Horticulture Impact Assessment Program:

Appendix 10: Improved management options for cucumber green mottle mosaic virus (VG15013 Impact Assessment)

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Delivery partner:

AgEconPlus and Agtrans Research

Project code:

MT18011

Date:

19 August 2020

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Contents

Tables

Figures

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 *VG15013: Improved Management Options for Cucumber Green Mottle Mosaic Virus.* The project was funded by Hort Innovation over the period February 2016 to January 2019.

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

Investment in this research project has identified improved on-farm management practices for cucurbit growers that, when implemented, will result in a reduction in crop yield and income loss. CGMMV causes yield losses of more than 50% in watermelons and up to 16% in cucumbers (CABI Crop Protection Compendium, January2019; https://www.cabi.org/cpc/datasheet/16951).

Investment Criteria

Total funding from all sources for the project was $1.78 million (present value terms). The investment produced estimated total expected benefits of $7.36 million (present value terms). This gave a net present value of $5.58 million, an estimated benefit-cost ratio of 4.13 to 1, an internal rate of return of 17.7% and a MIRR of 9.7%.

Conclusions

The Hort Innovation investment in Project VG15013 has generated management practices which will reduce cucurbit yield losses caused by CGMMV. Several economic and social impacts identified were not valued as the impacts 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, Cucumber green mottle mosaic virus, management options, cucurbits, Tobamovirus, weeds, honey bees, non-hosts, seeds, on farm biosecurity, extension, in-field diagnostics

Introduction

Horticulture Innovation Australia Limited (Hort Innovation) required a series of impact assessments to be carried out annually on a number of investments in the Hort Innovation research, development and extension (RD&E) portfolio. The assessments were required to meet the following Hort Innovation evaluation reporting requirements:

- Reporting against the Hort Innovation's current Strategic Plan and the Evaluation Framework associated with Hort Innovation's Statutory Funding Agreement with the Commonwealth Government.
- Annual Reporting to Hort Innovation stakeholders.
- Reporting to the Council of Rural Research and Development Corporations (CRRDC).

Under impact assessment program MT18011, the first series of impact assessments were conducted in 2019 and included 15 randomly selected Hort Innovation RD&E investments (projects). The second series of impact assessments (current series), undertaken in 2020, also included 15 randomly selected projects worth a total of approximately $7.11 million (nominal Hort Innovation investment). The second series of projects were selected from an overall population of 85 Hort Innovation investments worth an estimated $44.64 million (nominal Hort Innovation investment) where a final deliverable had been submitted in the 2018/19 financial year.

The 15 investments were selected through a stratified, random sampling process such that investments chosen represented at least 10% of the total Hort Innovation RD&E investment in the overall population (in nominal terms) and was representative of the Hort Innovation investment across six, pre-defined project size classes.

Project *VG15013: Improved Management Options for Cucumber Green Mottle Mosaic Virus* was randomly selected as one of the 15 investments under MT18011 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

Background

Cucumber green mottle mosaic virus (CGMMV) is an economically important Tobamovirus that infects cucurbits. The virus can be spread through plant debris, soil, water, and seed. Contaminated seed allows CGMMV to be transmitted between countries.

Until 2014, CGMMV was exotic to Australia. In September2014, CGMMV was identified in the Katherine region, by February 2016, it was identified on twenty five cucurbit growing properties in the Northern Territory (Katherine, Central Australia, and Darwin). CGMMV has since been detected in Queensland (isolated areas only), South Australia and Western Australia (Perth, Geraldton, Carnarvon, and Kununurra, 2016). Northern Territory (NT) fruit that have tested positive to CGMMV include watermelon, butternut pumpkin, cucumber, and bitter melon (CGMMV National Management Plan, 2016 and VG15013 Final Report, 2019).

Watermelon plants infected with CGMMV can look bleached - the leaves having mosaic-like mottling and the plant may be stunted. Affected cucumber plants may also wilt and the runners, or the whole plant, may die prematurely. Symptoms can include fruit abortion, uneven ripening, internal yellowing, breakdown of the flesh, and possibly a dirty red discolouration of the flesh. Infection may also cause fruit malformation. The combined effects of CGMMV virus can cause substantial crop losses (https://nt.gov.au/industry/agriculture/food-crops-plants-and-quarantine/cucumber-green-mottle-mosaic-virus/about-cucumber-green-mottle-mosaic-virus).

