Impact assessment of the investment:

Improved plant protection for the banana industry (BA16001)

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Hort Innovation

Previous page images from BA16001.

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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 the persimmon project *Improved plant protection for the banana industry (BA16001)*. The project was funded by Hort Innovation over the period March 2017 to December 2021 using the banana research and development levy and contributions from the Australian Government.

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

Contracts	Hort Innovation	Activities	RD&E costs	So what?
Milestones	Researchers	Outputs	Adoption curve	
Final reports	Growers	Outcomes	Adoption benefits	
	Supply chain	Impacts	NPV, BCR, IRR, MIRR	

Research background

The tropical and subtropical banana growing regions in Australia provide environmental conditions favourable for the development of a wide range of pest and disease problems, including several with a lack of effective control, most notably Fusarium Wilt Tropical Race 4 (TR4).

BA16001 supported improved banana industry production through a range of research areas including sourcing, screening banana varieties for disease resistance and agronomic performance (including screening privately imported varieties), investigating cost-effective and sustainable pest and disease management options, and communicating the findings to industry through a range of channels. BA16001 was part of continuum of research into plant protection. The project built on the work of previous banana investments (BA10020), and supported future research (BA21002 for import and evaluation and BA21004 for pest and disease management).

Key findings

The nominal investment cost of $5.8 million was adjusted for inflation (ABS, 2023) and discounted (using a 5% real discount rate) to a 2022-23 present value (PV) of costs equal to $23.5 million.

The analysis identified impact pathways for BA16001 to generate social and economic impacts for the banana industry. A review of available data and discussions with stakeholders allowed the quantification of three out of seven identified impacts, being:

- Earlier adoption of higher yielding, privately imported Rahan Meristem (Israeli) varieties.
- Reduced risk of Fusarium Wilt with resistant varieties particularly relating to TR4.
- improved tissue culture techniques that reduce the need for de-suckering.

From the three impact areas, benefits of $81.7 million were identified (2022-23 PV) with the benefits commencing in 2022 (with the Rahan Meristem varieties) and continuing beyond 2052 (the final year of analysis). Compared to the PV RD&E costs of $23.5 million these estimated benefits generated a benefit cost ratio (BCR) of 3.48:1, an internal rate of return (IRR) of 21%, and a modified internal rate of return (MIRR) of 9%.

Of the three impact areas modelled the baseline benefits were made up of 64% improved productivity from Rahan Meristem varieties, and 24% avoided risk (lost productivity) from TR4, and 12% reduced suckering costs.

Overall, the evaluation of the Israeli varieties, and the development of the new tissue culture method, BA16001 sat close to the end of the impact pathway with a relatively high confidence in adoption and impact. The importation and evaluation of new disease resistant varieties had a higher level of uncertainty given adoption of these lower yielding varieties is dependent on the continued spread of Fusarium Wilt (particularly TR4 in Queensland) and the difficulty in confidently estimating this.

To reflect the potential variability or uncertainty relating some of the underlying variables (particularly those relating to projections of TR4 spread) the results were tested to changes in data values. Sensitivity testing gave a high level of confidence that BA16001 would generate a positive impact (benefits greater than costs) with more than 99% of simulated results having a BCR greater than 1. There was a relatively wide range for the results across the sensitivity testing, with 90% of simulated results falling between 1.48:1 and 7.35:1. While the wide range of results reflects the high level of risk and uncertainty relating to many variables (particularly the adoption of Rahim Meristem varieties and the spread of TR4), the sensitivity testing gives a high level of confidence that the investment will generated a positive impact.

Additional social and environmental impacts are expected to be realised from the investment, but were not quantified as a result of data limitations. As such the quantified impacts represent a conservative estimate of the total potential impact from this investment. Through the impact assessment analysis, key data gaps were identified to support improved data collection and impact assessments in the future

The key findings of the BA16001 impact assessment are summarized in Figure 1 below.

Keywords

Impact assessment, cost-benefit analysis, banana, productivity, plant protection, Fusarium Wilt, Tropical Race 4 (TR4), Race 1

Figure 1. Summary of impact assessment findings

BA16001 Improved plant protection for bananas

Hort Innovation
Queensland Government
Department of Agriculture and Fisheries

RD&E activities

Total RD&E costs:

- $16.7 million (nominal value)
- 41% R&D levy and Government matching, and 59% QDAF in-kind.

Research activities:

From March 2017 to December 2021:

- Negotiate access to and trial banana varieties with improved pest and disease resistance.
- Ensure safe, disease-free importation of new and improved banana varieties through the maintenance and improvement of post entry quarantine facilities and processes.
- Investigate cost-effective and sustainable integrated pest and disease management (IPDM) options

Outcomes

Outcomes:

- 23 varieties were imported for future evaluation (e.g. in BA21002)
- 14 Cavendish varieties and 9 parental lines were identified with adequate resistance to Fusarium Wilt Tropical Race 4 (TR4). Yields were 8% to 49% lower than existing commercial varieties. From this, 3 new varieties were established in pre-commercialisation trials and a further 2 varieties recommended to commence to pre-commercialization in subsequent research (BA21002).
- 2 varieties with Race 1 resistance established in sub-tropical pre-commercialisation trials.
- 4 privately imported varieties from Israel evaluated with strong agronomic performance relative to Williams Cavendish.
- 5 Goldfinger selections (developed in BA14014) were identified through agronomic trails for formal consumer acceptability research.
- A new micropropagation cutting technique was identified to reduce sucker number in tissue culture bananas.
- New data and knowledge generated to inform future work (e.g. in BA21004) into alternative pest and disease management options.

Impacts

Economic impacts:

- Increased productivity through earlier adoption of high yielding Israeli varieties.
- Reduced TR4 risk through the availability of resistant (but lower yielding) varieties.
- Reduced cost of de-suckering through the application of improved micropropogation cutting.

Socio-economic impacts:

- A more reliable supply of fresh and affordable bananas, supporting consumption with associated health and wellbeing benefits
- Greater security for the economies and communities in banana producing regions.

Quantified impact:

- Present value (PV using 5% discount) RD&E costs of $23 million.
- PV benefits of $82 million over 30 years.
- Net PV (NPV) of $58 million
- BCR of 3.48:1 with a 90% confidence of a BCR between 1.48:1 and 7.35:1

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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.

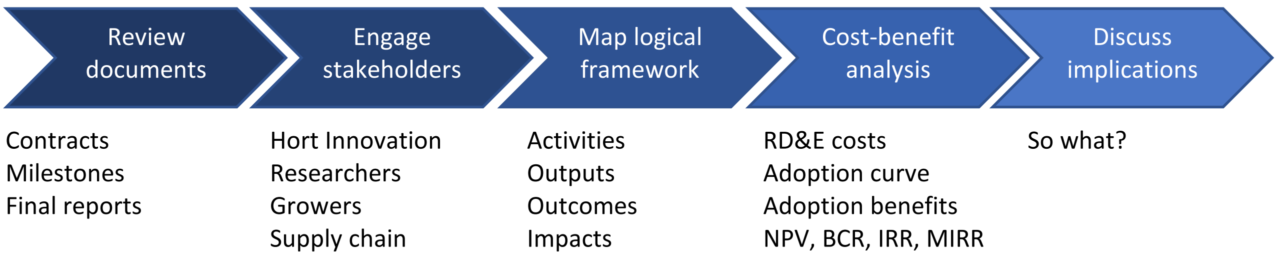
Reflecting its commitment to continuous improvement in the delivery of levy funded research, development and extension (RD&E), Hort Innovation required a series of impact assessments to be carried out annually on a representative sample of investments of its RD&E portfolio. Commencing with MT18011 in 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).

