Hort Innovation

Final Report

Industry-specific impact assessment program: Mango

Impact assessment report for project *Manipulating mango flowering to extend harvest window* (MG12012)

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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 *MG12012: Manipulating Mango Flowering to Extend Harvest Window.* The project was funded by Hort Innovation over the period March 2013 to May 2017.

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 2020/21 dollar terms and were discounted to the year 2020/21 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

Investment in MG12012 has delivered knowledge on why some current early season treatments work, how and when they should be applied. Correctly applied treatments are able to deliver profitable outcomes for growers on a consistent basis.

Investment Criteria

Total funding from all sources for the project was $4.42 million (present value terms). The investment produced estimated total expected benefits of $17.43 million (present value terms). This gave a net present value of $13.0 million, an estimated benefit-cost ratio of 4 to 1, an internal rate of return of 19.1% and a modified internal rate of return of 9.3%.

Conclusions

The Hort Innovation investment in Project MG12012 has delivered knowledge relating to technologies able to generate high value early-season mangoes for Northern Territory growers. Adoption of this technology will help spread the harvest window and reduce costs associated with harvest and packing bottlenecks. As five economic and social impacts identified were not valued, the investment criteria estimated by the evaluation may be underestimates of the actual performance of the investment.

Keywords

Impact assessment, cost-benefit analysis, flower manipulation; mango; Northern Territory; ethephon; paclobutrazol; climate; flower induction.

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 relevant 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 berry (RB + BS), mango (MG), turf (TU) and nursery (NY) RD&E investment funds.

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

- Four RB + BS projects were chosen worth $1.44 million (nominal Hort Innovation investment) from an overall population of 16 projects worth an estimated $8.59 million,
- Three MG projects worth $1.77 million (nominal Hort Innovation investment) from an overall population of 16 projects worth approximately $7.9 million,
- Four TU projects worth $0.66 million (nominal Hort Innovation investment) from a total population of 15 projects worth $4.81 million, and
- Three NY projects worth $0.96 million (nominal Hort Innovation investment) from an overall population of 19 projects worth $7.32 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2015 to 30 June 2020.

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 where possible given the small sample sizes.

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 mango industry has a five-year average production volume of 70,706 tonnes and a Farmgate Value of $188.9 million – Table 1.

Table 1: Mango Industry Performance 2016-2020

Year Ended 30 June	Producing Trees (000 trees)	Production (t)	Gross Value of Production ($m)	Farmgate Value ($m)
2016	1,217	61,800	210.3	199.8
2017	1,178	61,474	195.7	185.9
2018	1,262	83,314	204.3	194.1
2019	N/a	74,920	198.6	188.7
2020	N/a	72,022	185.2	175.9
Average	N/a	70,706	198.8	188.9

Source: Australian Horticulture Statistics Handbook 2017/18, 2018/19 and 2019/20.

Mangoes are a tropical fruit crop grown in the Northern Territory (NT) (51% of production), Queensland (QLD) (45%), Western Australia (WA) (3%) and New South Wales (NSW) (1%). Australian mango production is dominated by four main varieties – Kensington Pride, Calypso, R2E2, and Honey Gold. Other mangoes, such as Keitt, Tommy Atkins, Palmer, and Nam Dok Mai make a minor contribution to total production (Australian Horticulture Statistics Handbook 2019/20).

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

The recently completed SIP has been driven by levy payers and addressed the Australian mango industry's needs from 2017 to 2021. The SIP focussed on four outcome areas:

- Increased industry productivity through increased yields and reduced costs per hectare.
- Increased grower profitability through increased consumer demand for Australian mangoes.
- Increased R&D and extension capacity and resources supporting industry development.
- Improved industry sustainability and management of risks.

Rationale

At the commencement of this project, the Australian mango supply period started in late August in Darwin and ended in late January with fruit from NSW or WA. However, within each individual region or property, the harvest window may have only extended from five to seven weeks.

