

# Industry-specific impact assessment program: avocado

## Impact assessment report for project *Reducing flesh bruising and skin spotting in Hass avocado* (AV10019)

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**Project code:**

MT18009

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## 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 *AV10019 Reducing flesh bruising and skin spotting in Hass avocado*. The project was funded by Hort Innovation over the period July 2011 to November 2014.

### 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 2017/18 dollar terms and were discounted to the year 2018/19 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 AV10019 has contributed to improved knowledge and understanding of factors influencing bruising, bruise expression, and skin spotting. This knowledge led to the development of recommendations to reduce bruising and bruise expression across the value chain. The project communicated key findings and has contributed to reduced losses due to bruising and bruise expression. Further positive social impacts are possible including the future commercial development of a tool useful to consumers in determining avocado ripeness.

### Investment Criteria

Total funding from all sources for the project was \$0.84 million (present value terms). Project funding was provided by Hort Innovation, Queensland Department of Agriculture and Fisheries (DAF) and The University of Queensland. The investment produced estimated total expected benefits of \$4.11 million (present value terms). This gave a net present value of \$3.28 million, an estimated benefit-cost ratio of 4.9 to 1, an internal rate of return of 19.3% and a MIRR of 8.7%.

### Conclusions

One economic and one social impact of AV10019 were not valued. When inability to value all impacts is combined with conservative assumptions for the principal economic impacts valued, it is reasonable to conclude that the valuation may be an underestimate of the actual performance of the investment.

## Keywords

Impact assessment, cost-benefit analysis, AV10019, avocado, bruise intensity, bruise severity, dry matter, firmness, *Persea americana M.*, supply chain.

## 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 apple & pear (AP), avocado (AV), mushroom (MU) and table grape (TG) RD&E investment funds.

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

- Nine AP projects were chosen worth \$15.46 million (nominal Hort Innovation investment) from an overall population of 19 projects worth an estimated \$33.31 million,
- Seven AV projects worth \$1.91 million (nominal Hort Innovation investment) from an overall population of 27 projects worth approximately \$9.97 million,
- Five MU projects worth \$1.75 million (nominal Hort Innovation investment) from a total population of 20 projects worth \$7.94 million, and
- Six TG projects worth \$2.84 million (nominal Hort Innovation investment) from an overall population of 11 projects worth \$5.0 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2013 to 30 June 2018.

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.

Project AV10019: *Reducing flesh bruising and skin spotting in Hass avocado* was randomly selected as one of the 22 unique MT18009 investments 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

### Avocado industry

The Australian avocado industry is one of Australia's 'growth' horticultural industries as illustrated in Table 1 below.

Table 1: Avocado Industry Performance 2014-2018

Year ended June	Production (tonnes)	Gross Value of Production (m\$)	Farmgate value (m\$)	Export value (m\$)
2014	48,715	313	297	5.6
2015	57,595	356	331	6.4
2016	66,716	438	412	9.2
2017	65,992	398	374	12.5
2018	77,032	557	543	11.6
Average	63,210	412	391	9.1

Source: Facts at a Glance for the Australian avocado industry-2017/18 (Avocados Australia, 2018).

While avocados are grown in all Australian States and the Northern Territory, production is dominated by Queensland followed by Western Australia; together these two states produced 87% of avocados in 2017/18. Due to the broad range of climatic conditions and locations where avocados are grown, they are produced nearly all year round. Two varieties of avocados dominate the industry: Hass (78%) and Shepard (19%) (Avocados Australia, 2018).

Australian consumption of avocados has increased in line with the production increase. Based on new plantings, production of Australian avocados is expected to increase significantly in the next few years. Avocado exports are minimal at 2.3% of production in 2017/18, but growth in exports is expected in the future if the third desired outcome in the SIP is achieved (10% of production exported - see below).

The marketing and research and development activities of the avocado industry are guided by the industry's Strategic Investment Plan (SIP). The activities are funded by levies payable on avocados produced in Australia; the marketing and R&D levy funds are managed by Hort Innovation.

The previous avocado Industry Strategic Plan expired in 2015 and placed emphasis on development of the domestic market, increased production for year round supply, and the maintenance of demand and price via marketing programs and supply of consistent quality avocados.

The current SIP has been driven by levy payers and addresses the Australian avocado industry's needs from 2017 to 2021. Strategies and priorities in the Plan have been driven by a set of four desired outcomes (Avocados Australia, 2017a).

