Impact assessment of the investment:

Understanding and managing the role of honey bees in CGMMV epidemiology (VM18008)

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Hort Innovation

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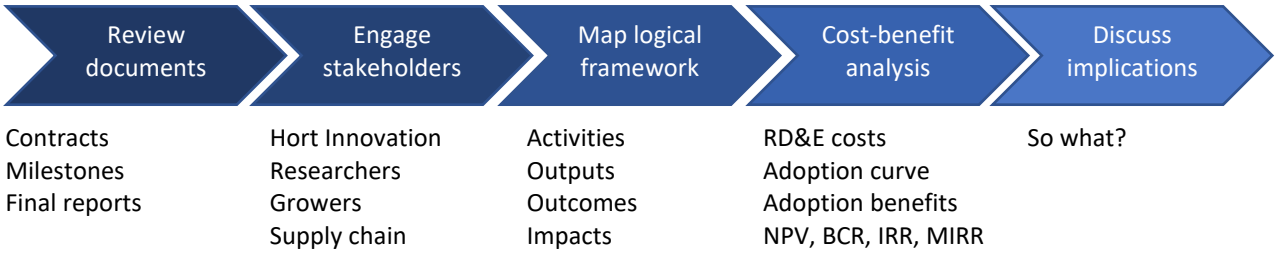
Executive summary

What the report is about

Ag Econ conducted independent analysis determine the economic, social, and environmental impact resulting from delivery of the melon project *Understanding and managing the role of honey bees in CGMMV epidemiology (VM18008)*. The project was funded by Hort Innovation over the period July 2019 to September 2022 using the melon research and development levy and contributions from the Australian Government. The project was delivered by the Northern Territory Department of Industry, Tourism & Trade.

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



Research background

VM18008 sought to understand the mechanisms by which honey bees can introduce Cucumber Green Mottle Mosaic Virus (CGMMV) to healthy cucurbit plants. While previous work through VG15013 had demonstrated that honey bees can carry CGMMV, the extent by which the virus could be spread through their activity was unclear. Given that cucurbit plants are reliant on pollination for fruit set, understanding the role of honey bees as a vector for the virus carries potentially significant management implications for both growers and apiarists. Through laboratory and field trials completed over the three year project period, the research was able to confirm the mechanism by which honey bees can spread CGMMV and the associated window where virus transmission could occur.

Key findings

The nominal investment cost of $0.65 million was adjusted for inflation (ABS, 2024) and discounted (using a 5% real discount rate) to a 2023-24 present value (PV) of costs equal to $0.89 million.

The analysis conducted a detailed evaluation of the VM18008 impact pathway through a logical framework. From this process, economic and social impacts were identified as being realised the projects findings supporting the removal of regulatory restrictions around hive movements in association with cucurbit properties. This outcome was modelled to result in reduced pollination costs for growers of melon and vegetable cucurbit (pumpkin, cucumber, zucchini) crops in the growing regions that had been impacted by regulations (NT and QLD).

A review of available data and discussions with stakeholders identified sufficient data to model the farm level benefits of reduced pollination costs.

This generated total PV benefits of $4.32 million, with a benefit cost ratio (BCR) of 4.86:1. Given the relationship between VM18008 with preceding (VG15013) RD&E the analysis took a program approach that estimated the total benefits from the program, and apportioned these to individual investments based on their cost share.

Reflecting the uncertainty for many variables, sensitivity testing showed a wide potential impact (BCR) range of between 0.76:1 and 19.87:1. The sensitivity testing also showed that 99% of the model simulations had a BCR greater than 1:1 (i.e. a positive impact), giving a high level of confidence that the VM18008 investment will generate a positive impact off the farm level benefits alone.

Despite the clear impact pathway for farm level benefits of avoided yield losses from restricted access to managed pollination services in QLD and NT cucurbit production, there was insufficient data identified to confidently quantify the benefits. Improved data relating to these benefits, as outlined in this analysis, would support an estimate of benefit and likely further increase the RD&E impact quantified in this analysis.

The key findings of the VM18008 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, melon, vegetable, cucurbit, Cucumber Green Mottle Mosaic Virus (CGMMV), honey bee, pollination, biosecurity, disease management

Figure 1. Summary of impact assessment findings

VM18008 Honey bee CGMMV spread

RD&E activities

Outcomes

Impacts

Total RD&E costs:

- $0.65 million (nominal value).
- 73% R&D levy and Government matching, and 27% NT DITT in-kind.

Research activities:

- Field surveillance and testing for CGMMV.
- Deliver honey bee CGMMV transmission and viability trials, focusing on correlating species of plant pollen with CGMMV presence to infer the role of alternative hosts in providing CGMMV inoculum
- Investigate alternative mosaic virus transmission pathways.