Project *Improved plant protection for the banana industry (BA16001)* was randomly selected as one of the 15 investments in the 2021-22 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 was 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 stakeholders (see *Stakeholder Consultation*)
3. Through a logical framework, qualitatively map the project's impact pathway, including activities, outputs, 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 2021-22 Summary Report* on the Hort Innovation project page Horticulture Impact Assessment Program 2020/21 to 2022/23 (MT21015)..

Project background

Cost effective and sustainable pest and disease control producing fruit that meets strict market specifications remains a significant challenge and cost for the Australian banana industry. The tropical and subtropical banana growing regions in Australia provide environmental conditions favourable for the development of a wide range of pest and disease problems. This are significant issue for the Australian banana industry because of a lack of effective control for many of the key pests and diseases, which can have serious and significant implications for producers.

In 2014, the Australian banana industry Strategic Investment Plan (2014-15 to 2018-19) (ABGA 2014) highlighted the pest and disease risks faced by the industry:

- A heavy reliance on one variety with Williams Cavendish making up around 97% of industry production in 2014-15. This presented a vulnerability for the industry in relation to disease threats, particularly relating to the globally significant disease Fusarium Wilt (Panama Disease) Tropical Race 4 (TR4) to which Williams Cavendish is highly susceptible. At the same time, the northern NSW banana industry, which has a higher dependence on lady finger and other niche varieties (3% of national production), is susceptible to Fusarium Wilt Subtropical Race 1 (Race 1).
- Reduced access to appropriate pest and disease management technologies (due to the withdrawal or ineffectiveness of common plant protection products)

The 2014-15 Strategic Investment Plan (SIP) (ABGA 2014) also acknowledged the importance of access to new varieties and pest management option to address these risks. During the 2014-15 SIP, the industry had invested in an ongoing varietal import and screening Banana plant protection program (BA10020) which was seeking to address the varietal and associated biosecurity risks faced by the industry, particularly relating to TR4 and Race 1. Another research focus in this area (in BA14014) was on developing new Goldfinger variants using mutagenesis to improve the consumer acceptability of this banana which has desirable disease resistance and agronomic performance but has poor consumer acceptability.

The discovery of TR4 on a Queensland farm in 2015 reenforced the importance of the widespread adoption of biosecurity best management practice (BMP) and the identification and availability of resistant varieties. (BA16001) was to develop and maintain a focus on industry varietal evaluation and pest and disease management options, and thereby enhance industry capacity to effectively mitigate the risk posed by endemic and exotic banana diseases

This was reinforced in the banana industry's subsequent SIPs, which highlighted the ongoing need to focus investments in plant protection through *New varieties introduced and improved pest and disease management that improve varietal diversity and biosecurity* (Outcome 1 2017-2021 SIP) and *Industry supply, productivity and sustainability* (Outcome 1 2022-2026 SIP)

Project details

Drawing on its existing knowledge and capacity, the department of Agriculture and Fisheries, QLD (QDAF) was selected as the lead delivery partner, with the project running from 2016-17 to 2021-22 (Table 1)

Table 1. Project details

Project code	BA16001
Title	Improved plant protection for the banana industry
Research organization(s)	The department of Agriculture and Fisheries, QLD (QDAF)
Project leader	Stewart Lindsay
Funding period	March 2017 to December 2021
Objective	Reduce the pest and disease risk faced by the banana industry.

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

Theme 1 – Sourcing and screening banana varieties for disease resistance and agronomic performance

- Banana Variety Subcommittee (BVS) formed to strategically overview the process of importation and evaluation.
- Identified breeding program partners: Taiwan Banana Research Institute (TBRI), the French Agricultural Research Centre for International Development (CIRAD), the Brazilian Agricultural Research Corporation (Embrapa), and the Brazilian Agricultural Research and Rural Extension Company of Santa Catarina (EPAGRI).
- Varietal screening trials for TR4 (NT), agronomic performance (far north QLD), Race 1 (NSW), as well as pre-commercialisation trials and consumer testing, focussing primarily on varieties imported through the previous project BA10020.
- Agronomic trials also included 4 privately imported varieties developed by Israeli biotech company, Rahan Meristem, and 20 Goldfinger selections inherited from TR4 research project BA14014.
- Field germplasm maintenance program. The Australian banana germplasm collection currently containing approximately 520 lines was maintained to support all Australian research, biosecurity strategies and banana producers.

Theme 2 – Ensuring safe, disease-free importation of new banana varieties

- Post-entry quarantine management and screening. New processes and facilities established by the previous banana plant protection program (BA10020) and maintained by BA16001 to safely import new banana varieties into Australia.

Theme 3 – Strengthening the banana industry diagnostic capacity

- This plant protection theme was delivered separately through BA16005.

Theme 4 – Investigating cost-effective and sustainable pest and disease management options

- Three separate priority setting workshops held with producers and industry service providers 2017 to 2018.
- Informed by the above, as well as outputs from the Strategic Agrichemical Review Process , the project identified bunch pests, pest mites, yellow Sigatoka leaf disease and plant parasitic nematodes for research focus.
- Investigated cultural, biological, and 'softer chemical' options in field and glasshouse trials, as well as timing and climate impacts, and chemical resistance.
- Provided diagnostic services for endemic banana diseases and pests.

Theme 5 – Foster a cohesive plant protection RD&E program for the banana industry

- Quarterly videoconferencing with project researchers and other researchers working in banana plant protection.
- Two Banana Scientific Symposia organized in 2018 and 2021.
- Project SharePoint site created and managed.

RD&E outputs and outcomes

Theme 1 – Sourcing and screening banana varieties for disease resistance and agronomic performance