1. By 2021, increase domestic demand for Australian avocados has increased by at least 20%.
2. By 2021, over 90 per cent of avocados received by consumers will meet or exceed their expectations of quality.
3. By 2021, over 10 per cent of production will be exported to markets where customers have a willingness and capacity to pay a premium for Australian avocados.
4. By 2021, productivity (marketable yield per hectare) has improved by 15 per cent on average, without increased production costs per kilogram.

### Rationale

Up to 80% of Hass avocados on the retail shelf have defects in the flesh which can reduce consumer purchasing. Bruising and rot are the two most significant defects. This project sought to understand how to reduce flesh bruising and skin spotting through laboratory experiments, avocado quality assessment along the value chain post-harvest to retail store display, and a survey to determine the impact of damage on sales prices and volumes (Source: Project Proposal).

AV10019 sought to reduce flesh bruising and skin spotting in Hass avocado, and is consistent with the objectives of the current Avocado Strategic Investment Plan 2017-2021. The project supports desired outcome 2: 'By 2021, over 90 per cent of avocados received by consumers will meet or exceed their expectations of quality'. In particular, AV10019 aligns with the Strategy to "Establish objective evidence and understanding of the primary sources of continued quality issues'.

AV10019 builds on over a dozen past and current Australian avocado research investments including:

- AV06025 'Australian Consumer's Perception and Preferences for Hass Avocado' that suggested if purchased fruit had more than 10% of the flesh volume affected by defects, then it can negatively affect the next intent to purchase.
- AV07018 'Avocado Retail Quality Surveys' determined in 2008 that 63% of fruit had flesh defects and that 29% of fruit had more than 10% of the flesh volume affected by defects. This study identified 41% of fruit was bruised, 23% with body rots and 16% with stem end rots.
- AV09026 'Shepard Avocado Maturity Consumer Sensory Research' indicated skin spotting severity can significantly reduce intent to purchase.

Furthermore, complementary project AV12009 focused on the potential contributions of shoppers and consumers in causing unsightly bruising of Hass avocado fruit.

To improve understanding of the causes of bruising and skin spotting and subsequently reduce the impact of such impacts, this research project was developed.

## Project Details

### Summary

Project Code: AV10019

Title: *Reducing flesh bruising and skin spotting in Hass avocado*

Research Organisations: Queensland Department of Agriculture and Fisheries; The University of Queensland.

Principal Investigator: Daryl Joyce, Department of Agriculture and Fisheries; and Honorary Professor, The University of Queensland.

Period of Funding: July 2011 to March 2015

### Objectives

The objectives of this project were to:

1. improve the efficiency of avocado bruise assessment;
2. identify critical points in the supply chain where events that lead to flesh bruising happen;
3. develop decision aids to reduce avocado bruising;
4. identify consumer and customer (riper/agent/retailer/importer) attitudes and expectations regarding skin spotting; and
5. improve understanding of the factors causing skin spotting at different stages of the supply chain to scope the need for future research on this defect.

### Logical Framework

Table 2 provides a logical framework description of AV10019, a research and extension project designed to reduce bruising and skin spotting in Hass avocados.

