESEARCH IN THE POTATO INDUSTRY?

D.1 Background

Horticulture Australia Limited (HA) is an industry owned corporation and is one of a number of rural research and development corporations (RDCs) established by the Federal Government under the *Primary Industries and Energy Research and Development Act 1989*. Horticulture Australia, in common with other RDCs, collects levy funds and administers public research and development conducted for the various parts of the horticultural industry.

D.2 The funding mechanism for the RDCs

The most common method of funding RDCs is that producers are levied a given percentage (usually 0.5%) of sale value of the commodity, when it is first sold. (In the past, statutory marketing authorities sold many agricultural commodities and the levy was easy to collect). The Federal Government matches the levy, dollar for dollar, with taxpayers' money (up to a maximum of 0.5% of the industry's gross value of production).

This method of funding does vary. In the case of the Land and Water Research and Development Corporation, the Federal Government provides virtually all funding as the research conducted is not commodity specific and much of it concerns environmental issues with 'public goods' aspects. Likewise the Federal Government provides most of the funding for the Rural Industries Research and Development Corporation as it researches new opportunities for Australian agriculture, but reverts to the above funding process for 'established industries'.

In the case of the Sugar Research and Development Corporation, growers and processors contribute to the levy equally before the Federal Government matching funds are applied. *[The collection of the levy from both producers and processors seems to occur where there is a close contractual arrangement between producers and processors, although I have been unable to find a statement of principle on this issue.]*

A similar mechanism is used by Horticulture Australia in that part of the potato industry concerned with processing. HA collects a statutory levy with rate set Primary Industries Levies and Charges Collection (Potato) Regulation. The current levy is $0.50 per tonne from potato producers (fresh, processing and seed) and $0.50 per tonne from potato processors (snack foods, chip etc).

D.3 Taxation treatment of the levy for research and development (R & D)

For individual growers, the cost of the levy is treated as a normal cost incurred in earning an income (alternatively income may be reported after levy deduction which has the same result.). The after tax cost is thus the amount of the levy minus the levy times the marginal tax rate (eg. for a $1000 cost and a marginal tax rate 30% the calculation is $1,000 - ($1,000 * 0.3) = $700.

For a large corporate grower, paying a levy of over $20.000 per year and for a processor in similar circumstances, a Section 73B deduction of the amount of the levy is allowed. The rate of this deduction has varied over time and, in recent years, has been 125%, but a 'premium rate' for labour related components of research and development of 175% was introduced in June 2001. The calculation is the levy minus the levy times the deduction rate times the corporate tax rate. For example, if a $50,000 levy is paid by a corporate processor, paying the corporate tax rate of 30%, and assuming the 125% Section 73B deduction, the calculation is $50,000 - ($50,000 * 1.25 * 0.3) = $31,250. Thus the after tax cost for the processor is $31,250.

For further details on the taxation treatment of research and development see Woellner *et al* 2001, pp. 870-879.

D.4 Who ends up 'paying' the levy?

In order to consider this question, the concept of a marketing margin is introduced. A marketing margin is the difference between the price paid by consumers at retail and the price obtained by producers. It can be considered as the price paid for all the marketing services between the producer and the consumer and reflects the demand for, and supply of, these services (Tomek and Robinson (1972) p. 110).

A research levy, or any other charge or tax, adds to the marketing margin. This change in the marketing margin is distributed between producers and consumers, and to any other participants in the marketing chain (including processors). The precise distribution of the change in the marketing depends on the 'elasticity' of supply and demand for the product at consumer and retail and on the elasticity of supply and demand for services added in the marketing chain. Elasticity of supply and demand is a measure of the responsiveness of the change in quantity either supplied or demanded, given a change in the price of the product. In agriculture, the quantities supplied or demanded tend to be quite unresponsive to changes in price. There is some tendency for demand to be less responsive (more inelastic) than supply.

Following an increase in the marketing margin, by the imposition of a levy, producers will receive a lower price than they did previously. However, the price received will not be previous price minus the levy. Instead producers will be able to pass some of the cost of the levy onto consumers who will pay more for the product, but not as much as the previous price plus the levy. The more inelastic the demand curve relative to the supply curve, the greater the proportion of the cost that is past on to the consumer, and vice versa. Campbell and Fisher (1991) pp. 62-65 show the concept applied to a change in a levy, and trace through the effects on producers and consumers, assuming two contrasting supply and demand situations. With demand tending to be more inelastic than is supply for agricultural commodities, there is a tendency for a relatively large part of the cost of the levy to be past on to the consumer. The diagrams used by Campbell and Fisher are reproduced in Appendix B.

