Industry-specific impact assessment program: Almond

Impact assessment report for project *Managing carob moth in almonds* (AL12004)

Impact analyst:

Michael Clarke

Delivery partner:

AgEconPlus and Agtrans Research

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Level 7
141 Walker Street
North Sydney NSW 2060

Telephone: (02) 8295 2300

www.horticulture.com.au

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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 *AL12004: Managing Carob Moth in Almonds.* The project was funded by Hort Innovation over the period October 2012 to May 2015.

Methodology

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

Results/key findings

The investment in AL12004 has delivered a sound understanding of carob moth as a pest of Australian almonds and made serious progress with development of a non-chemical, pheromone-based control. Results have been communicated to industry. Since completion of AL12004, other sources of kernel damage have been identified as priorities for almond industry research.

Investment Criteria

Total funding from all sources for the project was $0.97 million (present value terms). The investment produced estimated total expected benefits of $1.80 million (present value terms). This gave a net present value of $0.82 million, an estimated benefit-cost ratio of 1.85 to 1, an internal rate of return of 8.8% and a modified internal rate of return of 6.8%. A 10% discount rate, a 0.5% increase in net profit and an adoption rate of less than 28% of Nonpareil growing area all result in a failure of the project to 'breakeven'.

Conclusions

The Hort Innovation investment in project AL12004 has increased the almond industry's knowledge of carob moth and worked toward non-chemical solutions for its control. A number of the identified impacts were not valued as they were considered uncertain and difficult to value with credible assumptions. Hence, investment criteria provided by the valuation may be underestimates of the actual performance of the investment.

Keywords

Impact assessment, cost-benefit analysis, almond, carob moth, management.

Introduction

All research, development, and extension (RD&E) 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 22 projects worth approximately $16.72 million,
- Eight CT projects worth $5.4 million (nominal Hort Innovation investment) from a total population of 35 projects worth $15.78 million, and
- Four VN projects worth $2.4 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.

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

Background

The Australian almond industry is a significant horticultural sector with a five-year average production area of 36,206 ha, a production volume of 85,909 tonnes (kernel weight equivalent), and a Farmgate Value of $665.6 million – Table 1.

Table 1: Almond Industry Performance 2015-2019

Year Ended 30 June	Area of Production (ha)	Production (t)	Gross Value of Production ($m)	Farmgate Value ($m)
2015	29,437	82,509	707.5	672.1
2016	30,981	82,333	854.1	811.4
2017	35,866	80,800	553.6	525.9
2018	39,662	79,901	553.1	525.4
2019	45,089	104,000	835.1	793.3
Average	36,206	85,909	700.7	665.6

Source: Australian Horticulture Statistics Handbook and Almond Insights, various years. Tonnes is kernel weight equivalent.

The industry is comprised of a value chain that spans investors, almond growers through to end retail consumers and export markets. A number of the larger Australian growers have become vertically integrated and encompass processing, packing, domestic and export marketing (Hort Innovation, 2017).

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

The current SIP has been developed with levy payers and addresses the Australian Almond industry's needs from 2017 to 2021. Strategies and priorities in the Plan have been driven by a set of five desired outcomes (Hort Innovation, 2017):

1. Pest and disease damage to almonds has been reduced through enhanced integrated pest management and integrated disease management.
2. A major productivity gain in almond pollination by 2022 through a 25% reduction in honey bee stocking rate with no loss in pollination efficiency (nut set).
3. Improvements in the crop production system have lifted average industry kernel yield from 3 to 4 t/ha, 4ML of irrigation water generates a tonne of almond kernel yield and proven 'shake and catch' harvesting / processing technology is in place.
4. Australian almonds are an informed industry that adopts R&D outcomes and has the capacity to support current and future industry needs.
5. Increased domestic almond consumption up from 16,000 t in 2016 to 27,500 t in 2022. Increased export sales up from 61,000 t in 2016 to 110,000 t in 2022.