Table 2: Logical Framework for Project AV10019

<p>Activities and Outputs</p>	<p>The research project was completed in five parts. The activities and outputs associated with each part are detailed below:</p> <p><i>Part 1. Bruising laboratory experiments:</i>  Activities:  <ul style="list-style-type: none"> <li>Laboratory experiments determined the relationship between applied mechanical forces and bruise expression in Hass avocados.</li> <li>Proton magnetic resonance imaging (MRI) was evaluated as a non-destructive tool for assessing bruise development and severity over time</li> </ul> Outputs:  <ul style="list-style-type: none"> <li>The research determined bruise severity was increased with greater impact energies, tray dropping on an angle (compared to dropping from the horizontal), softer (i.e. less firm) fruit, fruit harvested earlier in the season, and ambient temperature handling versus lowered pre- and post-impact temperatures.</li> <li>The research determined MRI was a useful tool for non-destructively visualizing expansion in bruise volume over time after initial impact events.</li> </ul> </p> <p><i>Part 2. Bruise assessment through the supply chain:</i>  Activities:  <ul style="list-style-type: none"> <li>Fruit sampling was undertaken at six serial supply chain points: ripener arrival, ripener dispatch, distribution centre arrival, distribution centre dispatch, retail store arrival, and retail store display to determine bruising levels.</li> </ul> Outputs:  <ul style="list-style-type: none"> <li>The level of bruising of 'Hass' avocado tended to increase as the fruit passed through the supply chain.</li> <li>Bruise severity was significantly higher at the retail store display point than at all preceding sampling points.</li> </ul> </p> <p><i>Part 3. Potential impact decision aids evaluated:</i>  Activities:  <ul style="list-style-type: none"> <li>Three commercially available potential decision aid tools or devices involving the shopper in testing to determine fruit firmness (ShockWatch ShockLog, Impact Recording Device, and ShockWatch impact indicator clips) were evaluated to determine their ability to reliably discern impact events.</li> </ul> Outputs:  <ul style="list-style-type: none"> <li>The ShockWatch impact indicator clips attached to trays were insensitive.</li> <li>The ShockWatch ShockLog and the Impact Recording Device reliably discerned impact events when placed in trays of fruit.</li> </ul> </p> <p><i>Part 4. Skin spotting survey:</i>  Activities:  <ul style="list-style-type: none"> <li>Surveys of wholesalers, retailers and shoppers were completed to determine the impact of skin spotting on sales prices and volumes.</li> <li>Skin spotting data acquired by Avocados Australia Limited from 16 independent and supermarket retail stores in WA, Vic, NSW and Qld from September 2011 to May 2014 were analysed.</li> </ul> Outputs:  <ul style="list-style-type: none"> <li>Wholesalers considered that sales prices and volumes are negatively affected by increased skin spotting.</li> <li>It was determined skin spotting does not follow any particular patten for incidence of severity.</li> </ul> </p> <p><i>Part 5. Extension:</i>  Activities:  <ul style="list-style-type: none"> <li>Key findings were communicated to industry through articles in print, electronic and</li> </ul> </p>
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	<p>social media, presentations at conferences and industry meetings, and one-on-one discussions with key stakeholders including Avocados Australia Limited representatives, ripeners and retailers.</p> <ul style="list-style-type: none"> <li>• Key take-home messages were distilled.</li> <li>• Recommendations were developed for future research.</li> </ul> <p>Outputs:</p> <ul style="list-style-type: none"> <li>• The following key strategies to lessen bruising and bruise expression in Hass avocados were communicated to audiences: <ul style="list-style-type: none"> <li>- harvest fruit at and above the minimum recommended dry matter content;</li> <li>- maintain stringent low temperature management including at retail;</li> <li>- maintain rapid fruit handling through the supply chain to minimise time in the chain.</li> </ul> </li> <li>• The project provided the recommendation for future research to quantify the relationship between skin spotting and fruit physiochemical condition (e.g. turgor pressure) and transport conditions and associated handling operations in avocado supply chains.</li> <li>• A confidential report was presented to project participants on project findings and recommendations for improvement.</li> <li>• A public report on findings and recommendations relating to bruising and skin spotting was produced.</li> <li>• Three articles were published in “Talking Avocados” on project findings and recommendations (Avocados Australia, 2017b).</li> <li>• Two research papers were published in scientific journals.</li> <li>• A PhD was awarded within this research project.</li> <li>• A draft decision aid tool to reduce bruising caused by impacts was released.</li> </ul>
Outcomes	<ul style="list-style-type: none"> <li>• Contribution to reduced flesh bruising in Hass avocados on the retail shelf due to improved knowledge and understanding of the factors contributing to flesh bruising along the value chain, and recommendations for improved practices (Daryl Joyce, pers. comm.).</li> <li>• Improved knowledge regarding the value of decision aids informed future research to commercially develop a tool useful to consumers in determining avocado ripeness.</li> </ul>
Impacts	<ul style="list-style-type: none"> <li>• Improved external and internal avocado quality is likely to have contributed to improved customer and consumer satisfaction and consequently increased demand and increased future demand for avocados.</li> <li>• Improved quality of avocados will either increase demand and associated price and/or will allow the anticipated increased supply of avocados to be sold without any reduction in price resulting in economic benefits to growers.</li> <li>• Economic benefits to others in the avocado value chain are anticipated as a result of improved demand for avocados (traders, ripeners, transporters, etc).</li> </ul>

Note: AV10019 activities, outputs, outcomes and impacts were identified from the project proposal, final report and as a result of discussions with Daryl Joyce (DAF) and John Tyas (Australian Avocados Limited).

## Project Investment

### Nominal Investment

Table 3 shows the annual investment (cash and in-kind) in project AV10019 by Hort Innovation. Other investors in the project included DAF and The University of Queensland.