As enterprises and production develop within a region, the capacity to process and move significant volumes of fruit, whilst maintaining tight control on fruit quality, becomes increasingly taxing on management and logistics. While this is particularly true for larger orchards moving toward export, fruit losses are experienced across all regions, all growers, and all mango varieties. As newer, higher yielding varieties are introduced and younger trees mature, this scenario will be further exacerbated. Additionally, if the industry is to move to mechanisation of the harvesting process, technologies to spread the harvest window, and thereby manage the cost of mechanisation, will be critical.

This project is a component of a larger program to develop management options to manipulate the mango harvest window.

Within this specific project, studies focussed on how plant growth regulators, synthetic or natural, but especially gibberellic acid inhibitors, can retard vegetative growth and alternative products can

stimulate floral induction. These treatments were evaluated on a range of rootstocks as well as the vegetative and floral components of the plant. Climatic factors and agronomic factors were also assessed.

The project's focus was on the NT, especially outer Darwin, but eventually it is hoped that its findings will be applicable to all Australian mango growing regions.

When other research projects are complete, options in combination with crop forecasting and analysis of past orchard trends, will allow growers to target harvest windows around peaks in their production, meet specific market opportunities and achieve more efficient use of farm and packhouse resources.

Project Details

Summary

Project Code: MG12012

Title: Manipulating mango flowering to extend harvest window

Research Organisation: Department of Primary Industries & Fisheries, NT

Project Leader: Cameron McConchie and Lucy Tran-Nguyen

Period of Funding: March 2013 to May 2017

Objectives

The objective of the project was to use molecular tools to understand the modes of action of the various synthetic promotors and critical factors influencing performance, then through pot trials and field experiments to demonstrate how to consistently manipulate fruit maturity. The outcomes of this research will initially focus on the NT but will be conveyed to the broader mango industry through extension material, workshops, and conference presentations.

Specific project aims were:

- Assist growers to spread the harvest window on a property, and efficiently use picking staff and packhouse facilities.
- Facilitate the development of exports markets by extending the time fruit is available.
- Potentially reduce the supply peak during the middle and later part of the season, increasing wholesale prices.
- Reduce the risk caused by packing shed / supply chain breakdown by spreading the harvest over a longer interval.

Logical Framework

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

Table 2: Logical Framework for Project MG12012

Activities	• Work with the Bureau of Meteorology to review data and correlate changes in climatic conditions with mango flowering. Project investigated linkages to the Madden-Julian Oscillation and low night temperature. • Investigation of the plant growth regulator Ethephon to determine whether it could be used to remove immature vegetation flush that would otherwise have inhibited flower induction. Ethephon was tested at multiple application rates with a view to having the chemical registered in Australia for use on mangoes. • Investigation of effective and environmentally sustainable alternatives to soil applied paclobutrazol e.g., gibberellin synthesis inhibitors such as prohexidione calcium. NT mango growers almost universally use paclobutrazol to increase yield and deliver higher

