Industry-specific impact assessment program: Banana

Impact assessment report for project *Fusarium wilt Tropical Race 4 – biosecurity and sustainable solutions* (BA14013)

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What the report is about

This report presents the results of an impact assessment of a Horticulture Innovation Australia Limited (Hort Innovation) investment in project BA14013 titled "*Fusarium wilt Tropical Race 4 – Biosecurity and sustainable solutions"*. The project was funded by Hort Innovation over the period June 2015 to September 2017.

Methodology

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

Results/key findings

The investment in project BA14013 has provided new science, information and practices to address the priority needs for robust, science-based biosecurity measures to contain *Fusarium wilt* TR4 and prevent further spread, as well as to investigate measures for detecting and managing new incursions. The project also produced outputs that were used to provide input to the development of content and process for the Australian Banana Growers' Council Biosecurity Extension project workshops and activities and Biosecurity Queensland's development of the Panama disease Standards and Guidelines. Key project findings have been integrated into on-farm biosecurity practices in the Australian banana industry.

BA14013 is likely to have contributed to maintained productivity through avoided production losses for some Australian banana growers through the project's contribution to a reduced risk of the spread of *Fusarium wilt* TR4 in north Qld.

Investment Criteria

Total funding from all sources for the project was $3.27 million (present value terms). The investment produced estimated total expected benefits of $11.02 million (present value terms). This produced an estimated net present value of $7.75 million, a benefit-cost ratio of 3.37 to 1, an internal rate of return (IRR) of 13.43% and a modified IRR of 10.81% over 30-years at a discount rate of 5% and a reinvestment rate of 5%.

Conclusions

A number of other economic, environmental, and social impacts were identified but not valued as part of the current assessment. Thus, given the impacts not valued, combined with conservative assumptions made for the principal economic impacts valued, it is reasonable to conclude that the investment criteria reported may be an underestimate of the actual performance of the BA14013 investment.

Keywords

Impact assessment, cost-benefit analysis, BA14013, banana, Panama disease Tropical Race 4, Fusarium wilt, TR4, biosecurity

Introduction

All research and development (R&D) and marketing levy investments undertaken by Horticulture Innovation Australia Limited (Hort Innovation) are guided by and aligned to specific investment outcomes, defined through a Strategic Investment Plan (SIP). The SIP guides investment of the levy to achieve each industry's vision. The current industry SIPs apply for the financial years 2016/17 – 2020/21.

In accordance with the Organisational Evaluation Framework, Hort innovation has the obligation to evaluate the performance of its investment undertaken on behalf of industry.

This impact assessment program addresses this requirement through conducting a series of industry-specific ex-post independent impact assessments of the almond (AL), banana (BA), citrus (CT) and onion (VN) research, development and extension (RD&E) investment funds.

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

- Nine AL projects were chosen worth $5.84 million (nominal Hort Innovation investment) from an overall population of 21 projects worth an estimated $10.78 million,
- Eight BA projects worth $3.02 million (nominal Hort Innovation investment) from an overall population of 24 projects worth approximately $16.72 million,
- Eight CT projects worth $5.40 million (nominal Hort Innovation investment) from a total population of 35 projects worth $15.78 million, and
- Four VN projects worth $2.40 million (nominal Hort Innovation investment) from an overall population of 8 projects worth $3.89 million.

The project population for each industry included projects where a final deliverable had been submitted in the five-year period from 1 July 2014 to 30 June 2019. The projects for each industry sample were chosen such that the investments represented (1) at least 10% of the total Hort Innovation RD&E investment expenditure for each industry, and (2) the SIP outcomes (proportionally) for each industry. Four projects had been randomly selected as part of a related Hort Innovation project (MT18011) and were included in the samples for the AL industry (AL14006 and AL16004) and the CT industry (CT15006 and CT15013). This left 25 unique projects randomly selected for evaluation under MT19012.

Project BA14013*: Fusarium wilt Tropical Race 4 – Biosecurity and sustainable solutions* was randomly selected as one of the 25 unique MT19012 investments and was analysed in this report.

General Method

The impact assessment follows general evaluation guidelines that are now well entrenched within the Australian primary industry research sector including Research and Development Corporations (RDCs), Cooperative Research Centres (CRCs), State Departments of Agriculture, and some universities. The approach includes both qualitative and quantitative descriptions that are in accord with the impact assessment guidelines of the CRRDC (CRRDC, 2018).

The evaluation process involved identifying and briefly describing project objectives, activities and outputs, outcomes, and actual and/or potential impacts. The principal economic, environmental and social impacts were then summarised in a triple bottom line framework.

Some, but not all, of the impacts identified were then valued in monetary terms. Where impact valuation was exercised, the impact assessment used cost-benefit analysis as its principal tool. The decision not to value certain impacts was due either to a shortage of necessary evidence/data, a high degree of uncertainty surrounding the potential impact, or the likely low relative significance of the impact compared to those that were valued. The impacts valued are therefore deemed to represent the principal benefits delivered by the project. However, as not all impacts were valued, the investment criteria reported for individual investments potentially represent an underestimate of the performance of that investment.