This argument can be broadened to include all parts of the marketing chain. The chain might perhaps consist of producer, transporter, processor, transporter, wholesaler, transporter, retailer and final consumer. All participants in the chain will share the cost of levy by passing it up and down the chain depending on the elasticity of supply and demand for the product and on the elasticity of supply and demand for services added.

Thus it does not matter greatly where a research levy is collected because the additional cost will be passed up and down the marketing chain. It should be collected were the collection costs are minimised.

D.5 R&D levies and the 'leverage effect'

Much of the research administered by the RDCs is conducted in publicly funded institutions such as CSIRO, State Departments of Agriculture and Universities.

Advisory committees within the RDCs largely set research priorities. Growers, processors and other stakeholders have the opportunity to influence priorities through the committees (in what is partly a political process where geographical issues play a part). Scientists submit research proposals to the RDCs. The proposals are subjected to review by other scientists and selected by the RDCs. The selection process is based on the potential contribution of the proposed research to the research priorities.

In general, the public institutions in which the research is undertaken make substantial financial contributions to the research. The salaries and on costs of the principal researcher/s are usually funded by the institution and the RDC funds research assistance and research consumables etc. CSIRO and the Universities are largely (about half?) funded by the Federal Government and the state departments of agriculture are largely funded by state governments. Thus growers and processors who pay R&D levies benefit first from the matching Federal funding, then again by the state and Federal government contributions to the research institutions that conduct the R&D.

It should be noted that the funding of the public research institutions has been progressively squeezed over about the last 15 years. This process appears likely to continue and the state departments and the Universities, in particular, appear to be steadily loosing their research capacity. Thus the funding leverage effect that R&D levy payers have enjoyed in the past is likely to be reduced in the future.

D.6 A numerical example of leverage

Assume the situation of a processor contribution a levy of $50,000, with an after tax cost of $31,250. The Commonwealth matches the levy with $50,000. Suppose that a research project is undertaken by CSIRO, a state department or a university with grant from HA worth $100,000. Assume that the research institution funds the salary and on costs of the principal researcher, and these total a modest $25,000. For an after tax levy cost of $31,250 to the processor, research costing $125,000 is undertaken.

D.7 Economic justification for the organisation and funding of public research in agriculture

Knowledge produced from research has classic 'public goods' characteristics. In contrast to most goods or services, it is not 'used up' as it is applied. This characteristic is called non-rivalry in consumption. It is also difficult to prevent others from using knowledge, once it is produced. This characteristic is called non-excludability.

Private research is organised and undertaken within individual businesses. The knowledge generated from this research belongs to the business concerned and is often protected by some form of intellectual property rights (eg. patents or plant variety rights) and/or considerable secrecy. An optimum amount of private research occurs were the additional private costs of the research equal the additional private returns, where both costs and returns are discounted to reflect the time value of money.

Public research is undertaken when governments perceive a market failure that prevents research being undertaken, or less than an optimum amount of research being undertaken in the private sector. It is usually argued that farms and, in some cases, firms processing agricultural commodities are too small to organise and/or conduct research individually. Further, small firms may not be able to protect and use the knowledge generated efficiently. An optimum amount of public research occurs were the additional social costs of the research equal the additional social returns, again discounted.

The general responses of government to the perceived market failure are; to improve intellectual property rights; to create new R & D institutions; increase incentives for private R & D; and the provision of public funds for private or public R & D (Alston and Pardy (1999) p.12). Governments in many countries, including Australia, have responded in some or all of these ways to perceived market failure, although each country has taken a somewhat approach. A common element, however, is that over the last twenty years there has been a general trend around the world to reduce the rate of growth of the public funding of research relating to agriculture. This reduction in the rate of growth of the funding of research has been associated with a decreasing rate of growth of productivity in agriculture, although this is not necessarily a cause and effect process.

In Australia the establishment of the RDCs with funding via levies has produced a tendency to emphasise 'applied research' over 'basic research'. This contrasts to countries such as the USA and UK where funding tends to be directly from government and the mix of research tends to be more 'basic' than 'applied'. Some economists argue that market failure is more likely for basic research than for applied research and question the need for government involvement at the applied research level

D.8 Who benefits from the research in the potato industry?

Case 1—Competition in the marketing chain

When there is competition throughout the marketing chain, the benefits of research are distributed up and down the chain, based on the elasticities of supply and demand for the various products produced by the industry. Thus the beneficiaries include the potato producers, the various processors and suppliers of marketing services and consumers (domestic and overseas) of the various products. If the research causes a shift in the supply function parallel to the original supply function, the costs and benefits of the research will be shared in the same proportions. Unfortunately, in the absence of some knowledge of the elasticities of supply and demand, it is impossible to precisely predict how the costs and benefits will be shared throughout the marketing chain.

There can also be spill over effects so that producers and processors in other countries benefit from research conducted in Australia, just as Australian producers and processors may benefit from overseas research. There are similar spill over effects between industries in Australia.