Extension activities:

- 4 x industry fact sheets.
- 18 x communication articles.
- 2 x industry-focused webinars.
- 5 x scientific conference presentations.
- 3 x public information display.

Outcomes:

- Increased knowledge of the mechanisms by which honey bees can spread CGMMV into melon plants, informing grower practices and government regulation regarding managed pollination and CGMMV.

Industry adoption:

- Low risk of CGMMV transmission from honey bee resulted in limited capacity to change existing grower practices regarding managed pollination.
- Evidence informed adjustment to regulation in key melon producing jurisdictions facilitating increase grower access to pollination services in context of broader CGMMV management.

Industry economic impacts:

- Reduced pollination costs for cucurbit growers through improved access to managed pollination services.
- Avoided yield losses from restricted access to managed pollination services.

Social impacts:

- Avoided loss of melon and cucurbit vegetable production, and associated consumption declines.
- Avoided loss of industry spillovers that would result from a decline in the melon and vegetable industry.

Total attributable benefits and impact:

- Present value (PV @ 5% discount) RD&E costs of $0.89 million.
- PV estimated benefits of $4.32 million between 2023 and 2027.
- Net PV (NPV) of $3.43 million.
- Benefit cost Ratio (BCR) of 4.86:1 with a 90% confidence of a BCR between 1.94:1 and 11.98:1.

Introduction

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

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

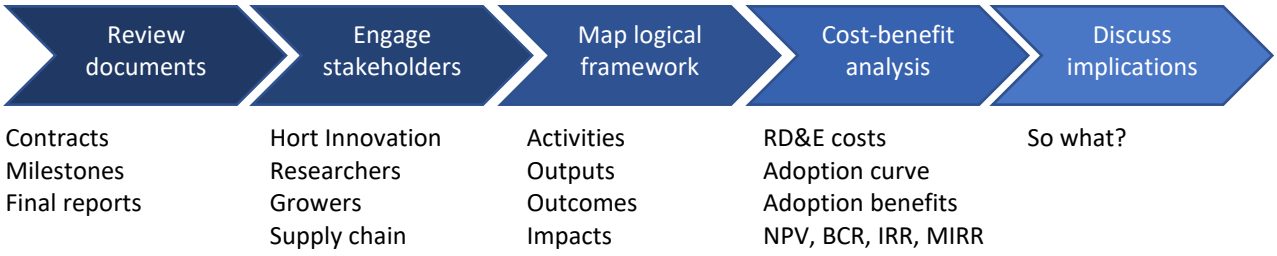
Understanding and managing the role of honey bees in CGMMV epidemiology (VM18008) was randomly selected as one of the 15 investments in the 2022-23 sample. This report presents the analysis and findings of the project impact assessment.

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

General method

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

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



The analysis identified and quantified (where possible) the direct and spillover impacts arising from the RD&E. The results did not incorporate the distributional effect of changes to economic equilibrium (supply and demand relationships) which was beyond the scope of the MT21015 impact assessment program. A more detailed discussion of the method can be found in the *MT21015 2022-23 Summary Report* on Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015).

Project background

The Cucumber Mottle Mosaic Virus (CGMMV) was first detected in September 2014 within melon crops located in Katherine, Ti Tree and Darwin in the Northern Territory (NT). Since the initial 2014 outbreak, additional detections occurred in Queensland (April 2015 - melons, pumpkins), Western Australia (July 2016 - cucumbers), South Australia (June 2019 – cucumbers) and NSW (March 2019 – cucumber, March 2020 - watermelon) (NSW DPI 2020). CGMMV is easily transmitted by contact with plant sap, plant material and soil, making it a significant biosecurity risk and threat to the melon and vegetable (cucumber, pumpkin, zucchini) industries given that infected plants can experience yield losses of between 15-48% (Reingold

et al. 2015, Nilsson 1977, and Zhou et al. 2008).

Since the outbreak of CGMMV, research was undertaken through project VG15013 (*Improved management options for cucumber green mottle mosaic virus*) from 2016 to 2019 to understand the factors impacting virus spread, potential hosts, diagnosis and to inform appropriate biosecurity management controls for industry. This research identified the presence of CGMMV in cucurbit flowers suggesting the virus could be potentially introduced by pollinators. Further testing of bee hive products in the NT and QLD confirmed the presence of the virus thus flagging the potential for honey bees to be a vector of virus spread.

Given that much of the commercial cucurbit production relies on pollination services provided by honey bees, the identified potential of honey bees in spreading CGMMV represented an unknown risk for the industry at the time. This uncertainty also contributed to additional emergency regulation being imposed by State (QLD) and Territory (NT) governments which limited hive movements when in associated with cucurbit crops. These combined factors served to reduce the availability of pollination services and increase pollination costs for cucurbit crops.