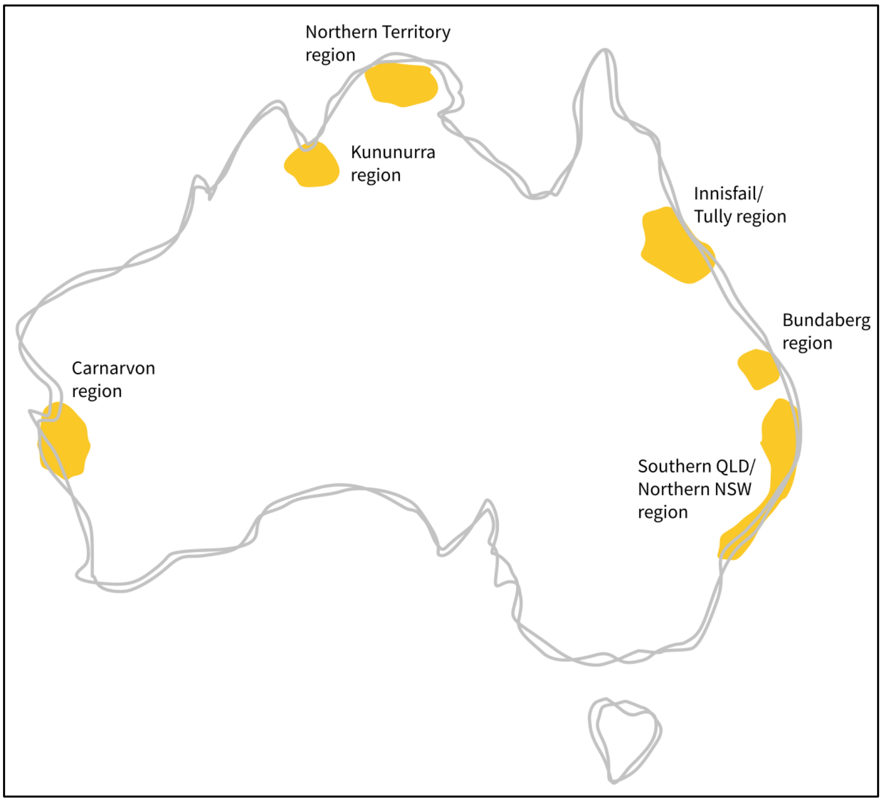
Background & Rationale

Background

The Australian Banana Industry

Bananas have been grown in Australia since the 1880s. Today, bananas are grown in subtropical and tropical regions including in Queensland (Qld), northern New South Wales (NSW), the Northern Territory (NT) and Western Australia (WA) (Hort Innovation, 2020). On average, Qld accounts for approximately 90% of the total area of bananas grown and over 95% of total Australian production (10-year average[1]). Figure 1 shows Australia's banana growing regions and Table 1 provides a summary of the data for production of bananas for both Australia and Qld.

Figure 1: Australia's Banana Growing Regions



Source: https://australianbananas.com.au/Pages/all-about-bananas/the-banana-story

[1] Based on area data from the Australian Bureau of Statistics (ABS), series 7121.0 *Agricultural Commodities, Australia* 2009/10 to 2018/19 and production data from the Australian Banana Growers' Council (ABGC)

Table 1: Production Statistics for the Australian and Qld Banana Industry (year ended 30 June 2010 to 2019)

Australia											
Year ended 30 June	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**10yr Avg.**
Total area (ha)	12,497	13,296	15,484	15,348	12,879	11,788	16,612	14,021	12,477	11,902	13,630
Area (bearing age) (ha)	11,543	11,196	13,496	14,218	12,085	10,936	15,610	13,274	11,551	10,962	12,487
Production[(a)] (t)	309,505	330,980	202,423	339,922	370,176	370,989	395,878	413,660	388,265	371,915	349,371
Yield (t/ha)	26.8	29.6	15.0	23.9	30.6	33.9	25.4	31.2	33.6	33.9	28.0
Gross value ($m)	488.1	316.0	466.8	490.7	341.3	455.0	409.0	538.5	487.6	490.9	448.4
QLD											
Year ended 30 June	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**10yr Avg.**
Total area (ha)	10,869	11,480	13,576	13,886	11,356	10,101	15,794	13,182	11,502	10,829	12,258
Area (bearing age) (ha)	10,083	9,727	11,810	12,986	10,726	9,446	14,933	12,597	10,693	10,030	11,303
Production[(b)] (t)	270,358	287,553	177,135	310,468	328,548	320,442	378,709	392,562	359,425	340,294	316,549
Yield (t/ha)	26.8	29.6	15.0	23.9	30.6	33.9	25.4	31.2	33.6	33.9	28.0
Gross value ($m)	448.3	283.1	415.4	456.5	322.8	440.8	401.2	525.8	472.0	468.3	423.4

Source: ABS Series 7121.0 *Agricultural Commodities, Australia* (2009/10 to 2018/19) and ABS Series 7503.0 *Value of Agricultural Commodities Produced, Australia* (2009/10 to 2018/19)

(a) Production data from the ABGC based on compulsory levies.

(b) Derived from ABS area (bearing age plants) and the Australian average yield for each year.

Panama Disease Tropical Race 4

Fusarium wilt, also known as Panama disease, is a destructive fungal disease of banana plants. It is caused by *Fusarium oxysporum f. sp. cubense* (*Foc*). It first became epidemic in Panama in 1890 and proceeded to devastate the Central American and Caribbean banana industries that were based on the 'Gros Michel' (AAA) variety in the 1950s and 1960s. Once *Foc* is present in the soil, it cannot be eliminated.

