Industry-specific impact assessment program: Citrus

Impact assessment report for project *Increasing market access, profitability and sustainability through integrated approaches to fungal disease control* (CT13020)

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What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in *CT13020: Increasing market access, profitability and sustainability through integrated approaches to fungal disease control.* The project was funded by Hort Innovation over the period October 2013 to December 2016.

Methodology

The investment was analysed qualitatively within a logical framework that included activities and outputs, outcomes and impacts. Impacts were categorised into a triple bottom line framework. Principal impacts identified were then considered for valuation. 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.

Results/key findings

The project investment focused on fungal disease control in the citrus industry with aim of reducing the financial impact on growers and reducing barriers to export market access to some countries. The project also provided support to another project by producing EBS resistance hybrids ; a key finding was that was under relatively simple genetic control that can be exploited through hybridisation and screening for resistance.

A major component of the project addressed improved protocols for export entry to the US market for mandarins associated with citrus black spot (CBS). However, progress here was thwarted by a change in the US with regard to CBS (it was found it was already present in the US). Hence, the investment in Project CT13020 cannot claim any impact on USA market access for QLD mandarins, as the change in the USA position with regard to CBS was unforeseen.

However, the project was successful in producing two other impacts. The two most important impacts produced by the project investment were:

- a reduction in economic losses due to Emperor Brown Spot (EBS) associated with the registration and use of a new fungicide, and
- the new EBS resistant planting material to which the project investment made some contribution.

Investment Criteria

Total funding from all sources for the project was $0.56 million (present value terms). The investment produced estimated total expected benefits of $1.42 million (present value terms). This gave a net present value of $0.86 million, an estimated benefit-cost ratio of 2.53 to 1, an internal rate of return of 16.0% and a modified internal rate of return of 8.7%.

Conclusions

Project CT13020 was a successful investment that has positively impacted on the Queensland mandarin industry. The investment has already contributed to improved management of Emperor brown spot via the availability of a new fungicide. In addition, the project has made a contribution to the potential future use of new planting material that is resistant to Emperor brown spot.

Keywords

Impact assessment, cost-benefit analysis, CT13020, citrus, mandarin, fungal, Emperor brown spot, citrus black spot

Introduction

All research and development (R&D) and marketing levy investments undertaken by Horticulture Innovation Australia Limited (Hort Innovation) are guided and aligned to specific investment outcomes, defined through a Strategic Investment Plan (SIP). The SIP guides investment of the levy to achieve each industry's vision. The current industry SIPs apply for the financial years 2016/17 – 2020/21.

In accordance with the Organisational Evaluation Framework, Hort innovation has the obligation to evaluate the performance of its investment undertaken on behalf of industry.

This impact assessment program addresses this requirement through conducting a series of 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 CT13020: *Increasing market access, profitability and sustainability through integrated approaches to fungal disease control* was randomly selected as one 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 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 uses 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

Citrus Industry

The most recent production and value of the Australian citrus industry is provided in Table 1. Sources of exports by state are provided in Table 2.

Table 1: Australian Citrus Production and Value for Years ending June 2017 to 2019

Year ended June	Total Production (tonnes)	Fresh Supply (tonnes)	Fresh Supply Wholesale Value ($m)	Fresh Supply Wholesale Value ($/tonne)
2017	714,740	309,822	572.2	1,847
2018	747,032	294,956	534.7	1,813
2019	744,354	294,568	539.0	1,830
Average	735,375	300,115	548.6	1,830

Source: Australian Horticultural Statistics Handbook 2018/19

Table 2: Australian Fresh Mandarin Exports by State Years ending June 2017 to 2019

State	Year ended June		
	2017	2018	2019
Queensland	30,525	44,374	36,820
South Australia	10,695	15,210	16,956
Victoria	7,324	3,472	4,377
New South Wales	418	839	1,185
Western Australia	30	42	132
Other	2,048	23	1
Total	51,041	63,960	59,471

Source: Australian Horticultural Statistics Handbook 2018/19

Project Rationale

When the project commenced in 2014 the Australian citrus industry was losing profitability via two major fungal diseases, citrus black spot (CBS) and Emperor brown spot (EBS). A major loss of potential profitability was due to restricted export market access to the United States and the fungal diseases were also a trade barrier for exports to New Zealand and European markets. Apart from the potential export market loss, these fungal diseases and their control added significant costs to growers. Even after incurring the costs of fungicide control, there were additional losses still incurred via fungal damage, for example, via fruit downgrading.