VM18008 sought to understand the role of honey bees in spreading CGMMV to support ongoing management of transmission in mitigating infection and crop losses, whilst also informing suitable management practices regarding pollination practices given the pollination requirement by cucurbit crops.

VM18008 aligned with the Melon Strategic Investment Plan (SIP) 2022-2026 through:

- Outcome 2: Industry supply, productivity and sustainability. Strategy 3. Improve industry preparedness and resilience to biosecurity threats; Strategy 6. Strengthen pollination security through robust honey bee health.

Project details

VM18008 was funded from 2019-2022 (Table 1).

Table 1. Project details

Project code	VM18008
Title	Understanding and managing the role of honey bees in CGMMV epidemiology
Research organization(s)	Department of Industry, Tourism and Trade Northern Territory (NT DITT)
Project leader	Dr. Mary Finlay-Doney and Dr. Brian Thistleton
Funding period	July 2019 to September 2022
Objective	Identify the role of honey bees in the transmission of CGMMV to support management practices that mitigate the risk of spread.

Logical framework

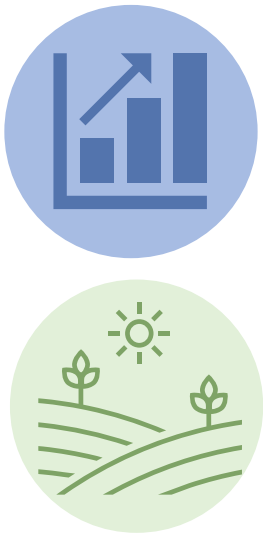
The impact pathway linking the project's activities and outputs, and their assessed outcomes and impacts have been laid out in a logical framework (Table 2).

Table 2. Project logical framework detail

RD&E activities		**Field surveillance of CGMMV**
		• Sample apiaries from known CGMMV affected areas over three years.
		• Test for the presence of CGMMV using a range of RT-PCRs and RT-qPCR methods.
		Honey bee CGMMV transmission and viability trials
		• Conduct x2 laboratory tests and x2 field tests. Establish and deliver study design focusing on:
		  ○ Virus transmission from infected plants to healthy plants.
		  ○ Virus transmission from positive hive to healthy plants.
		• Test CGMMV viability by storing portions of CGMMV positive honey comb, obtaining monthly samples and testing at 12 month intervals.
		• Extract honey samples and rest to determine the extent that hive transmission risk is removed.
		• Identify and correlate species of plant pollen with CGMMV presence to infer the role of alternative hosts in providing CGMMV inoculum
		• Set monitoring traps across eight potential sites.
		• Deploy for eight weeks and count Qfly captures.
		Alternative mosaic virus transmission pathways
		• Samples 3 honey bees per hive across from 18 apiaries that delivered managed pollination to cucurbit crops in NT and NSW.
		• Extract bee RNA and test for virus presence.
		Deliver project extension
		• Draft fact-sheets, field days and conduct stakeholder engagement.

RD&E outputs		• **1 x final report** on the Hort Innovation website. • **4 x industry fact sheets.** Published on the Hort Innovation and NT Government websites • **18 x communication articles:** Including contributions to industry newsletters for Melons, Vegetables, NT Government and Honey Bee Industry Council. • **5 x stakeholder meetings:** Content preparation and delivery to support industry meetings informing stakeholders of project progress. • **2 x webinars:** NT Ag Webinars 2020 series and Australian Melon Association. • **5 x scientific conference presentations:** including for the Australian Entomological Society and Australian Plant Pathology Society. • **3 x public information display** provided at agricultural shows and research precinct open days.
Outcomes		• Increased knowledge of the mechanisms by which honey bees can spread CGMMV into melon plants. • Increased knowledge of suitable grower practices and government policy requirements informing apiary management, melon production and managed pollination regarding CGMMV.

Impacts



The risk of CGMMV transmission by honey bees was found to be low, requiring no immediate change to apiarist or grower management practice. However the knowledge generated through the research contributed to revised regulation for honey bee hive movement in QLD and NT, supporting:

- [Economic] Reduced pollination costs for cucurbit growers in QLD and NT through improved availability of managed pollination services and avoided management costs (e.g. treatment and/or movement restrictions).
- [Economic] Avoided yield losses from restricted access to managed pollination services in QLD and NT cucurbit production.
- [Social] Avoided loss of fresh and affordable melon and cucurbit vegetable production, resulting in decreased fruit/vegetable consumption and a decline in associated health and wellbeing benefits.
- [Socio-economic] Avoided loss of industry spillovers that would result from a decline in the melon and vegetable industry as a source of employment and economic stimulant to local communities (The CIE 2023).