There are four recognised races of the pathogen which are separated based on host susceptibility (Pegg, Coates, O'Neill, & Turner, 2019):

- Race 1 (*Foc* R1), was responsible for the epidemics in 'Gros Michel' plantations, and also attacks 'Lady Finger' (AAB) 'Silk' (AAB) and Ducasse (ABB) varieties.
- Race 2 (*Foc* R2) affects cooking bananas such as 'Bluggoe' (ABB).
- Race 3 (*Foc* R3) affects *Heliconia spp.*, a close relative of banana, and is not considered to be a banana pathogen.
- Race 4 (*Foc* R4) is capable of attacking 'Cavendish' (AAA) as well as the other varieties of banana affected by R1 and R2. Races 1, 2 and 4 have been present on the east coast of Australia for many years and R1 also is present in WA.

R4 is further divided into 'sub-tropical' and 'tropical' strains. 'Subtropical' race 4 (SR4) generally only causes disease in Cavendish varieties growing sub-optimally (cool temperatures, water stress, poor soil). 'Tropical' race 4 (TR4) is a more virulent form of the pathogen and is capable of causing disease in 'Cavendish' growing under any conditions. TR4 was first identified in Taiwan in 1989 but has spread rapidly.

TR4 is one of the most severe threats facing the banana industry worldwide. TR4 has rapidly spread throughout Southeast Asia since first being reported and is a serious threat to the Australian Cavendish banana industry.

Panama disease TR4 was first discovered in Australia in 1997 in the Northern Territory (NT) where strict quarantine management restricted its spread only to the NT banana industry for almost two decades. However, in March 2015, another outbreak was detected in Tully, north Qld, where a large percentage of Australian bananas are grown (Andre Drenth, pers. comm., 2017).

Rationale

Following the detection of Panama TR4 in Qld, the banana industry and Qld government funded the Panama TR4 Program. Industry and government continue to work together to contain and control the disease through surveillance on farms, compliance on known infested properties and communication and education activities (DAF, 2020).

After the detection of TR4 on a property in the Tully Valley, the way that banana businesses were managed in north Qld had to change. Project BA14013 (*Fusarium wilt Tropical Race 4 – Biosecurity and sustainable solutions*) was funded to provide new science, information and practices that addressed key areas of need for the industry to:

1. Successfully contain the disease and prevent further spread of the pathogen through the adoption of robust, science-based biosecurity practices, and
2. Identify and investigate options to facilitate the development of economically viable production systems, capable of minimising inoculum build up, that are suitable for use on infected or at risk farms.

Project Details

Summary

Project Code: BA14013
Title: *Fusarium wilt Tropical Race 4 – Biosecurity and sustainable solutions*
Research Organisation: The Department of Agriculture and Fisheries Qld (DAF)
Principal Investigator: Irene Kernot
Period of Funding: June 2015 to September 2017

Objectives

The overall aim of project BA14013 was to provide new science, information and practices that addressed key areas of need in the Australian banana industry given the detection of Fusarium wilt TR4. The five main objectives of the project were to:

1. Conduct research to underpin improved biosecurity practices on farm.
2. Improve access to new cultivars and build capacity in propagation.
3. Develop resilient disease management options.
4. Update biosecurity protocols for banana production to reflect project outcomes.
5. Facilitate rapid adoption of the research findings.

Logical Framework

Table 2 briefly describes the activities, outputs, outcomes, and actual and potential impacts of project BA14013 in a logical framework.

Table 2: Logical Framework for Project BA14013

Activities	• The project delivered new science, information and practices to address key areas of need in the banana industry.
	• The priority areas were identified and distilled from a Fusarium wilt R&D gap analysis workshop held in 2009 and from questions recorded at industry meetings held in north Qld at the beginning of the incursion in 2015.
	• These identified knowledge gaps were then allocated into three different scenarios:
	    ○ I don't have the disease, what do I need to do to avoid getting it?
	    ○ I have the disease on one part of the farm, how do I contain it and limit its spread?
	    ○ I have the disease across the farm, how can I continue to farm safely and economically?
	• These scenarios served to provide a structure with which to frame the RD&E response to Fusarium wilt TR4.
	• In addressing the RD&E needs, existing information and research work from Australia and overseas was accessed, particularly on disease epidemiology, but significant knowledge gaps were revealed that required additional research effort.
	
	<u>Conduct research to underpin improved biosecurity practices on farm</u>
	• The project's initial focus was to provide the banana industry with the information and planning required to implement robust, science-based biosecurity measures to contain the disease and prevent further spread. Key components of this were:
	    ○ The rapid establishment of a common level of understanding about Fusarium wilt TR4 in bananas including disease biology, mechanisms of spread and potential impact.

  - Development of a planning process for landholders to identify the Fusarium wilt TR4 risk pathways associated with individual banana production system to help identify the best biosecurity options for each.
  - Identification and refinement of a range of biosecurity practices such as boot exchange, footbaths, vehicle washing facilities and processes, and the application of differential access zoning to a property.
- The project contributed to content for a series of interactive workshop modules on farm biosecurity practices for Fusarium wilt TR4 that were rolled out to industry through the Australian Banana Growers' Council (ABGC)-led biosecurity extension project from July 2015 to February 2016.
- Research and development (R&D) activities also were undertaken to support biosecurity practice implementation. The activities included investigation of the efficacy and optimal use of sanitisers/disinfectants effective against the Fusarium wilt TR4 pathogen.
- Researchers at the South Australian Research and Development Institute (SARDI) undertook activities to develop a quantitative polymerase chain reaction (PCR) assay for identifying TR4 in soil and water samples.
- Assay sensitivity was assessed against soil samples that were both naturally and artificially infected with Fusarium wilt TR4 to test the ability of the assay to detect the TR4 organism at a range of spore concentrations in soil.
- Laboratory and field trials were conducted to identify effective chemical and/or biological treatments to destroy inoculum in infected plants and infested soil.
- Laboratory and field trials also were undertaken to test chemical and biological treatments to enhance decomposition of banana pseudostem material to prevent saprophytic colonisation by Fusarium wilt.