The distribution of CBS and EBS is limited to Queensland and the Northern Territory and coastal New South Wales and is predominantly focused on mandarins that were grown in Queensland (54% of all mandarins). Murcott mandarins grown in Queensland were particularly susceptible.

When the project commenced in 2014, the potential export market loss due to CBS for Murcott mandarins grown in Queensland was estimated at $67.5 m per annum, as the majority were then sold on the domestic market at a lower price than could be achieved from exporting. Effective market access protocols require demonstration that the fruit being exported meet quarantine specifications.

It was estimated also that $7m per annum was incurred on fungicides for the management of CBS ($4.8m) and EBS ($1.9m). In addition, it was estimated that the remaining losses via fruit downgrading was $8.5m per annum for CBS and $3.5m per annum for EBS. Further, an existing screening project (CT017012) on resistance to EBS, would save growers $5m annually; project CT13020 also contributed to this potential impact by improving the screening process.

The project set out to redeem or decrease some of these losses by:

(a) addressing the CBS market access issue to better meet quarantine specifications via field control methods, as well as developing an improved postharvest fungicide treatment process.
(b) ensuring that new improved mandarin varieties are resistant to EBS via screening and improving the screening process, so reducing the need for fungicide use.
(c) seeking additional fungicide options to improve fruit protection and minimise resistance development through alternating different resistance development groups.

Project Details

Summary

Project Code: CT13020

Title: *Increasing market access, profitability and sustainability through integrated approaches to fungal disease control.*

Research Organisation: Research and Development for Primary Industries, Queensland

Principal Investigator: Andrew Miles

Period of Funding: July 2013 to December 2016

Objectives

The project investment focused generally on fungal disease control in the citrus industry with the aim of reducing the financial impact of control costs on growers and reducing barriers to export market access to some countries.

Specific objectives were:

(1) To improve quarantine protocols for export of mandarins
(2) To ensure new improved mandarin varieties are resistant to EBS via screening and improving the screening process.
(3) To seek additional fungicide options to improve fruit protection and minimise resistance development through alternating different resistance development groups.

Logical Framework

Table 3 provides a description of Project CT13020 in a logical framework.

Table 3: Logical Framework for Project CT13020

Activities	• Field screening was undertaken for 11 alternative fungicides for efficacy against CBS and EBS over four seasons • The duration of fungicide efficacy in the field was evaluated by producing 'efficacy decline curves' for commercially used fungicides and promising new fungicides. • Preliminary evaluations were undertaken of fungicide residue profiles and post-harvest residue removal treatments. • The residue profiles of any new fungicides, and the potential for post-harvest residue removal, needed to be determined in order the maximise the likelihood of registration of new fungicides • The project also provided support to another project by producing additional EBS resistance hybrids. • Laboratory screening was undertaken to test the sensitivity of CBS to commercial post-harvest fungicides. The researchers note that a major step forward for overcoming trade barriers due to CBS would be the development of a post-harvest fungicide, but current commercial treatments did not offer reliable control.
Outputs	• Four promising fungicides were identified with registration potential for EBS (fluxapyroxad, boscalid, captan and dithianon); these were considered up to twice as effective as standard mancozeb.