Project costs

The project was funded by Hort Innovation, using the melon research and development levy and contributions from the Australian Government, with additional funding from research partner NT DITT.

Nominal investment

The project funding period was 2019 to 2022 (Table 3). Hort Innovation overhead costs were added to the direct project cost to capture the full value nominal of the RD&E investment.

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs ($)	Hort Innovation overheads[1] ($)	Other funding ($)[2] (includes overheads)	Total nominal cost ($)
2020	192,003	40,134	82,759	314,896
2021	130,000	22,169	56,034	208,202
2022	80,501	13,718	34,698	128,917
Total	**402,504**	**76,021**	**173,491**	**652,016**

1. The overhead and administrative costs were calculated from the Financial Operating Statement of the Melon Fund Annual Reports, averaging 18.3% for the VM18008 funding period (2020-2022).
2. Other funds from the NT DITT included in-kind salaries of key staff. These were provided in the contract as a lump sum, so have been apportioned yearly based on Hort Innovation cash costs.

Present Value of investment

The nominal total investment cost of $0.65 million identified in Table 3 was adjusted for inflation (ABS, 2024) into a real investment of $0.76 million (2023-24 equivalent values). This was then further adjusted to reflect the time value of money using a real discount rate of 5% (CRRDC 2018), generating a present value (PV) of costs equal to $0.89 million (2023-24 PV).

Project impacts

The impact pathways identified in Table 2 were evaluated against available data to determine if their impact could be quantified with a suitable level of confidence.

Impact pathway and available data

VM18008 was able to provide conclusive evidence demonstrating that honey bees present a low risk to the spread of CGMMV. While a range of best management practices were identified following the research delivery, these practices did not represent a significant change compared to what was already being practiced by growers and apiarists.

However the research did contribute evidence that was used by state and territory agencies to inform adjustments to CGMMV regulation relating to the movement of honey bees to/from cucurbit properties. Until the conclusion of VM18008, the movement of honey bees was subject to strong restriction, which was impacting the availability and cost of pollination services for cucurbit growers. Without VM18008, the period of restriction and associated grower costs, would have remained over a longer period of time given the absence of evidence demonstrating the low risk presented by honey bees for CGMMV transmission.

A range of data sources were used to quantify the impact pathway, including historical plantings (ABS Agricultural Commodities), hive densities for relevant cucurbit crops (melon, pumpkin, cucumber, zucchini) and hive costs (HA21005).

Impacts valued and valuation framework

Given the above, the impact assessment focused on the contribution of the VM18008 for supporting ongoing access to pollination services by cucurbit growers.

A model was developed reflecting a baseline level of cost for accessing paid pollination services at the time of the CGMMV outbreak within QLD and NT, considering the total cucurbit area planted and the hive requirement/ha. The restricted movement of hives within QLD and the NT at the time of the research (2019-2022) increased the cost of pollination compared to a scenario where movement was not subject to restriction. As the findings of VM18008 provided an evidence base demonstrating the low risk of honey bees spreading CGMMV within cucurbit plants, restrictions were modelled as being removed in 2022/23 the year following the project results (the "with investment" scenario) compared to without the investment, where the restrictions were assumed to remain in place for a longer period of time.

Having established the change in hive costs and timing of restrictions, the model valued the following economic benefit:

- [Economic] Reduced pollination costs for cucurbit growers in QLD and NT through improved availability of managed pollination services and avoided management costs (e.g. treatment and/or movement restrictions).

Finally, the attribution of the total identified impact to VM18008 was considered. It was deemed to be highly unlikely that an equivalent knowledge base on the role of honey bee in spreading CGMMV would have been fostered in the absence of the VM18008 research given the limited access to testing equipment, laboratory infrastructure and technical expertise offered by the research team. Given that the research focus of VM18008 was informed by results from VG15013, the outcome attribution was appropriately scaled to reflect the proportional cost share of VM18008 (Appendix A).

Impacts unable to be valued

Additional economic impacts could not be quantified primarily for the following reasons.

- [Economic] Avoided yield losses from restricted access to managed pollination services in QLD and NT cucurbit production. Data on the extent to which pollinator restrictions impacted the capacity to deliver sufficient levels of pollination for growers could not be validated due to the variability in grower arrangements with paid pollinators.

The social impacts identified through the logical framework could not be quantified for the following reasons.