Rationale

In recent years, the Australian almond industry has experienced increasing concern regarding the level of crop damage caused by carob moth (*Ectomyelois ceratoniae*). Carob moth is a pest of Mediterranean origin that affects numerous crops including almonds. Its larvae feed on almond hulls and kernels, reducing kernel value to processing grade or rendering the kernel unfit for human consumption. Concerns about the level of carob moth damage in the almond industry between 2009/10 and 2011/12 led major growers to introduce insecticide spraying to their orchards.

Prior to 2009/10, carob moth was regarded as a minor pest. However, in the three years between 2009/10 and 2011/12 it became more significant. Increased significance may have been due to consecutive wet years, an increase in fungal problems, retention of mummy nuts on almond trees (where carob moth overwinters) and the large increase in the number of trees reaching bearing age. In 2020 it is understood that carob moth damage is not an issue of economic concern in all years.

During the 2010/11 season and prior to this project, some growers noticed significant levels of kernel damage from carob moth, particularly in the Nonpareil variety, and raised concerns regarding the lack of carob moth management options.

Carob moth has the potential to reduce the profitability of almond growing in Australia through the added cost of field applied insecticides, the reduced value of chewed kernels, rejection of good quality kernels together with chewed kernels, direct consumption of nutmeal, the off-target impacts of insecticide use (including the destruction of beneficial insects), and a possible association between feeding damage and the increased risk of fungal /

aflatoxin infection.

This project aimed to begin developing an effective management program for carob moth in almonds by:

- Building a good local knowledge of the seasonal phenology of carob moth.
- Relating the pest's phenology to the development and handling of the almond crop.
- By combining this knowledge with techniques that may be used to suppress the carob moth population and/or prevent egg laying.

Project Details

Summary

Project Code: AL12004

Title: Managing Carob Moth in Almonds

Research Organisation: Department of Primary Industries (DPI), Victoria

Project Leader: David Madge

Period of Funding: October 2012 to May 2015

Objectives

The objectives of this project were to:

1. Develop a good understanding of carob moth as an almond pest.
2. Develop and evaluate strategies to minimise nut infestation by carob moth.
3. Inform industry of best practices for management of the pest.

The project would investigate the use of the non-chemical, pheromone-based, mating disruption technique developed in California for the control of carob moth in date orchards.

Logical Framework

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

Table 2: Logical Framework for Project AL12004

Activities	Important activities associated with AL12004 included: • Formation of a steering committee that included industry, Almond Board of Australia, and Hort Innovation to guide the project. • Review of the scientific literature on carob moth. • Maintain and expand the current grower-based pheromone trapping program. • Maintain and expand the current mummy nut and new crop sampling program for infestation with carob moth eggs, larvae, and pupae throughout the year. • Sample stockpiled almonds to follow postharvest development of the pest. • Assess the feasibility and value of a degree-day model to predict key moth life events. • Assess the efficacy and cost-effectiveness of mating disruption to prevent nut infestation by carob moth. • Investigate the role of alternative plant hosts in the carob moth life cycle, and their potential influence on the application and success of mating disruption. • Investigate the effect that mummy removal has on seasonal population dynamics of carob moth, including infestation of, and damage to, the new nut crop. • Investigate the period of infestation post hull split (the period in which carob moth eggs laid on almonds are most likely to result in kernel damage) and the window of opportunity to apply moth ovicides (egg kill) and/or larvicides to prevent kernel damage. • Assess the impact of pesticide application on beneficial invertebrates and secondary pests. • Transfer knowledge on carob moth biology and management to all relevant sectors of the almond industry.
Outputs	Important outputs associated with AL12004 included:

	• A literature review with a focus on opportunities for research and management of carob moth in almonds. The literature review did not quantify the impacts of the pest. • Draft scientific papers on the seasonal abundance and distribution of carob moth in Australian almond orchards and the timing of carob moth oviposition and its relationship to kernel damage. • Revised factsheets/guidelines on carob moth and its seasonal behaviour on almonds; using pheromone traps to monitor carob moth in almond orchards; and management of carob moth in almonds stored in stockpiles prior to processing. • A degree-day calculator and predictive model for key carob moth life events. • A report on the impacts that pesticides used against carob moth have on beneficial invertebrates in the orchard. • A report on the assessment of mating disruption for carob moth in almonds. • Recommendations for industry regarding the use and timing of pesticides for carob moth management. • A chapter on carob moth management for an industry Integrated Pest Management (IPM) manual. • A factsheet on carob moth identification and monitoring. • Grower and service provider workshops on carob moth monitoring and management. • Conference presentations on project findings. • Milestone reports, a draft and final report consistent with Hort Innovation requirements.
Outcomes	The outcomes delivered by AL12004 included: • Knowledge that insecticide application reduces carob moth damage but is not cost-effective in all seasons. The timing and application rate for insecticide needs further research for Australian conditions. • Pheromone-based mating disruption has potential for carob moth control. However, more work is required on the efficiency and cost effectiveness of this approach. • The correlation between mummified nuts and carob moth activity/damage highlights the need to maximise mummy removal during hygiene activities. • Protection from carob moth is required for the whole period from hull split to harvest and this is beyond the scope of a single insecticide application. Anything industry can do to reduce the gap between hull split and harvest will decrease the impact of carob moth damage. • Overall outcome: progress toward an effective non-chemical control for carob moth with reductions in damage related profit loss.
Impacts (potential)	• Economic – increase in grower profit associated with improved kernel yield and quality from adoption of an effective non-chemical, carob moth control. • Economic – increase in processor profitability/flexibility with additional ability to supply high value whole nuts as well as meal markets. • Environmental – increased ability to run effective no/low chemical IPM programs with less need to apply insecticides to control carob moth. • Social – less risk of fungal/aflatoxin contamination of almonds with subsequent health risks and loss of the industry's wholesome credentials. • Social – less OH&S risk with orchard workers using fewer chemical agents. • Capacity – researchers with an improved understanding of the phenology and management of the carob moth. • Capacity – growers with an improved understanding of carob moth control. • Social - contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project AL12004 by Hort Innovation, the Almond Board of Australia (ABA), and almond grower Olam Orchards Australia.

Table 3: Annual Investment in Project AL12004 (nominal $)

Year ended 30 June	Hort Innovation ($)	ABA ($)	Olam Orchards ($)	TOTAL ($)
2013	80,000	56,813	9,000	145,813
2014	174,000	36,052	12,000	222,052
2015	164,836	44,213	14,983	224,032
Total	**418,836**	**137,078**	**35,983**	**591,897**

Source: AL12004 Revised Schedule

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 purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). No additional extension costs are envisaged. Post this project industry investment has refocussed on kernel damage caused by carpophilus beetle, sealed nut varieties that prevent pest access and getting nuts out of the orchard before insect damage can occur.

Impacts

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

Table 4: Triple Bottom Line Categories of Principal Impacts from Project AL12004

Economic	• Increase in grower profit associated with improved kernel yield and quality from adoption of an effective non-chemical, carob moth control. • Increase in processor profitability/flexibility with additional ability to supply high value whole nuts as well as meal markets.
Environmental	• Increased ability to run effective no/low chemical IPM programs with less need to apply insecticides to control carob moth.
Social	• Less risk of fungal/aflatoxin contamination of almonds with subsequent health risks and loss of the industry's wholesome credentials. • Less OH&S risk with orchard workers using fewer chemical agents. • Researchers with an improved understanding of the phenology and management of the carob moth. • Growers with an improved understanding of carob moth control. • Contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

Public versus Private Impacts

The impacts identified from the investment are predominantly private impacts accruing to almond growers and to a lesser extent almond processors i.e. additional profit associated with reduced carob moth damage. However, a number of public benefits have also been produced including the potential for improved environmental outcomes with less chemical application, improved consumer health and worker safety, capacity building, and spill-over benefits to regional communities.

Distribution of Private Impacts

The private impacts (additional profit) will be distributed between growers, processors, and the balance of the supply chain. The share of impact realised by each link in the supply chain will depend on both short- and long-

term supply and demand elasticities in the almond market.