Case 2—Lack of competition in the marketing chain

In cases where there is a lack of competition in the marketing chain, the benefits of research tend to be concentrated in the non-competitive parts of the industry. This situation is likely in the potato industry where there are contractual arrangements to purchase potatoes for various uses from growers. The contractual arrangements occur in the purchase of fresh potatoes by the supermarket chains and the purchase of processing potatoes for snack foods or chips. This concentration of the benefits can be a source of conflict between growers and processors and the final outcome depends on the relative bargaining strength of the parties to the contractual agreements. The market power of the purchasers of potatoes is limited by the possible entry of competitors for market share into the industry. The economic theory explaining how the benefits of research tend to be concentrated in the non-competitive parts of the industry is outlined in Appendix C.

Depending on the amount of competition in the retail sector, processors may pass some or all of the benefits on to consumers. This is sometimes used as an argument for taxpayer's (consumers are more or less the same group of people as taxpayers) funding some part of the research effort.

Growers facing a non-competitive part of the industry might reasonably question their support of research, when the some, or all, of the benefits are likely to end up elsewhere. However, if the research were not conduced potato growing, where the product is procured by contractual arrangement, would (sooner or later) become uncompetitive and the product could source offshore.

D.9 References

Alston, J.M., Norton, G.W. and Pardy, P.G. 1998, *Science under Scarcity*, CAB, Wallingford.

Alston, J.M and Pardy, P.G. 1999, The economics of agricultural R&D in Alson, J.M., Pardy, P.G. and Smith, V.H (eds) *Paying for Agricultural Productivity*, Johns Hopkins University Press, Baltimore.

Campbell, K.O. and Fisher, B.S. (1991), *Agricultural Marketing and Prices*, 3rd ed, Longman, Melbourne.

Tomek, W.G. and Robinson, K.L. 1972, *Agricultural Product Prices*, Cornell University Press, Ithaca.

Woellner, R.H, Barkoczy, S., Murphy, S. and Evans, 2001, *Australian Taxation Law 2002*, CCH, North Ryde.

APPENDIX E THE PROGRAMS

E1 Cadmium

Code	Project	Researcher	Cost	Start	Finish
PT342	Cadmium Workshop for the Potato Industry, Adelaide, August 1993	J Eccles	$12,694	05-Aug-93	06-Aug-93
PT661	Publication of cadmium brochure	Jonathan Eccles	$7,300	03-Feb-97	04-Feb-97
VX99042	Coordination of the National Cadmium Minimisation Strategy	L Cook	$37,500	01-Oct-99	30-Jun-05
VG011	The reduction of cadmium contamination in Tasmanian vegetables and poppies	L Sparrow	$51,904	01-Aug-90	30-Jun-96
PT212	A national survey of cadmium in potato tubers and soils	M McLaughlin	$67,750	01-Jul-92	30-Jun-94
PT423	A national strategy to reduce cadmium accumulation in potato crops	M McLaughlin	$410,486	01-Jul-94	30-Jun-98
PT620	Mechanisms of cadmium accumulation by potato tubers (cont'd PT9620)	M McLaughlin	$31,000	01-Oct-96	29-Feb-00
PT94023	A national strategy to reduce cadmium accumulation in potato crops (cont'd PT423)	M McLaughlin	$93,278	01-Jul-97	30-Oct-98
PT96020	Mechanisms of cadmium accumulation by potato tubers (cont'd PT620)	M McLaughlin	$67,760	01-Jul-97	30-Sep-00
VX99040	Workshop to review cadmium R&D in potatoes and vegetables, August 1999	M McLaughlin	$3,912	01-Jul-99	30-Sep-99
PT99058	Production and distribution of Cadmium brochures for the Potato Industry	M McLaughlin	$7,200	01-Jul-99	30-Oct-99
VX99040	Workshop to review cadmium R&D in potatoes and vegetables, August 1999	M McLaughlin	$3,912	01-Jul-99	30-Sep-99