	priced, earlier maturing fruit. Anecdotal evidence is that paclobutrazol was being used in parts of the NT at higher, non-registered, rates. Overseas studies indicate that paclobutrazol may have negative environmental effects. • Testing of the effectiveness of potassium nitrate in stimulating mango flowering. Potassium nitrate was tested at higher concentrations (4%) than used in previous research and its success was measured against changes in climate, age and the nutritional status of the tree and the physiological and temporal timing of application. • Other compounds shown to offer potential to induce early mango fruit production were also tested including thiourea (used successfully on pears and grapes), and thidiazuron. • In addition to the use of chemical treatments to remove immature flush and reset flushing patterns, mechanical pruning was investigated. By careful monitoring of regrowth and concurrent temperatures, precise temperature lower and upper limits for floral induction were defined for two commercial mango cultivars.
Outputs	• The project has increased researcher and industry knowledge in relation to climate and growth regulators on mango flowering and subsequent fruit production in the NT. • Precise knowledge on temperature requirements for flowering of NT mango cultivars. • Identification of industrial chemicals that are effective in promoting mango flowering. • An effective alternative to paclobutrazol that is rapidly metabolised, and biodegraded within 48 hours i.e., prohexidione calcium. • Identification of the relevant conditions under which both potassium nitrate and ethephon are effective in inducing flowering and early fruit production. • Data sets that may facilitate the registration of ethephon for use on mango trees. • Progress toward economically viable and sustainable techniques that allow manipulation of harvest time and increase early (August) first grade mango production in the NT. • Presentations at the AMIA national mango conference June 2013 and May 2015. • Presentation to the NT R&D mango workshop February 2014. • On farm demonstration of the ethephon/potassium nitrate trial June 2014. • Master class on mango flower manipulation, 11th international mango conference, Darwin September 2015. • Mango flower manipulation grower meeting July 2016. • Presentation to the 12th international mango conference Guangxi China July 2017. • Outcomes of the flower manipulation trial AMIA pre-harvest meetings Darwin and Katherine, August 2017. • Managing mango flowering and implications for growers AMIA national mango conference May 2017. • Acta Horticultureae journal article: Asis, CA, Alexander, T, Sarkhosh, A, Umar, M, and McConchie, C “Optimising foliar nitrogen uptake of mango: effect of adjuvant, leaf position and time of potassium nitrate spray”. • Paper in conference proceedings: 30th International Horticultural Congress, Istanbul August 2018. • A comprehensive final report for Hort Innovation.
Outcomes	The outcomes this project will contribute to include: • An understanding of why some current early season treatments work, how and when they should be applied. • NT growers more able to consistently meet market demand for early season mangoes. • Assistance to growers to spread the harvest window and increase the efficiency of picking staff and packhouse operations. • Facilitation of export market development by extending the time fruit is available. • Potentially reduce the supply peak during the middle and later part of the season, increasing average wholesale prices. • Reduce the risk caused by packing shed/supply chain breakdown by spreading the harvest over a longer interval.
Impacts (potential)	• Economic – Improved profitability for NT growers able to apply project findings, consistently deliver early season fruit, achieve production cost savings (harvesting labour and packhouse operation efficiencies) and realise additional early season price premiums.

	• Environmental – Additional understanding of Australian mango variety performance in a changing climate. • Environment – improved environmental outcomes with a potential shift from paclobutrazol to biodegradable prohexidione calcium. • Additional researcher skills in mango phenology with PhD students trained as part of the project. • Contribution to improved regional community wellbeing from spill-over income and employment benefits as a result of a more profitable and sustainable mango industry.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project MG12012 by Hort Innovation and others. Other funds were managed by the Department of Primary Industries & Fisheries (DPIF), NT.

Table 3: Annual Investment in Project MG12012 (nominal $)

Year ended 30 June	HORT INNOVATION ($)	DPIF, NT ($)	TOTAL ($)
2013	107,366	222,346	329,712
2014	131,523	444,693	576,216
2015	135,085	778,212	913,297
2016	144,664	444,693	589,357
2017	148,560	333,520	482,080
Total	**667,198**	**2,223,464**	**2,890,662**

Source: MG12012 Final Contract Variation, 18 May 2017.

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, the investment costs of all parties were expressed in 2020/21 dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2021). DPIF have communicated project findings to growers through industry conferences, field days, industry publications and relevant websites as part of the project and no additional extension costs were incurred.

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 MG12012

Economic	• Improved profitability for NT growers able to apply project findings, consistently deliver early season fruit, achieve production cost savings (harvesting labour and packhouse operation efficiencies) and realise additional early season price premiums.
Environmental	• Additional understanding of Australian mango variety performance in a changing climate. • Improved environmental outcomes with a potential shift from paclobutrazol to biodegradable prohexidione calcium.
Social	• Additional researcher skills in mango phenology with PhD students trained as part of the project. • Contribution to improved regional community wellbeing from spill-over income and employment benefits as a result of a more profitable and sustainable mango industry.