Impacts on Other Australian Industries

Carob moth is a pest of economic importance to a range of Australian plant industries including apple, citrus, carob, date, fig, and pomegranate. Progress toward more effective carob moth controls that do not require chemical sprays may also be relevant to these industries.

Impacts Overseas

Technologies developed may have relevance to both overseas almond industries and other overseas tree crop industries impacted by carob moth. With this said, it is noted that carob moth impacts the California date industry but not the California almond industry which is physically separated from date production.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project outcomes and related impacts will contribute to Rural RD&E Priority 2 and Science and Research Priority 1 and 8.

Table 5: Australian Government Research Priorities

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

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

Alignment with the Almond Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the almond industry are outlined in the Almond Industry's Strategic Investment Plan 2017-2021[1] (Hort Innovation, 2017). Project AL12004 addressed Outcome 1, (reduce damage caused by pests and diseases), Strategy 1 (reduce damge caused by pests with a key focus on carob moth and carpophilus beetle).

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 valued was additional grower profit with effective non-chemical carob moth control.

Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. Those not valued included:

- Increase in processor profitability/flexibility with additional ability to supply high value whole nuts as well as meal markets.
- Increased ability to run effective no/low chemical IPM programs with less need to apply insecticides to

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

control carob moth.

- Less risk of fungal/aflatoxin contamination of almonds with subsequent health risks and loss of the industry's wholesome credentials.
- Less OH&S risk with orchard workers using fewer chemical agents.
- Researchers with an improved understanding of the phenology and management of the carob moth.
- Growers with an improved understanding of carob moth control.
- Contribution to improved regional community wellbeing in almond growing areas from spill-over benefits as a result of a sustainable, profitable almond industry.

These impacts were not valued due to lack of data to support credible assumptions.

Valuation of Impact 1: Additional grower profit with effective non-chemical carob moth control

The AL12004 investment contributed to the development of a non-chemical, pheromone-based control for carob moth. If effective carob moth control can be realised using this technology, there will be an increase in grower profit. The increase in grower profit will be associated with improved saleable kernel yield and quality. The benefit will be applicable to growers of the Nonpareil variety which constitutes approximately 46% of the Australian almond industry's total production area.

Attribution

An effective carob moth control using pheromone-based mating disruptors will owe its success to technology developed in the California date industry, investment in AL12004 and subsequent research to refine the technique for Australian almond growing conditions. For these reasons, an attribution estimate of 50% has been assumed for AL12004.

Counterfactual

If project AL12004 had not been funded, it is assumed that ABA and Olam Orchards Australia would have supported a similar project – carob moth was a significant production issue that required an effective solution. Consequently, a 50% counterfactual has been applied.

Summary of Assumptions

A summary of the key assumptions is provided in Table 6.

Table 6: Summary of Assumptions for Impact Valuation

Variable	Assumption	Source/Comment
Impact 1: Additional grower profit with effective non-chemical carob moth control		
Area of the Nonpareil almond variety – the variety most susceptible to carob moth.	27,740 ha	Total production area of 45,089 ha of which Nonpareil accounts for 46% (ABA 2020).
Reduction in kernel damage and increase in profit attributable to effective non-chemical, pheromone-based, carob moth control.	1%	Analyst assumption consistent with the *ex-ante* benefit cost analysis of AL12004 completed by Hort Innovation and data collected as part of AL12004.
Profit on almond production – without AL12004.	$11,360/ha	Gross receipts of $25,000/ha (Australian Nut Industry Council, undated) less production costs of $13,640 (adapted from Waycott, 2011).
Year of first impact.	2019/20	Five years after AL12004 completion to allow for additional research required to deliver an effective pheromone-based control.
Year of maximum impact.	2022/23	Three years after initial adoption.
Level of first adoption.	13%	VIC DPI data presented in the ex-ante benefit cost analysis of AL12004 completed by Hort Innovation.
Level of maximum adoption.	51%	VIC DPI data presented in the ex-ante benefit cost analysis of AL12004 completed by Hort Innovation.