Table 3: Annual Investment in the Project AV10019 (nominal \$)

Year ended 30 June	Hort Innovation (\$)	Other (\$)	Total (\$)
2012	103,796	271,783	375,579
2013	10,326	27,038	37,364
2014	10,000	26,184	36,184
2015	31,030	81,250	112,280
<b>Totals</b>	<b>155,152</b>	<b>406,255</b>	<b>561,407</b>

### 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 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 2017/18 dollar terms using the GDP deflator index. There were no additional costs associated with project extension. Results were communicated to growers and others in the value chain as part of the project.

## Impacts

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

Table 4: Triple Bottom Line Categories of Principal Impacts from Project AV10019

Economic	<ul style="list-style-type: none"> <li>Improved external and internal avocado quality is likely to have contributed to improved customer and consumer satisfaction and consequently increased demand and increased future demand for avocados.</li> <li>Improved quality of avocados will either increase demand and associated price and/or will allow the anticipated increased supply of avocados to be sold without any reduction in price resulting in economic benefits to growers.</li> <li>Economic benefits to others in the avocado value chain are anticipated as a result of improved demand for avocados (traders, ripeners, transporters, etc).</li> </ul>
Environmental	<ul style="list-style-type: none"> <li>Nil.</li> </ul>
Social	<ul style="list-style-type: none"> <li>Improved knowledge and information regarding the value of decision aids informed future activities by commercial entities to progress the development of a tool useful to consumers in determining avocado ripeness and further minimising avocado bruising by consumers.</li> <li>Contribution to increased research capacity including potential commercial development of a ripeness assessment tool mentioned above.</li> </ul>

### Public versus Private Impacts

Impacts identified in this evaluation are mostly private in nature. Private benefits are expected to be realised by avocado growers and others in the supply chain as a result of additional profitable sales of avocados. Minor public benefits are anticipated including increased research capacity, and improved knowledge regarding the value of decision aids, which may be utilised to inform the future development of a commercial tool useful to consumers in determining avocado ripeness.

### Distribution of Private Impacts

The impacts on the avocado industry from investment in this project will be shared along the supply chain with growers, ripeners, transporters, wholesalers, retailers and consumers all sharing impacts produced by the project.

### Impacts on Other Australian Industries

Impacts are expected to be confined to the Australian avocado industry.

### Impacts Overseas

No overseas impacts were identified.

### Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project findings and related impacts will contribute to Rural RD&E priorities 1 and 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	1. Food
2. Biosecurity	2. Soil and Water
3. Soil, water and managing natural resources	3. Transport
4. Adoption of R&D	4. Cybersecurity
	5. Energy and Resources
	6. Manufacturing
	7. Environmental Change
	8. Health

Sources: (DAWR, 2015) and (OCS, 2015)

### Alignment with the Avocado Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the avocado industry are outlined the Avocado Strategic Investment Plan 2017-2021<sup>1</sup> (Hort Innovation, 2017). Project AV10019 addressed Outcome 2 (Strategy 2.1) and Outcome 4 also was addressed via several strategies.

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

## 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.

The impact that was valued was the quality improvement and resulting future anticipated demand and profitability of avocado production to growers.

### Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. The impact of improved knowledge and understanding was hard to value due to lack of evidence/data, and difficulty in quantifying the causal relationship and pathway between AV10019 and the future anticipated impact. Hence, economic benefits to participants in the avocado value chain anticipated as a result of AV10019 were not valued due to the difficulties in obtaining data to enable credible assumptions to be made.

### Summary of Assumptions

A summary of the key assumptions made for valuation of the reduced avocado damage due to project AV10019 is provided in Table 6.

Table 6: Summary of Assumptions

Variable	Assumption	Source/Comment
<b>Impact of avocado flesh bruising without project AV10019</b>		
Gross value of Australian avocado production before project AV10019	\$316.20 m per annum	Five year average 2011-2015 (Avocados Australia, 2018)
Proportion of Australian avocado production made up of Hass variety	78%	Avocados Australia, 2018, p10
Gross value of Australian Hass avocado production before project AV10019	\$246.64 m per annum	Calculated (316.20*78%)
Assumed drop in gross value due to current flesh bruising	2.5%	Agtrans Research (Based on discussions with Daryl Joyce (DAF), Simon Newett (DAF) and John Tyas (Australian Avocados Limited))
<b>Impact of avocado flesh bruising with project AV10019</b>		
Gross value of Australian Hass avocados if all flesh bruising removed	\$252.80 m per annum	Calculated (246.64*(1+2.5%))
Increase in gross value if all flesh bruising removed	\$6.17 m per annum	Calculated (246.64-252.80)
Assumed annual cost of achieving reduced damage/improved quality	10% of gross value gain	Agtrans Research (Based on discussions with Daryl Joyce (DAF), Simon Newett (DAF) and John Tyas (Australian Avocados Limited))
Potential increase in net value if all flesh bruising removed from Hass avocados	\$5.55 m	Calculated (6.17m*(1-10%))
Proportion of damage assumed eliminated by Project AV10019	10%	Agtrans Research (Based on discussions with Daryl Joyce (DAF), Simon Newett (DAF) and John Tyas (Australian Avocados Limited))
Maximum gross value of damage eliminated by Project AV10019	\$0.55 m per annum	Calculated (5.55m x 10%)
Year in which improvement commences	2015/16	Agtrans Research