<u>Improve access to new cultivars and build capacity in propagation</u>

- Australia invests heavily in identifying, importing and screening banana cultivars with potential pest and disease resistance (through project BA16001: *Improved plant protection for the banana industry*) and in developing resistant varieties (project BA14014: *Fusarium wilt TR4 research program*).
- A review of the current global banana breeding activities, describing their origins, objectives, methodologies, current status, and progeny suitable for the Australian industry, was undertaken.

<u>Develop resistant crop management options</u>

- The project assessed the use of cover crops to reduce inoculum in infested soil. Living groundcovers had previously been shown to reduce Fusarium wilt symptoms by 20% in fields infected by Race 1 and reduce water run-off that can be a pathway for inoculum transport by 85%.
- Also, how root exudates affect Fusarium wilt TR4 populations was assessed. This activity was undertaken to investigate the role of exudate profiles under banana and cover crops to determine if they induce or reduce chlamydospore germination, and whether certain root exudates attract beneficial microorganisms to the roots.
- Additional activities were undertaken to assess the use of microbes to suppress Fusarium wilt. Characteristics of a suppressive soil microbiome were investigated by analysing the metagenics of soil organisms and assessing the influence of crop management practices on the banana microbiome.
- The role of plant stress in susceptibility of Fusarium wilt TR4 infection was assessed. Field and glasshouse trials were conducted to investigate how plant stress interacts with TR4 and the role of plant stress in reducing plant defence mechanisms and increasing susceptibility to TR4.
- The study also investigated the use of rapid plant physiological assessment methods (proline accumulation in leaf tissue, chlorophyll fluorescence , chlorophyll content, stomatal conductance and thermal imaging) to determine the potential for effective detection of plant stress and disease prior to the appearance of symptoms.

<table>
<tr><td></td><td><u>Update biosecurity protocols for banana production to reflect project outcomes</u>

As project outputs from Objective 1 (Conduct research to underpin improved biosecurity practices on farm) became available, they were communicated to banana growers, industry service businesses and key members of the Biosecurity Qld (BQ) Panama Response team at a range of regular meetings, R&D meeting updates, discussion groups, and industry activities.
The costs of implementing identified biosecurity practices as well as the relative productivity of alternative Cavendish varieties in possible alternative production systems were modelled.
A Best Management Practice (BMP) guide for on-farm biosecurity was developed with input from banana growers and BQ. It consisted of a self-assessment checklist for growers to audit their adoption of biosecurity practices, a management plan template that could be populated with gaps identified from the audit, and comprehensive resource material to assist in identifying what improved practices were available.
The project also supported networking and communication with international scientists working on Fusarium wilt TR4 at a range of industry and scientific conferences both internationally and domestically.

<u>Facilitate rapid adoption of the research findings</u>

An engagement and communication plan was developed that identified key stakeholders and described the activities and channels for extension and communication of research outputs to occur.
Extensions, communication and training activities were conducted to assist banana growers and other target audiences to prepare for the three critical scenarios identified.
As the project progressed, results and scientifically validated practices were disseminated through participation in industry events coordinated by other projects such as the Banana Industry Roadshows and Australian Banana Industry Congress, and through industry publications including ‘Banana Growers’ and the ABGC e-Newsletter.
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<tr><td>Outputs</td><td><u>Conduct research to underpin improved biosecurity practices on farm</u>

The most likely movement pathways for Fusarium wilt TR4 associated with north Qld banana production systems were identified.
A Panama disease risk assessment tool (RAT) was produced.
At the completion of the ABGC-led biosecurity workshops, each participant had developed some or all of a draft biosecurity plan for their farm. The ABGC Biosecurity Extension project delivered 37 workshops involving 246 growers, partners and farm managers from 228 farms representing 77% of farms and 82% of the production area in north Qld.
A range of effective biosecurity methods were identified. The foundation principle for effective biosecurity adoption was one of exclusion of all non-essential vehicles/ machinery/ tools/ people/ planting material from the property.
Where exclusion was not practical or feasible, access should only occur subject to practices to manage the associated risk. Practices proposed to manage these risks include:

Use of dedicated vehicles, footwear and tools within specific zones,
Procedures and facilities for footwear change at zone boundaries,
Use of footbaths and vehicle washing and disinfestation procedures,
Physical barriers such as fencing to minimise people and animal movement across zones, drainage to intercept surface water movement from external sources onto the farm zone where practical, and
Use of certified clean planting material.

