Industry-specific impact assessment program: Citrus

Impact assessment report for project *Development of national strategies to manage citrus gall wasp* (CT15006)

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Contents

Tables

Figures

Executive Summary

What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in *CT15006: Development of national strategies to manage citrus gall wasp.* The project was funded by Hort Innovation over the period September 2015 to October 2018.

Methodology

The investment was first analysed qualitatively within a logical framework that included activities and outputs, outcomes and impacts. Actual and/or potential impacts then were categorised into a triple bottom line framework. Principal impacts identified were then considered for valuation in monetary terms (quantitative assessment). Past and future cash flows were expressed in 2019/20 dollar terms and were discounted to the year 2019/20 using a discount rate of 5% to estimate the investment criteria and a 5% reinvestment rate to estimate the modified internal rate of return (MIRR).

Results/key findings

The investment in this citrus pest project addressing national strategies to manage the citrus gall wasp (CGW) resulted in valuable information for citrus growers including strategies based on one or more of:

- monitoring,
- cultural control,
- biological control,
- careful use of chemicals, and
- encouraging areas within the orchard where build-up of CGW parasitoids can be effected.

In addition, the project identified areas of future R&D investment that would be valuable, including:

- Estimate the effect of CGW on fruit yield,
- Develop a cost-effective method of rearing parasitoids,
- Assemble data to support registration of a kaolin-based repellent,
- Identify effective control methods in nursery trees,
- Collect CGW phenology data in Western Australia and Queensland to expand existing phenology models.

Investment Criteria

Total funding from all sources for the project was $0.93 million (present value terms). The investment produced estimated total expected benefits of $2.47 million (present value terms). This gave a net present value of $1.54 million, an estimated benefit-cost ratio of 2.65 to 1, an internal rate of return of 12.6% and a MIRR of 8.6%.

Conclusions

The investment in CT15006 will likely contribute to improved amelioration of CGW damage by citrus growers, particularly southern orange growers. This impact, resulting in yield increases for citrus growers and a higher quality product moving through the various regional supply chains. The first of these two potential impacts was valued using conservative assumptions. However, some of the assumptions on which the valuations are based are not overly well supported by evidence, hence a number of risk factors are used in developing the key assumptions.

Keywords

Impact assessment, cost-benefit analysis, citrus industry, citrus gall wasp, yield, quality

Introduction

Horticulture Innovation Australia Limited (Hort Innovation) required a series of impact assessments to be carried out annually on a number of investments in the Hort Innovation research, development and extension (RD&E) portfolio. The assessments were required to meet the following Hort Innovation evaluation reporting requirements:

- Reporting against the Hort Innovation's current Strategic Plan and the Evaluation Framework associated with Hort Innovation's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to Hort Innovation stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

Under impact assessment program MT18011, the first series of impact assessments were conducted in 2019 and included 15 randomly selected Hort Innovation RD&E investments (projects). The second series of impact assessments (current series), undertaken in 2020, also included 15 randomly selected projects worth a total of approximately $7.11 million (nominal Hort Innovation investment). The second series of projects were selected from an overall population of 85 Hort Innovation investments worth an estimated $44.64 million (nominal Hort Innovation investment) where a final deliverable had been submitted in the 2018/19 financial year.

The 15 investments were selected through a stratified, random sampling process such that investments chosen represented at least 10% of the total Hort Innovation RD&E investment in the overall population (in nominal terms) and was representative of the Hort Innovation investment across six, pre-defined project size classes.

Under a separate impact assessment program (MT19012), a second series of impact assessments addressed a requirement for industry-specific ex-post independent impact assessments of the almond (AL), banana (BA), citrus (CT) and onion (VN) RD&E investment funds.

Twenty-nine RD&E investments (projects) were selected through a stratified, random sampling process. The industry samples were as follows:

- Nine AL projects were chosen worth $5.84 million (nominal Hort Innovation investment) from an overall population of 21 projects worth an estimated $10.78 million,
- Eight BA projects worth $3.02 million (nominal Hort Innovation investment) from an overall population of 24 projects worth approximately $16.72 million,
- Eight CT projects worth $5.40 million (nominal Hort Innovation investment) from a total population of 35 projects worth $15.78 million, and
- Four VN projects worth $2.40 million (nominal Hort Innovation investment) from an overall population of 8 projects worth $3.89 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2014 to 30 June 2019. The projects for each industry sample were chosen such that the investments represented (1) at least 10% of the total Hort Innovation RD&E investment expenditure for each industry, and (2) the SIP outcomes (proportionally) for each industry.