	• There was one promising fungicide identified for both CBS and EBS (multisite fungicide dithianon). • Subsequently, efficacy and residue data were provided to support the application for a new minor use permit for Captan, for the control of EBS in mandarins. A permit was issued by the Australian Pesticides and Veterinary Medicines Authority in October 2016. The rate and use pattern of the permit were determined by the project, with the use pattern focused on a major gap that occurs in the existing fungicide use patterns during autumn/winter, when EBS is typically most damaging. • The fungicide efficacy decline curves showed rapid decline can occur within as little as 11 days after application but can persist for up to 30 or so days; this was surprising as it had been accepted hitherto that four-to-six-week spray intervals may be sufficient. A recommendation was made that for a change in fungicide application practices towards targeting forecast infection events, as opposed to calendar-based applications. • Residue data supported favourable residue levels in fruit treated with promising new fungicides and indicated up to five-fold reductions in fruit residues from standard packing line procedures. • The support to the industry's breeding program produced an additional 12,750 resistant mandarin hybrids during the project's life. The researchers noted that resistance to EBS is under simple genetic control and is readily achievable through hybridisation breeding followed by screening of hybrids for resistance. • The laboratory screening of the sensitivity CBS to commercially available fungicides supported the proposition that the poor post-harvest fungicide efficacy against CBS is actually due to poor fungus/fungicide contact, leading to a recommendation that further investigation was required.
Outcomes/ Potential Outcomes	<u>Market access for QLD mandarins to USA, Europe and New Zealand</u> • The market access request for Queensland mandarins to the United States has been in the system for nearly 20 years. At the time the market access request was first submitted, CBS was a critical quarantine pest for the USA. • This situation has now changed. Citrus black spot is now known to occur in parts of the USA and while still considered to be a quarantine pest (as it is under official control in the USA), the United States regulators have changed their position on the disease. In 2014, the USA released a risk assessment that determined that commercial fresh fruit is not an epidemiologically significant pathway for the entry, establishment and spread of CBS. Any progress that was made here in Australia therefore became somewhat redundant. (David Daniels, Citrus Australia, pers. comm., 2020). • A USDA risk assessment that included Queensland mandarins in 2015 concluded that here were only 3 quarantine pests (all fruit flies) that required risk mitigation measures. Cold disinfestation was proposed by Australia as a risk mitigation measure and the USDA published the proposed treatments in the USDA Treatment manual in 2017 (David Daniels, pers. comm., 2020). • The administrative final stages in the process are purely administrative but there have been extensive delays in progressing through to formal rule-making. To the knowledge of Citrus Australia, the USDA has drafted a proposed rule and the publication of that rule on the Federal Register was supposed to take place in July 2020. • The USDA has advised that the final rule to allow trade should be published in time for the 2021 season (David Daniels, pers. comm., 2020). • Hence, the investment in Project CT13020 cannot claim any impact on USA market access for QLD mandarins, as the change in the USA position with regard to CBS was unforeseen. • Qld mandarins now have access to Europe and New Zealand, given the improved quarantine protocols; while the market access conditions are challenging (in relation to CBS) they are not insurmountable (David Daniels, pers. comm., 2020). However, very little trade takes place to these countries due to relative market prices compared to high-returning Asian markets (e.g. China and Thailand). Transport cost to Europe are high and the European market is supplied largely by South Africa. At least one Qld business is

	exporting to New Zealand but it is not a high-returning market like some of the markets in Asia. <u>Adoption of a new approved fungicide (Captan) by mandarin growers for control of EBS.</u> • Captan is now being used by mandarin growers in Queensland for the control of EBS. The fungicide has proved highly effective and seems to give a longer period of control so is useful early in the season against lingering infection levels. The availability of Captan is critical under conditions of a warm wet spring and a cool wet summer (Malcolm Smith, pers. comm., 2020). Relying solely on dithiocarbamates for control was a precarious situation faced by growers. • Hence, the registration of Captan is a huge step forward as it is cost-effective and the chemical was unlikely to proceed to registration from a chemical company without the project investment by Hort Innovation. <u>Contribution to production of hybrid material with EBS resistance.</u> • The first block of ABS-screened hybrids was only planted in 2011, and citrus seedlings commonly take 5-10 years before first fruiting. It then takes many seasons of fruiting to know if selections have all the required traits (Malcolm Smith, pers. comm., 2020). • Hence, it would likely to be some years before resistant material enters commercial production. • As the world citrus market is highly developed and Australia competes at the top end of this market, the citrus Australia produces needs to be high quality as well as disease resistant. The current commercial releases from the breeding program are all susceptible to ABS, and this is a legacy of failing to address the disease issues early enough (Malcolm Smith, pers. comm., 2020).
Impacts	• No change in U.S. export status for Queensland mandarins due to Project CT13020; however, exporting to U.S., Europe and New Zealand is now possible but exports are minimal due to higher returns from other export markets. • A more effective fungicide against EBS in current use by Queensland mandarin growers, resulting in reduced quantity of fruit damage. • Potentially, reduced costs of total fungicide applications by Queensland growers due to the cost effectiveness of Captan and reduced use of dithiocarbamates. • Reduced usage of potentially human health affecting dithiocarbamates via potential endocrine disruption). • Contribution to production and future use of hybrid planting material with EBS resistance.