E2 Potato genetic improvement

Code	Project	Researcher	Cost	Start	Finish
Breeding french fry potatoes					
PT637	Breeding French fry potato varieties - Stage 2 (cont'd)	R Kirkham,	113,117	1-Jul-96	30-Jun-99
PT96037	Breeding French fry potato varieties - Stage 2 (cont'd PT637)	R Kirkham,	366,000	1-Jul-97	30-Jun-01
PT309	Breeding French fry potato varieties	R Kirkham,	304,072	1-Jul-93	30-Jun-96
Breeding crisping potatoes					
PT638	Breeding crisp potato varieties - Stage 2 (cont'd)	R Kirkham,	40,015	1-Jul-96	30-Jun-99
PT96038	Breeding crisp potato varieties - Stage 2 (cont'd PT638)	R Kirkham,	102,000	1-Jul-97	30-Jun-01
PT311	Breeding crisp potato varieties	R Kirkham,	90,036	1-Jul-93	30-Jun-96
Breeding fresh market potatoes					
PT96034	Breeding fresh market potato varieties - Stage 2 (cont'd PT634)	R Kirkham,	328,000	1-Jul-97	30-Jun-01
PT310	Breeding fresh market potato varieties	R Kirkham,	206,152	1-Jul-93	30-Jun-96
PT634	Breeding fresh market potato varieties - Stage 2 (cont'd)	R Kirkham,	82,726	1-Jul-96	30-Jun-99
Core breeding program					
PT02027	Core Breeding Program for New Potato Varieties	TBA, TBA,	1,000,000	1-Jul-02	30-Jun-09
Evaluation					
PT231	Potato breeding and cultivar trials in Australia - NSW	B Dowling,	40,398	1-Jul-92	30-Jun-95
PT519	Potato variety improvement in New South Wales	C Beckingham,	11,216	1-Jul-95	30-Jun-96

PT02009	Evaluation and development of new potato genotypes in South Australia	C Williams,	200,800	1-Jul-02	20-Dec-07
PT110	Evaluation & development of new potato genotypes for South Australia	C Williams,	106,407	1-Jul-91	30-Jun-94
PT426	Evaluation and development of new potato genotypes for South Australia	C Williams,	73,952	1-Jul-94	30-Jun-96
PT96004	Evaluation and development of new potato genotypes - South Australia (cont'd PT604)	C Williams,	149,000	1-Jul-97	31-Dec-02
PT615	Selection and evaluation of potato cultivars in Queensland (cont'd)	K Jackson	24,000	1-Jul-96	30-Jun-99
PT513	Potato improvement and evaluation in Queensland	K Jackson	32,000	1-Jul-95	30-Jun-96
PT443	Analysis of the process of evaluating potato breeding lines and introduced cultivars	Mr Jonathan Eccles	3,000	1-Jul-94	30-Jun-95
PT96017	Potato breeding & cultivar evaluation - Western Australia (cont't PT617)	P Dawson,	81,000	1-Jul-97	30-Jun-00
PT214	Potato breeding & cultivar trials in Australia - Western Australia	P Dawson,	120,570	1-Jul-92	30-Jun-95
PT515	Potato breeding and cultivar evaluation - Western Australia	P Dawson,	48,000	1-Jul-95	30-Jun-96
PT617	Potato breeding & cultivar evaluation - Western Australia (cont'd PT9617)	P Dawson,	24,000	1-Jul-96	30-Jun-99
PT96017	Potato breeding & cultivar evaluation - Western Australia (cont't PT617)	P Dawson,	81,000	1-Jul-97	30-Jun-00
PT223	Potato breeding and cultivar trials in Victoria	R Kirkham,	60,000	1-Jul-92	30-Jun-93
PT352	Potato cultivar evaluation in Victoria	R Kirkham	110,252	1-Jul-93	30-Jun-96
PT604	Evaluation and development of new potato genotypes - South Australia (cont'd PT9604)	R Kirkham	24,000	1-Jul-96	30-Jun-99

PT96027	Potato cultivar evaluation in Victoria and New South Wales (cont'd PT627)	R Kirkham	216,000	1-Jul-97	30-Jun-01
PT605	Potato cultivar accession and testing in Tasmania (cont'd PT9605)	R Laurence	24,000	1-Jul-96	30-Jun-99
PT96005	Potato cultivar accession and testing in Tasmania (cont'd PT605)	R Laurence	151,000	1-Jul-97	30-Jun-02
PT343	Potato cultivar accession and testing in Tasmania	J Fennell	105,866	1-Sep-93	30-Jun-96
PT204	Potato breeding and cultivar trials in Australia - Tasmania	J Fennell	20,000	1-Oct-92	30-Jun-93
PT01033	Potato variety evaluation, commercialisation and adoption: Interim project	R Sully	95,805	1-Jul-01	15-Aug-02
PT96015	Selection and evaluation of potato cultivars in Queensland (cont'd PT615)	S Harper	81,000	1-Jul-97	30-Jun-00
PT651	NaPIES Management Committee	Mr Jonathan Eccles	10,000	1-Jul-96	30-Jun-99
PT347	NaPIES management committee	Mr Jonathan Eccles	25,016	1-Jul-93	30-Jun-96
PT96051	NaPIES Management Committee	Mr Jonathan Eccles	0	1-Jul-96	30-Jun-00
PT02028	Evaluation of new potato varieties	TBA, TBA,	600,000	1-Jul-02	30-Jun-06
Gene technology					
PT00015	Development of genetically engineered virus resistant fresh market potatoes	J Hutchinson,	465,006	1-Jul-00	30-Jun-04
PT97011	DNA fingerprints and cryopreservation of potato cultivars for improved quality assurance	J Hutchinson	181,222	1-Jul-97	30-Jun-00
PT338	Production of virus resistant potato plants to enable reduced use of insecticides on potatoes	J Hutchinson	183,976	1-Jul-93	30-Jun-96
PT97013	Production and assessment of virus resistant potato cultivars	J Hutchinson	150,000	1-Jul-97	30-Jun-00