Year in which maximum improvement reached	2019/20	Agtrans Research
<b>Risk factors</b>		
Probability of outcome (management improvements to reduce flesh bruising occurring along the supply chain)	75%	Already evidence of outcomes
Probability of impact (assuming successful outcome)	75%	Agtrans Research
<b>Counterfactual</b>		
If Project AV10019 had not been funded it is assumed that, while some improvement in flesh bruising by some growers and supply chains would have been made, such improvements would have been significantly less in their aggregate impact and consistency of impact over time, compared to the impact of AV10019		
Proportion of benefits estimated that would have been delivered without Project AV10019	20%	Agtrans Research

Note: Assumptions were made based on discussions with Daryl Joyce (DAF), Simon Newett (DAF) and John Tyas (Australian Avocados Limited).

## Results

All costs and benefits were discounted to 2018/19 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the Modified Internal Rate of Return (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 (2014/15) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

### Investment Criteria

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

Table 7: Investment Criteria for Total Investment in Project AV10019

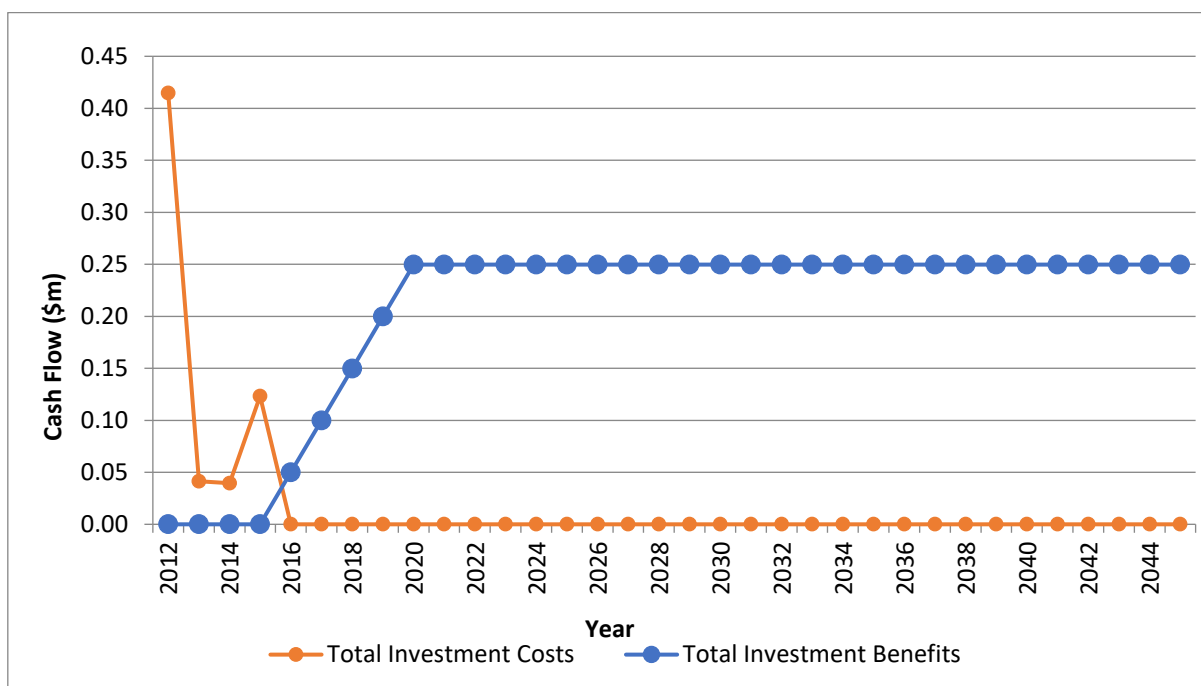
Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits (\$m)	0.00	0.76	1.79	2.60	3.23	3.73	4.11
Present Value of Costs (\$m)	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Net Present Value (\$m)	-0.84	-0.08	0.95	1.76	2.39	2.89	3.28
Benefit-Cost Ratio	-	0.91	2.14	3.10	3.85	4.44	4.90
Internal Rate of Return (%)	negative	3.3	15.3	18.0	18.8	19.2	19.3
MIRR (%)	negative	negative	16.5	13.6	11.4	9.9	8.7