Project Investment

Nominal Investment

Table 4 shows the annual investment (cash and in-kind) in project CT13020 by Hort Innovation. There were no 'other' investors in this project.

Table 4: Annual Investment in the Project CT13020 (nominal $)

Year ended 30 June	Hort Innovation ($)	Other ($)	Total ($)
2014	99,000	0	99,000
2015	134,462	0	134,462
2016	46,409	0	46,409
2017	69,124	0	69,124
Totals	348,995	0	348,995

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 (x1.162). This multiplier was estimated based on the share of 'payments to suppliers and employees' in total Hort 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.

Real Investment and Extension Costs

For the purposes of the investment analysis, investment costs of all parties were expressed in 2019/20 dollar terms using the GDP deflator index. There were no additional costs assumed associated with project extension. Results were communicated to growers and others as part of the project.

Impacts

Table 5 provides a summary of the principal types of impacts delivered by the project. Impacts have been categorised into economic, environmental and social impacts.

Table 5: Triple Bottom Line Categories of Principal Impacts from Project CT13020

Economic	• Some progress towards developing exports of Murcott mandarins from Queensland to Europe and New Zealand, via improved quarantine protocols. • Potentially, more effective fungicide and its application against EBS now available and used by Queensland mandarin growers, resulting in reduced quantity of discarded fruit. • Potentially, reduced costs of fungicide applications by Queensland growers. • Contribution to production and future use of hybrid planting material with EBS resistance.
Environmental	• Reduced use of potentially human-health affecting fungicide chemicals.
Social	• Regional community spill-over impacts driven by increased profits by mandarin growers in Queensland.

Public versus Private Impacts

Predominantly private impacts were identified in this evaluation. Private benefits are being realised by Queensland mandarin growers, as well as packers, wholesalers, and others in the citrus supply chain. Public impacts will be restricted to some future potential positive environmental and human health impacts from some changes in fungicide application practices by growers, as well as some community spill-over impacts derived from increased profitability of mandarin growing in Queensland.

Distribution of Private Impacts

The positive impacts on the citrus industry from investment in this project are likely to be shared along the supply chain among growers, packers, wholesalers, retailers and consumers.

Impacts on Other Australian Industries

Impacts on industries other than the citrus industry are not anticipated from the CT13020 investment.

Impacts Overseas

No significant overseas impacts of CT13020 were identified.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 6.

The project findings and related impacts will contribute to Rural RD&E priorities 1 and 2 and to Science and Research Priority 1, and potentially 8.

Table 6: 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, 2015)

Alignment with the Citrus Strategic Investment Plan 2017-2021

The current strategic outcomes and strategies of the citrus industry are outlined the Citrus Strategic Investment Plan 2017-2021[1] (2017). Project CT13020 is directly relevant to a number of the desired outcomes in the SIP. First the project directly addresses Outcome 1: "Market opportunities in both domestic and especially export markets have been developed and maintained, leading to increased demand and support for citrus prices". This outcome is directly addressed through the strategy 1.1: Identify and develop new and existing export market opportunities especially for market access.

In addition, the project addresses Outcome 2 via strategy 2.2 to safeguard the Australian citrus industry from injudicious use of agrichemicals throughout the value chain. Also, the project addressed outcome 3 (fruit quality and productivity, through strategies 3.1 (productivity and efficiency) and 3.2 (product quality).

Valuation of Impacts

Impacts Valued

This investment in CT13020 produced several impacts as listed in Table 3. However, it was possible to value only two of these impacts:

- The availability of a new cost-effective fungicide and its use against EBS by Queensland mandarin growers, resulting in a lower cost of EBS damage to growers.
- The contribution to production and future use of hybrid planting material with EBS resistance, again resulting in a lower cost of EBS damage to mandarin growers.

Impacts Not Valued

This project contributed to four other impacts/potential impacts as reported in Table 3. The progress made in developing exports of Murcott mandarins from Queensland to Europe and New Zealand via improved quarantine protocols was not valued as little exports of mandarins to these markets takes place due to higher returns from other export markets.

Any reduction in costs of total fungicide applications by Queensland growers was not valued as such would require the changes in use of individual fungicides to be defined, as well as their relevant costs before and after the project.

The positive impacts on the environment and human health from the use of an alternative to the

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

dithiocarbamate fungicide was not valued due to the difficulties in making a range of associated assumptions.