Public versus Private Impacts

The impacts identified from the investment are both private and public in nature. Private impacts accrue to mango growers (improved profitability for NT growers able to apply project findings, consistently deliver early season fruit, achieve cost savings and realise additional early season price premiums) as well as an additional understanding of Australian mango variety performance in a changing environment. Public impacts include improved environmental outcomes with a reduction in the use of paclobutrazol, additional researcher skills (training of PhD students) and potential spill-overs to regional communities from enhanced mango grower profit.

Distribution of Private Impacts

Private impacts will be distributed between growers, packers, wholesalers, retailers, and exporters depending on both short- and long-term supply and demand elasticities in the mango market.

Impacts on Other Australian Industries

Knowledge on effective interventions for early flowering/fruit production to capture out of season market premiums may be applicable to a range of Australian horticultural industries. In the same way that knowledge relating to thiourea use in pears and grapes was transferred to mango, knowledge of prohexidione calcium (replacement for paclobutrazol) may be transferred to other horticultural tree crops.

Impacts Overseas

Mangoes are grown in the tropics around the world and markets operate on the same principles paying more for early season fruit when supply is limited. The knowledge generated by this project, available through the scientific literature, will eventually be available to overseas mango growing industries.

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 1 and 3, and to Science and Research Priorities 1 and 2.

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 Mango Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the mango industry are outlined in the Mango Industry's Strategic Investment Plan 2017-2021[1] (Hort Innovation, 2017). Project MG12012 addressed outcome one ('increased industry productivity through increased yields and reduced costs per hectare).

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 improved profitability for NT growers able to consistently access higher priced early season markets and save production and packing costs.

Impacts Not Valued

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

- Additional understanding of Australian mango variety performance in a changing climate.
- Improved environmental outcomes with a potential shift from paclobutrazol to biodegradable prohexidione calcium.
- Additional researcher skills in mango phenology with PhD students trained as part of the project.
- Contribution to improved regional community wellbeing from spill-over income and employment benefits as a result of a more profitable and sustainable mango industry.

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

Summary of Assumptions

A summary of the key assumptions made for valuation of progress toward higher yielding and more profitable mango orchards is provided in Table 6.

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

Table 6: Summary of Assumptions for Impact Valuation

Variable	Assumption	Source/Comment
Mango trees in production in the NT.	622,000 trees	Based on 3-year average of total trees 2016-2018 (see Table 1) and NT accounting for 51% of production (Australian Horticulture Statistics Handbook 2019/20).
Share of NT trees routinely capturing additional profit (price premium/cost saving) as a result of MG12012.	30%	Australian Horticulture Statistics Handbook 2019/20 shows current NT supply window of 6 months with sales in both July and August.
Profit on mango production.	$19.50/tree/year	AgEconPlus 2019 prepared in consultation with Trevor Dunmall, long serving IDM at AMIA.
Increase in profit attributable to MG12012 findings.	50%	AgEconPlus assumption that allows for strong prices at the beginning of the season (July, August), as well as cost savings associated with labour use and packing shed cost savings. The cost of sprays (new vs old chemistry mixes) was assumed to remain the same.
Year of first impact.	2016/17	Project findings were communicated to growers prior to project completion. In the first year of adoption 30% of total production that will adopt project findings embrace the technology, second year 60% (2017/18), third year 90% (2018/19) and 100% of adoption occurs in 2019/20.
Attribution of impacts to this project.	80%	Prior to this project impacts were achieved on an inconsistent basis by NT growers.
Probability of the project generating useful outputs.	100%	Outputs have been delivered through research and communicated to industry.
Probability of valuable outcomes.	90%	There is some risk that chemical treatment options will not be adopted.
Probability of impact (assuming successful outcome)	90%	Increased yields are subject to market conditions.
Counterfactual.	80%	In the absence of MG12012 research, it is 20% likely that results would have been generated by another project.