Four projects had been randomly selected as part of a related Hort Innovation project (MT18011) and were included in the samples for the AL industry (AL14006 and AL16004) and the CT industry (CT15006 and CT15013). This left 25 unique projects randomly selected for evaluation under MT19012.

Project CT15006: *Development of national strategies to manage citrus gall wasp* was randomly selected as one of the 15 investments under MT18011 and also was randomly selected as one of the investments under MT19012 and was analysed in this report.

General Method

The impact assessment follows general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations, Cooperative Research Centres, State Departments of Agriculture, and some universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and actual and/or potential impacts. The principal economic, environmental and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. Where impact valuation was exercised, the impact assessment used cost-benefit analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for individual investments potentially represent an underestimate of the performance of that investment.

Background & Rationale

The Australian citrus industry is one of Australia's 'traditional' horticultural industries. While the citrus gall wasp (CGW) has been an endemic pest of citrus in Australia (Queensland and northern New South Wales (NSW) for many years, it was largely absent from the major orange production areas of the Riverina, Sunraysia and Riverland. However, in the past ten years the wasp has had an increasing presence and impact in the southern orange production areas, stimulating an increased Research Development and Extension (RD&E) investment including Project CT15006. Further, the only chemical for CGW control was methidathion and its continuing availability was uncertain.

Projects preceding CT15006 had focused on wasp biology, life cycles, and alternative chemical control options. While these early projects improved understanding and improved management to some extent, a more comprehensive approach was required to develop sustainable CGW management strategies across a number of areas; Project 15006 was funded to play this role.

CGW is controlled to various degrees in its natural habitat by other parasitic wasp species, depending on the extent of the parasitoid wasp populations. In southern Australia, the parasitoid wasps are present but populations are still low. The role of the parasitoid wasps in controlling CGW in the future are paramount so reliance on chemical control is limited (other than for spot spraying applications), due to the parasitoid wasps being in the same family as CGW. New chemical options were needed that were compatible with integrated pest management as well as improved strategies for conserving and managing the parasitoid wasps.

Oranges are the predominant citrus type grown in Australia followed by mandarins, lemons/limes and grapefruit in that order by tonnage as illustrated in Table 1 below.

Table 1: Australian Orange Industry Production and Value 2017-2019

Year ended June	Production (tonnes)	Gross Value of Production ($m)	Farmgate value ($/tonne)
2017	506,391	333.5	659
2018	526,079	373.0	709
2019	528,095	398.8	755
Average	520,188	368.4	708

Source: Hort Innovation (2019) Australian Horticultural Statistics Handbook, 2018/19

While citrus is grown in all Australian states and the Northern Territory, production of oranges is dominated by regions in the southern states of NSW, Victoria and South Australia. Exports of fresh oranges are significant and make up on average about 35% of the annual tonnage of oranges produced in Australia. A further 41% of the orange tonnage are processed, predominantly for orange juice.

The research and development activities of the citrus industry are guided by the industry's Strategic Investment Plan (SIP). The activities are funded by levies payable on citrus produced in Australia.

The process of preparing this SIP was managed by Hort Innovation in consultation with the Industry Representative Body and the Strategic Investment Advisory Panel. The current SIP has been driven by levy payers and addresses the Australian citrus industry's research and development (R&D) needs (and marketing specifically for the orange industry) from 2017 to 2021.

Project Details

Summary

Project Code: CT15006

Title: *Development of national strategies to manage citrus gall wasp*

Research Organisation: Department of Primary Industries (DPI), New South Wales (NSW)

Project Leader: Jianhua Mo, Research Entomologist, NSW DPI

Period of Funding: September 2015 to October 2018

Objectives

This project aims to develop coordinated national strategies to manage the increasing pressure and damage from the CGW in the southern citrus regions of Australia. Within this broad aim the priority management strategies included the development of:

1) cultural control methods,
2) biological control methods,
3) Integrated pest management - compatible chemical control options, and
4) a degree-day tool to guide control timing.