- [Social] Avoided loss of fresh and affordable melon and cucurbit vegetable production, resulting in decreased fruit/vegetable consumption and a decline in associated health and wellbeing benefits. There is a recognised link between health and wellbeing benefits of fruit and vegetable consumption (Angelino et al 2019, Mujcic et al 2016). However, to quantify the benefit of avoided decreases in melon and vegetable consumption in the context of cost benefit analysis requires a clear relationship between unit consumption and unit health and wellbeing, as well as a dollar value for unit health and wellbeing changes. These relationships and values could not be confidently estimated through available data or stakeholder consultation.
- [Socio-economic] Avoided loss of industry spillovers that would result from a decline in the melon and vegetable industry as a source of employment and economic stimulant to local communities. The CIE (2023) highlighted the flow-on (spillover) effects of the melon and vegetable industries as a source of employment and economic stimulant to regional communities. By supporting ongoing production through informed biosecurity practices, VM18008 contributes to corresponding increase in spillovers to local communities. While this analysis quantified the direct impacts for melon and vegetable pollination costs, the flow-on effects require additional analysis using economic models that capture regional and national linkages, which are beyond the scope of the R&D impact assessment program (CRRDC 2018).

Data and assumptions

The required data relating to the impact pathway was collected from the project documents and other relevant resources (Table 4). Where available, actual data was applied to the relevant years, with estimates applied for any data gaps and

projections into the future based on analytical techniques (for example correlations and trend analysis), or stakeholder estimates, or both. A data range was incorporated to reflect underlying risk and uncertainty. This was particularly relevant where estimates were needed due to data gaps, and where projections were made into the future. These ranges were then analysed through sensitivity testing (see *Results*).

Table 4. Summary of data and assumptions for impact valuation

Variable	Value	Source & comment
General data and assumptions		
Discount rate	5% (± 50%)	CRRDC Guidelines (2018)
Melon hive/ha	3.25 (2.00, 7.50)	Average of recommended hive stocking density for commercial cucurbit crops, tested at maximum and minimum densities (NSW DPI 2013, HA21005, BeeAware, DPIRD 2016) data.
Pumpkin hive/ha	3.50 (1.00, 4.00)	
Cucumber hive/ha	4.00 (1.00, 8.00)	
Zucchini hive/ha	3.50 (1.00, 8.00)	
Hive cost ($/hive))	116 (50, 180)	Average hive cost provided from HA21005 (adjusted to 2023-24 dollars), tested at maximum and minimum supplied hive cost for relevant crops.
Hives effected	50.00% (± 50%)	Assumed rate of hive movement practically influenced by CGMMV biosecurity regulations in NT and QLD.
Hive cost increase with CGMMV (%)	87.5%	Average cost increase % assumed to be comparable to costs experienced from the Varroa outbreak in New Zealand (Somerville (2008). Low cost increase informed by expert opinion shared by Dr Cooper Schouten (Science Media Centre 2023) and high cost increase by maximum reported change in crop pollination cost (Somerville 2008).
Counterfactual attribution	80% (± 12.5%)	A low likelihood that the VM18008 research would have been undertaken even without Hort Innovation funding given the technical expertise, equipment and establishment of trial conditions that were required to be managed in support of the findings.
Counterfactual years of restrictions	5 years (± 3)	Without VM18008 it is assumed that an additional 5 years would have lapsed before an equivalent understand would have been reached regarding the risk presented by honey bee in spreading CGMMV within cucurbits. Under the 'best case' only two years would have lapsed, while under the 'worst case', eight years would have lapsed between the time taken to develop an equivalent understanding and support a reduction in the hive cost for cucurbit producers.
Impact attributable to VM18008	70%	The modelling framework calculated the total benefit resulting from the reduced cost in pollination. However, VM18008 only makes up part of the research that had supported this outcome. As such, the attributable benefits considered the cost share of VM18008 relative to the related investment VG15013 that identified the research requirement. See *Appendix A. Total program cost.*

Results

The analysis identified PV costs (PVC) of $0.89 million (2023-24 PV) between 2019-20 and 2021-22, and estimated PV benefits (PVB) of $4.32 million (2023-24 PV) accruing between 2023 and 2027 (Table 5). When combined, these costs and benefits generate a net present value (NPV) of $3.43 million, an estimated benefit-cost ratio (BCR) of 4.85 to 1, an internal rate of return (IRR) of 56% and a modified internal rate of return (MIRR) of 11%.

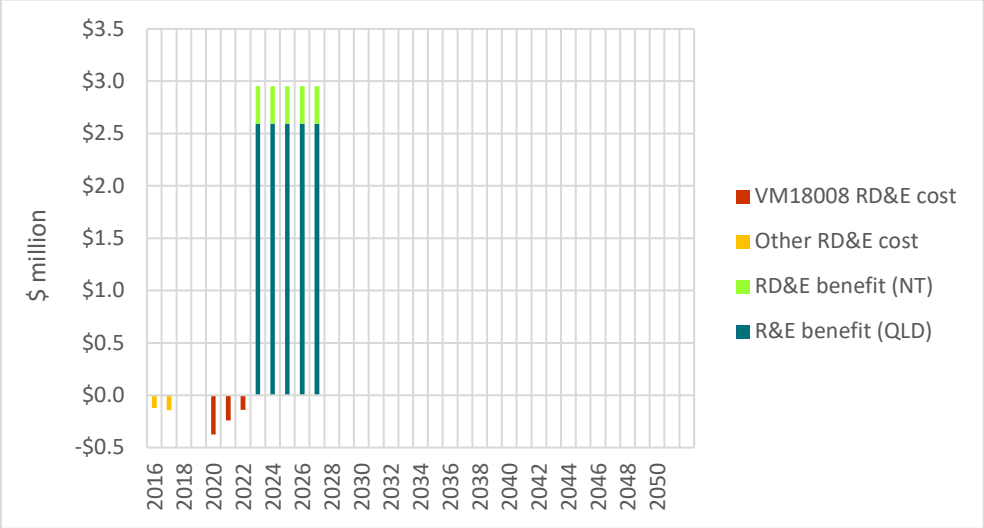
Table 5. Impact metrics for the total investment in project VM18008

Impact metric	Years after last year of investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
PVC ($m)	0.89	0.89	0.89	0.89	0.89	0.89	0.89
PVB ($m)	1.87	4.32	4.32	4.32	4.32	4.32	4.32
NPV ($m)	0.98	3.43	3.43	3.43	3.43	3.43	3.43
BCR	2.10	4.86	4.86	4.86	4.86	4.86	4.86

IRR	36%	56%	56%	56%	56%	56%	56%
MIRR	31%	27%	19%	15%	14%	12%	11%

Figure 2 shows the annual undiscounted benefit and cost cash flows for the total investment of VM18008, showing total RD&E costs compared to benefits.

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

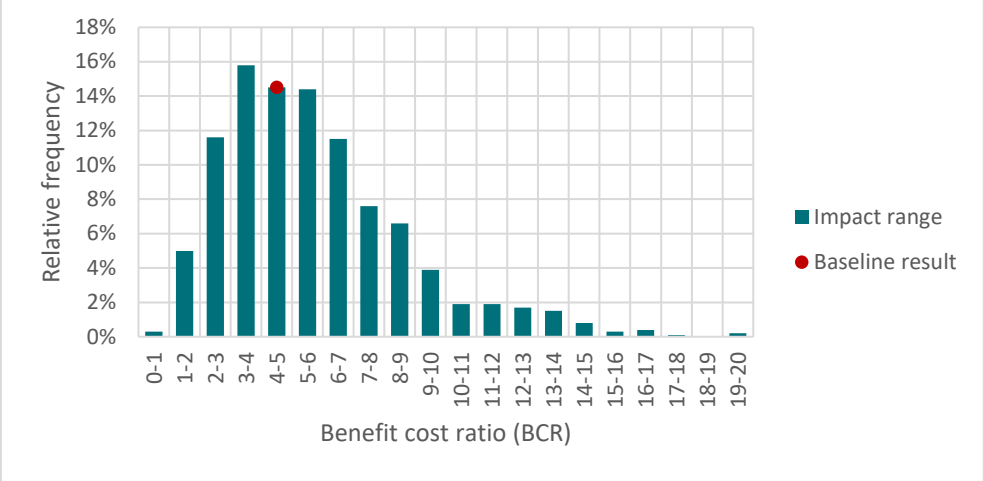


Sensitivity analysis

Given the risk and uncertainty associated with a number of underlying modelling variables, the potential model variation was estimated and drivers of variation identified. The sensitivity testing used @Risk stochastic modelling to incorporate the combined effect of changing all variables across their full ranges over 1000 simulations. This process showed:

Impact variation (Figure 3). Compared to the baseline BCR of 4.86:1, the 1000 simulation showed a potential BCR range of between 0.75:1 and 19.87:1, with 90% of results falling between 1.94:1 and 11.98:1 (i.e. excluding the low probability tails), and a simulation average of 5.72:1 (above the baseline results). Of the 1000 simulations, 99.7% had a BCR greater than 1:1 (benefits greater than RD&E costs), giving a high level of confidence that the investment will generate a positive impact.

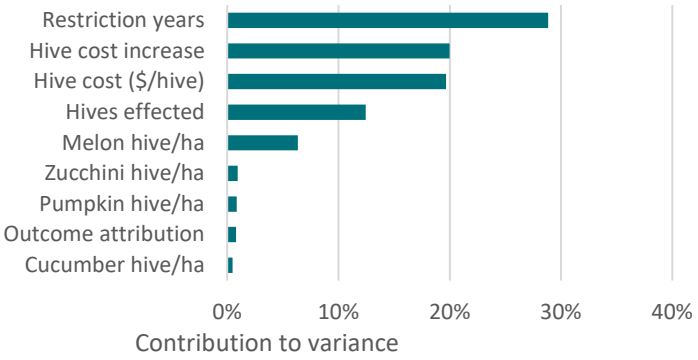
Figure 3. Impact variation in results over 1000 simulations



Contribution to variance (Figure 4). Contribution to variance is a measure of how much a variable contributes to the total variance of an output. Contribution to variance also shows whether a variable is positively or negatively correlated with impact. A negative contribution to variance, with bar extending to the left, indicates that this input has a negative effect on BCR: increasing this input will decrease the impact.