Probability of outputs.	70%	Analyst assumption – further research required on pheromone-based control before a cost-effective carob moth control can be delivered.
Probability of outcomes.	80%	Analyst assumption – there is some risk of a loss of focus on carob moth damage with an increasing importance of other nut quality measures – carpophilus beetle control, removal of mummies, early harvest, etc..
Probability of impact.	60%	Analyst assumption – there is some risk that pheromone-based control measures will not be adopted.
Attribution	50%	See above.
Counterfactual.	50%	See above.

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 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 Hort Innovation investment, respectively. The present value of benefits (PVB) attributable to Hort Innovation investment only, shown in Table 8, has been estimated by multiplying the total PVB by the Hort Innovation proportion of real investment (74%).

Table 7: Investment Criteria for Total Investment in Project AL12004

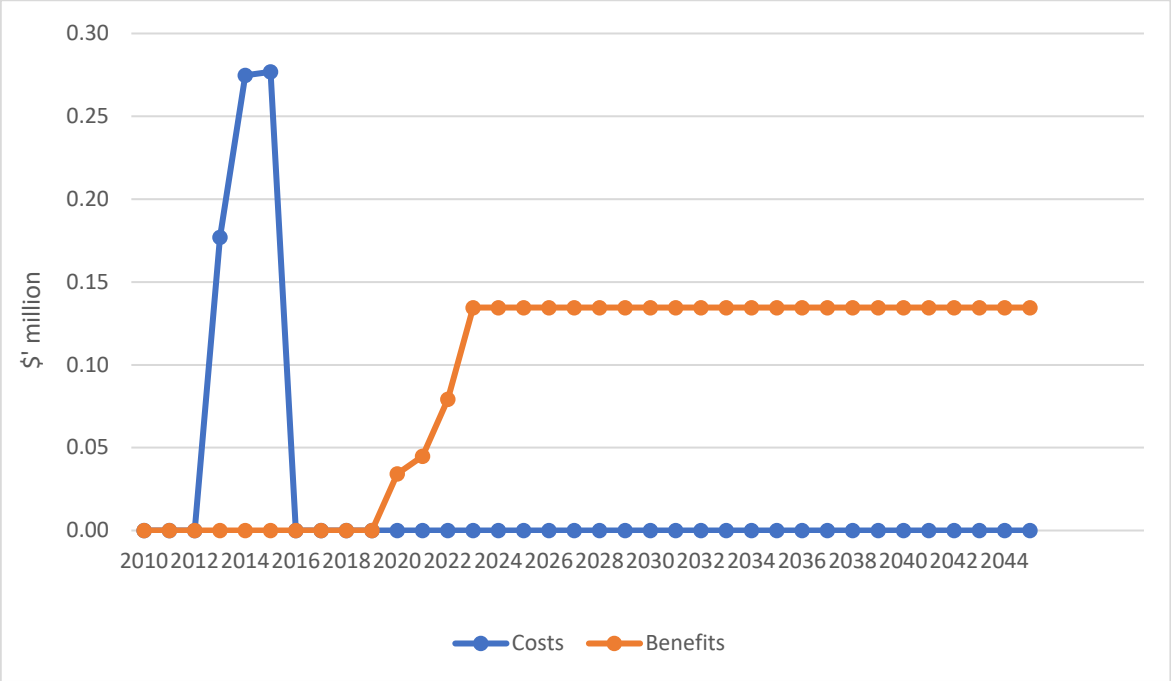
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.03	0.48	0.94	1.30	1.58	1.80
Present Value of Costs ($m)	0.97	0.97	0.97	0.97	0.97	0.97	0.97
Net Present Value ($m)	-0.97	-0.94	-0.49	-0.03	0.32	0.61	0.82
Benefit-Cost Ratio	0.00	0.04	0.50	0.97	1.33	1.62	1.85
Internal Rate of Return (%)	negative	negative	-8.3	2.8	6.4	8.0	8.8
MIRR (%)	negative	negative	-5.6	3.5	5.8	6.6	6.8