CGMMV causes gross yield losses of more than 50% in watermelon. In cucumber gross yields are reduced by between 5-16% and fruit quality in the balance of the crop may be reduced (CABI Crop Protection Compendium, January2019; https://www.cabi.org/cpc/datasheet/16951).

Three year average production and value of Australian cucurbit crops is shown in Table 1.

Table 1: Australian Cucurbit Production and Value 2015/16 to 2017/18

Cucurbit Crop	Production (t)	Farmgate Value ($/t)	Total Farmgate Value ($)
Watermelon	164,320	396	65,070,720
Muskmelon	59,811	1,088	65,074,005
Cucumber	88,431	1,641	145,115,818
Pumpkin	118,673	547	64,914,131
Zucchini	37,880	1,707	64,661,160
Total	469,115		404,835,834

Source: data adapted from Horticulture Statistics Handbook 2017/18

The Australian cucurbit industry had approximate production of 469,000 tonnes and a farm gate value of $404.8 million in the three years ending 2017/18. The estimate does not include other cucurbit species such as squash and Asian melons for which Hort Innovation data was not available.

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

The current SIP has been driven by levy payers and addresses the Australian vegetable 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. Growth in the domestic market
2. Growth in export markets
3. Improved farm productivity
4. Increased levels of post-farmgate integration
5. Improved industry capabilities for adoption and innovation.

Rationale

A critical part of CGMMV management is identifying the possible sources of CGMMV reservoirs that could retain CGMMV and allow cucurbit reinfection to occur. These include susceptible weed hosts and, potentially, honey bees and apiaries. It is also important to identify non-hosts of CGMMV so that crops can be selected and grown on CGMMV infected land. Rapid and accurate CGMMV diagnostics are required so that growers can make informed management decisions. Information on CGMMV reservoirs, resistant crops, diagnosis, and farm management options needed to be communicated to growers with English as a second language.

Project Details

Summary

Project Code: VG15013

Title: *Improved Management Options for Cucumber Green Mottle Mosaic Virus*

Research Organisation: Northern Territory Department of Primary Industry and Resources (DPIR)

Project Leader: Lucy Tran-Nguyen

Period of Funding: February 2016 to January 2019

Objectives

Specific objectives of project VG15013 were:

1. Determine the importance of weeds, non-host plants and honey bees on CGMMV in disease epidemiology.
2. Examine the potential for in-field diagnostics to assist rapid detection of the virus on farms known/suspected to be infected with CGMMV.
3. Develop multilingual communication and extension materials to assist with management options for cucurbit growers including on-farm biosecurity protocols.

Logical Framework

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

Table 2: Logical Framework for Project VG15013

Activities	Major project activities included: • Identification of CGMMV weed hosts and non-hosts – weed species were surveyed at three NT sites, two QLD sites and two NSW sites. The project reviewed data from CGMMV research being undertaken in WA. Susceptibility/resistance to CGMMV was tested on weed species and crops using pot trials in bio-secure glasshouses. • Understanding CGMMV biology (persistence and viability) in contaminated soil – soil and plant debris was tested at five sites at three different time intervals to generate data on the effects of soil temperature and quality on the viability of CGMMV in host-free soils. • Improving CGMMV diagnostics for plant and seed material – the project built on seed testing systems developed by the Plant Breeding Cooperative Research Centre to ensure they are relevant to smaller NT cucurbit crops (luffa, bitter gourd and bottle gourd). A review of the genetic profiles of Australian and overseas CGMMV strains was completed to determine differences and develop appropriate field diagnostic tools. • Understanding the role of honey bees in CGMMV transmission and the persistence of CGMMV in honey bee hives– expand existing knowledge linking honey bees to the spread of CGMMV and virus persistence in the hive. Hives in the Katherine region were monitored over 18 months to determine whether CGMMV persists inside the hive or is reintroduced from the pollen of weed species. • Extension and (grower) capacity building – work with the NT Farmers Association to determine appropriate training and communication materials and extend these materials via industry partners (AUSVEG, Australian Melon Association), extension officers, agronomists, seed companies, and seedling growers. Project training and communication materials focussed on how to avoid CGMMV contamination and how to manage CGMMV if the farm is infected. Extension was delivered via face-to-face meetings, workshops, and industry events. Project material was hosted on relevant websites. Home gardeners, who have a role in observing and reporting possible CGMMV outbreaks, were targeted through the Darwin Royal Show and NT gardening events.