The regional community spill-over impacts driven by increased profits by mandarin growers in Queensland was not valued largely due to a lack of data to support credible assumptions.

Summary of Assumptions

The specific assumptions for the valuation of the two impacts that were valued are provided in Table 7.

Table 7: Summary of Assumptions for Impacts Valued

Variable	Assumption	Source/Comment
Impact 1: Reduction in EBS damage from the new fungicide		
Annual value of damage from EBS incurred by QLD mandarin growers	$3.5m per annum	Project proposal
Reduction in annual value of damage due to the more effective fungicide Captan	10%	Analyst assumption; no project data were available as it was too soon after project completion. Malcolm Smith indicated Captan was being used but had no information on the extent of adoption and the damage avoided; hence a conservative assumption on the reduced industry damage was used.
Annual cost reduction due to project	$350,000 per annum	$3.5 x 10%
First year of impact (year ended June)	2019	Analyst assumptions
Year of maximum impact (year ended June)	2023	
Year of final impact (year ended June)	2028	
Attribution and risk factors		
Probability of outcome (above adoption)	75%	Analyst assumptions
Probability of impact (reduced damage)	75%	
Attribution	100%	
Impact 2: Potential savings from new planting material		
Annual value of savings from EBS from increased resistance in planting material	$5m per annum	Existing screening project (CT17012) on resistance to EBS.
Effectiveness of resistance in new plantings	50%	Analyst assumption
Proportion of savings recovered by industry introducing new planting material (new area plantings and replacement area plantings)	2.5% per annum (assumes these growers would have planted new areas or replanted old areas anyway)	Analyst assumption; the adoption rate is equal to the 2.5 % per annum of growers assumed to be planting new areas or re-planting old areas
First year of some impact (year ended June)	2029	Analyst assumption, based on outcomes described earlier

Year of final impact (year ended June)	2035	
Attribution and risk factors		
Probability of outcome (above adoption)	75%	Analyst estimates
Probability of impact (reduced damage)	75%	
Attribution to CT13020	25%	Based on only a minor contribution from Project CT13020

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 (2016/17) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

Table 8 and Table 9 show the investment criteria estimated for different periods of benefits for the total investment and the Hort Innovation investment alone. As all investment was from Hort Innovation, results in both tables are the same.

Table 8: Investment Criteria for Total Investment in Project CT13020

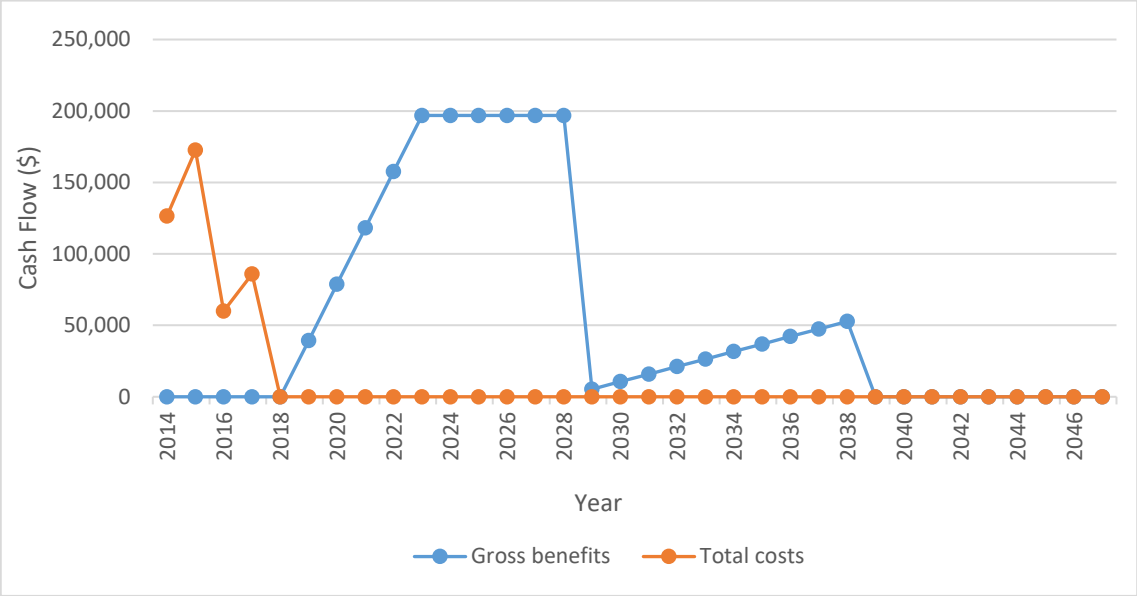
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.38	1.15	1.31	1.40	1.42	1.42
Present Value of Costs ($m)	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Net Present Value ($m)	-0.56	-0.19	0.59	0.75	0.84	0.86	0.86
Benefit-Cost Ratio	0.00	0.67	2.04	2.34	2.49	2.53	2.53
Internal Rate of Return (%)	negative	negative	14.51	15.70	15.99	16.04	16.04
MIRR (%)	negative	negative	16.29	12.70	10.79	9.53	8.68