Studies were also aimed at improved understanding of the biology and behaviour of the wasp and its interactions with its parasitoids.

Logical Framework

Table 2 following provides a detailed description of the project in a logical framework format.

Table 2: Logical Framework for Project CT15006

Activities	A range of activities aimed at improved control of the CGW was undertaken. The activities/investigations were grouped into the following broad activities: Use of chemicals/repellents Biological control, Phenology (cyclic and seasonal characteristics of the wasp), Cultural control, and Communication/extension. **Use of chemical/repellent options for CGW control** • Five new insecticides were initially investigated, four of which were worthy of further investigation in the field. • Petroleum spray oil was investigated and it was concluded that 0.5% was not sufficient to eliminate CGW egg-lay. • The 'Surround' crop protectant is a 'particle film' technology; the protectant is made up of modified particles of naturally occurring kaolin; four field trials confirmed the effectiveness of the product as a repellent. • The rate of applications of 'Surround' was likely to be excessively costly for growers and a further study was carried out by the project that showed the cost can be halved by using an adjuvant and less water. • Field trials showed that a number of other chemicals provided effective control of CGW larvae in late spring and summer/autumn; however, they are disruptive to beneficial parasitoid insects, so their frequent use is not recommended.

	Biological control • Mass rearing of CGW parasitoids continued throughout the duration of the project. • A mother culture of the parasitoids has been established by the project. • A survey of parasitoid populations in Queensland was effected to assess the potential for natural biological control vis the correlation between parasitoid populations and CGW infestation levels. **Phenology** • CGW phenology models were updated and will assist in the timing of control methods for the wasp. **Cultural control** • Optimal timing for pruning was investigated via a number of field trials. **Communication and extension activities** • A project monitoring and evaluation plan was developed Communication activities included: o Project workshops o Field days with guest speakers o Presentations to Citrus Technical Forum 2017 o Publications in Australian Citrus News o An updated factsheet on CGW has been published by NSW DPI in December 2018, after the project finished.
Outputs	Improved knowledge and information produced including: • Gall wasp oviposition in citrus shoots can be greatly reduced by Surround sprays but the rate needed further investigation. • Optimal pruning timing appears to be four weeks or earlier before gall wasp emergence; this would ensure no adult CGW would emerge from pruned galls and no burning or mulching of the galls is needed. • Improved monitoring practices for the CGW were developed. • The appropriate use of chemical controls was communicated. • The use of a kaolin-based spray (Surround) reduced next seasons galls by 90%. • Identification of areas within the orchard where build-up of CGW parasitoids can be effected. • Areas of further investment in R&D were defined including: o Definition of the impacts of CGW infestation on yield o Investigation of cost-effective ways to rear CGW parasitoids o Collection of further efficacy/residue data to support the registration of the kaolin-based repellent o Find potential chemical options for CGW control in nursery trees o Collect CGW phenology data in Western Australia (WA) and Queensland to expand the application range of the phenology models o Find safe and effective ways to manage CGW in peri-urban environments in WA to slow/stop the spread of the wasp into commercial orchards.
Outcomes	• The availability and application of the project outputs by some growers has most likely delivered some yield improvements and higher quality fruit (fruit size) by selected management practice changes by growers. • While some grower practice change based on the project findings is expected, evidence of the extent of these expected changes by growers is not available. • As a result of the project, an updated factsheet on CGW has been published by NSW DPI (NSW DPI, 2018). The factsheet covers o monitoring practices, o pruning, o an online timing guide was published for CGW adult emergence, o biological control methods (encouraging beneficials), o how to manage CGW in orchards of different infestation levels,

	○ an increased focus on orchard areas where build-up of CGW parasitoids can be effected. • Most of the changes in the updated factsheet are a result of information generated in Project CT15006; data collected from a previous project (CT 10021) was used to update the CGW phenology model (Jianhua Mo, pers. comm., 2020). • Use of Kaolin based sprays was not explicitly recommended in the factsheet because it has not yet been registered for CGW control. • Chemical efficacy data collected in CT15006 has led to the availability of Confidor Guard and Samurai as new chemical options for growers; Samurai is more expensive than methidathion, which was the only registered chemical for CGW control before CT15006. • Both Confidor Guard and Samurai are soil applied systemic insecticides; unlike methidathion, applications of these two insecticides would directly kill canopy feeding general predators in citrus (Jianhua, Mo, pers. comm., 2020). • Grower adoption of information in the factsheet is likely; for example, judging by the enquiries received by Jianhua Mo, the timing guide is widely used.
Impacts	• Increased orange yields and quality/size for a number of orange growers in southern Australia due to the application of findings produced by the project. • Orange growers in southern Australia may have incurred some additional costs associated with application of the updated control methods adopted (including labour).

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project CT15006 by Hort Innovation and the NSW Department of Primary Industries (NSW DPI).

Table 3: Annual Investment in Project CT15006 (nominal $)

Year ended 30 June	Hort Innovation ($)	NSW DPI ($)	TOTAL ($)
2016	135,897	95,133	231,030
2017	90,958	63,674	154,632
2018	131,755	92,233	223,988
2019	49,441	34,610	84,051
Totals	**408,051**	**285,650**	**693,701**

Source: Project proposal

Program Management Costs

For the Hort Innovation investment the cost of managing the Hort Innovation funding was added to the Hort Innovation contribution for the project via a management cost multiplier (1.162). This multiplier was estimated based on the share of 'payments to suppliers and employees' in total Hot Innovation expenditure (3-year average) reported in the Hort Innovation's Statement of Cash Flows (Hort Innovation Annual Report, various years). This multiplier was then applied to the nominal investment by Hort Innovation shown in Table 3.

For the NSW DPI investment, the management and administration costs for the project were assumed already built into the nominal $ amounts appearing in Table 3.

Real Investment and Extension Costs

For purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). No additional costs of extension were included as the project itself involved growers and was extension oriented; the project also maintained communication channels with citrus interests (e.g. State Departments and grower organisations) in all Australian regions.

Impacts

Table 4 provides a summary of the principal types of impacts delivered by the project, based on the logical framework. Impacts have been categorised into economic, environmental and social impacts.

Table 4: Triple Bottom Line Categories of Principal Impacts from Project CT15006

Economic	• Potential for increased value of orange production in southern Australia, driven by both yield and quality (fruit size) improvements due to improved control of CGW. • Potential for increased value of other citrus types including grapefruit, lemon/limes, and oranges in non-southern Australian states.
Environmental	• More judicious use of chemicals by some growers.
Social	• Some minor regional social impacts may have been derived from increased spill-overs to families and businesses along the supply chain from yield and grower profitability increases and less variability of orange quantity flows from year to year. • Increased scientific knowledge and research capability.

Public versus Private Impacts

The impacts identified from the investment are predominantly private impacts accruing to citrus growers in most Australian citrus producing regions, with an emphasis on orange producers in southern Australia. However, some minor public benefits may have been incurred produced in the form of spill-overs to regional communities from enhanced grower incomes, and increased supply chain activity from the increased marketable citrus production. Also, the project has delivered increased scientific knowledge and scientific capability.

Distribution of Private Impacts

The private impacts will have been distributed along the citrus supply chains. The share of impact realised by supply chain participants will depend on both short- and long-term supply and demand elasticities experienced along the linkages in the supply chain.

Impacts on Other Australian Industries

It is likely that most impacts will be mostly confined to the citrus industry, particularly orange producers in Southern Australia.

Impacts Overseas

As the citrus gall wasp is an Australian native insect, it is unlikely that there will be any significant spill-over impacts from the research to overseas interests. However, the research methods used and their findings could contribute to an improved general understanding of galling insects in other countries.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project outcomes and related impacts will contribute primarily to Rural RD&E Priority 4, and to Science and Research Priority 1.

Table 5: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy and Resources 6. Manufacturing 7. Environmental Change 8. Health

Sources: DAWR (2015) and OCS (2016)

Alignment with the Citrus Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the Australian citrus industry are outlined in the Citrus Strategic Investment Plan 2017-2021[1] (Hort Innovation, 2017). Project CT15006 addressed primarily Outcomes 2 and 3. Outcome 2 is 'Growers and the industry reduce biosecurity, phytosanitary and agrichemical-related risks' (via Strategies 2.1 and 2.2). Strategy 2.1 is to safeguard the Australian citus industry from future biosecurity, phytosanitary and agri-chemical -related risks and was funded against the deliverables of 'enhanced programs to manage serious endemic pests, diseases and weeds, including fruit fly, citrus gall wasp and fungal pathogens'..). Strategy 2.2 is to safeguard the Australian cirus industry from injudicious use of agrichemicals throughout the value chain. Outcome 3 is "Improve product quality and increased productivity from the application of innovation". Project CT15006 addressed ths outcone via Strategy 3.1 to underale R&D and extension to improve productivity and efficiency

Valuation of Impacts

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when some uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. The impact of increased regional community spill-overs was not valued largely due to lack of data to support credible assumptions. Also, any impacts from the project were not valued that related to an increased value of other citrus types including grapefruit, lemon/limes, and oranges in non-southern Australian states. Any such impacts were not valued due to lack of information on such impacts and due to the major focus of the project being on southern orange production.

Summary of Assumptions

The impact that was valued was the increased yield and quality of orange production in southern Australia due to improved management of the CGW.

The specific assumptions that have driven orange value increases in yield due to the improved management of the wasp by a number of growers in southern Australia are provided in Table 6.

[1] For further information, see: https://www.horticulture.com.au/hort-innovation/funding-consultation-and-investing/investment-documents/strategic-investment-plans/

Table 6: Summary of Assumptions for Impact Valued

Variable	Assumption	Source/Comment
Impact 1: Yield increase by some growers		
Annual value of loss of orange yield in southern Australia before investment, based on a 5% yield reduction assumption	$600,000	Project final report
Reduction in annual value of yield loss due to project investment	75%, allowing for implementation costs	Analyst assumption
Annual cost reduction due to project	$450,000	$600,000 x 75%
First year of some impact (year ended June)	2019	Analyst estimates
Year of maximum impact	2028	
Probability of outcome (above adoption)	75%	
Probability of impact (yield increase)	75%	
Attribution	75%	In recognition that further R&D and extension investment will be required to deliver the assumed benefits

Results

All costs and benefits were discounted to 2019/20 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the MIRR. The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment (2018/19) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

Tables 7 and 8 show the investment criteria estimated for different periods of benefits for the total investment and the Hort Innovation investment alone.

Table 7: Investment Criteria for Total Investment in Project CT15006

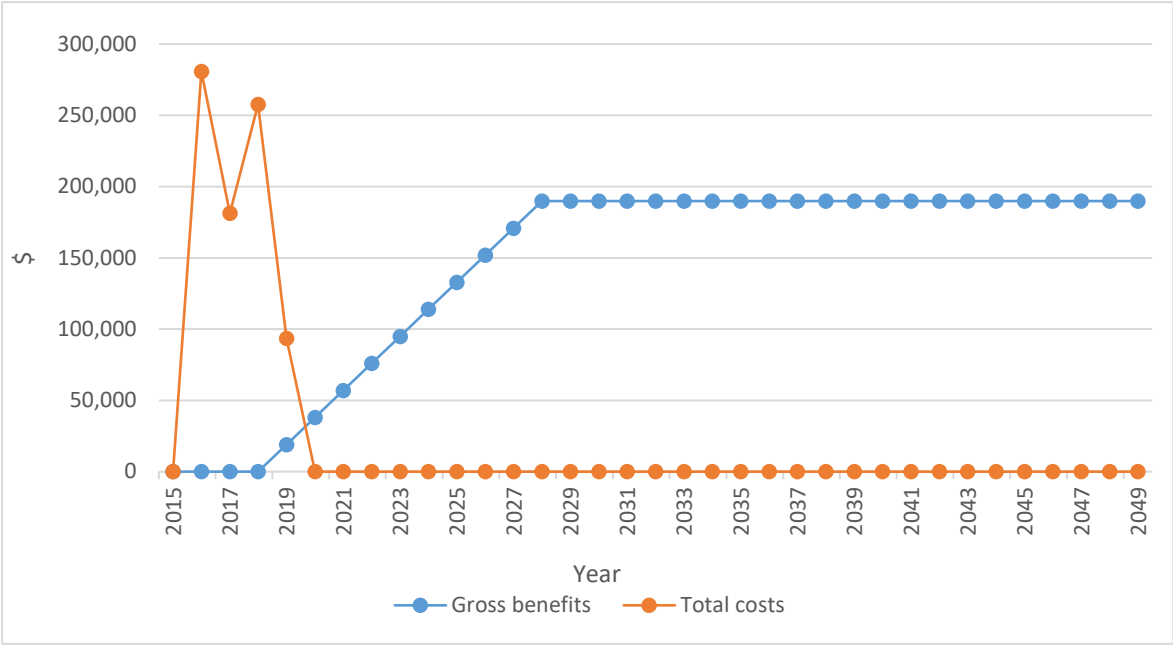
Investment Criteria	Years after Last Year of Investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.02	0.36	0.95	1.48	1.89	2.22	2.47
Present Value of Costs ($m)	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Net Present Value ($m)	-0.91	-0.58	0.01	0.54	0.96	1.28	1.54
Benefit-Cost Ratio	0.02	0.38	1.01	1.58	2.03	2.37	2.65
Internal Rate of Return (%)	negative	negative	5.18	9.84	11.51	12.22	12.56
MIRR (%)	negative	negative	5.16	8.56	9.04	8.91	8.64