PT520	Molecular markers for potato cyst nematode resistance	J Hutchinson	56,798	1-Jul-95	30-Jun-96
Varietal maintenance					
PT01046	Verification plots & refreshment of the certified seed public variety in-vitro collection	K Blackmore,	28,750	30-Dec-01	30-Dec-04
PT01047	Maintenance of the certified seed public variety in-vitro collection	K Blackmore,	65,510	1-Apr-02	1-Mar-05
Germplasm development					
PT01032	Breeding Australia's potato germplasm : the resource for varietal development	R Kirkham,	202,671	1-Jul-01	30-Jun-02
Program review					
HG98058	Review of HRDC involvement with plant breeding, 1998	ACIL Consulting	103,567	2-Jan-99	31-May-99
PT235	Review of potato breeding and variety evaluation in Australia	Mr Jonathan Eccles	11,696	30-Nov-92	6-Dec-92
PT625	Potato breeding study tour to UK, Netherlands & USA, July 1996	R Kirkham,	14,000	1-Jul-96	1-Oct-96
Miscellaneous					
PT96031	Technology transfer of new potato cultivars (cont'd PT631)	R Kirkham,	123,738	1-Jul-97	30-Jun-01

E3 Integrated pest and disease management

Code	Project	Researcher	Cost		
BIOFUMIGATION					
PT01008	Monitoring and developing management strategies for soil insect pests of potatoes	S Learmonth	$278 500	01-Jul-01	30-Jun-04
PT021	Soil insect pests of potatoes	J Matthiessen	$405 437		
PT447	Integrated management with biofumigation to control soil pests and diseases in potatoes	J Matthiessen	$322 983		
PT632	Influence of rotation and biofumigation on soil borne diseases of potatoes (cont'd PT9632)	D de Boer	$119 558	01-Jul-96	30-Jun-99
PT96032	Influence of rotation and biofumigation on soil-borne diseases of potatoes (cont'd PT632)	D de Boer	$491 194	01-Jul-97	30-Jul-02
VG97050	Biofumigation - bioactive Brassica rotations for IPM of soil borne pests and diseases	J Matthiessen	$305 561	01-Jul-97	30-Jun-00
VX00013	Biofumigation - optimising biotoxic Brassica rotations for soil-borne pest and disease management	J Matthiessen	$327 428	01-Jul-00	30-Jun-03
Ipm for tuber moth and foliar insects					
PT348	Potato integrated pest management coordination meeting, October 1993	J Eccles	$7 853	26-Oct-93	27-Oct-93
PT216	Development of a commercial assessment method to detect parasitoids of the potato moth	P Horne	$42 852	01-Jul-92	30-Jun-94
PT336	Implementation of integrated pest management in Northern Australian potato production districts	R Spooner-Hart	$76 891	01-Nov-93	30-Jun-96
PT437	Development of IPM strategies for potato moth	P Horne	$204 840	01-Jul-94	30-Jun-96
PT449	Review of potato integrated pest management implementation activities, 1994	J Eccles	$1 896	01-Jul-94	30-Dec-94

PT538	Comparative benefit cost of IPM and conventional pest management in potatoes	Pam Strange	$5 000	01-Jul-95	30-Jun-96
PT656	National IPM program for potato pests	P Horne	$127 710	01-Jul-96	30-Jun-97
PT98043	Preparation of field guide and reference books for pests, beneficials and diseases of potato crops	P Horne	$48 500		
Metham sodium					
PT618	Developing management for enhanced pesticide biodegradation and International Entomology Congress	J Matthiessen	$11 430		
PT619	Enhanced biodegradation of fumigants: determination, risk assessment and prevention strategies	J Matthiessen	$109 311		
Virus in WA					
PT00034	Communicating the strategies to management potato virus diseases for Western Australia potato crops	S Learmonth	$18 182		
PT01040	Pilot commercial crop monitoring for pests and diseases in WA seed potato crops	S Learmonth	$39 273		
PT96054	Integrated management of early and late potato blights in Australia	F Berlandier	$42 386		
Disease					
PT341	Integrated management of early and late potato blights in Australia	T Wicks	$149 306	01-Jul-93	30-Jun-97