From the disinfectant trials, quaternary ammonium compounds and Evo Tech 213 (bioflavonoid) were found to be effective at achieving a ‘zero detectable’ level of Race 1 at rates of 1% across a range of contact times and in the presence of soil.
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	• Further, the project found that the use of detergent based products, which are the primary products used by the cotton industry for management of Fusarium wilt of cotton, appeared only to suppress or delay colony development. • In general, the results achieved from the disinfectant trials were consistent between Race 1 and TR4. • From the results, clear recommendations were made to industry regarding effective disinfectant use. • Results from the disinfectant trials also have identified options for managing wash down water. The best options showed that a number of disinfectant products can be used to treat waste water containing soil for 24 hours at the lowest effective chemical concentration that achieves zero colony counts. • Wash down/vehicle dip/footbath waste treated in this fashion can then be disposed of following the recommended method for that disinfectant treatment. • A TaqMan MGB qPCR assay targeting the Intergenic Spacer of ribosomal DNA was created for the detection of Fusarium wilt TR4. • The assay detected TR4 with a high sensitivity but cross reacted at a low level with most other Fusarium wilt races. • Testing on a new collection of isolates indicated that the qPCR assay preferentially detects TR4 but that some isolates are detected better than others. • The assay consistently detected TR4 in spiked soil samples and the results indicated that the limit of detection of the new assay was about 2.5 spores per gram of soil. • Overall, the results showed that the assay was sensitive and specific enough for TR4 detection in soil, however where a new incursion is detected it was recommended that this be confirmed by sequencing to confirm identification. The assay is now commercially available through the SARDI Molecular Diagnostics Centre. • Field testing of banana pseudostem destruction and decomposition methods was completed. The project found that ammonia (NH_3) from any source that produced a concentration equal to or greater than 2500 ppm was effective at preventing Fusarium wilt from being recovered from the soil. These data have helped to inform field trials undertaken by BQ to confirm the efficacy of their destruction protocol. • To establish likely hosts for Fusarium wilt surveys of north Qld banana farms were conducted to determine the most common weed and groundcover species co-habiting banana farms. The survey results established that the six most common species found on banana farms were Sour Grass (*Paspalum conjugatum*), Crowsfoot Grass (*Eleusine indica*), Mullumbimby Couch (*Cyperus brevifolius*), Cinderella Weed (*Synedrella nodiflora*), Broadleaf Carpet Grass (*Axonopus compressus*), and Pennywort (*Centella asiatica*). • The results showed that, across 18 species tested, the pathogen was recovered from all 18 species, and it was more consistent from some species than others. For example, the pathogen was recovered from 80% of Mullumbimby Couch replicates, whereas the pathogen was only recovered from 20% of Green Amaranth replicates. <u>Improve access to new cultivars and build capacity in propagation</u> • The project review found that here are relatively few breeding programs actively breeding or selecting Cavendish style replacements. • Most programs developing hybrid crosses are focusing on Lady Finger (AAB Pome subgroup) or Silk (AAB Silk subgroup) types with only limited success in developing replacement varieties with Foc resistance and market acceptable fruit quality. • Access to breeding outputs of many of the programs is increasingly restricted or unavailable and ready access to varieties suitable for the Australian marketplace is not assured in the future. • To improve access to new varieties options for co-investment in some programs have been examined, particularly the Cavendish improvement program at the Taiwan Banana Research Institute. <u>Develop resistant crop management options</u>

	• Nineteen potential tropical rotation crops and groundcovers growing in the pasture collection at Walkamin Research Station were tested for their microbial profile and ability to host a complex soil microbial community, to determine differences from bare soil. • The differing pasture species demonstrated differences in soil microbial communities, using both the soil nematode community and substrate utilization profiles. • Four pasture plot soils completely suppressed the recovery of Foc R1 from a baiting bioassay –*Leucaena leucocephala*, *Dismanthus bicornutus*, *Arachis pintoi* and *Chloris gayana* – although there was some variation in the recovery of Foc from pasture species that had multiple entries, such as *Chloris gayana* which ranged from zero to 50% recovery and *Arachis pintoi* which ranged from zero to 90%. • Results from the analyses indicate that *Leucaena leucocephala* is worthy of further investigation. Soil taken from *Leucaena* plots completely suppressed the recovery of Fusarium wilt R1 from soil and altered the microbial community based on nematode community structure and substrate utilisation profiles. • The suppression of Fusarium wilt R1, determined using a bioassay of trial site soil, indicated that less R1 was recovered from soil with increasing time. The reduction in R1 recovery tended to correspond with increased microbial activity. • Further, characterisation of the soil microbiome demonstrated that there was a shift in the utilisation patterns of different carbon substrates over time. This "maturity" of the microbial community appeared to be linked with increased suppression of Fusarium wilt R1. • Measuring the concentration of plant pigments (particularly chlorophyll) assisted in determining the severity of stress or Fusarium wilt infection, due to the relationship this pigment has with leaf function. • Measuring chlorophyll fluorescence may also be useful for quantifying stress severity, however the instrument and method used in the project trials would need to be reconsidered and improved for future work • In this study, stomatal conductance, levels of proline accumulation and thermography could not be verified as useful measurements for stress quantification or disease detection in banana plants, and further work is required before they are worth incorporating into early detection protocols. <u>Update biosecurity protocols for banana production to reflect project outcomes</u> • A BMP guide for on-farm biosecurity was developed and can be found at http://horticulture.com.au/wp-content/uploads/2017/06/On-farm-Biosecurity-Manual.pdf • Comparisons of modelled scenarios for a hypothetical small-medium banana farm in north Qld (56 ha) showed that key characteristics of properties had a major influence on the ability to effectively implement exclusion and zoning to manage the spread of Fusarium wilt TR4. • Based on the application of identified effective practices the cost of capital investment ranged from $3,070 to $8,500 per hectare for a contiguous and non-contiguous scenario respectively. • Estimates of operating costs for crossing zone boundaries safely (washing vehicles/machinery, changing boots, provision and maintenance of disinfectant products) ranged from $134 to $546 per hectare per year for the modelled contiguous and non-contiguous scenarios respectively. • Comparison of modelled productivity outputs for alternative Cavendish production systems show that none of the alternative systems yields more than 50% of the industry standard 'Williams' Cavendish in a disease-free situation based on the currently available data. • Project staff hosted a range of international banana scientists and producers and shared project activities and results. • Project staff also travelled to Taiwan (February 2016) and discussed research opportunities and access to cultivars that are being developed.