Table 8: Investment Criteria for Hort Innovation Investment in Project CT15006

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.01	0.22	0.59	0.92	1.18	1.38	1.54
Present Value of Costs ($m)	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Net Present Value ($m)	-0.57	-0.36	0.01	0.34	0.60	0.80	0.96
Benefit-Cost Ratio	0.02	0.38	14.37	1.58	2.03	2.37	2.65
Internal Rate of Return (%)	negative	negative	5.18	9.84	11.51	12.22	12.56
MIRR (%)	negative	negative	5.16	8.56	9.04	8.91	8.64

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the CT15006 investment plus 30 years from the last year of investment are shown in Figure 1.

Figure 1: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 9 presents the results that show a moderately high sensitivity to the discount rate.

Table 9: Sensitivity to Discount Rate (Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5%	10%
Present Value of Benefits ($m)	5.03	2.47	1.43
Present Value of Costs ($m)	0.81	0.93	1.07
Net Present Value ($m)	4.22	1.54	0.37
Benefit-cost ratio	6.19	2.65	1.34

A sensitivity analysis was then undertaken for the reduction in yield loss that could be ascribed to the project investment. Results are provided in Table 10. The yield loss reduction that is required in order for the investment to break even is 28.3%.

Table 10: Sensitivity to Assumption on Yield Loss Reduction (Total investment, 30 years)

Investment Criteria	Yield Loss Reduction Assumed		
	25%	50%	75% (base)
Present Value of Benefits ($m)	0.82	1.65	2.47
Present Value of Costs ($m)	0.93	0.93	0.93
Net Present Value ($m)	-0.11	0.71	1.54
Benefit-cost ratio	0.88	1.77	2.65

Confidence Rating

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 11). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 11: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
High	Low-Medium

Coverage of benefits was assessed as High. The most important impact was the increased yield likely to be captured by improved control of CGW. The impacts relating to improved fruit quality and increased regional community spill-overs were not valued. Also, not valued was any increased value of the investment to other citrus types including grapefruit, lemons and limes, and oranges in non-southern Australian states. Consequently, the investment criteria as provided by the valued benefits are likely to be underestimated.

Confidence in assumptions for valuation was rated as Low-Medium as many of the assumptions made were not supported by surveys or other forms of evidence and had to be made according to the limited evidence and estimates provided by the project and the analyst's experience (e.g. risk parameters).

Conclusion

The investment in CT15006 is likely to contribute to improved management of the CGW, resulting in quality and yield increases.

Total funding from all sources for the project was $0.93 million (present value terms). The investment produced estimated total expected benefits of $2.47 million (present value terms). This gave a net present value of $1.54 million, an estimated benefit-cost ratio of 2.65 to 1, an internal rate of return of 12.6% and a modified internal rate of return of 8.6%.

As several of the identified impacts were not valued (the fruit quality improvement, the regional spill-over impact and the impact on other citrus types external to southern oranges), the investment criteria estimated by the evaluation may have somewhat underestimated the total value of the investment.

Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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Abbreviations

CGW	Citrus gall wasp
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
GDP	Gross Domestic Product
$m	million $
MIRR	Modified Internal Rate of Return
NSW DPI	New South Wales Department of Primary Industries
OCS	Office of Chief Scientist, Canberra
R&D	Research and development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan
WA	Western Australia