Table 9: Investment Criteria for Hort Innovation Investment in Project CT13020

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.38	1.15	1.31	1.40	1.42	1.42
Present Value of Costs ($m)	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Net Present Value ($m)	-0.56	-0.19	0.59	0.75	0.84	0.86	0.86
Benefit-Cost Ratio	0.00	0.67	2.04	2.34	2.49	2.53	2.53
Internal Rate of Return (%)	negative	negative	14.51	15.70	15.99	16.04	16.04
MIRR (%)	negative	negative	16.29	12.70	10.79	9.53	8.68

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the CT13020 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



Source of Benefits

Table 10 shows the contribution of each impact to the total Present Value of Benefits (PVB). Table 10 shows that the major source of the discounted benefits was the contribution to the registration of the new fungicide. The contribution to the resistant planting material was small due to the minor contribution of CT13020 and the long period of time before time the improved planting material will be available for planting.

Table 10: Contribution of Benefits by Source

Impact	PVB ($M)	% of Total PBV
Impact 1: New fungicide development and use	1.28	90.1
Impact 2: Contribution to EBS-resistant planting material	0.14	9.9
Total	1.42	100.0

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 11 presents the results that show a moderate sensitivity to the discount rate.

Table 11: Sensitivity to Discount Rate
(Total investment, 30 years)

Investment Criteria	Discount rate		
	0%	5%	10%
Present Value of Benefits ($m)	1.87	1.42	1.14
Present Value of Costs ($m)	0.44	0.56	0.70
Net Present Value ($m)	1.42	0.86	0.44
Benefit-cost ratio	4.19	2.53	1.62

A sensitivity analysis was then undertaken for the reduction in disease damage that could be ascribed to the project investment. Results are provided in Table 12. The damage loss reduction that is required in order for the investment to break even is 3.3%.

Table 12: Sensitivity to Assumption on Reduction in Damage Loss
(Total investment, 30 years)

Investment Criteria	Yield Loss Reduction Assumed		
	5%	10% (base	20%
Present Value of Benefits ($m)	0.78	1.42	2.70
Present Value of Costs ($m)	0.56	0.56	0.56
Net Present Value ($m)	0.22	0.86	2.14
Benefit-cost ratio	1.39	2.53	4.81

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 13). 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 13: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
High	Medium

Coverage of benefits was assessed as High. The two most important impacts valued in monetary terms were the loss in damage due to the registration and use of the new fungicide and the new EBS resistant planting material to which the project investment made a minor contribution. The impacts relating to the increased opportunity to export mandarins to Europe and New Zealand was not valued as these markets would be low-return markets. Any reduction in costs of total fungicide applications, the positive potential impacts on human health, and the regional community spill-over impacts were not valued in monetary terms for reasons explained earlier in the assessment.

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 Medium-Low as many of the assumptions had to be made concerning future developments and were not supported by surveys or extensive consultation with growers and industry advisers.

Conclusion

The investment in CT13020 is likely to contribute to improved management of EBS via a new fungicide and a contribution to new future planting material.

Total funding from all sources for the project was $0.56 million (present value terms). The investment produced estimated total expected benefits of $1.42 million (present value terms). This gave a net present value of $0.86 million, an estimated benefit-cost ratio of 2.53 to 1, an internal rate of return of 16.0% and a modified internal rate of return of 8.7%.

As several of the identified impacts were not valued, 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

CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
GDP	Gross Domestic Product
OCS	Office of Chief Scientist Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan