Impact assessment of the investment:

Citrus Agrichemical and Export MRL Program (CT18001)

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Hort Innovation

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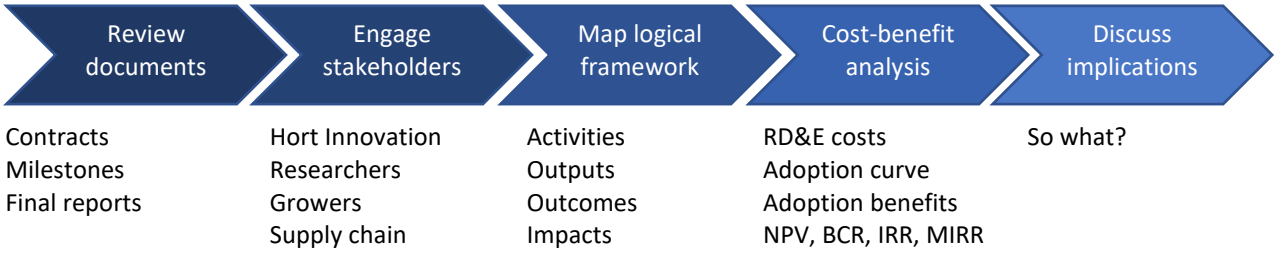
What the report is about

Ag Econ conducted independent analysis to determine the economic, social, and environmental impact resulting from delivery of the project CT18001 – *Citrus agrichemical and export MRL program*. The project was funded by Hort Innovation over the period Jan 2018 to Jan 2022 using the fresh vegetable research and development levy and contributions from the Australian Government.

The analysis applied a five step analytical process to understand the impact pathway and collect supporting data.



Research background

The Australian citrus industry prides itself on being recognised in export and domestic markets as producing fruit that meets the most stringent quality specifications. To achieve those specifications, the citrus industry requires access to modern and effective agrichemicals to control pests and diseases and optimise post-harvest quality. At the same time, it is of paramount importance that residues on fruit do not exceed regulatory limits in Australia and overseas.

Project CT18001 sought to directly assist Australian citrus growers with a coordinated approach to agrichemical risk management. Through CT18001 Citrus Australia managed the residue testing program, provided dedicated resources for the citrus industry to monitor, interpret, communicate and adhere to export market maximum residue limits (MRLs), and supported new product registrations and minor use permits.

Findings

The nominal investment cost of $0.52 million was adjusted for inflation (ABS, 2023) and discounted (using a 5% real discount rate) to a 2022-23 present value (PV) of costs equal to $0.69 million.

The analysis conducted a detailed evaluation of the CT17008 impact pathway through a logical framework, and a review of the available data to quantify the impact pathway. From this process the impacts were estimated for three key areas:

- A reduction in export market risk by assisting growers to identify potential MRL breaches before shipments were exported, thereby avoiding long term export market consequences such as additional in-market testing or loss of market access. The benefit of this impact across 16 priority export markets was calculated at $1.2 million (2022-23 PV) for the three years of residue testing covered by the project (2018-19 to 2020-21).
- A reduction in export risk to Thailand, specifically relating to the detection of omethoate residue in 2019. Through the project, Citrus Australia was able to engage with stakeholders in a timely manner to minimize the consequences for citrus exporters, including adjusting the content and format of residue screening and reporting in Australia to accommodate the requirements of the Thai authorities. The benefit of this impact was calculated at $0.44 million for 2019-20 and 2020-21 (2022-23 equivalent value).
- A reduction in residue sampling prices paid by packers/exporters through the negotiation of bulk pricing with the testing laboratory. This benefit was estimated to have benefited the participating packers/exporters by $0.30 million (2022-23 equivalent value) over the three years of testing covered by the project (2018-19 to 2020-21). Additional benefits relating to improved access to pest management chemicals, and increased community wellbeing from a more economically sustainable citrus industry were not able to be valued due to a lack of data.

In total, the project was estimated to have generated benefits of $1.95 million (2022-23 PV), compared to RD&E costs of $0.69 million (2022-23 PV), generating a net present value (NPV) of $1.26 million and a benefit cost ratio (BCR) of 2.84:1.

Sensitivity analysis tested the results for uncertainty around the underlying variables. Over 1000 simulations, the results ranged from a BCR of 0.72:1 (benefits lower than costs) to 10.86:1 (benefits higher than costs), with 99% of simulations showing a positive impact (BCR of greater than 1:1).

This sensitivity testing gave a high level of confidence in a positive impact being generated from investment in CT18001; however, it is also important to consider that there were additional socio-economic impacts that were unable to be quantified relating to improved industry access to crop protection products, and increased community wellbeing from a more economically sustainable citrus industry. As such, the results represent a conservative estimate of impact.

Overall, the funding of the citrus agrichemical and export MRL program through CT18001 was found to have delivered a positive impact for the citrus industry by reducing the risk associated with chemical residues.

The key findings of the CT18001 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, citrus, agrichemical, maximum residue limit, MRL

Figure 1. Summary of impact assessment findings

CT18001 Agrichemical and export MRL program

Total RD&E costs:

- $0.52 million (nominal values)
- 100% R&D levy and Government matching funds

Project activities:

- Export readiness and development was provided through a wide range of work primarily focused on growers, packers, and exporters.
- Appointment of Agrichemical Manager for Citrus Australia.
- Provided a contact point for enquiries from growers, packers, chemical companies, auditors, resellers, and government.
- Managed the industry residue monitoring program 2018-19 to 2020-21.
- Negotiated bulk residue test pricing for participating packers/exporters.
- Provided technical and commercial advice to government in response to agrichemical issues impacting the citrus industry.
- Engaged with agrichemical companies and resellers, pest scouts and agronomists regarding industry's pest management and residue issues.