Results

All costs and benefits were discounted to 2020/21 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 (2016/17) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

Table 7 and 8 show the investment criteria estimated for different periods of benefits 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 (25%).

Table 7: Investment Criteria for Total Investment in Project MG12012

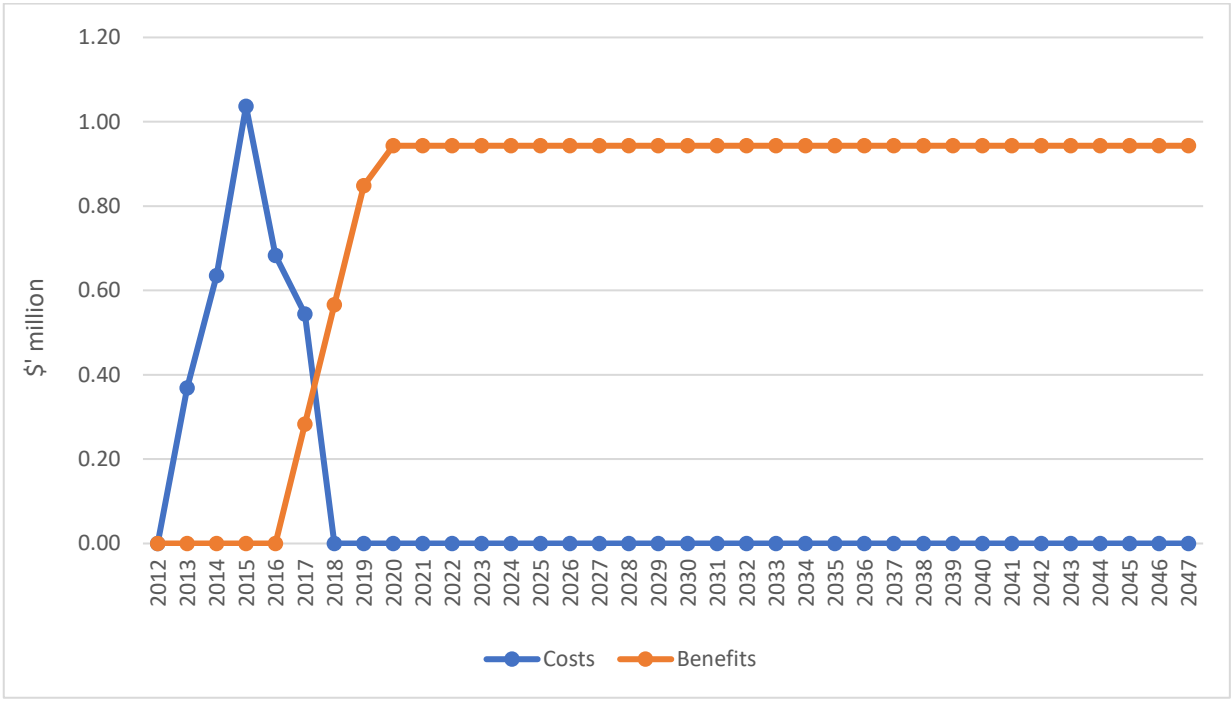
Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.34	4.77	8.66	11.70	14.09	15.96	17.43
Present Value of Costs ($m)	4.42	4.42	4.42	4.42	4.42	4.42	4.42
Net Present Value ($m)	-4.08	0.34	4.23	7.28	9.67	11.54	13.00
Benefit-Cost Ratio	0.08	1.08	1.96	2.65	3.19	3.61	3.94
Internal Rate of Return (%)	negative	2.5	14.8	17.7	18.7	19.0	19.1
MIRR (%)	negative	3.3	10.2	10.7	10.3	9.8	9.3

Table 8: Investment Criteria for Hort Innovation Investment in Project MG12012

Investment Criteria	Years after Last Year of Investment						
	0	5	10	15	20	25	30
Present Value of Benefits ($m)	0.09	1.23	2.24	3.02	3.64	4.12	4.50
Present Value of Costs ($m)	1.14	1.14	1.14	1.14	1.14	1.14	1.14
Net Present Value ($m)	-1.05	0.09	1.09	1.88	2.50	2.98	3.36
Benefit-Cost Ratio	0.08	1.08	1.96	2.65	3.19	3.61	3.94
Internal Rate of Return (%)	negative	2.9	15.2	18.1	19.0	19.4	19.5
MIRR (%)	negative	3.6	10.4	10.8	10.4	9.9	9.4

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the MG12012 investment plus 30 years from the last year of investment are shown in Figure 1[2].

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



[2] Assumptions used to assess the rate of adoption between 2016-2020 are described in Table 6.

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 are moderately sensitive to the discount rate.

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

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present Value of Benefits ($m)	28.11	17.43	12.82
Present Value of Costs ($m)	3.31	4.42	5.85
Net Present Value ($m)	24.79	13.00	6.97
Benefit-cost ratio	8.49	3.94	2.19

A sensitivity analysis was then undertaken for the share of NT mango production achieving a profit increase as a result of the project. Results are provided in Table 10. When assumed increase in profit is 7.5%, and all other factors remain unchanged, project benefits are approximately equal to project costs.

Table 10: Sensitivity to Share of NT Production Achieving Profit Increase After MG12012 (Total investment, 30 years)

Investment Criteria	**Share of NT Mango Production Achieving Profit Increase**		
	7.5%	**30% (base)**	**40%**
Present Value of Benefits ($m)	4.36	17.43	23.24
Present Value of Costs ($m)	4.42	4.42	4.42
Net Present Value ($m)	-0.07	13.00	18.81
Benefit-cost ratio	0.98	3.94	5.25

A final sensitivity analysis tested the increase in profit as a result of adopting MG12012 recommendations. The results (Table 11) show that assumed profit increase would need to fall to 12.5% before project benefits are approximately equal to project costs.

Table 11: Sensitivity to Increase in Profit for Trees Harvested Early After MG12012 (Total investment, 30 years)

Investment Criteria	**Increase in Profit**		
	12.5%	**50% (base)**	**75%**
Present Value of Benefits ($m)	4.36	17.43	26.14
Present Value of Costs ($m)	4.42	4.42	4.42
Net Present Value ($m)	-0.07	13.00	21.72
Benefit-cost ratio	0.98	3.94	5.91

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-Low

Coverage of benefits valued was assessed as Medium, while the key impact (additional grower profit) was valued other environmental and social benefits were not. Confidence in assumptions was rated as Medium-Low, key data was estimated by the analyst.

Conclusion

Investment in MG12012 has delivered knowledge on why some current early season treatments work, how and when they should be applied. Correctly applied treatments are able to deliver profitable outcomes for growers on a consistent basis.

Total funding from all sources for the project was $4.42 million (present value terms). The investment produced estimated total expected benefits of $17.43 million (present value terms). This gave a net present value of $13.0 million, an estimated benefit-cost ratio of 4 to 1, an internal rate of return of 19.1% and a modified internal rate of return of 9.3%.

As five economic and social impacts identified 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

AMIA	Australian Mango Industry Association
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
GDP	Gross Domestic Product
GVP	Gross Value of Production
IDM	Industry Development Manager
IRR	Internal Rate of Return
KP	Kensington Pride
MIRR	Modified Internal Rate of Return
NT	Northern Territory
OCS	Office of Chief Scientist Queensland
PVB	Present Value of Benefits
R&D	Research and Development
RD&E	Research, Development and Extension
SIP	Strategic Investment Plan