E4 Potato cyst nematode

Code	Project	Researcher	Cost	Start	Finish
PT99055	National PCN management strategy	Berg	50 634	1-Feb-00	1-Sep-02
PT 346	Identification of PCN pathotypes	Hinch	39 114	1-Sep-93	1-Jun-95
PT 436	Characterisation and detection of potato cyst nematode	Marshall	79 290	1-Jul-94	1-Jul-97

E5 Soil borne disease

Code	Project	Researcher	Cost	Start	Finish
PT205	Integrated management of potato common scab	C Wilson	139,402	01-Jul-92	30-Jun-95
PT006	Rapid identification of Streptomyces spp. on potato, the key to integrated management of common scab	Ransom	37,084	01-Jul-91	30-Jun-92
PT315	Rhizoctonia control on fresh market potatoes	T Wicks	164,458	01-Oct-93	01-May-96
PT505	Development of codes of practice within the Tasmainain potato industry	Ransom	48,974	01-Jul-95	01-Apr-98
PT537	Review of potato tuber borne diseases, October 1995	J Eccles	7,262	01-Jul-95	30-Jun-96
PT632	Influence of rotation and biofumigation on soil-borne diseases of potatoes	De Boer	$110,558	30-Jul-97	30-Jul-02
PT96032	Influence of rotation and biofumigation on soil-borne diseases of potatoes (cont'd PT632)	De Boer	$491,194	01-Jul-96	01-07-99
PT97015	New chemical treatments for fungal diseases of seed potatoes	D de Boer	264,205	01-Jul-97	30-Jul-02

PT98015	Development of extreme resistance (immunity) to common scab disease within current commercial potato cultivars	C Wilson	167,760	01-Jul-98	31-Oct-01
PT98018	Cleaning and disinfection practices for potato farms	D de Boer	304,730	01-Jul-98	30-Sep-02
VG98076	Screening potato and vegetable soil borne diseases that may be controlled by Eucalyptus leaf mulch - pilot study	Melita Shalders	11,200	01-Jul-98	30-Sep-99
PT01019	Prediction and molecular detection of soil-borne pathogens of potato	N Crump	330,000	01-Jul-01	30-Jun-04
PT01017	Understanding the implications of pastures on the management of soil-borne diseases of seed potatoes	D de Boer	452,224	01-Jul-01	30-Jun-04
PT01020	Evaluation and commercialisation of common scab resistant clones of commercial potato varieties	C Wilson	353,758	31-Aug-01	01-Oct-04
PT02013	International R&D workshop and industry extension meetings on common scab disease	C Wilson	53,000	01-Jul-02	30-Jun-04
PT610	Investigation on common scab disease of potatoes and development of control methods (cont'd PT9610)	Hoong Pung	53,986	01-Jul-96	30-Jun-99
PT96010	Investigation on common scab disease of potatoes and development of control methods (cont'd PT610)	Hoong Pung	187,386	01-Jul-97	30-Jun-00
PT02016	Common scab threshold on tuber seeds for processing potato crops	Hoong Pung	192,000	01-Jul-02	30-Nov-05

E6 Quality assurance

Code	Project	Researcher	Cost	Start	Finish
PT 96014	Development of a quality assured production and marketing system for fresh potatoes	Coleman	201 058	30-09-07	31-12-98

E7 Regional industry development – Southern and Northern Highlands

Code	Project	Researcher	Cost	Start	Finish
PT97010	Sustainable potato production in highland NSW	Lanz	98 455	15-Oct-97	31-Mar-00
PT659	Sustainable production in highland potato growing districts of NSW - Stage 2	Lanz	35 360	1-Dec-96	1-June-97

E8 Regional industry development – Atherton

Code	Project	Researcher	Cost	Start	Finish
PT402	Sustainable crop management for potato farms on the Atherton Tablelands	Gunton	76 697	01-Jul-94	30-Jun-97
PT012	Soil fertility management for potatoes on the Atherton Tablelends	Gunton	38 790	1 july 90	30-June-93

E9 Resource management and protection

Code	Project	Researcher	Cost	Start	Finish
PT428	Information packages and decision support software for improved nutrient management of potato crops (cont'd PT9428)	N Maier	191,550	01-Jul-94	30-Jun-97
PT107	Development of crop management strategies for improved productivity & quality of potatoes grown on highly acid soils	N Maier	122,421	01-Jul-91	30-Jun-94
PT97026	Developing soil and water management systems for potato production on sandy soils in Australia	Bob Peake	132,542	01-Sep-97	30-Jun-00
VG97081	Sustainable use of recycled water for horticultural irrigation on the Northern Adelaide Plains	DStevens	578,765	05-Jan-98	30-Sep-02
PT97003	More economic and environmentally responsible use of phosphorus fertiliser in potato cropping on krasnozem soils in Australia	LSparrow	60,100	01-Jul-97	31-Dec-01
HG98034	Enhanced biodegradation of soil-applied pesticides - determination, risk assessment and prevention strategies	JMatthiessen	467,548	01-Nov-98	31-May-03
HG98034	Enhanced biodegradation of soil-applied pesticides - determination, risk assessment and prevention strategies	JMatthiessen	467,548	01-Nov-98	31-May-03
HG98034	Enhanced biodegradation of soil-applied pesticides - determination, risk assessment and prevention strategies	JMatthiessen	467,548	01-Nov-98	31-May-03
PT94028	Information packages and decision support software for improved nutrient management of potato crops (cont'd PT428)	N Maier	27,577	01-Jul-97	30-Jun-98