- **The number of restricted hive access years** in the counterfactual (without investment) scenario showed the showed the largest contribution to variance (29%).
- **The increase in hive costs resulting from biosecurity restrictions** imposed during the CGMMV outbreak showed the second highest contribution to the variance (20%).
- **The hive cost** baseline had a similar contribution to variance (19.6%).
- **The discount rate** had an immaterial contribution to variance and is not profiled in Figure 4. The breakeven discount rate is reflected in the IRR (56%), or the MIRR (11%) if we assume that generated cashflows are reinvested at the risk-free discount rate.

Figure 4. Contribution to variance



Implications and learnings

The analysis identified a clear pathway to impact for VM18008. Expanding on the preliminary research findings delivered through VG15013, the VM18008 project was able to confirm whether it was possible for honey bees to spread CGMMV in melon (and other cucurbit) crops. The research findings confirmed that the risk of CGMMV being spread through the activity and movement of honey bees was low. Several best management practices were informed from the research findings to ensure that risk of CGMMV spread would be controlled through the actions of apiarists and growers, however these recommendations were practically not different from existing practices.

While the research findings did not inform material change to management practices, findings were used to inform changes to regulation regarding the movement of hives around cucurbit crops. Prior to the findings of VM18008, state and territory regulation regarding hive movements in QLD and NT were introduced as a mechanism control the potential risks to CGMMV spread that were presented by honey bees through managed pollination. These movement restrictions were identified as increasing costs for growers in accessing managed pollination, a key factor that is required to support fruit set in cucurbit crops. Following the results of VM18008 demonstrating the low risk of CGMMV spread through honey bees, regulators adjusted the restrictions, which contributed to improved accessibility and reduced cost of pollination services for cucurbit growers. The difference in the time required to reach an equivalent regulatory outcome in the absence of the VM18008 (assumed at 5 years) was modeled to reflect the impact of avoided pollination costs for industry.

While the magnitude of impact was found to be most significant for the timeframe where regulation would have remained in the absence of the VM18008 research findings, the magnitude of impact was also determined by the increased cost to pollination as a result of the restrictions, the base level cost of hives and the total number of hives affected by the restrictions. Impacts were modelled for four cucurbit crops (melons, pumpkin, cucumber, zucchini) in the NT and QLD, with total impacts being highest for QLD melons as a result of the extent of production and subsequent reliance on pollination.

Through the analysis of this impact pathway, moderate benefits relative to the RD&E costs were quantified with a baseline BCR of 4.85:1. In addition, sensitivity testing was undertaken to understand the potential variation in the results given changes in the underlying variables. This identified a potential impact range of between 0.76:1 and 19.87:1, with 90% of results falling between 1.94:1 and 11.98:1 giving a high level of confidence that the investment will generate a positive impact.

In conclusion, the impact assessment of VM18008 was able to demonstrate how the investment supported impact for melon and relevant vegetable growers through providing evidence that supported ongoing access to pollination services, supporting production outcomes in the context of CGMMV management.

Stakeholder consultation

Where possible, Ag Econ sought to engage multiple stakeholders across key areas of the logical framework and impact pathway to augment existing information and data sources, and reduce any uncertainty or bias from individual stakeholders. All stakeholders were engaged through telephone or online meetings, with follow up emails as necessary. Consultation followed a semi-structured approach in line with broad topics relating to the impact pathway and associated data requirements. Table 4 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 4. Stakeholder consultation by theme

Stakeholder details		Consultation topics						
Stakeholder and organisation	**Stakeholder type**	**Related research**	**Research inputs**	**Research outputs**	**Research immediate outcomes**	**Follow on research**	**Stakeholder adoption**	**Impact areas and data**
Ashley Zamek, Hort Innovation R&D Manager	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Dr Mary Finlay-Doney, NT DITT Research Entomologist Victoria	RD&E practitioner	✓	✓	✓	✓	✓	✓	✓
Dr Brian Thistleton, NT DITT Principal entomologist	RD&E practitioner	✓	✓	✓	✓	✓	✓	✓
Joanna Embry, Australian Melons Association Biosecurity Officer	RD&E beneficiary and industry representative				✓	✓	✓	✓