- **Importation:** Imported 23 new banana varieties into Australia based on the options paper delivered by project BA14013. Four of the 23 varieties were released from quarantine in early 2020 while the others were released after BA16001 was completed (in the subsequent BA21002).
- **Varietal screening:** Focussing primarily on varieties imported through the previous project BA10020.
    - TR4 (NT). From 37 varieties screened across 2 field trials, 14 Cavendish were identified with adequate TR4 resistance, and considered for agronomic and consumer testing. From 17 parental lines, 9 were highly resistant to TR4 and suitable parents for breeding purposes, supporting improved TR4 resistance outcomes in conventional breeding programs (CIRAD, EMBRAPA and the Honduran Foundation for Agricultural Research (FHIA) which had previously supplied varieties to Australian research).
    - Race 1 (NSW). Due to banana weevil borer infestation, and adverse weather conditions, it was only possible to obtain data for 7 of the 19 varieties, of which 2 were advanced to pre-commercialisation trials – the Lady Finger hybrid JV42.41 and the dwarf Cavendish selection Plantanera Brier.
    - Agronomic.
        - Agronomic data for 32 varieties evaluated (3 crop cycles). Of the TR4 resistant varieties most were significantly taller than Williams, increasing wind risk. Lower bunch weights and slower cycle times resulted in yields between 57 – 92% of Williams.
        - The 4 Cavendish selections from Rahan Meristem performed at a high level compared to the industry standard Williams. Despite the expectation that these varieties do not have any resistance to TR4, growers made it clear that the opportunity to see plants and bunches in the research trial during extension activities was important in their decision making to implement their own plantings, with >50,000 plants established by the end of BA16001.
        - 20 Goldfinger variants from BA14014 with favourable eating characteristics were selected for agronomic trails, from which 5 variants were selected for later more detailed consumer testing, with later post-harvest research and on-farm pre-commercialisation trials of the best 1-2 varieties.
    - **Consumer testing**: It was recommended that the two “best bet” varieties from BA10020 were not pursued through to commercialization.
    - **Pre-commercialisation**: Of the 14 TR4 resistant Cavendish, three (GCTCV 247, GCTCV 215 and CJ19) were selected for pre-commercialisation trials on five commercial properties commencing in 2019, 2020, and 2021.
        - Overall, the GCTCV lines performed similarly to the research trial results with longer crop cycles (resulting in lower yields) and taller plant stature (resulting in high wind losses) compared to Williams, except for CJ19 which is a semi-dwarf Cavendish variety. In the NT trial (with TR4 presence) all three new varieties showed much lower death (4-8%) or mild symptoms (14%) from TR4 compared to Williams (death around 50% and mild symptoms of 36%)
        - No significant difference in post-harvest (weight loss, firmness, colour, defect, and destructive parameters).
        - Consumer feedback of 77% liking the flavour of new varieties compared to 88% for standard Williams Cavendish, with 68%-74% indicating they would consider purchasing new varieties.
        - One Cavendish variety recommended for future pre-commercialisation trials (in BA21002).

RD&E outputs and outcomes

Theme 2 – Ensure safe, disease-free importation of new and improved banana varieties

- PEQ Tissue Culture laboratories Q2264/Q2860 and Glasshouse Q2325 and the banana germplasm import process Q2762 remained compliant with Federal Biosecurity procedures throughout the project. All audits were passed, and no corrective actions were received. Additionally, the diagnostic assay suite for PEQ virus indexing was strengthened by incorporation of the test developed for the recently detected banana picorna-like virus.
- Maintenance and provision of banana germplasm
  - During the project 30,403 banana tissue culture plantlets from the germplasm collection were supplied for commercial and research purposes (fee for service when outside of BA16001), including:
    - BA16001 Theme 1, 3, and 4.
    - BA14014 – Fusarium wilt Tropical Race 4 research program
    - ACIAR 2018/192 – An integrated management response to the spread of Fusarium wilt of banana in SE Asia
    - BA17006 – Development of molecular markers for Fusarium wilt resistance in banana
    - BA19002 – Understanding the latency of Banana Bunchy Top Virus symptom expression
    - Queensland University of Technology (Prof J Dale) and University of Queensland (Dr J Anderson) research trials
  - 178 varieties held in the Australian banana germplasm collection were renewed with fresh in-vitro cultures as part of the maintenance of the germplasm collection for future research.

Theme 4 – Investigating cost-effective and sustainable pest and disease management options

- Preliminary efficacy data generated for a range of chemical and biological pest management alternatives, with ongoing research recommended.
  - Informed future research (particularly BA21004) relating to rust thrip damage correlation with bunch cover colours; the efficacy of the *Neoseiulus californicus* predatory mite species on spider mite in bananas; and plant-parasitic nematodes and virus management.
  - Yellow Sigatoka leaf disease experiments were inconclusive due to inconsistent symptom expression.
- Research into Corm Rot found the disease is a function of suckers. Changing laboratory techniques of tissue culture to reduce suckers removed the risk or Corm Rot and also increases productivity from reduced labour-intensive de-suckering. Adopted by commercial production nurseries.

Theme 5 – Foster a cohesive plant protection RD&E program for the banana industry

- Growers/industry focussed outputs (and audience)
  - 53 Roadshow presentations (218 participants)
  - 9 Seminar/meeting presentations (115 participants)
  - 8 Industry workshops (127 participants)
  - 11 Field walks (231 participants)
  - 36 Australian Bananas magazine articles (1200 recipients)
  - 24 Conference presentations/posters (843 participants)
  - 3 Radio interviews (unknown)
- Scientific community focussed outputs
  - 3 peer reviewed papers (unknown)
  - 3 Conference papers (unknown)
  - 16 Conference presentations/posters (2110 participants)
  - 14 Workshop/seminar presentations (217 participants)
  - 2 Banana Scientific Symposia (BSS) held (137 participants)

In discussions with stakeholders, the key direct impact areas from BA16001 were:

- [Economic] Support higher levels of productivity, both through the earlier adoption of four privately imported cavendish varieties from Rahan Meristem, and through the availability of TR4 resistant varieties that allow continued production in the event of TR4 spread rendering Williams Cavendish production unviable.
- [Economic] Support the adoption of improved tissue culture techniques to reduce the requirement for and cost of de-suckering.
- [Economic] Support improved pest and disease management (with increased yield, reduced costs or both) through the use of chemical and biological options with increased efficacy.

These in turn would support spillover socio-economic benefits:

- [Socio-economic] Greater productivity and production security means a more reliable supply of fresh and affordable bananas, supporting consumption with associated health and wellbeing benefits.
- [Socio-economic] A more economically viable industry means greater security for the economies and communities of Tully and Innisfail, Lakeland, and the Atherton Tablelands in Queensland; Darwin in the Northern Territory; the Coffs Harbor and Northern Rivers regions of New South Wales; and the Carnarvon region in Western Australia.
- [Socio-economic] Avoided health and wellbeing costs to farm staff including psychological stress and strains on business and community relationships related to biosecurity events (CSIRO, 2020).

Project costs

The project was funded by Hort Innovation, using the banana research and development levy and contributions from the Australian Government, with in-kind funding from research partners QDAF (Figure 4). Where relevant, overhead and extension costs were added to the direct project cost to capture the full value of the RD&E investment. Total nominal costs were adjusted to 2022-23 values using the Implicit Price Deflator (ABS 2023a)

Nominal investment

Table 3. Project nominal investment

Year end 30 June	Hort Innovation project costs[1] ($)	Hort Innovation overheads[2] ($)	QDAF ($)[3] project costs	Total nominal ($) investment costs
2017	1,516,389	248,825	2,640,750	4,405,964
2018	474,556	92,845	839,211	1,406,612
2019	1,104,340	187,799	1,846,789	3,138,928
2020	1,163,132	181,039	1,875,241	3,219,411
2021	451,403	68,256	799,756	1,319,415
2022	1,177,455	174,138	1,849,108	3,200,701
Total	**5,887,275**	**952,902**	**9,850,854**	**16,691,031**

1. Costs based on the final contract variation dated 20 January 2021.
2. The overhead and administrative costs were calculated from the Financial Operating Statement of the Banana Fund Annual Reports (Hort Innovation 2023a), averaging 16.4% for the BA16001 funding period (2017-2022).
3. Other funds from QDAF were provided in the contract as a lump sum of in-kind salaries and operational costs, so have been apportioned yearly based on Hort Innovation cash costs.