PT02001	Biodegradable plastics: The potential for Australian potato as an input for biodegradable polymers	D Michael	98,400	01-Jul-02	30-Jun-04
PT02014	Sustainable agronomy packages for export potatoes	I McPharlin	243,000	01-Jul-02	31-Dec-05
PT447	Integrated management with biofumigation to control soil pests and diseases in potatoes	JMatthiessen	322,983	01-Jul-94	30-Jun-97
VG97050	Biofumigation - bioactive Brassica rotations for IPM of soil borne pests and diseases	JMatthiessen	305,561	01-Jul-97	30-Jun-00
VX01006	Developing cost effective UV protection of biological pesticides	B Hawkett	96,588	01-Dec-01	31-Dec-03
PT96047	Control of black nightshade and other weeds in potatoes	I Macleod	80,000	01-Jul-96	30-Jun-99
HG98034	Enhanced biodegradation of soil-applied pesticides - determination, risk assessment and prevention strategies	JMatthiessen	467,548	01-Nov-98	31-May-03
VX00013	Biofumigation - optimising biotoxic Brassica rotations for soil-borne pest and disease management	JMatthiessen	327,428	01-Jul-00	30-Jun-03
PT94028	Information packages and decision support software for improved nutrient management of potato crops (cont'd PT428)	N Maier	27,577	01-Jul-97	30-Jun-98
VG97081	Sustainable use of recycled water for horticultural irrigation on the Northern Adelaide Plains	DStevens	578,765	05-Jan-98	30-Sep-02
VX99002	Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry	J McPhee	20,000	01-Jul-99	31-May-02
HG98034	Enhanced biodegradation of soil-applied pesticides - determination, risk assessment and prevention strategies	JMatthiessen	467,548	01-Nov-98	31-May-03
PT304	Review of potato waste utilisation in Australia	Karen Freeman	10,400	01-Jul-93	30-Jul-94
PT409	Evaluation of the economic opportunities for potato by-product industries in Australia	Karen Freeman	34,825	01-Jul-94	30-Jun-95
VX99002	Increasing the opportunities for use of organic wastes in the Tasmanian vegetable industry	J McPhee	20,000	01-Jul-99	31-May-02

E10 Export market development

Code	Project	Researcher	Cost		
PT 98022	Potato export market development-Australian potato export opportunities, Bonanza or Myth?	R Sully and D McKinna	$119 947	01-Jul-98	22-Feb-01
PT97031	Innovative transport and disease control systems: Potato exports to Asia	A Sharp	$208 690	01-Jan-98	01-Jan ‘00

APPENDIX G Regional production (hectares), 1992 to 2000

Year	NSW	Vic	Qld	SA	WA	TAS	Total
1992	6528	12121	4739	7233	2969	7021	40610
1993	6537	11850	4771	7421	2919	7033	40531
1994	6545	11579	4803	7610	2869	7045	40451
1995	6553	11308	4835	7798	2819	7058	40371
1996	6562	11038	4867	7986	2769	7070	40291
1997	6570	10767	4898	8174	2719	7082	40211
1998	6579	10496	4930	8363	2669	7095	40132
1999	6587	10226	4962	8551	2619	7107	40052
2000	6595	9955	4994	8739	2569	7120	39972
2001	6604	9684	5026	8928	2519	7132	39892
2002	6612	9413	5058	9116	2469	7144	39812
2003	6621	9143	5089	9304	2419	7157	39733
2004	6629	8872	5121	9492	2369	7169	39653
2005	6637	8601	5153	9681	2319	7181	39573
2006	6646	8331	5185	9869	2269	7194	39493
2007	6654	8060	5217	10057	2220	7206	39414
2008	6663	7789	5248	10246	2170	7218	39334
2009	6671	7518	5280	10434	2120	7231	39254
2010	6679	7248	5312	10622	2070	7243	39174
2011	6688	6977	5344	10810	2020	7255	39094
2012	6696	6706	5376	10999	1970	7268	39015
2013	6705	6436	5408	11187	1920	7280	38935
2014	6713	6165	5439	11375	1870	7293	38855
2015	6721	5894	5471	11564	1820	7305	38775
2016	6730	5623	5503	11752	1770	7317	38695
2017	6738	5353	5535	11940	1720	7330	38616
2018	6747	5082	5567	12128	1670	7342	38536
2019	6755	4811	5599	12317	1620	7354	38456
2020	6763	4541	5630	12505	1570	7367	38376