	• Project personnel also presented at a variety of domestic and international conferences and Australian banana industry events. The cost of travel for some of these events was funded through BA14014 (*Fusarium wilt Tropical Race 4 Research Program*). <u>Facilitate rapid adoption of the research findings</u> • A communication and engagement plan was created. • The project delivered a range of extension and communication activities including group R&D coordination activities and industry activities including attendance and presentations at key meetings. • A number of articles and other media releases were published in scientific and industry publications.
Outcomes	• The project was very successful in achieving the objective of providing new science, information and practices to address the priority needs for robust, science-based biosecurity measures to contain the disease and prevent further spread, and investigate measures for detecting and managing new incursions. • The project also made progress in the investigation of different elements of an integrated production system based on tolerant or resistant varieties and management practices to limit inoculum production. • The Panama disease RAT was used to provide input to the development of content and process for the ABGC Biosecurity Extension project workshops and activities. • The RAT also was considered by BQ in their development of the Panama disease Standards and Guidelines that were intended to provide banana growers with guidance on their biosecurity requirements if they become infected and are quarantined. • Key project findings have been integrated into on-farm biosecurity practices in the Australian banana industry. • Plans are progressing to develop an on-line based system based on the Fusarium wilt TR4 biosecurity BMP guide, similar to the environmental BMP system as part of BA14014 '*Fusarium wilt Tropical Race 4 Research Program*'. • Banana growers, related supply chain businesses and other industry stakeholders have adopted new and improved biosecurity BMPs to contain Fusarium wilt TR4 and prevent/limit further spread including the appropriate use of sanitiser products for farm biosecurity. • Researchers now are better able to detect/identify TR4 in soil samples at levels as low as 2.5 spores per gram of soil thanks to development of the new assay. • The assay also offers opportunities for researchers to quantify the impact of management practices on disease inoculum that may accelerate the investigation and development of management practices fundamental to the development of an integrated crop management system for banana production in the presence of the disease. • BQ has implemented an effective and reliable destruction protocol for pseudostems infected with TR4 using very high rates of urea in plastic bags. • The protocol was confirmed as highly effective in destroying disease inoculum in laboratory trials undertaken by the project and field trials with Fusarium wilt R1. • The investigation of weeds and ground covers as hosts of Fusarium R1 and SR4 did not reveal an effective non-host crop that could be used to reduce inoculum in the soil. The work informed further trial work with Fusarium wilt TR4 being conducted in the NT within the project 'BA14014 *Fusarium wilt TR4: Research program*'. • The banana breeding program review document formed the basis of an options paper considered by the banana Variety Committee of BA16001 '*Improved Plant Protection for the Australian Banana Industry*' in setting a strategic focus for variety importation and improvement. • Further, the review identified that the best prospects of delivering TR4 resistance in a Cavendish banana in the near future appears to lie with somaclonal variants and

	mutagenesis, although the limited screening capacity in Australia will likely hamper on-going efforts using mutagenesis. • Results from the assessment of a range of factors that affect Fusarium wilt inoculum loads (e.g. ground cover, microbes, etc.) has informed research under current projects (such as BA14014) and led to new areas for future RD&E investment. • For example. the influence of stress on Fusarium wilt infection and alternative hosts has informed activities in other projects so that they could direct their efforts into more promising lines of investigation. • The modelled data on the implementation cost for on-farm biosecurity practices and the productivity of potential alternative production systems have informed policymakers and managers at both ABGC and the Queensland Government on the relative value of different investment scenarios. • The modelled cost of biosecurity practice adoption reinforced the evaluation data showing cost was a major barrier to adoption, particularly for farms with non-contiguous parcels of land. • The implications reinforced that RD&E investment in the identification of productive, resistant banana varieties with market acceptance will be key. • Data from this activity also have contributed to a more detailed investigation of the cost of biosecurity to the banana industry via the industry benchmarking project. • The project built significant links with international researchers that has raised the international profile of Australian banana RD&E on Fusarium wilt TR4. • The Australian banana industry now has access to a framework and significant information resources for benchmarking and improving biosecurity practices through the biosecurity BMP guide and other extension materials produced during the project. • Surveys of participants at the AGBC-led Fusarium wilt workshops indicated that 91% of participants improved their knowledge of Fusarium wilt 'quite a lot' or better (4 or 5/5 rating). • Further, 81% understood the risk pathways associated with the disease 'quite a lot' or better and 84% understood suitable, effective on-farm biosecurity practices for their farms 'quite a lot' or better.
Impacts	• Maintained productivity for some Australian banana growers through the project's contribution to a reduced risk of the spread of Fusarium wilt TR4 in north Qld associated with avoided production losses. However, this maintained productivity may be associated with increased costs to growers and other supply chain businesses for the adoption of on-farm biosecurity BMPs. This impact may be driven by: o Increased or improved adoption of on-farm biosecurity BMPs, o Enhanced understanding of Fusarium wilt and its risk pathways by industry, researchers and government, o Improved government policy and responsiveness to banana industry biosecurity issues, o More rapid and accurate detection of Fusarium wilt incursions, and o Improved on-farm management to suppress and minimise inoculum loads through variety selection, ground cover and other mechanisms. • Increased effectiveness and/or efficiency of resource allocation for RD&E associated with Fusarium wilt of bananas. • Increased scientific knowledge and capacity associated with Fusarium wilt of bananas in Australia (including enhanced international networks). • Potentially, some contribution to increased regional community wellbeing through spill-over benefits from maintained banana grower incomes.