Outputs	The important outputs of the project included: • Knowledge of host weeds and alternative crops which are non-hosts of CGMMV. Host weeds included wild melon, wild luffa, Amaranth, pigweed, black nightshade, fat hen, wild gooseberry and sabi grass. Non host crops were sweet corn, snake bean, capsicum, okra, sorghum, and peanut. • Understanding of CGMMV persistence and viability in different soil types and temperatures. Direct sowing into infected land is superior to transplanting seedlings – transplanting causes root damage that facilitates CGMMV infection. • Understanding of the role honey bees play in CGMMV transmission and the persistence of CGMMV in bee hives. The CGMMV remains viable in adult bees, pollen and honey. A hive testing regime was developed for the virus. • Validated soil assay using CGMMV immunoprecipitation method that provides an indicator as to whether a section of land is or is not infected. • Validation of the usefulness of RT-RPA technology for improved in-field diagnostics and the development of better in-field and user friendly tools for industry. • Improved and validated seed testing for CGMMV to safeguard Australian industry from future CGMMV introductions. • Multilingual communication and extension materials in three languages (English, Vietnamese, and Khmer), that are currently in use by the Australian cucurbit industry. • Papers published in relevant scientific journals.
Outcomes	The outcomes driven by the project included: • Adoption of improved management practices that reduce crop losses incurred by cucurbit growers in the NT.
Impacts	• Economic – avoided loss of cucurbit yield due to improved CGMMV management. • Capacity – increased cucurbit grower skills in virus prevention and management. • Capacity – increased researcher skills in disease epidemiology and field diagnostic systems. • Social - contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yield and grower income.

Project Investment

Nominal Investment

Table 3 shows the annual investment made in Project VG15013 by Hort Innovation.

Table 3: Annual Investment in Project VG15013 (nominal $)

Year ended 30 June	HORT INNOVATION ($)	DEPARTMENT OF PRIMARY INDUSTRIES AND RESOURCES ($)	TOTAL ($)
2016	185,000	34,090	219,090
2017	360,844	66,492	427,336
2018	360,000	66,337	426,337
2019	241,285	44,461	285,746
Total	**1,147,129**	**211,380**	**1,358,509**

Source: VG15013 Executed Research Agreement

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 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 VG15013

Economic	• Avoided loss of cucurbit yield due to improved CGMMV management.
Environmental	• Nil
Social	• Increased cucurbit grower skills in virus prevention and management. • Increased researcher skills in disease epidemiology and field diagnostic systems. • Contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yield and grower income.

Public versus Private Impacts

The impacts identified from the investment are predominantly private impacts accruing to cucurbit growers. However, some public benefits also have been produced in the form of capacity built and spill-overs to regional communities from enhanced grower yield and income.

Distribution of Private Impacts

The private impacts will have been distributed between growers, agents, wholesalers, distributers, and vegetable retailers. 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 fresh vegetable market.

Impacts on Other Australian Industries

Recommendations from the project will be relevant to the management and testing of honey bee hives used to pollinate cucurbit crops.

Impacts Overseas

Scientific knowledge and crop management recommendations generated by the project will be relevant to cucurbit industries in other countries with an interest in preventing and managing CGMMV infections.

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 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 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 Vegetable Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the cucurbit industry are outlined in the Vegetable Industry's Strategic Investment Plan 2017-2021[1] (Hort Innovation, 2017). Project VG15013 primarily addressed Outcome 3, Strategy 3.3 'Protect the vegetable industry from both endemic and exotic pests and diseases that significantly impact the industry'.

[1] 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 avoided loss of cucurbit yield due to improved CGMMV management.

Impacts Not Valued

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

- Increased cucurbit grower skills in virus prevention and management.
- Increased researcher skills in disease epidemiology and field diagnostic systems.
- Contribution to improved regional community wellbeing from spill-over benefits as a result of increased crop yield and grower income.

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 avoided loss of cucurbit yield due to improved CGMMV management is provided in Table 6.