Source: Data from 1992 to 2000 Australian Bureau of Statistics (various dates) *Agriculture Australia 7113.0*, Australian Bureau of Statistics, Canberra. Data from 2000 to 2020 is based on a time trend calculated using simple regression. No attempt was made to project how production might switch from state to state in the period 2000 to 2020.

APPENDIX H Potato production, by end use,1992 to 2020

Year	Crisping†	French fry#	Fresh‡	Seed*	Total*
1992	106000	773000	309000	98000	1286000
1993	108000	788000	311000	102000	1309000
1994	109000	803000	314000	106000	1332000
1995	111000	818000	316000	109000	1354000
1996	113000	834000	318000	113000	1377000
1997	114000	849000	320000	116000	1400000
1998	116000	865000	322000	120000	1422000
1999	117000	880000	324000	123000	1445000
2000	119000	896000	326000	127000	1468000
2001	121000	912000	327000	130000	1490000
2002	122000	928000	329000	134000	1513000
2003	124000	944000	331000	138000	1535000
2004	125000	960000	332000	141000	1558000
2005	127000	976000	333000	145000	1581000
2006	128000	992000	335000	148000	1603000
2007	130000	1008000	336000	152000	1626000
2008	132000	1025000	337000	155000	1649000
2009	133000	1041000	338000	159000	1671000
2010	135000	1058000	339000	162000	1694000
2011	136000	1074000	340000	166000	1717000
2012	138000	1091000	341000	169000	1739000
2013	140000	1108000	342000	173000	1762000
2014	141000	1125000	342000	177000	1785000
2015	143000	1141000	343000	180000	1807000
2016	144000	1159000	343000	184000	1830000
2017	146000	1176000	344000	187000	1852000
2018	147000	1193000	344000	191000	1875000
2019	149000	1210000	344000	194000	1898000
2020	151000	1227000	345000	198000	1920000

*Seed and total production from 1992 to 2000 were derived from ABS data. These data were used to establish time trends using simple regression for the period 2000 to 2020.
† Crisping data from 1994 to 2000 was collected by survey. The time trend was used to estimate the period 1992-93 and 2000 to 2020.
# It was intended that French fry data would be derived in the same way as crisping data. However data was not forthcoming from processors in that part of the industry. Thus French fry data is the residual in this table, and is subject to considerable possible error.
‡ It was intended that fresh market use would be calculated as the residual. Without the French fry data this could not be done. Thus it was assumed that the fresh market amounted to 26% of production (not including seed) in 1992 and will decrease to 20% by 2020.
The data was rounded after the calculations were carried out.

APPENDIX I LEVY COLLECTIONS– MATCHED

Table L1 Potato industry levy and voluntary contributions and government matching funds, 1992-2001

Year	Production (tonnes)	Calculated grower levy	Total levy collections reported in HRDC Annual Reports	Calculated processor levy	Voluntary contributions reported in HRDC Annual Reports	Total Commonwealth matching contributions reported in HRDC Annual Reports *	Total funding (levy+voluntary+Cwealth)	Calculated grower levy as % of total funding	Calculated processor levy as % of total funding
1992	1,187,917	$593,959				$43,634			
1993	1,139,696	$569,848			$355,745	$688,277			
1994	1,184,705	$592,353	$880,107	$287,755	$413,287	$1,088,216	$2,381,610	24.87%	12.08%
1995	1,122,416	$561,208	$879,269	$318,061	$261,432	$1,144,271	$2,284,972	24.56%	13.92%
1996	1,308,099	$654,050	$917,485	$263,436	$180,272	$1,000,899	$2,098,656	31.17%	12.55%
1997	1,286,131	$643,066	$956,768	$313,703	$119,951	$1,013,003	$2,089,722	30.77%	15.01%
1998	1,371,644	$685,822	$986,919	$301,097	$93,456	$394,553	$1,474,928	46.50%	20.41%
1999	1,326,764	$663,382	$914,947	$251,565	$91,947	$343,512	$1,350,406	49.12%	18.63%
2000	1,199,621	$599,811	$870,620	$270,810	$116,695	$387,505	$1,374,820	43.63%	19.70%

Source: Horticultural Research and Development Corporation (various dates), Annual Reports

* The split of government contributions into those matching the levy and those matching voluntary contributions by industry were reported in the years 1998-2000 only.