Present Value of investment

The nominal total investment cost of $16.7 million identified in Table 3 was adjusted for inflation (ABS, 2023) into a real investment of $19.44 million (2022-23 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 $23.48 million (2022-23 PV). The results were sensitivity tested changes in the discount rate between 2.5% and 7.5%.

Project impacts

The impact pathways identified in Table 2 was evaluated against available data to determine if their impact could be quantified with a suitable level of confidence. From this process, three impacts were selected for valuation.

Impacts valued and valuation framework

[Economic] Earlier adoption of higher yielding Rahan Meristem varieties. The benefit of BA16001 with regards to the Israeli varieties was quantified as a shift in the adoption curve, with the independent evaluation of BA16001 supporting faster adoption than would otherwise have occurred. A counterfactual (without BA16001) scenario was estimated, including the production and price effects of slower adoption of the Israeli varieties, as well as production and price effects of continued TR4 spread (using Cook et al 2015). Adoption of the four high yielding Israeli varieties was estimated through a review of project documentation, discussion with stakeholders and the application of the CSIRO ADOPT framework (Kuehne 2017). The agronomic benefit (increased yield) of the Israeli varieties was taken from BA16001 data and discussion with stakeholders. A new lower industry farmgate price was calculated based on the higher industry production and supply. For the additional yield of the Israeli varieties, benefit was quantified using the new industry banana price, less yield related costs (fertilizer, harvest and post-harvest). This benefit of additional yield for adopting growers was partly offset by the lower price received for existing banana production.

[Economic] Reduced risk of Fusarium Wilt with resistant varieties. The focus for this analysis was on TR4 rather than Race 1 given the 97% production share of TR4 susceptible Cavendish varieties, and the greater level of data availability on the TR4 risk. Given the lower agronomic performance of the identified TR4 resistant varieties relative to existing Cavendish varieties (including the Israeli varieties from Rahan Meristem), stakeholders (researchers and growers) advised there would be little adoption while higher yielding varieties are viable. However, in the event of greater TR4 pressure, the new varieties present an option for continued banana production. As such, the benefit of BA16001 with regards to TR4 resistant varieties was quantified as a reduced consequences in the event of continued TR4 spread. The counterfactual (without BA16001) was consistent with the Rahan Meristem variety scenario, including the production and price effects of adoption of Israeli varieties and continued TR4 spread (using Cook et al 2015). In the event of TR4 spread, a 100% loss of non-resistant banana production was valued (decreasing production and higher prices). In the event of increased TR4 spread, the new varieties were assumed to be made commercially available in agreement with the international breeders and local nurseries. The varieties would be planted once a decision point is reached whereby biosecurity rules allow replanting in TR4 infected areas. The industry benefit from the ability to continue production with the new (lower yielding) varieties was estimated using the agronomic data from BA16001 and industry gross margins. The banana price was also considered, reflecting both the change in supply relative to the counterfactual. The benefit of additional production with TR4 resistant varieties was partly offset by the lower price received for existing (TR4 free) banana production. A final attributable benefit was estimated in consideration of the contribution of previous (BA14013 and BA10020) and subsequent (BA21002) investments and other contributing factors.

[Economic] Reduced de-suckering requirement. The adoption and cost of improved tissue culture techniques was estimated in discussion with a commercial nursery. The benefit was calculated by estimating the total industry adoption of the new tissue culture method for propagation, and considering the number of plants required for projected industry growth as well as replacement. The counterfactual growth and replacement incorporated the effects of TR4 spread offset by the availability of the TR4 resistant varieties. The cost of applying the new tissue culture technique in propagation nurseries was also considered in discussion with stakeholders, and assumed to be passed on to growers in higher plant costs. The grower benefit of the new technique in the form of reduced labour requirement for de-suckering was estimated using industry GM data (QDAF, 2018). A final attributable benefit was estimated in consideration of the contribution of other research investments to achieving this outcome.

Impacts unable to be valued

The following impacts were not able to be quantified for the reasons identified:

[Socio-economic] Increased banana consumption with associated health and wellbeing benefits. There is a recognised link between health and wellbeing benefits of banana consumption (Mengstu et al 2021) and fruit and vegetable consumption more broadly (Angelino et al 2019, Mujcic et al 2016). However, to quantify the benefit of increased banana consumption (or avoided decreases in banana 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] Greater social and economic resilience for farm and local communities. The CIE (2023) highlighted the flow-on (spillover) effects of the banana industry for regional economies, particularly around the communities of Tully, Innisfail, Lakeland, and the Atherton Tablelands in Queensland; Darwin in the Northern Territory; the Coffs Harbor and Northern Rivers regions of New South Wales; and the Carnarvon region in Western Australia. By supporting increased industry productivity and sustainability, the project supports a corresponding increase in spillovers to local communities. While this analysis is able to quantifiy the direct impacts for banana industry production and value, the flow-on effects require additional analysis in economic models that capture regional and national linkages, which are beyond the scope of the R&D impact assessment program (CRRDC 2018). Increased resilience also relates to avoided health and wellbeing costs associated with biosecurity events. These health and wellbeing effects, such as avoided or reduced psychological stress that can affect growers and their communities, may be more profound than the direct economic impact (CSIRO, 2020 and CSIRO 2021). The CSIRO research also notes that the health and wellbeing affects are harder to quantify than economic impacts, which is consistent with the lack of data identified through this analysis to value health and wellbeing effects.

Data and assumptions

For the impacts where valuation was possible, the necessary data was collected from the project documents and other relevant resources. Where available, actual data was applied to the relevant years, with estimates applied for any data gaps and projections into the future based on identified analytical techniques (for example correlations and trend analysis), or stakeholder estimates, or both. Where estimates were used, a data range was considered to reflect underlying risk and uncertainty, which was further analysed through in sensitivity testing (see Results). A summary of the key data, assumptions and sources is provided in Table 4.

Table 4. Summary of the data and assumptions for impact valuation

Variable	Assumption	Source / comment
Discount rate	5% (± 50%)	CRRDC Guidelines (2018)
Industry production (without TR4) (t)	Av 381,000	Actual data used up to 2022 (Hort Innovation 2023b), with projections based on 10 year trend growth of 1% per year.
Industry production area (ha)	Av 12,741	Based on actual data for industry production (Hort Innovation 2023b) and average yield in productive areas (ABS 2023b). Projections incorporating production estimates (above) and the 5 year average yield per hectare.
Fusarium Wilt TR4 spread (% area)	58% by 2052 (± 60%)	A maximum spread based on Cook et al (2015). See appendix A.
Farmgate banana price $/kg	1.66 (± 15%)	Historical banana farmgate prices to 2022 were calculated based on Hort Innovation (2023b) and adjusted for inflation (ABS 2023a). Projected prices from 2023 were based off the 5-year (2017-18 to 2021-22) inflation adjusted minimum, average, and maximum.
Higher yielding Rahan Meristem varieties		
Adoption start	2021-22	Project reporting.
Adoption speed without BA16001 evaluation (of max adoption)	50% by 2027 100% by 2032	Adoption curve developed using CSIRO ADOPT Framework (Kuehne 2017) (see Appendix B). The adoption curve was applied to a maximum adoption range of 21% (from ADOPT) to 50% (Mission Beach nursery pers comm), with a midpoint of 36%.
Adoption speed with BA16001 evaluation	50% by 2026 (± 1 yr) 100% adoption by 2029-2032.	Adoption curve developed using CSIRO ADOPT Framework (Kuehne 2017), adjusted for improved industry awareness (see Appendix B). Applied to the same maximum adoption level as above.
Adoption cost $/ha	$340	$0.2/plant royalty fee to Rahan Meristem (Mission Beach nursery pers comm) and 1700 plants/ha (QDAF 2018)
Yield change	2.8% (-100% +9.0%)	BA16001 agronomic data using average performance of four varieties relative to Cavendish Williams (tested at the highest performer relative to Williams, and also at a zero productivity gain in the event the varieties other factors end up negating any yield gain).

Average annual yield related costs $/kg	$0.83	Annual yield related costs (fertilizer, harvest and post-harvest) across plant crop and 6 ratoon crops (QDAF 2018), adjusted to 2022-23 values (ABS 2023a).
Outcome attribution (higher adoption)	75% (± 33%)	Discussion with stakeholders highlighted the importance of the objective 3rd party trial data in supporting industry adoption.
R&D counterfactual	75% (± 33%)	Discussion with stakeholders indicated it would be unlikely for the 3rd party trials to have been undertaken without QDAF; and further, it is unlikely this would be undertaken without industry levy funds.
Reduced de-suckering requirement from improved tissue culture		
Adoption start	2021-22	BA16001 reporting and Mission Beach nursery pers comm.
Adoption level % of total industry propagation	75% (± 33%) in 4 years (± 1 yr)	Time to re-train staff (estimated from Mission Beach nursery pers comm).
Adoption cost $/plant	Nil	Requires a change in training and technique but no change in cost (Mission Beach nursery pers comm).
De-suckering cost (without new tissue culture) $/ha	$960	Requiring 6 hours per hectare 4 times per year (QDAF 2018), with a labour cost of $40/hr.
Reduction in de-suckering with BA16001 %	75% (± 33%)	Estimated through discussion with stakeholders. Likely reducing but not eliminating the need for de-suckering.
Outcome attribution (new tissue culture method)	100% (-25%)	Identified principally through BA16001 research into Corm Rot.
Attribution period (years)	15 years (± 33%)	Potential for changes in varieties or production systems may reduce the relevance of this outcome in the future.
R&D counterfactual	75% (± 33%)	Unlikely to have been identified without research into this area, which was unlikely to have been conducted without levy funding.
Reduced risk of Fusarium Wilt with resistant varieties		
TR4 resistant varieties available	2025	Based on pre-commercialisation starting from 2019-20 (including through BA16001 and follow on BA21002) and taking 5 years (stakeholder consultation). While estimated to be available from this time, planting will not occur until 1) agronomic parity is achieved with non-resistant varieties (not achieved during this project), or 2) TR4 spread destroys non-resistant varieties AND there is regulatory approval to replant in infected areas.
Approval threshold for replanting in TR4 areas (% of industry area loss)	15% (± 50%)	Current rules prevent replanting in TR4 infected areas. Given the closed supply of Australian bananas (zero imports) the continued spread of TR4 with associated production loss would likely trigger a review to allow replanting with TR4 resistant varieties (or trigger the importation of bananas, not considered in this analysis).
Yield performance (% of Williams Cavendish)	-30% (-62% + 75%)	BA16001 agronomic performance data for TR4 resistant varieties (AP1, AP3, GCTV215, GTCV247, CJ19)
Replanting costs $/ha	$9,474	One off costs relating to crop removal (of dead or diseased crop as a result of TR4) and ground prep and replanting with TR4 resistant varieties before returning to normal cost structure (below) (QDAF 2018), adjusted to 2022-23 values (ABS 2023a).
Average annual variable costs $/kg	$0.99	Annual variable costs across plant crop and 6 ratoon crops, including replanting 1/7 of area each year (QDAF 2018), adjusted to 2022-23 values (ABS 2023a).
Outcome attribution (replanting with TR4	50% (± 50%)	Contribution of other research investments in identifying (BA14013) and importing (BA10020) banana varieties, and

resistant varieties)		finalising varietal and pre-commercialisation trials (BA21002). Also considering the need for regulatory approval to replant bananas into TR4 infected areas.
Attribution period	15 years (± 50%)	The relevance of the five TR4 resistant varieties identified in BA16001 is likely to decline given the ongoing program to breed (AS20000) and import (BA21002) new TR4 resistant varieties being developed overseas, as well as private investments to import resistant varieties (such as R Gal from Rahan Meristem soon to be commercially available in Australia (Mission Beach pers comm)).
R&D counterfactual	75% (± 33%)	The importation and evaluation of these banana varieties is unlikely to have been undertaken without levy funding.

Results

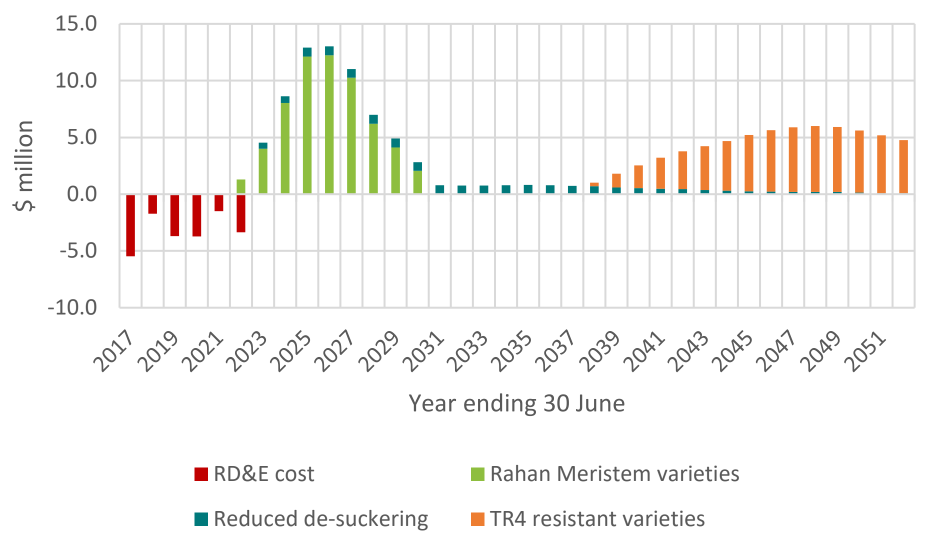
The analysis identified a PV costs (PVC) of $23.48 million (2022-23 PV) between 2016-17 and 2021-22, and estimated PV benefits (PVB) of $81.72 million (2022-23 PV) accruing between 2021-22 and 2051-52 (Table 5). When combined, these costs and benefits generate a net present value (NPV) of $73.05 million, an estimated benefit-cost ratio (BCR) of 3.48 to 1, an internal rate of return (IRR) of 21% and a modified internal rate of return (MIRR) of 9%.

Table 5. Impact metrics for the total investment in project BA16001

Impact metric	Years after last year of investment						
	0	5	10	15	20	25	30
PVC ($m)	23.48	23.48	23.48	23.48	23.48	23.48	23.48
PVB ($m)	1.36	46.14	58.24	60.41	65.62	74.31	81.72
NPV ($m)	-22.12	22.66	34.76	36.93	42.14	50.83	58.25
BCR	0.06	1.97	2.48	2.57	2.80	3.17	3.48
IRR	Negative	17%	20%	20%	20%	20%	21%
MIRR	Negative	13%	12%	10%	10%	9%	9%

Figure 2 shows the annual undiscounted benefit and cost cash flows for the total investment of BA16001. Cash flows are shown for the duration of the investment plus 30 years from the last year of investment. The benefit of supporting adoption of the high yielding Rahan Meristem varieties accounted for 64% of the estimated benefits, followed by the benefit of the new TR4 resistant varieties decreasing risk associated with potential TR4 spread (24%), and the benefit of the new tissue culture method with associated decline in de-suckering costs (12%).

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

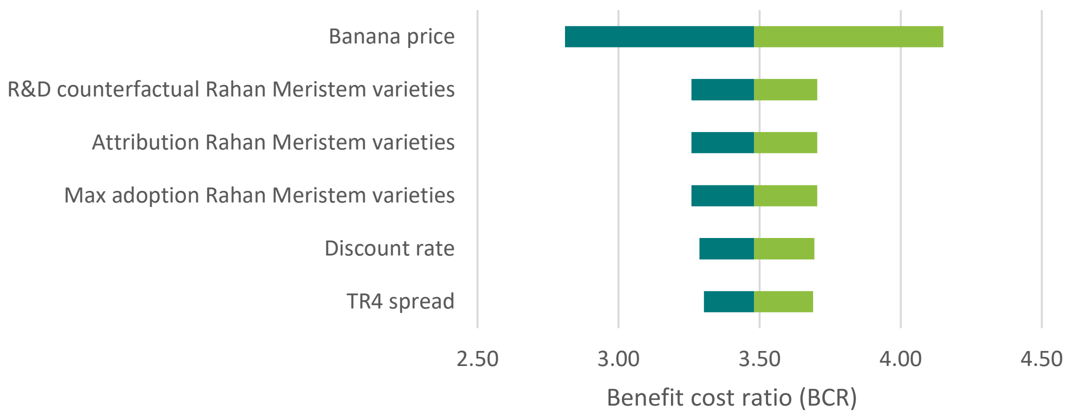


Sensitivity analysis

Given the risk and uncertainty associated with a number of underlying modelling inputs (particularly due to the forward projections inherent in the impact assessment process), the results were tested to sensitivity to changes in the variable where a potential value range was identified (Table 4).

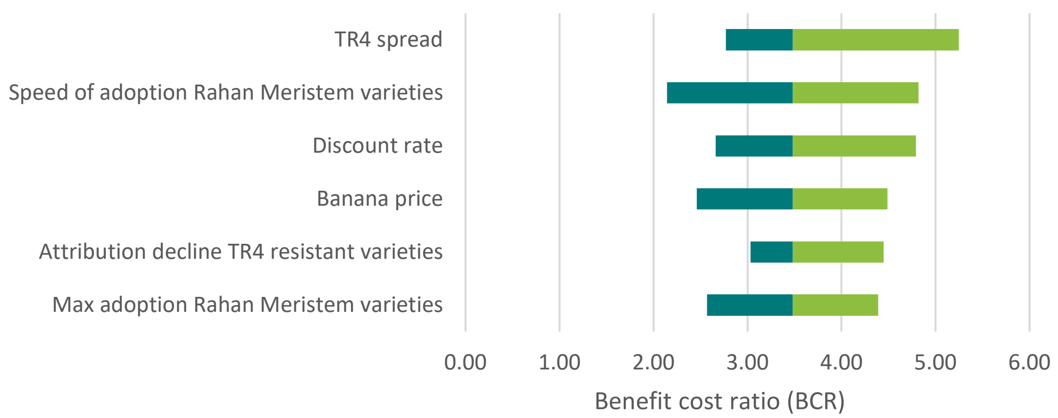
Results were first tested for sensitivity to uniform changes in underlying variables (tested individually), with the top 6 variables shown in Figure 3. This highlighted that the results were most sensitive to 10% changes in the banana price which influenced the size of the productivity benefits for both the Rahan Meristem varieties and also the TR4 resistant varieties. The results were also sensitive to variables relating to the Rahan Meristem varieties given this impact area accounted for the largest proportion of benefits. A 10% change in the rate of TR4 spread had a lower impact given the primary impact of this on the benefits of TR4 resistant varieties which accounted for a smaller proportion of benefits in the baseline results.

Figure 3. Sensitivity of the results to a 10% change in variables



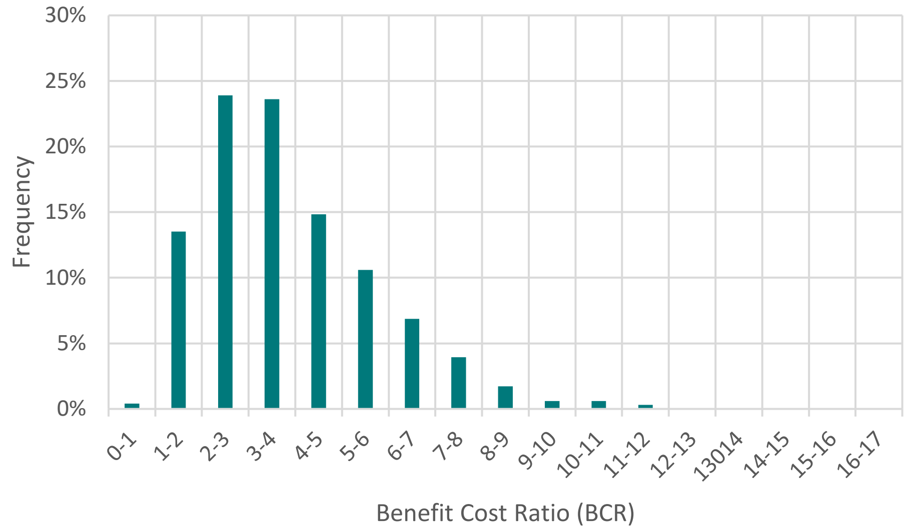
The results were next tested for sensitivity to individual changes across the full value range for each variable to reflect the differences in risk and uncertainty for each variable. The results were most sensitive to the full range of the six variables shown in Figure 4. The results were highly sensitive to changes in the rate of TR4 spread particularly on the upside due to this variable’s wide tested range (reflecting the uncertainty of future TR4 spread) as well as the effects of discounting and declining attribution in the future. A slower rate of TR4 spread pushes the benefit of TR4 resistant varieties further into the future, which is less consequential to the results due to the combined effects of discounting and attribution decline. In contrast, a more rapid rate of TR4 spread brings the benefit forward with lower discounting and higher attribution. Changes in the discount rate and the rate of attribution decline also had a higher upside benefit (but at lower levels as they are shown individually, rather than their combined effects in the R&D counterfactual). Variables relating to the Rahan Meristem varieties were also shown to have a high level of significance at their full range, particularly the speed and maximum adoption of these varieties which had a large significance on the upside and downside. The results were still sensitive to the banana price, but with a lower significance due to the narrower value range relative to some of the other variables.