Project Investment

Nominal Investment

Table 3 shows the annual investment (cash and in-kind) in project BA14013 by Hort Innovation and DAF.

Table 3: Annual Investment in the Project BA14013 (nominal $)

Year ended 30 June	Hort Innovation ($)	DAF ($)	Total ($)
2015	359,979	850,365	1,210,344
2016	100,106	236,475	336,581
2017	100,000	236,226	336,226
2018	140,021	330,766	470,787
Totals	700,106	1,653,832	2,353,938

Source: derived from BA14013 Project Agreement and Variation documents supplied by Hort Innovation 2020

Program Management Costs

For the Hort Innovation investment the cost of managing and administrating the Hort Innovation funding was added to the Hort Innovation contribution for the project via a management cost multiplier (1.162). This multiplier was estimated based on the share of 'payments to suppliers and employees' in total Hort Innovation expenditure (3-year average) reported in the Hort Innovation's Statement of Cash Flows (Hort Innovation Annual Report, various years). This multiplier was then applied to the nominal investment by Hort Innovation shown in Table 3.

For the DAF investment, it was assumed that management and administration costs were already included in the cost data shown in Table 3.

Real Investment and Extension Costs

For the purposes of the investment analysis, investment costs of all parties were expressed in 2019/20 dollar terms using the Gross Domestic Product deflator index (ABS, 2020). No additional costs associated with project extension were incorporated as the project dedicated significant resources to communication and extension activities under Objectives 4 and 5 and included a high level of industry and other stakeholder interaction/engagement.

Impacts

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

Table 4: Triple Bottom Line Categories of Principal Impacts from Project BA14013

Economic	• Maintained productivity for some Australian banana growers through the project's contribution to a reduced risk of the spread of Fusarium wilt TR4 in north Qld associated with avoided production losses. However, this maintained productivity may be associated with increased costs to growers and other supply chain businesses for the adoption of on-farm biosecurity BMPs. This impact may be driven by: o Increased or improved adoption of on-farm biosecurity BMPs, o Enhanced understanding of Fusarium wilt and its risk pathways by industry, researchers and government, o Improved government policy and responsiveness to banana industry biosecurity issues, o More rapid and accurate detection of Fusarium wilt incursions, and o Improved on-farm management to suppress and minimise inoculum loads through variety selection, ground cover and other mechanisms. • Increased effectiveness and/or efficiency of resource allocation for RD&E associated with Fusarium wilt of bananas.

Environmental	• Nil.
Social	• Increased scientific knowledge and capacity associated with Fusarium wilt of bananas in Australia (including enhanced international networks). • Potentially, some contribution to increased regional community wellbeing through spillover benefits from maintained banana grower incomes.

Public versus Private Impacts

The impacts identified in this evaluation are both private and public in nature. Private benefits are likely to be realised by banana growers and associated supply chain businesses primarily through maintained industry productivity, with some benefits coming from increased efficiency of resource allocation for industry funded RD&E.

Public benefits also may occur and include increased efficiency of public resource allocation for banana industry RD&E, increased scientific knowledge and capacity, and, potentially, enhanced regional community wellbeing.

Distribution of Private Impacts

The impacts on the Australian banana industry from investment in project BA14013 will be shared along banana supply chains according to relevant short- and long-term supply and demand elasticities.

Impacts on Other Australian Industries

No direct or significant impacts to other Australian industries were identified. However, other Australian primary industries may benefit from improved scientific knowledge and information sharing because of better coordination, collaboration and communication between researchers and service providers.

For example, the project found that that the use of detergent based products, which are the primary products used by the cotton industry for management of Fusarium wilt of cotton, appeared only to suppress or delay colony development in bananas. This may contribute to further RD&E investments and potential benefits to the Australian cotton industry.

Impacts Overseas

No direct impacts to overseas parties were identified. However, the enhanced international industry and scientific linkages may contribute to benefits for other countries where growing bananas given the presence of Fusarium wilt TR4 is an ongoing challenge.

Match with National Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 5. The project findings and related impacts will contribute to Rural RD&E Priorities 2 and 4, and to Science and Research Priority 1.

Table 5: Australian Government Research Priorities

Australian Government	
Rural RD&E Priorities (est. 2015)	**Science and Research Priorities (est. 2015)**
1. Advanced technology 2. Biosecurity 3. Soil, water and managing natural resources 4. Adoption of R&D	1. Food 2. Soil and Water 3. Transport 4. Cybersecurity 5. Energy 6. Resources 7. Advanced Manufacturing 8. Environmental Change 9. Health

Sources: (Commonwealth of Australia, 2015) and (Australian Government, 2015)

Alignment with the Banana Strategic Investment Plan 2017-2021

The strategic outcomes and strategies of the banana industry are outlined in the Banana Strategic Investment Plan 2017-2021[2] (2017). Project BA14013 primarily addressed Outcome 1 through Strategies 1.1 (conduct research into new disease-resistant varieties that also have consumer appeal), 1.2 (collaborate with the international community to accelerate the identification and development of disease-resistant varieties) and 1.3 (continue research to improve pest and disease management and biosecurity).