Table 8: Investment Criteria for Hort Innovation Investment in Project AV10019

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits (\$m)	0.00	0.23	0.55	0.80	0.99	1.15	1.26
Present Value of Costs (\$m)	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Net Present Value (\$m)	-0.26	-0.02	0.29	0.54	0.74	0.89	1.01
Benefit-Cost Ratio	-	0.91	2.14	3.10	3.85	4.44	4.90
Internal Rate of Return (%)	negative	3.3	15.3	18.0	18.8	19.2	19.3
MIRR (%)	negative	negative	16.5	13.6	11.4	9.9	8.7

The annual undiscounted benefit and cost cash flows for the total investment for the duration of AV10019 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 present the results. The results are moderately sensitive 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)	6.99	4.11	2.84
Present Value of Costs (\$m)	0.62	0.84	1.13
Net Present Value (\$m)	6.37	3.28	1.71
Benefit-cost ratio	11.30	4.90	2.52

A sensitivity analysis was then undertaken for the proportion of total damage reduction assumed that was driven by Project AV10019. Results are provided in Table 10. The breakeven proportion of total damage reduction assumed to be driven by the project, given all other assumptions remaining unchanged, was 2.0%.

Table 10: Sensitivity to Assumed Proportion of Damage Reduction due to Project AV10019  
(Total investment, 30 years)

Investment Criteria	Maximum Increase in Value of Production		
	5%	10%	15%
Present Value of Benefits (\$m)	2.06	4.11	6.17
Present Value of Costs (\$m)	0.84	0.84	0.84
Net Present Value (\$m)	1.22	3.28	5.33
Benefit-cost ratio	2.45	4.90	7.36

A final sensitivity analysis (Table 11) tested the sensitivity of the investment criteria to the risk factors of probability of outcome and impact. The results show that the investment criteria are quite sensitive to the uncertainty related to these two assumptions.

Table 11: Sensitivity to Probabilities of Outcome and Impact  
(Total investment, 30 years)

Investment Criteria	Probability of Outcome and Impact		
	Both 50%	Both 75%	Both 100%
Present Value of Benefits (\$m)	1.83	4.11	7.32
Present Value of Costs (\$m)	0.84	0.84	0.84
Net Present Value (\$m)	0.99	3.28	6.48
Benefit-cost ratio	2.18	4.90	8.72

### 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 12). 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 12: Confidence in Analysis of Project

Coverage of Benefits	Confidence in Assumptions
Medium	Low-Medium

Coverage of benefits was assessed as medium – one major benefit was quantified, however potentially important benefits were not valued including the contribution of the project to the potential future development of a tool useful to consumers in determining avocado ripeness and so further minimising avocado bruising by consumers. Confidence in the assumptions was rated as Low-Medium, as the key assumption of the maximum increase in the value of production due to reduced damage/improved quality can only be validated over time.

### Conclusion

The investment resulted in the avocado industry potentially improving operations to deliver higher quality Hass avocados with reduced bruising and bruise expression. Total funding from all sources for the project was \$0.84 million (present value terms). The investment produced estimated total expected benefits of \$4.11 million (present value terms). This gave a net present value of \$3.28 million, an estimated benefit-cost ratio of 4.90 to 1, an internal rate of return of 19.3% and a modified internal rate of return of 8.5%.

Additional social and economic benefits were identified but not valued; hence the investment criteria estimated by the evaluation may be underestimates of the actual performance 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

AP	Apple and Pear
AV	Avocado
CRRDC	Council of Research and Development Corporations
DAF	Department of Agriculture and Fisheries (Queensland Government)
DAWR	Department of Agriculture and Water Resources (Australian Government)
GDP	Gross Domestic Product
MIRR	Modified Internal Rate of Return
MRI	Magnetic Resonance Imaging
MU	Mushroom
OCS	Office of Chief Scientist Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan
TG	Table Grape