Figure 4. Sensitivity of the results to changes across the full variable ranges



Finally, the full range of potential variation in the impact was estimated using stochastic modelling to incorporate the combined effect of changing all variables across their full ranges over 1000 simulations. This process showed an impact (BCR) range of between 0.92:1 and 11.89:1, with 90% of results falling between 1.48:1 and 7.35:1 (i.e. excluding the low probability tails) (Figure 5). More than 99% of the 1000 simulations had a BCR greater than 1 (benefits greater than RD&E costs). While the wide range of results reflects the high level of risk and uncertainty relating to many variables (as reflected in Figures 3 and 4), this testing gives a high level of confidence that the investment has generated a positive impact.

Figure 5. Impact histogram: Frequency of results (BCR) from 1000 simulations



Implications and learnings

BA16001 supported improved banana industry production through a range of research areas including sourcing, screening and evaluating banana varieties for disease resistance and agronomic performance (including independent evaluation of privately imported varieties), and investigating cost-effective and sustainable pest and disease management options. In both instances BA16001 built on the work of previous banana investments (BA10020), and supported future research (split into BA21002 for import and evaluation and BA21004 for pest and disease management)

From the three impact areas (discussed below), benefits of $81.7 million were estimated (2022-23 PV) compared to PV RD&E costs of $23.5 million. Together, these generated an impact (BCR) of 3.48:1, an internal rate of return (IRR) of 21%, and a modified internal rate of return (MIRR) of 9%.

The three main impact areas that could be attributed to BA16001, and quantified with available data were:

Earlier adoption of higher yielding Rahan Meristem (Israeli) varieties. Accounting for $52 million (64%) of the total benefits in the baseline results. BA16001 provided an independent evaluation of (non-TR4 resistant) varieties developed in Israel that had been privately imported into Australian and recently made commercially available. Stakeholders noted that this independent evaluation supported increased grower confidence in the agronomic performance of the newly available varieties in Australian conditions, and thereby supported earlier adoption than would otherwise have occurred. This adoption was estimated through a review of project documentation, discussions with stakeholders, and the application of the CSIRO ADOPT framework (Kuehne 2017). For adopting growers, a 3% yield benefit was estimated, with the net benefit also considering additional yield based costs (fertilizer, harvest and postharvest costs) as well as the price effect of increased industry production given the closed Australian banana market.

Reduced risk of Fusarium Wilt with resistant varieties particularly relating to TR4. Accounting for $20 million (24%) of the total benefits in the baseline results. From an evaluation of 37 new banana varieties (imported through the previous project BA10020) BA16001 identified 14 varieties with adequate TR4 resistance and progressed 3 to pre-commercialisation trials. While providing resistance to TR4, the varieties displayed lower agronomic performance (e.g. yield averaging 30% lower) relative to existing Cavendish varieties. As such, stakeholders advised there would be little adoption of these TR4 resistant varieties while higher yielding varieties are viable. However, in the event of greater TR4 pressure, the new varieties present an option for continued banana production. This reduced risk (consequences) of continued TR4 spread was quantified by estimating the production and price effects of TR4 spread without resistant varieties (but including the adoption of high yielding Israeli varieties), and comparing this to the possibility of the industry re-planting with the identified TR4 resistant varieties. The analysis also considered the need for regulatory approval to replant bananas into TR4 infected areas, the contribution of previous investments in identifying (BA14013) and importing (BA10020) banana varieties evaluated in BA16001, and also the implications of ongoing investments to breed (AS20000) and import (BA21002) new TR4 resistant varieties being developed overseas, including private import programs not funded by levy investments.

Reduced de-suckering requirement. Accounting for $1 million (12%) of the total benefits in the baseline results. Through the project's research into corm rot, an incidental outcome was achieved through the identification of improved tissue culture techniques that reduce the growth of suckers and thereby reduce the significant labour cost associated with de-suckering in banana production. The adoption rate and cost of this new technique, and the subsequent benefit to growers was estimated in discussion with researchers, growers, and nurseries and the use of industry gross margin data.

Other than the incidental impact of reduced de-sucking costs, the outcomes of the research into cost-effective and sustainable pest and disease management options was found to primarily inform other research (such as BA21004) rather than result in direct benefits to the industry. Future analysis of the impact of BA21004 should consider the contribution of BA16001 in informing any identified impacts.

Overall, the evaluation of the Israeli varieties, and the development of the new tissue culture method, BA16001 sat close to the end of the impact pathway with a relatively high confidence in adoption and impact. The importation and evaluation of new disease resistant varieties had a higher level of uncertainty given adoption of these lower yielding varieties is dependent on the continued spread of Fusarium Wilt (particularly TR4 in Queensland) and the difficulty in confidently estimating this. To reflect the potential variability or uncertainty relating some of the underlying variables (particularly those relating to projections of TR4 spread) the results were tested to changes in data values. Variable ranges were drawn from empirical data where available (such as BA16001 trial results), with estimates otherwise made based on previous detailed analysis (such as projections on TR4 spread) or in discussions with stakeholders. Different combinations of input data values were tested over 1000 simulations of the impact model, with 90% of simulated results (i.e excluding the low probability tails) falling between 1.48:1 and 7.35:1. A refinement of the identified variables through improved data and assumptions would allow a more accurate estimate of impact; however, the sensitivity testing gave a high level of confidence that the investment will generated a positive impact.

Additional social and environmental impacts are expected to be realised from the investment , but were not quantified as a result of data limitations. As such the quantified impacts represent a conservative estimate of the total potential impact from this investment. Through the impact assessment analysis, key data gaps were identified to support improved data collection and impact assessments in the future.

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 6 outlines the stakeholders consulted as part of this impact assessment and the topics on which they were consulted.

Table 6. 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**
Vino Rajandran, Hort Innovation Head of Production R&D	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Brenda Kranz, Hort Innovation R&D manager (former)	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Stewart Lindsay, QDAF	RD&E process owner / manager	✓	✓	✓	✓	✓	✓	✓
Steve Lavis, Mission Beach Nursery	RD&E Stakeholder				✓		✓	✓
Clinton Welch, grower	RD&E beneficiary and levy payer				✓		✓	✓
Raymond White, grower	RD&E beneficiary and levy payer				✓		✓	✓
Steven Lowe, grower	RD&E beneficiary and levy payer				✓		✓	✓

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

ABGC Australian Banana Growers Council

ADOPT Adoption and Diffusion Outcome Prediction Tool

CIRAD The French Agricultural Research Centre for International Development

CRRDC Council of Rural Research and Development Corporations

CSIRO The Commonwealth Scientific and Industrial Research Organisation

Embrapa The Brazilian Agricultural Research Corporation

EPAGRI The Brazilian Agricultural Research and Rural Extension Company of Santa Catarina