Table 8: Investment Criteria for Hort Innovation Investment in Project AL12004

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.03	0.35	0.69	0.96	1.16	1.32
Present Value of Costs ($m)	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Net Present Value ($m)	-0.71	-0.69	-0.36	-0.02	0.24	0.45	0.61
Benefit-Cost Ratio	0.00	0.04	0.50	0.97	1.34	1.63	1.86
Internal Rate of Return (%)	negative	negative	-8.2	2.8	6.5	8.0	8.8
MIRR (%)	negative	negative	-5.5	3.6	5.9	6.6	6.8

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the AL12004 investment plus 30 years from the last year of investment are shown in Figure 1.

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



Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 9 presents the results. The results show sensitivity to the discount rate. At a 10% discount rate, project costs exceed project benefits.

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

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present Value of Benefits ($m)	3.25	1.80	1.13
Present Value of Costs ($m)	0.73	0.97	1.28
Net Present Value ($m)	2.52	0.82	-0.15
Benefit-cost ratio	4.47	1.85	0.88

A sensitivity analysis was then undertaken on the assumed increase in profit attributable to effective carob moth control using pheromone-based mating disruption. Results are provided in Table 10. If the increase in profit is reduced from 1% to 0.5%, the project fails to 'breakeven'.

Table 10: Sensitivity to Increase in Profit with Carob Moth Control
(Total investment, 30 years)

Investment Criteria	**Increase in Profit with Carob Moth Control**		
	0.5%	**1% (base)**	**1.5%**
Present Value of Benefits ($m)	0.90	1.80	2.69
Present Value of Costs ($m)	0.97	0.97	0.97
Net Present Value ($m)	-0.07	0.82	1.72
Benefit-cost ratio	0.92	1.85	2.77

A final sensitivity test examined the share of Nonpareil growing area adopting pheromone-based mating disruption as a control for carob moth (Table 11). The project breaks even if 28% of the Nonpareil growing area adopts pheromone-based carob moth control.

Table 11: Sensitivity to Adoption Rate for Pheromone-based Carob Moth Control
(Total investment, 30 years)

Investment Criteria	Maximum Share of Nonpareil Adopting Carob Moth Control		
	25.5%	28%	51% (base)
Present Value of Benefits ($m)	0.90	0.98	1.80
Present Value of Costs ($m)	0.97	0.97	0.97
Net Present Value ($m)	-0.07	0.00	0.82
Benefit-cost ratio	0.92	1.00	1.85

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	Medium

Coverage of benefits valued was assessed as Medium – while the major benefit was valued, secondary benefits including benefits to processors, the environment and community were not. Confidence in assumptions was rated as Medium, some key assumptions were made by the analyst.

Conclusion

The investment in AL12004 has delivered a sound understanding of carob moth as a pest of Australian almonds and made serious progress with development of a non-chemical, pheromone-based control. Results have been communicated to industry. Since completion of AL12004, other sources of kernel damage have been identified as priorities for almond industry research.

Total funding from all sources for the project was $0.97 million (present value terms). The investment produced estimated total expected benefits of $1.80 million (present value terms). This gave a net present value of $0.82 million, an estimated benefit-cost ratio of 1.85 to 1, an internal rate of return of 8.8% and a modified internal rate of return of 6.8%. A 10% discount rate, a 0.5% increase in net profit and an adoption rate of less than 28% of Nonpareil growing area all result in a failure of the project to 'breakeven'.

However, as a number of the identified impacts were not valued, 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

ABA	Almond Board of Australia
AL	Almond
BA	Banana
CRRDC	Council of Research and Development Corporations
CT	Citrus
DAWR	Department of Agriculture and Water Resources (Australian Government)
DPI	Department of Primary Industries (Victoria)
EOI	Expression of Interest
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GVP	Gross Value of Production
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
OCS	Office of Chief Scientist Queensland
OH&S	Occupational Health and Safety
PVB	Present Value of Benefits
RD&E	Research, Development and Extension
RIRDC	Rural Industries Research and Development Corporation (now AgriFutures Australia)
VN	Onion