Glossary of economic terms

Benefit-cost ratio (BCR)	The ratio of the present value of investment benefits to the present value of investment costs.
Cost-benefit analysis (CBA)	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Direct Effects	Impacts generated for the funding industry as a result of adoption of the RD&E outputs and recommendations, typically farm level outcomes relating to productivity and risk.
Discounting and Present Values	The process of relating the costs and benefits of an investment to a base year to reflect the time value of money or opportunity cost of RD&E investment. The analysis applies a real discount rate of 5% in line with CRRDC Guidelines (CRRDC 2018) with results sensitivity tested at discount rates of 2.5% and 7.5%.
Economic Equilibrium	Due to a market's underlying supply and demand curves, changes in supply will have an impact on price and vice-versa. The Economic Equilibrium is the point at which market supply and price are balanced. Estimating the magnitude of market response to changes in supply or demand is a complex and demanding task that is considered beyond the scope of most CRRDC Impact Assessments (CRRDC 2018).
Gross Margin (GM)	The difference between revenue and cost of goods sold, applied on a per hectare basis and excluding fixed or overhead costs such as labour and interest payments.
Internal rate of return (IRR)	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Modified internal rate of return (MIRR)	The internal rate of return of an investment that is modified so that the cash inflows generated from an investment are re-invested at the rate of the cost of capital (in this case the discount rate).
Net present value (NPV)	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Nominal and real values	Nominal values reflect the actual values in a given year (e.g. contracted RD&E expenses). These are converted to real (inflation adjusted) values to make them comparable across time.
Spillover Effects	Impacts generated for stakeholders who did not fund the RD&E, including other agricultural industries, consumers, communities, and the environment.

Abbreviations

CGMMV Cucumber Green Mottle Mosaic Virus

CRRDC Council of Rural Research and Development Corporations

DPIRD Department of Primary Industries and Regional Development Western Australia

NT Northern Territory

NT DITT Northern Territory Department of Industry, Tourism and Trade

QLD Queensland

RD&E Research, Development and Extension

SIP Strategic Investment Plan

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Appendix A. Total Program costs

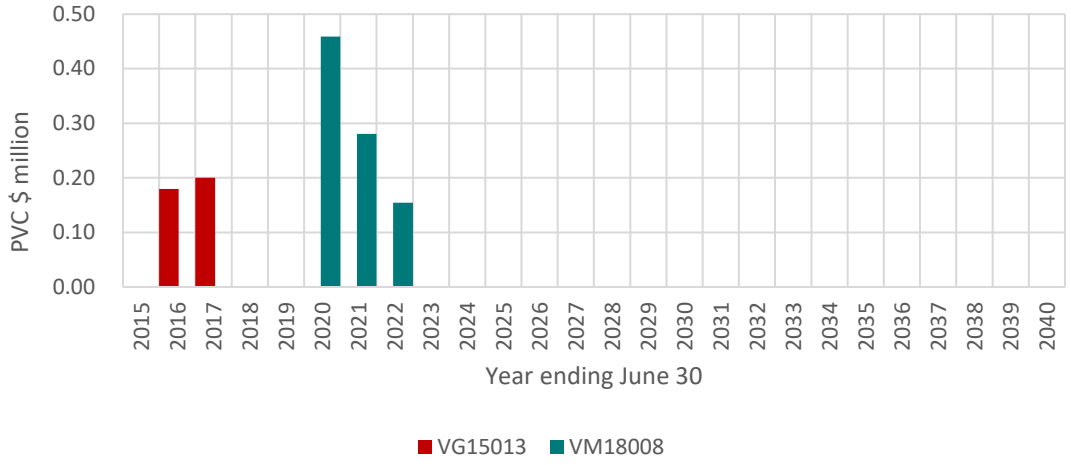
Two stages of investment were identified in support of informing the risk of CGMMV transmission from honey bees. The cost share of VM18008 (in present value (PV) terms) was used to attribute a share of the total program benefits to the project (Table 7 and Figure 5).

- **Exploratory CGMMV research**. VG15013 *Improved management options for cucumber green mottle mosaic virus*. A component of this research focused on testing the presence of CGMMV in honey bee products. The findings triggered the need for future research to determine the extent to which they also contributed to transmission. *Note while VG15013 delivered a range of research focused on CGMMV, only the relevant component focusing on honey bees was used to inform the cost share.*
- **Focus research trials**. VM18008 *Understanding and managing the role of honey bees in CGMMV epidemiology*. Focus research of the impact assessment informed by VG15013.

Table 7 Total program cost by investment stage

Investment stage	Total PVC ($m)	% Total PVC	Years	Annual PVC
VG15013	0.38	30%	2	0.19
VM18008	0.89	70%	3	0.30
Total program	1.27	100%	25	0.39

Figure 5 Total present value of program cost by investment stage



Ends.