FHIA Honduran Foundation for Agricultural Research

QDAF The department of Agriculture and Fisheries, Queensland

Race 1 Fusarium Wilt Subtropical Race 1

RD&E Research, Development and Extension

SIP Strategic Investment Plan

TBRI Taiwan Banana Research Institute

TR4 Fusarium Wilt Tropical Race 4

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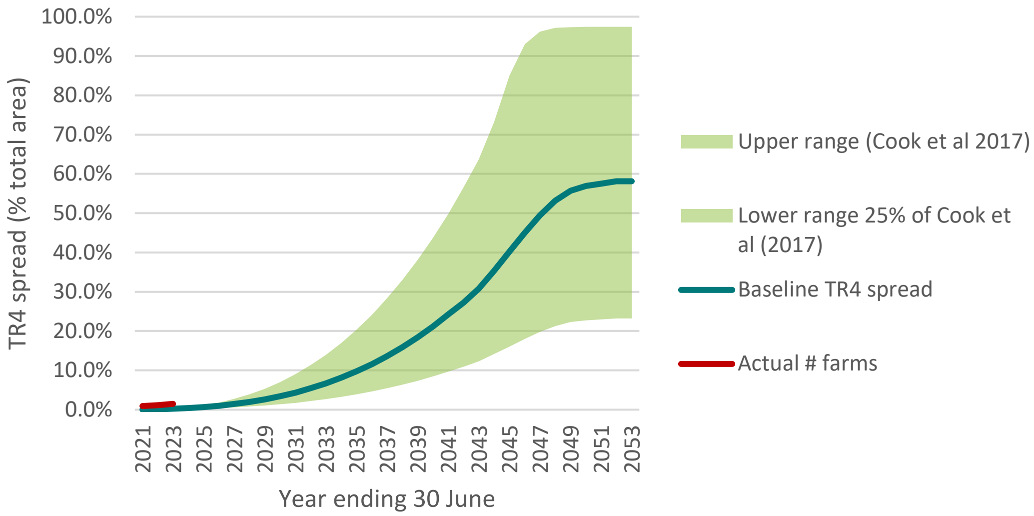
Appendix A Projected spread of Tropical Race 4 (TR4) in Australia

Williams cavendish make up around 97% of Australian industry banana production (Hort Innovation 2023). This presents a vulnerability for the industry in relation to disease threats, particularly relating to the globally significant disease Fusarium Wilt (Panama Disease) Tropical Race 4 (TR4) to which Williams Cavendish is highly susceptible. TR4 has been established (and contained) in the Northern Territory since 1997. In 2015, TR4 was discovered on a Queensland farm in 2015, and has since spread to a total of eight QLD farms as of July 2023. Cook et al (2017) estimated the potential rate of spread of TR4 at approximately 97% of production area within 30 years. Given the significance of this assumption relating to the benefit of TR4 resistant varieties, and the ongoing and changing work being undertaken to contain TR4 and mitigate the likelihood of further spread, a lower spread rate at 25% of that estimated in Cook et al (2017) was included in this analysis as a lower range, with an average of the two used in the baseline (Figure 6). While the number of farms with TR4 infection does not directly equate to the % of industry area, this data is also included for comparison.

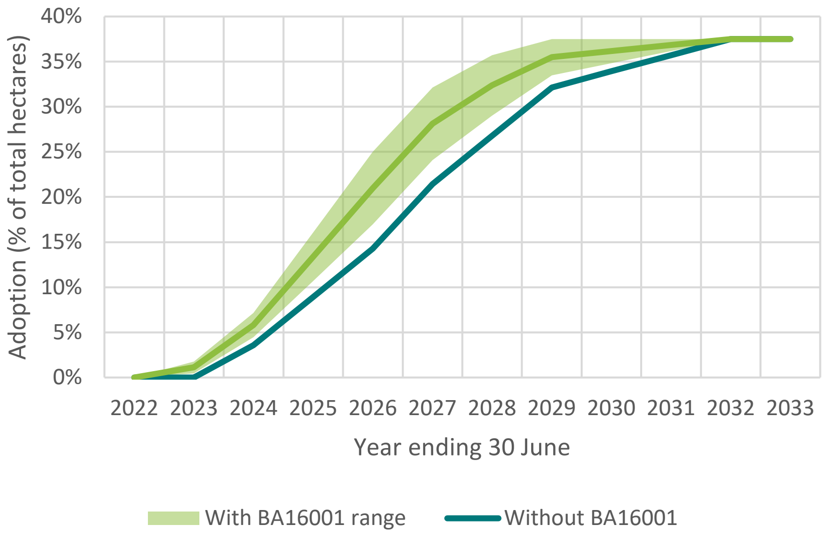
Figure 6. Projected area of TR4 spread over time used in the analysis, and actual number of infected farms.



Appendix B Adoption and diffusion using the ADOPT framework

Appendix B includes the data inputs for the ADOPT model (Kuehne et al 2017) used in the analysis of the adoption of the Israeli banana varieties. The ADOPT model incorporates the project findings and discussions with industry stakeholders. The improved industry confidence to adopt because of the independent evaluation and extension conducted through BA16001 was reflected in changes to advisory support (Q10) and grower/advisor awareness (Q13). The revised ADOPT curve (reaching full adoption 3 years earlier in 2029) was taken as the upper rate of "with BA16001" adoption. A more conservative "with BA16001" adoption was estimated from stakeholder consultation equal to 25% of the upper level ADOPT curve. The resultant adoption curves can be seen in Figure 7.

Figure 7. Adoption of Israeli banana varieties over time with and without BA16001.



ADOPT inputs for mealybug pest management

1. What proportion of farms have maximising profit as a strong motivation?

A majority all have maximising profit as a strong motivation

2. What proportion of farms has protecting the natural environment as a strong motivation?

About half have protection of the environment as a strong motivation

3. What proportion of farms has risk minimisation as a strong motivation?

About half have risk minimisation as a strong motivation

4. On what proportion of farms is there a major enterprise that could benefit from the technology?

Almost all of the target farms have a major enterprise that could benefit

5. What proportion of farms have a long-term (greater than 10 years) management horizon for their farm?

About half have a long-term management horizon

6. What proportion of farms are under conditions of severe short-term financial constraints?

A minority currently have a severe short-term financial constraint

7. How easily can the innovation be trialled on a limited basis before a decision is made to adopt it on a larger scale?

Moderately trialable

8. Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?

Not at all difficult to evaluate due to complexity

9. To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?

Not observable at all

10. What proportion of growers use paid advisors capable of providing advice relevant to the innovation?

A minority use an advisor capable of providing advice on the Israeli varieties (without BA16001)

Almost all use an advisor capable of providing advice on the Israeli varieties (with BA16001)

11. What proportion of growers participate in groups that enable discussion relevant to the innovation?

A majority of growers participate in relevant discussion groups

12. What proportion of growers/advisors will need to develop substantial new skills and knowledge to use the innovation?

A minority will need to develop substantial new skills and knowledge

13. What proportion of growers would be aware of the trialling of this innovation in their district?

The Israeli varieties had never been planted or trialled in Australia (without BA16001)

Almost all would be aware of the use of trialling of the Israeli varieties (with BA16001).

14. What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?

Minor initial investment of $0.20 royalty per tree (additional 5% above standard costs).

15. To what extent is the adoption of the innovation able to be reversed?

Easily reversed

16. To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?

Moderate profit advantage from higher productivity.

17 To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?

No profit advantage outside of the years that it is used.

18 How long after the innovation is first adopted would it take for effects on future profitability to be realised?

Not applicable.

19. To what extent would the use of the innovation have net environmental benefits or costs?

No net environmental effects

20. How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realised?

Not applicable

21. To what extent would the use of the innovation affect the net exposure of the farm business to risk?

No increase in risk

22. To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?

No change in ease and convenience.

Ends.