Table 6: Summary of Assumptions for Impact Valuation

Variable	Assumption	Source/Comment
Cucurbit production.	469,000 tonnes.	Three year average of watermelon, muskmelon, cucumber, pumpkin, and zucchini production sourced from Horticulture Statistics Handbook 2017/18.
Share of crop adopting project findings.	90%.	AgEconPlus estimate made after considering that improvement in profit is significant and the project was comprehensively communicated to growers in Khmer and Vietnamese.
Share of total cucurbit crop impacted by CGMMV in absence of the VG15013 project outputs.	1% in 2019/20 2.5% from 2024/25.	AgEconPlus estimate assuming that in the absence of project generated management options, the area impacted increases from 1% to 2.5% as the virus spreads into new production areas.
Loss in saleable plant yield in CGMMV affected crops.	35%	More than 50% in watermelon and 5-16% loss in cucumber (https://www.cabi.org/cpc/datasheet/16951)
Farmgate price of cucurbits.	$863/tonne	Weighted average of watermelon, muskmelon, cucumber, pumpkin, and zucchini farmgate values adapted from the Horticulture Statistics Handbook 2017/18.
Cost to growers of implementing improved CGMMV management practices.	$120/tonne	AgEconPlus estimate after considering total variable costs associated with cucurbit production (QLD Agbiz Tools, Rock Melon and Honeydew Gross Margins (https://www.publications.qld.gov.au/dataset/agbiz-tools-plants-fruits-and-nuts/resource/a9b1c091-fb77-4c76-9ab2-6390dbca8feb).
Farmgate value of increased yield	$743/tonne	$863/tonne less $120/tonne.
Attribution of impacts to this project.	50%	The project built on preliminary work conducted in the NT (NT Government invested $426,000 to investigate whether CGMMV remained viable in farm soil), current seed testing in Victoria and NSW

		and cucurbit research in WA.
Risk factors		
Probability of the project generating useful outputs that reduce CGMMV related crop loss.	100%	AgEconPlus – outputs have been communicated to growers.
Probability of impact (assuming successful outcome)	80%	AgEconPlus – there is some chance that growers will not successfully implement recommendations.
Counterfactual		
If Project VG15013 had not been funded there is a 50% chance that another source of funding or another research organisation would have completed the research.		
Proportion of benefits estimated that would have been delivered without Project VG15013.	50%	AgEconPlus.

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 (2018/19) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

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

Table 7: Investment Criteria for Total Investment in Project VG15013

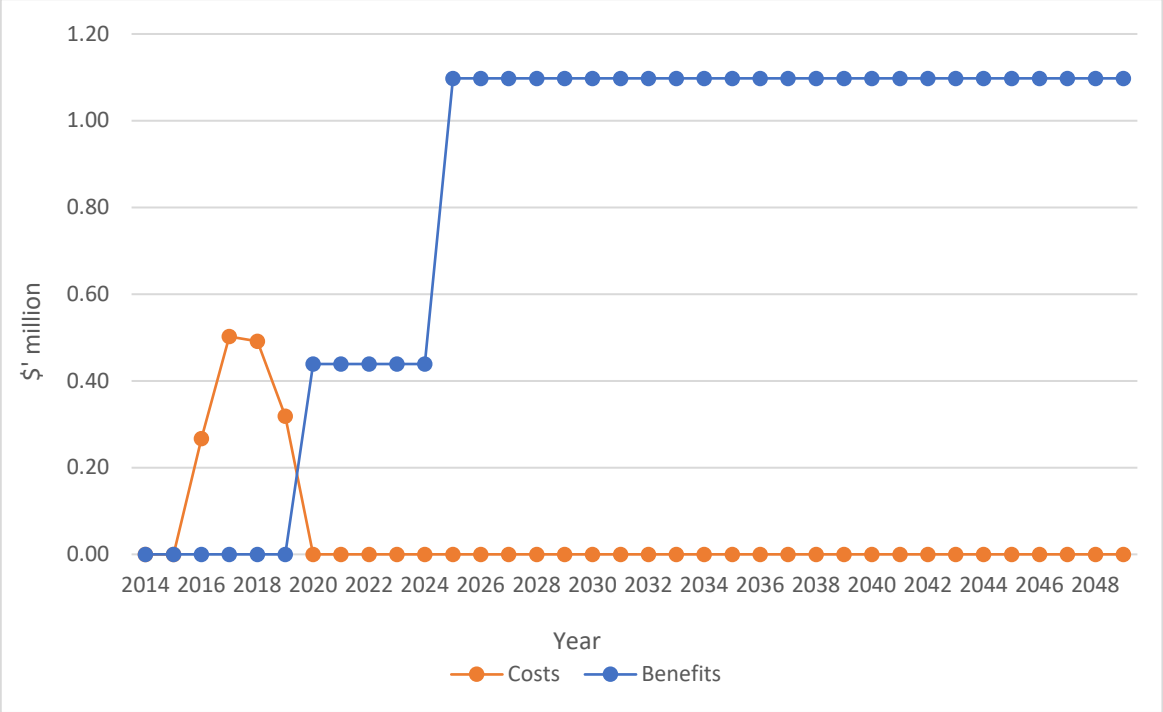
Investment Criteria	Years after Last Year of Investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	1.00	2.95	4.48	5.68	6.63	7.36
Present Value of Costs ($m)	1.78	1.78	1.78	1.78	1.78	1.78	1.78
Net Present Value ($m)	-1.78	-0.78	1.17	2.70	3.90	4.84	5.58
Benefit-Cost Ratio	0.00	0.56	1.66	2.52	3.19	3.72	4.13
Internal Rate of Return (%)	negative	negative	12.1	15.9	17.1	17.5	17.7
MIRR (%)	negative	negative	9.3	10.7	10.5	10.1	9.7