Project outcomes:

- Growers, packers and exporters have increased awareness and knowledge of MRL requirements for citrus export markets and practices to meet those requirements, reducing the risk of MRL breaches while maximizing pest management options.
- In event of MRL breaches Citrus Australia was able to engage directly and immediately with international authorities, agents, service providers, pack-houses and growers, reducing industry impact.
- Negotiated bulk residue test pricing for participating packers/exporters.
- Engaged with chemical companies and regulatory authorities to bring the needs of the citrus industry to the attention of companies registering new chemistry and, where appropriate, to defend the continued use of chemistry under review.

Economic impacts:

- Reduce export risk (consequences of MRL breach) by encouraging maximum engagement in residue testing, and providing participant feedback regarding testing results. Including in response to the detection of omethoate residue in exports to Thailand in 2019.
- Reduced residue testing costs for exporters through bulk pricing.

Socio-economic impacts:

- Increased community wellbeing and resilience from a more sustainable citrus industry.

Total attributable benefits and impact:

- Present value (PV) costs of $0.69 million (5% discount rate).
- PV benefits of $1.95 million over 30 years.
- Net present value of $1.26 million.
- Benefit cost ratio (BCR) of 2.84:1, with a 90% confidence of a BCR between 1.28:1 and 5.23:1

Introduction

Evaluating the impacts of levy investments is important to demonstrate the economic, social and environmental benefits realised through investment to levy payers, Government and other industry stakeholders. Understanding impact is also an important step to inform the ongoing investment agenda.

Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. Commencing with MT18011 in 2017-18, the impact assessment program consisted of an annual impact assessment of 15 randomly selected Hort Innovation RD&E investments (projects) each year. In line with this ongoing program, Ag Econ was commissioned to deliver the *Horticulture Impact Assessment Program 2020-21 to 2022-23* (MT21015).

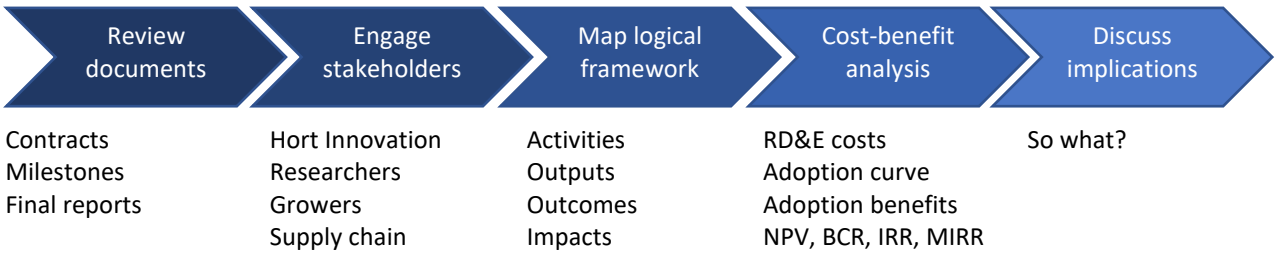
Project CT18001 – Citrus agrichemical and export MRL program was randomly selected as one of the 15 investments in the 2021-22 sample. This report presents the analysis and findings of the project impact assessment.

The report structure starts with the general method of analysis used, followed by the RD&E background and an outline of the impact pathway in a logical framework, then describes the approach used to quantify the identified costs and benefits including any data gaps and limitations to the analysis, presents the results including from the sensitivity analysis, and finally discusses any implications for stakeholders.

General method

The impact assessment built on the impact assessment guidelines of the Council of Rural Research and Development Corporations (CRRDC, 2018) and included both qualitative and quantitative analysis. The general method that informed the impact assessment approach is as follows:

1. Review project documentation including project plan, milestone reports, outputs and final report
2. Discuss the project delivery, adoption and benefits with the Hort Innovation project manager, project researcher/consultant, growers and other relevant stakeholders (see *Stakeholder consultation*)
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, and outcomes to identify the principal economic, environmental, and social impacts realised through the project
4. Collect available data to quantify the impact pathway and estimate the attributable impacts using cost-benefit analysis (over a maximum 30 years with a 5% discount rate), and then sensitivity test the results to changes in key parameters.
5. Discuss the implications for stakeholders.



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program.

A more detailed discussion of the method can be found in the *MT21015 2021-22 Summary Report* also on Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015).

Project background

The farmgate value of the Australian citrus industry —including oranges, mandarins, lemons and grapefruit— has increased from $0.8 billion in 2016-17 to $0.9 billion in 2021-22 (Hort Innovation 2023), making it the second highest value fruit industry behind berries. In 2022, the citrus industry had approximately 1500 growers across key growing regions in the Riverland (South Australia (SA)), Murray Valley (Victoria (Vic) and New South Wales (NSW)), Riverina (NSW), and the Central

Burnett (Queensland (QLD)) (Hort Innovation 2022).

The Australian citrus industry exports a high proportion of production relative to other Australian horticulture, rising from 30% in 2016-17 to 34% in 2021-22 (Hort Innovation 2023). The Australian citrus industry prides itself on being recognised in export and domestic markets as producing fruit that meets the most stringent quality specifications — optimum fruit size, blemish free, optimum sugar to acid ratios, compliant with all phytosanitary specifications, and free from any unacceptable chemical residues.

To achieve those specifications, the citrus industry requires access to modern and effective agrichemicals to control pests and diseases and optimise post-harvest quality. At the same time, it is of paramount importance that residues on fruit do not exceed regulatory limits in Australia and overseas.

Withholding periods stated on Australian chemical labels are to ensure that from time of application, residues decay to meet Australian maximum residue limits (MRLs). For some of the products registered for use on Australian citrus, key importing countries have a lower MRL than Australia or have no MRL established. The withholding period indicated on the label may be insufficient for residues to decay to meet export MRLs that are lower than the Australian MRL.

A failure to meet market MRL requirements can lead to additional testing requirements and potentially a loss of market access. As such, understanding market MRLs and managing production appropriately is a well established risk mitigation process for citrus exporters and the industry at large.

The citrus industry had undertaken levy investments since 2011 to support the Australian Government's National Residue Survey (NRS) and ensure a coordinated residue testing program. Levy funding pays for the administration of the program and freight costs for samples, with exporters paying commercial rates to have samples analysed at Symbio Alliance laboratories in Brisbane.

Project CT18001 was designed to continue the citrus agrichemical and MRL program, but to allow Citrus Australia to directly manage the annual citrus residue survey (without the NRS) so that data could be more accessible, allowing Citrus Australia to engage immediately with international authorities, agents, service providers, packing-houses and growers, in event of MRL breaches. Equally, Citrus Australia would be able to liaise directly with the contracted laboratory regarding testing and reporting. The project aligned to 2017-2021 Strategic Investment Plan (SIP) Outcome 2: Plant protection – Growers and the industry reduce biosecurity, phytosanitary and agrichemical related risks (Hort Innovation 2017).

Project details

Citrus Australia was selected as the lead delivery partner, with the project running from 2018 to 2022 (Table 1)

Table 1. Project details

Project code	CT18001
Title	Citrus agrichemical and export MRL program
Research organization(s)	Citrus Australia
Project leader	Nathan Hancock
Funding period	Jan 2018 to Jan 2022
Objective	Develop a coordinated approach to agrichemical risk management for the Australian citrus industry

Logical framework

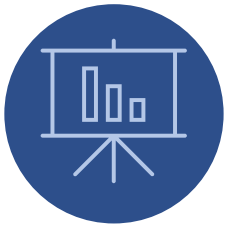
The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework (Table 2).

Table 2. Project logical framework detail

RD&E activities

- Appointment of Agrichemical Manager for Citrus Australia
  - Provided a contact point for enquiries from growers, packers, chemical companies, auditors, resellers, and government. Managing enquiries, the Agrichemical Manager responded to an average 1.6 new enquiries per day.
  - Manage the national residue monitoring program.
  - Provided technical and commercial advice to government in response to issues that impact the citrus industry
- Annual citrus residue monitoring program
  - Facilitate residue testing for 18 major packing companies from QLD, NSW, Vic., SA and WA, with a total 1760 samples from 2019-2021.
  - Liaise directly with Symbio Alliance laboratories regarding testing and results, including negotiating bulk prices to halve the cost of testing to approximately $200/sample (Citrus Australia pers comm).
  - Maintain a database of Citrus Export MRLs for:
    - Australia and New Zealand
    - The International Food Standards *Codex*
    - The EU, Canada, China, Hong Kong, India, Indonesia, Japan, South Korea, Malaysia, Oman, Philippines, Singapore, Taiwan, Thailand, and the United States of America (USA).
- Support new product registrations and minor use permits
  - Assisted the regulatory approval process for a number of products including facilitating trials towards an application for the use of bifenthrin (Talstar®) as a control option for citrus gall wasp in lemons.
  - Supported two agrichemical retailers to apply for research permits.
  - Liaise with projects ST16006, ST17000, and MT20007 regarding new pest and disease management products.
- Engage with growers and agronomists to update on project and related work, including collaboration with Citrus Australia's communications team (CT18000).

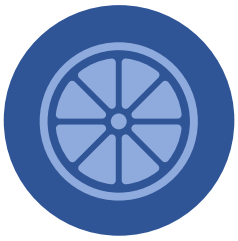
RD&E outputs



Through the above activities, the following outputs were delivered:

- Testing results and feedback for 18 major packing companies from QLD, NSW, Vic., SA and WA, with a total 1760 samples from 2019-2021.
- An MRL Guide for industry including a table of citrus export MRLs, updated at least biannually. In total, there were 16 official updates during the three-year life of project.
- Agrichemical Updates. Nine alerts regarding changes to MRLs or registration were sent via email to approximately 800 subscribers.
- Three short videos on fruit fly baiting in citrus were distributed via social media and reached a wide audience, with more than 8000 viewings.
- Resources to improve the efficiency of orchard chemical application made available on Citrus Australia's website.
- The Agrichemical Manager participated in Citrus Australia's regional committees and issues committees.
- Delivered presentations at workshops and regional and national forums
- Provided content for Australian Citrus News (quarterly tabloid), Citrus eNews (fortnightly newsletter), the Juice (periodic industry snapshot) and videos in social media in collaboration with project CT18000.
- 10 field days in Vic., SA and QLD, providing practical information about spray application and baiting to manage QLD fruit fly.
- Six orchard visits with spray application demonstrations in Sunraysia and Western Australia.

Outcomes



From the above activities and outputs, the following outcomes were achieved:

- Annual citrus residue monitoring program
- Analysis of residue data in project CT18001 enabled Citrus Australia to monitor the industry's progress towards being an ultra-low residue crop. Based on residue testing data from 2019 – 2021, 385 of the 715 samples (54%) with residues at or below the limit of reporting and which could be considered a 'ultra-low'. Of the remaining samples, an average 30% were above at least one market's MRL allowing grower/exporter management to minimize risk.
- Growers, packers and exporters had increased awareness and knowledge of MRL requirements for citrus export markets and practices to meet those requirements, reducing the risk of MRL breaches while maximizing pest management options, including through:
  - Growers calibrating in-field spray programs to avoid MRL breaches.
  - Packers optimising fungicide application by ensuring that residues are both within the efficacious range and below the consigned market MRL.
  - Test result feedback that fruit meets the consigned market MRLs.
- By engaging directly with all stakeholders, MRL data was more readily accessible, allowing Citrus Australia to engage immediately with international authorities, agents, service providers, packing-houses and growers, in event of MRL breaches. For example
  - In 2019 omethoate was detected in Australian citrus exports in Thailand. Using residue survey data and technical expertise from CT18001, Citrus Australia was able to provide Thailand with a timely and satisfactory explanation and exports suffered minimal interruption.
  - In response to MRL changes in 2020 and an increasing focus on glyphosate and paraquat in some overseas markets, the project leaders worked with the contract laboratory to offer a sample submission form that included testing for glyphosate/glufosinate/AMPA testing, and for paraquat/diquat/amitrole at a negotiated price.
- Bulk residue test pricing was negotiated for participating packers/exporters.
- Engaging with chemical companies and regulatory authorities brought the needs of the citrus industry to the attention of companies registering new chemistry and, where appropriate, to defend the continued use of chemistry under review.

Impacts

Through the increased export capacity developed from the project, the following impacts were generated:

- [Economic] Reduce industry risk (consequences of MRL breach) by encouraging maximum engagement in residue testing, and providing participant feedback regarding testing results. Particularly including the response to the detection of omethoate in exports to Thailand in 2019, thereby minimizing the broader long-term consequences for exports to that market.
- [Economic] Reduced residue testing costs for exporters through bulk pricing.
- [Economic] Supported improved access to existing and new chemistries to enhance the citrus industry's ability to manage pests and diseases, and thereby supporting increased productivity.
- [Socio-economic] Increased community wellbeing and resilience from a more economically sustainable citrus industry.

Project costs

The project was funded by Hort Innovation, using the fresh vegetable research and development levy and contributions from the Australian Government (Table 3). Overhead costs were added to the direct project cost to capture the full value of the RD&E investment.

Nominal investment

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	Total nominal ($)
2018	59,556	11,696	71,252
2019	59,556	9,386	68,942
2020	119,112	21,376	140,488
2021	119,112	19,494	138,606
2022	89,334	14,771	104,105
Total	**446,670**	**76,723**	**523,393**

1. The overhead and administrative costs were calculated from the Statement of Comprehensive Income in the Citrus Growers Fund Annual Report 2017-18 to 2021-22, averaging 16.1% for the CT18001 funding period (2018-2022).

Present Value of investment

The nominal total investment cost of $0.52 million identified in Table 3 was adjusted for inflation (ABS, 2023) into a real investment of $0.60 million (2022-23 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.69 million (2022-23 PV). The results were sensitivity tested changes in the discount rate between 2.5% and 7.5%.

Project impacts

The potential impacts identified in Table 2 were evaluated against available data to determine if they could be quantified with a suitable level of confidence.

Impacts valued and valuation framework

[Economic] Reduced residue testing costs for exporters through bulk pricing. Discussion with Citrus Australia highlighted that through the project a discounted bulk testing price was negotiated with Symbio Alliance laboratories, reducing the cost to grower by approximately $200 per sample (50% reduction). This saving was applied to the number of samples conducted each year from 2019 to 2021, while also considering the attribution of this outcome to CT18001.

[Economic] Reduced industry risk (consequences of MRL breach)

Reduced citrus export risk in key markets. The project supported a risk reduction relating to MRLs in all 16 priority export markets (see Table 3 *Activities*). The impact of CT18001 was quantified as a decreased likelihood of MRL breach:

- Counterfactual or "without CT18001" scenario: The at-risk volume of exports was quantified as the proportion of samples exceeding any country's MRLs (excluding Thailand's dimethoate/omethoate MRL which was included in a specific analysis below) (CT18001 reporting). Without testing the samples prior to export, Australian exporters have a higher likelihood of an MRL breach with potential long-term consequences. The potential consequences included increased importer/exporter testing requirements (additional cost) and the potential for a loss of market, requiring produce to be exported to alternative (lower value) markets. These consequences have the potential to last for several years (Citrus Australia consultation). No data was identified for the additional cost of testing in market. The cost of sending to lower value markets was quantified through citrus trade data comparing the average market price of the 16 priority markets with the average total export price (TradeMap, 2023).
- With CT18001 scenario. With the CT18001 residue testing program the potential MRL breaches could be identified before shipment and redirected to appropriate markets with higher residue limits, incurring a one off cost (potential lower prices) but avoiding long term consequences such as loss of access to priority markets. This risk reduction was applied to a proportion of citrus exports to the 16 priority markets based on participation in CT18001 (CT18001 reporting), with higher rates of participation supporting lower overall risk.

Reduced risk of citrus exports to Thailand after the detection of omethoate in 2019. This was quantified in a similar manner to above, but focussed on Thailand's dimethoate/omethoate MRLs. Omethoate is banned from use on all crops in Australia but it appears as a metabolite of the insecticide dimethoate. The QLD sector relies heavily upon dimethoate as a post-harvest treatment for fruit flies to access interstate markets. Thailand has an established MRL for dimethoate but not for omethoate. In 2020, as a result of a 2019 omethoate detection, Thailand classified Australian citrus as high risk. The situation was managed effectively by early intervention through CT18001 and frequent communication with Australian growers, packers

and exporters, as well as other Australian and Thai stakeholders, and by adjusting the content and format of residue screening and reporting in Australia to accommodate the requirements of the Thai authorities. As a result of the management through the project, citrus exports to Thailand suffered minimal interruption. Participation in the CT18001 residue testing program rapidly increased, particularly with growers/exporters focused on the Thai market. The avoided cost of sending to lower value markets was quantified through citrus trade data comparing Thailand with alternative markets (TradeMap, 2023).

Impacts unable to be valued

[Economic and environmental] Improved access to crop protection products. While the project provided support for industry access to existing and new crop protection products, no direct impact was identified to have occurred. However, it is possible that the underlying engagement between Citrus Australia, growers, packers, exporters, and chemical companies will support future impact in this area by maintaining relationships and a collective understanding of the industry's pest management and residue issues. Once there is a clear picture of improved access to crop protection products, any future impact assessment could consider the contribution of CT18001.

[Socio-economic] Increased community wellbeing and resilience from a more sustainable citrus industry were not able to be valued due to a lack of supporting data. The CIE (2023) highlighted the flow-on (spillover) effects of the citrus industry as a source of employment and economic stimulant to regional communities. By supporting increased industry productivity and sustainability, CT17008 supports a corresponding increase in spillovers to local communities. While this analysis quantified the direct impacts for citrus industry production and value, the flow-on effects require additional analysis using economic models that capture regional and national linkages, which are beyond the scope of the R&D impact assessment program (CRRDC 2018).

Data and assumptions

The data required to quantify the impact pathway was collected from the project documents and other relevant resources (Table 4). Where available, actual data was applied to the relevant years, with estimates applied for any data gaps and projections into the future based on appropriate analytical techniques (for example correlations and trend analysis), or stakeholder estimates, or both. A data range was incorporated to reflect underlying risk and uncertainty. This was particularly relevant where estimates were needed due to data gaps, and where projections were made into the future. These ranges were then analysed through sensitivity testing (see *Results*).

Table 4. Summary of data inputs for impact valuation

Variable	Assumption	Source / comment
Discount rate	5% (± 50%)	CRRDC Guidelines (2018)
Reduced residue testing costs		
Samples per year	496 in 2018-19 547 in 2019-20 715 in 2020-21	CT18001 reporting
Baseline "without CT18001" cost of sampling	$400/sample	CT18001 reporting and Citrus Australia consultation. This cost would have been paid directly by participating growers.
"With CT18001" cost of sampling $/sample	$200/sample	CT18001 reporting and Citrus Australia consultation. Bulk price negotiated by Citrus Australia, which was paid directly by participating growers.
Attribution of outcome (lower price)	75% (± 33%)	Considering that the project built on existing Citrus Australia experience.
R&D counterfactual	100% (-25%)	Unlikely to be available through individual grower funding (due to lower volumes) but possibly through NRS funding model.
Reduced citrus export risk in priority markets		
Period of impact	2018-19 to 2020-21	Reflecting project delivery of MRL testing.
Exports to 16 priority markets (million tonnes)	236 Mt in 2018-19 263 Mt in 2019-20 223 Mt in 2020-21	Based on actual trade volumes to the 16 priority export markets (see Table 2 *Activities*) (TradeMap 2023).
Residue testing program participants (% of exports)	66% (± 20%)	No Empirical data provided relating to volumes. Out of an estimated total of 34 citrus exporters (Citrus Australia 2014) a reported 18 exporters participated in the testing program (53%

		approximate lower bound); however, as these were identified as "major" exporters (CT18001 reporting) an upper bound of 80% was estimated, with an average 66% used in the baseline.
% at risk of exceeding at least one market MRL.	20% in 2018-19 45% in 2019-20 32% (± 40%) in 2020-21	Results from the CT18001 residue testing showed the proportion of samples that exceeded at least one market MRL. Actual figures were used for 2019 and 2020 (2021 not provided). An average of 2019-2020 was used for 2021 and tested at the highest and lowest observed range.
Likelihood of market loss	50% (± 50%)	May result in additional costs at market for importers/exporters (no data), or worst case a loss of market.
Duration of consequences without CT18001	4 years (± 50%)	Reflecting a similar shut down of Australian table grapes to Vietnam after a quarantine breach with four years taken to recover to pre-breach levels (Citrus Australia pers comm).
Duration of consequences with CT18001	1 year	With the CT18001 residue testing program the potential dimethoate/omethoate MRL breaches could be identified before shipment and redirected to appropriate markets with higher residue limits, this would incur a one off cost (potential lower prices) but avoid long term consequences such as loss of market access.
Price difference in alternative markets ($/kg)	0.03 (-43%, +62%)	Actual market price data (TradeMap 2023) was used for 2019-2022 (adjusted for inflation to 2022-23), reflecting the price premium of protocol markets targeted in CT18001's MRL testing compared to alternative citrus export markets. An average of $0.03/kg (min $0.02/kg and max $0.06/kg) was identified for the period and used for forward projections.
Attribution of outcome (risk reduction for participating exporters)	75% (± 33%)	Considering that the project built on existing Citrus Australia experience, networks and relationships and leveraged the levy funded communication / extension project.
R&D counterfactual	50% (± 50%)	R&D counterfactual is set at 50% and tested at ± 50% reflecting the potential for the project/outcomes to have been funded in the absence of Hort Innovation levy funding. It is likely that some exporters would have funded residue testing themselves directly given the importance of MRL compliance but with poorer risk mitigation outcomes due to a more limited ability to engage with key stakeholders to understand and respond to MRL changes, or potentially through the NRS (itself an industry levy funded scheme), which may again have poorer outcomes due to a reduced capacity to engage directly with citrus industry stakeholders.
Reduced risk of citrus exports to Thailand		
Period of impact	2019-20 and 2020-21	Omethoate first detected 2019, project conclusion in 2020-21. Beyond 2020-21 any benefits would be attributable to the work completed in the subsequent projects (e.g. *Across horticulture support for export MRL compliance* (MT19006))
Exports to Thailand (million tonnes)	16 Mt 2010-20 11 Mt 2020-21	Based on actual trade volumes to Thailand (TradeMap 2023).
Residue testing program participants (% of exports to Thailand)	66% (± 20%)	No specific data was identified for Thailand. Value calculated as per *Reduced citrus export risk in key markets*
% at risk of MRL breach (dimethoate/omethoate)	26% in 2019-20 20% (± 33%) in 2020-21	Results from CT18001 residue testing showed the proportion of samples that exceeded Thai omethoate/dimethoate limits. Actual figures were used for 2019 and 2020 (2021 not provided). An average of 2019-2020 was used for 2021 and tested at the highest and lowest observed range.
Likelihood of market loss	50% (± 50%)	No specific data was identified for Thailand. Value calculated as per *Reduced citrus export risk in key markets*

Duration of consequences without CT18001	4 years (± 50%)	No specific data was identified for Thailand. Value calculated as per *Reduced citrus export risk in key markets*
Duration of consequences with CT18001	1 year	No specific data was identified for Thailand. Value calculated as per *Reduced citrus export risk in key markets*
Price difference in alternative markets ($/kg)	0.42 (± 74%)	Actual market price data (TradeMap 2023) was used for 2019-2022 (adjusted for inflation to 2022-23), reflecting the price premium of Thailand compared to alternative citrus export markets. An average of $0.42/kg (min $0.11/kg and max $0.73/kg) was identified for the period and used for forward projections.
Attribution of outcome (risk reduction for participating exporters)	75% (± 33%)	Value calculated as per *Reduced citrus export risk in key markets*
R&D counterfactual	50% (± 50%)	Value calculated as per *Reduced citrus export risk in key markets*

Results

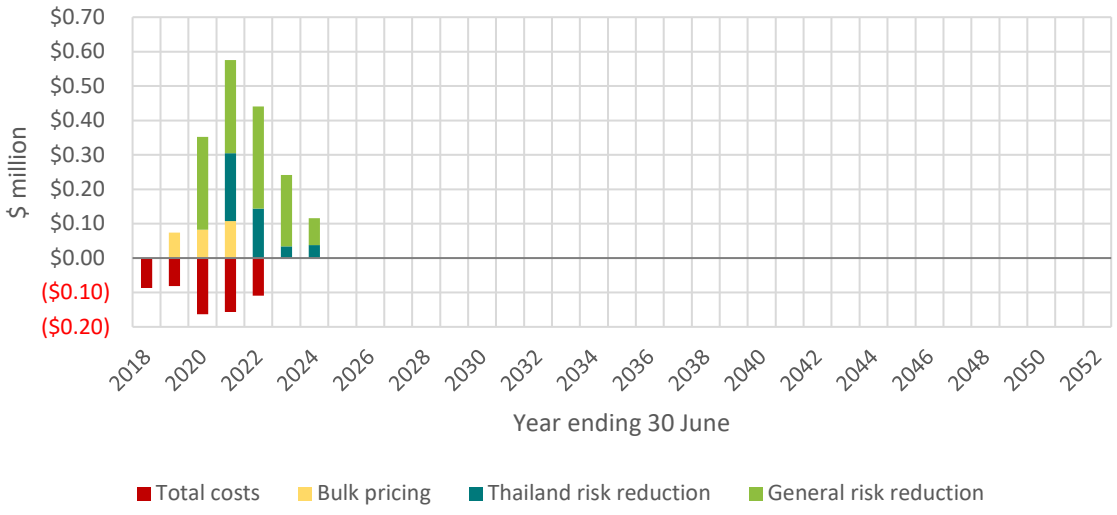
The PV costs (PVC) from all sources was $0.69 million (2022-23 PV) between 2018 and 2022, compared to estimated PV benefits (PVB) of $1.95 million (2022-23 PV) accruing between 2019 and 2024 (Table 5). When combined, these costs and benefits generate a net present value (NPV) of $1.26 million, an estimated benefit-cost ratio (BCR) of 2.84 to 1, an internal rate of return (IRR) of 127% and a modified internal rate of return (MIRR) of 13%.

Table 5. Impact metrics for the total investment in project CT18001

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	0.69	0.69	0.69	0.69	0.69	0.69	0.69
PVB ($m)	1.59	1.95	1.95	1.95	1.95	1.95	1.95
NPV ($m)	0.91	1.26	1.26	1.26	1.26	1.26	1.26
BCR	2.32	2.84	2.84	2.84	2.84	2.84	2.84
IRR	122%	127%	127%	127%	127%	127%	127%
MIRR	80%	38%	25%	19%	16%	14%	13%

Figure 2 shows the annual undiscounted benefit and cost cash flows for the total investment of CT18001. Of the total benefits, 62% were generated from the risk reduction across the 16 key markets, 22% from the Thai specific risk reduction, and 16% from the reduction in cost with bulk pricing. Cash flows are shown for the duration of the investment plus 30 years from the last year of investment.

Figure 2. Annual cash flow of undiscounted total benefits and total investment costs

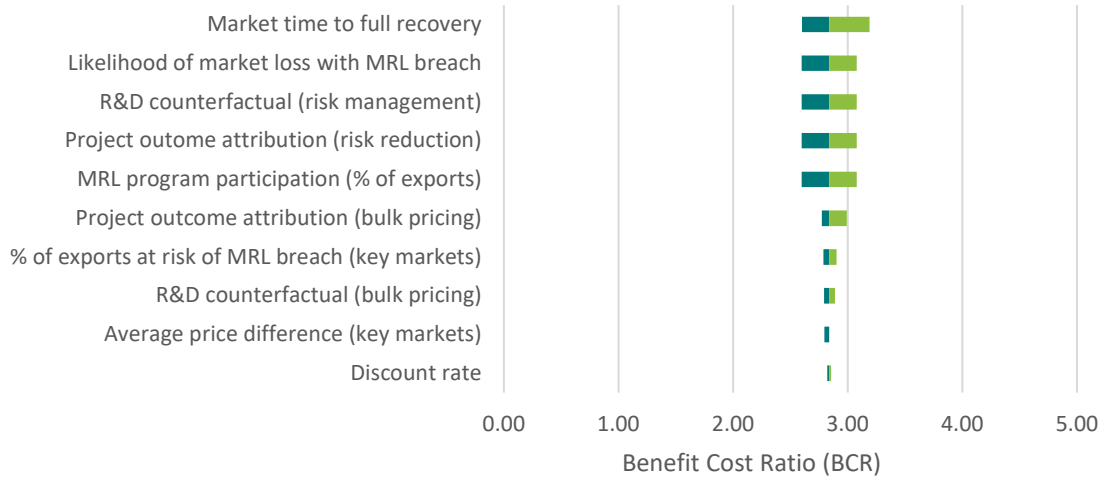


Sensitivity analysis

Given the risk and uncertainty associated with a number of underlying modelling inputs, the results were tested for sensitivity to changes in the variable where a potential value range was identified (Table 4). The results were first tested for sensitivity to individual changes in the variables, followed by combined changes.

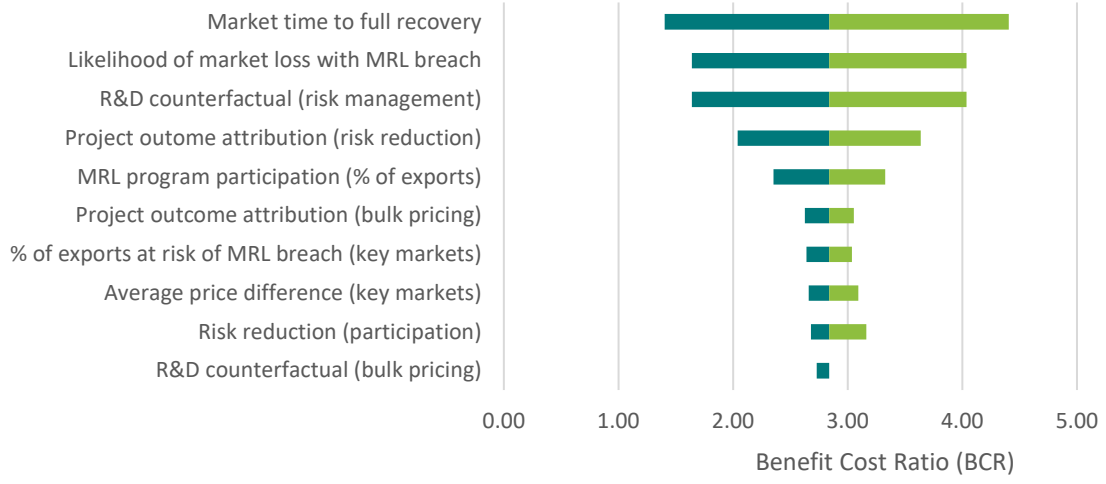
Individual changes of a uniform 10% were undertaken to identify the variables to which the results were most sensitive. The results were most sensitive uniform changes to the five variables shown in Figure 3. The largest change in the results came from a 10% change in the market time to full recovery following an in-market MRL breach (reflecting the avoided consequence of an in-market MRL breach as a result of CT18001); the likelihood of market loss with an MRL breach (recognising that less severe consequences may be incurred such as a strict import testing regime, which was unable to be valued due to a lack of data); the R&D counterfactual for MRL risk management (reflecting the potential for the export MRL program to have been funded through other means); the project outcome attribution (recognising that the project leveraged existing relationships and external resources); the R&D counterfactual attribution for the bulk pricing (reflecting the potential for bulk pricing to have been achieved without CT18001); and the level of participation in the export MRL program (with higher participation corresponding with lower risk of in-market MRL breaches).

Figure 3. Variables to which the results were most sensitive for uniform 10% changes



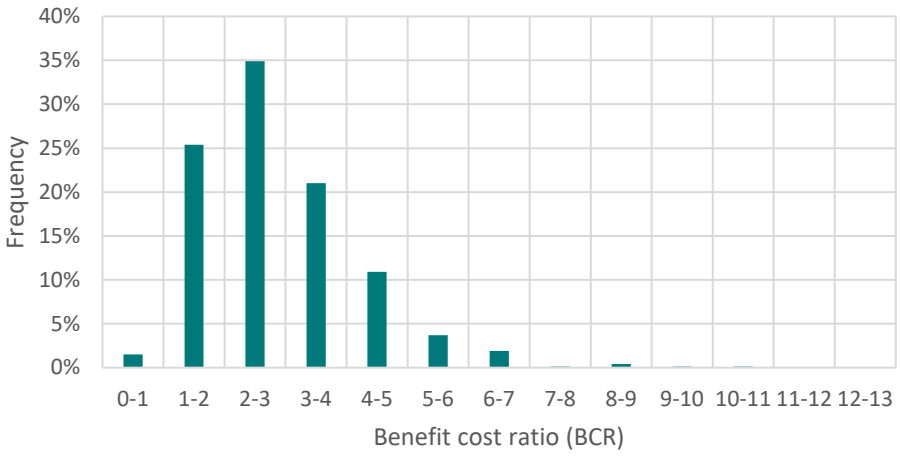
The results were next tested for sensitivity to changes across the full value range for each variable (tested individually) to reflect the differences in risk and uncertainty for each variable. The variables to which the results were most sensitive across their full range are shown in Figure 4. The results were most sensitive to changes in the market time to full recovery following an in-market MRL breach, followed by the likelihood of market loss with an MRL breach, and the R&D counterfactual.

Figure 4. Variables to which the results were most sensitive when tested at their full range



Finally, the full range of potential variation in the impact was estimated using @Risk stochastic modelling to incorporate the combined effect of changing all variables across their full ranges over 1000 simulations. This process showed an impact (BCR) range of between 0.72 and 10.86 (Figure 5). Excluding the lower and upper 5% (the low probability tails), the middle 90% of results fell between 1.28 and 5.23. The results also showed that 99% of simulations had a BCR greater than 1 (benefits greater than RD&E costs). This indicates a high level of confidence that this investment generated a positive impact.

Figure 5. Impact histogram. Distribution of results over 1000 simulations.



Implications and learnings

Project CT18001 sat at the end of the impact pathway, directly assisting Australian citrus growers with a coordinated approach to agrichemical risk management for the industry. In particular, under CT18001 the residue testing program was managed through Citrus Australia and provided a dedicated resource within the citrus industry to monitor, interpret, communicate and adhere to export market MRLs. A clear path to impact was identified within the analysis.

The project contributed to a reduction in export market risk by assisting growers to identify potential MRL breaches before shipments were exported, thereby avoiding long term export market consequences such as additional in-market testing or loss of market access. The benefit of this impact across 16 priority export markets was calculated at $1.2 million (2022-23 PV) for the three years of residue testing covered by the project (2018-19 to 2020-21).

CT18001 also helped to reduce the risk specifically for citrus exports to Thailand after the detection of omethoate residue in 2019. Through the project, Citrus Australia was able to engage with stakeholders in a timely manner to minimize the consequences for citrus exporters, including adjusting the content and format of residue screening and reporting in Australia to accommodate the requirements of the Thai authorities. The benefit of this impact was calculated at $0.44 million for 2019-20 and 2020-21 (2022-23 PV).

CT18001 also helped to reduce residue sampling prices paid by packers/exporters through the project by negotiating a bulk pricing agreement with the testing laboratory. This benefit was estimated to have benefited the participating packers/exporters by $0.30 million (2022-23 PV) over the three years of testing covered by the project (2018-19 to 2020-21). Additional benefits relating to improved access to pest management chemicals, and increased community wellbeing from a more economically sustainable citrus industry were not able to be valued due to a lack of data.

In total, the project was estimated to have generated benefits of $1.95 million (2022-23 PV), compared to PV RD&E costs of $0.69 million (2022-23 PV), generating an NPV of $1.26 million. Sensitivity testing showed that there was a high level of confidence that CT18001 would generate a positive impact (benefits greater than costs) with 99% of simulated results falling between 1.28:1 and 5.23:1. The results were most sensitive to changes in the market time to full recovery following an in-market MRL breach (reflecting the avoided consequence of an in-market MRL breach as a result of CT18001); the likelihood of market loss with an MRL breach (recognising that less severe consequences may be incurred such as a strict import testing regime, which was unable to be valued due to a lack of data); and the R&D counterfactual for MRL risk management (reflecting the potential for the export MRL program to have been funded through other means).

Overall, the funding of the citrus agrichemical and export MRL program through CT18001 was found to have delivered a positive impact for the citrus industry by reducing the economic risk associated with chemical residues.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Anthony Baker, Hort Innovation, R&D Manager – Market Access	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
David Daniels, Citrus Australia, General Manager– Market Development	RD&E practitioner and industry stakeholder	✓	✓	✓	✓	✓	✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	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.
Direct Effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting and Present Values	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018) with results sensitivity tested at discount rates of 2.5% and 7.5%.
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Internal rate of return (IRR)	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.
Modified internal rate of return (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	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.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover Effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

MRLs Maximum residue limits

NRS The Australian Government's National Residue Survey

RD&E Research, Development and Extension

SIP Strategic Investment Plan

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Ends.