Table 8: Investment Criteria for Hort Innovation Investment in Project VG15013

Investment Criteria	Years after Last Year of Investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.00	0.86	2.53	3.85	4.88	5.69	6.32
Present Value of Costs ($m)	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Net Present Value ($m)	-1.53	-0.67	1.00	2.32	3.35	4.16	4.79
Benefit-Cost Ratio	0.00	0.56	1.66	2.52	3.19	3.72	4.13
Internal Rate of Return (%)	negative	negative	12.1	15.9	17.1	17.5	17.7
MIRR (%)	negative	negative	9.3	10.7	10.5	10.1	9.7

The annual undiscounted benefit and cost cash flows for the total investment for the duration of the VG15013 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 a moderate sensitivity 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 ($m)	14.82	7.36	4.32
Present Value of Costs ($m)	1.58	1.78	2.01
Net Present Value ($m)	13.24	5.58	2.31
Benefit-cost ratio	9.38	4.13	2.15

A sensitivity analysis was then undertaken for the share of cucurbit crop impacted by CGMMV in the absence of VG15013. Results are provided in Table 10. Even when share of crop impacted is halved, and given all other assumptions remaining unchanged, the project returns a favourable benefit cost ratio.

Table 10: Sensitivity to Share of Cucurbit Crop Impacted by CGMMV in Absence of VG15013 (Total investment, 30 years)

Investment Criteria	**Share of Australian Cucurbit Crop Impacted CGMMV**		
	0.5% increasing to 1.25% after 2024/25	**1% increasing to 2.5% after 2024/25**	**2% increasing to 5% after 2024/25**
Present Value of Benefits ($m)	3.68	7.36	14.72
Present Value of Costs ($m)	1.78	1.78	1.78
Net Present Value ($m)	1.90	5.58	12.94
Benefit-cost ratio	2.06	4.13	8.26

A final sensitivity analysis tested the sensitivity of the investment criteria to the loss of yield avoided in CGMMV affected cucurbit crops. The results (Table 11) show that even if yield loss avoided in CGMMV affected crops was as low as 8.5%, the project investment would breakeven.

Table 11: Sensitivity to Yield Loss Avoided in CGMMV Affected Crops (Total investment, 30 years)

Investment Criteria	Yield Loss Avoided		
	8.5%	20%	35% (base)
Present Value of Benefits ($m)	1.79	4.21	7.36
Present Value of Costs ($m)	1.78	1.78	1.78
Net Present Value ($m)	0.00	2.42	5.58
Benefit-cost ratio	1.00	2.36	4.13

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
High	Medium

Coverage of benefits valued was assessed as High as the key impact – avoided loss of cucurbit yield due to improved CGMMV management was valued. Confidence in assumptions was rated as Medium, most data used came from credible sources.

Conclusion

The investment in VG15013 has identified improved on-farm management practices for cucurbit growers that, when implemented, will result in a reduction of crop yield and income loss.

Total funding from all sources for the project was $1.78 million (present value terms). The investment produced estimated total expected benefits of $7.36 million (present value terms). This gave a net present value of $5.58 million, an estimated benefit-cost ratio of 4.13 to 1, an internal rate of return of 17.7% and a modified internal rate of return of 9.7%.

As several 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

CGMMV	Cucumber Green Mottle Mosaic Virus
CRRDC	Council of Research and Development Corporations
DAWR	Department of Agriculture and Water Resources (Australian Government)
DPIR	Department of Primary Industries and Resources (NT Government)
GDP	Gross Domestic Product
GVP	Gross Value of Production
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
NT	Northern Territory
OCS	Office of Chief Scientist Queensland
PVB	Present Value of Benefits
RD&E	Research, Development and Extension