The project also contributed to Outcome 2 through Strategies 2.1 (continue to drive adoption of BMP for on-farm biosecurity to ensure biosecurity risks are minimised) and 2.2 (strategically communicate the industry's biosecurity and environmental BMP to the community).

Valuation of Impacts

Impacts Valued

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions, particularly when some uncertainty was involved. Sensitivity analyses were undertaken for those variables where there was greatest uncertainty or for those that were identified as key drivers of the investment criteria.

Impacts Not Valued

Not all of the impacts identified in Table 4 could be valued in the assessment. In particular, one economic and two social impacts identified were hard to value due to a lack of evidence/data on which to base credible assumptions, difficulty in quantifying the causal relationship and the pathway between BA14013 and the impact and/or the complexity of assigning magnitudes and monetary values to the impact.

The economic impact identified but not valued was:

- Increased effectiveness and/or efficiency of resource allocation for RD&E associated with Fusarium wilt of bananas.

The social impacts identified but not valued were:

- Increased scientific knowledge and capacity associated with Fusarium wilt of bananas in Australia (including enhanced international networks).
- Potentially, some contribution to increased regional community wellbeing through spillover benefits from maintained banana grower incomes.

Valuation of Impact 1: Avoided production losses through reduced risk of spread of *Foc* TR4

Foc TR4 is named 'tropical race 4' because the TR4 strain of the fungus is capable of infecting Cavendish banana varieties growing in tropical conditions (Biosecurity Queensland, 2016). The wet tropical coast of northern QLD between Babinda and Cardwell is Australia's main banana growing area, accounting for about 70% of the country's production (DAF, 2016).

Project BA14013 provided new science, information and practices to address the priority needs for robust, science-based biosecurity measures to contain the disease and prevent further spread, and investigate measures for detecting and managing new incursions. The project also produced outputs that were used to provide input to the development of content and process for the ABGC Biosecurity Extension project workshops and activities and BQ's development of the Panama disease Standards and Guidelines. Key project findings have been integrated into on-farm biosecurity practices in the Australian banana industry.

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

Industry losses WITH the investment

Once a plantation becomes infected with *Foc* TR4, prevention of spread can only be achieved by the destruction of infected plants, maintenance of a surrounding buffer zone with no banana plants, limiting water run-off and restricting access using fences and long-term fallow of affected land. There are no known long-term chemical options for management of Foc TR4 (Cook, Taylor, Meldrum, & Drenth, 2015).

The outbreak in 2015 was detected on a single farm in the Tully Valley. A containment strategy currently is in place for TR4 with only 5 farms quarantined over the last 5 years (2015/16 to 2019/20) and only approximately 90 plants confirmed positive (Jim Pekin, pers. comm., 2020). It was assumed that the restriction of TR4 to five properties would remain the case for the foreseeable future.

Additionally, it was assumed that with the investments the risk of future incursions of *Foc* TR4 spreading to a proportion of the QLD tropical banana industry would be lower and that quarantine efforts would be more effective therefore slowing the spread of the disease by half.

Specific assumptions for the valuation of Impact 1 are described in Table 6.

Counterfactual

It was assumed that, without the investment in BA14013, the industry's quarantine response to *Foc* TR4 would have been delayed due to a lack of local technical expertise and advice. This would have allowed the disease to spread to additional properties surrounding the source incursion and would have led to a larger quarantine zone and destruction of banana plants across a greater area.

Additionally, it was assumed that without the technical expertise, biosecurity information and extension, and other capacity provided by the investment, there would be a greater risk of future *Foc* TR4 incursions becoming established and spreading to a proportion of the tropical QLD banana industry causing significant economic losses. Without the investment, it also was assumed that quarantine efforts for future incursions would be less effective, therefore the potential spread of *Foc* TR4 would be faster than it would be with the investment.

Attribution

In the aftermath of detection of *Foc* TR4 in QLD in 2015 a wide range of RD&E investments were funded to better understand the disease and to work to contain its outbreak and potential further spread. The number and total investment in such RD&E was uncertain but likely to be substantial for Australian banana RD&E. Thus, to recognise the contribution of other *Foc* TR4 investments, it was assumed that 20% of Impact 1 was driven specifically by the BA14013 investment.

Summary of Assumptions

A summary of the key assumptions made for valuation of the impacts is shown in Table 6.

Table 6: Summary of Assumptions

Impact 1: Reduced potential industry losses from Foc TR4 in Australia		
Key baseline data		
Total average Australian banana production area (bearing age)	12,487 ha	10-year average derived from ABS Series 7121.0 *Agricultural Commodities, Australia* (2009/10 to 2018/19) (see Table 1)
Total average Australian banana production	349,371 t	10-year average, derived from ABGC production statistics based on the compulsory industry levy (see Table 1)
Average Australian yield (derived)	28.0 t/ha	349,371 t / 12,487 bearing ha
Estimated Australian average net return to growers	$22.00 / 15kg carton	Analyst estimated based on the average net return to grower after marketing and ripening

		costs reported in the Banana Enterprise Comparison Report 2016/17 (Appendix 1) (Pinnacle Agribusiness, 2018)
WITHOUT the investment		
Number of farms assumed to be affected by *Foc* TR4 and then quarantined	10 properties between 2015/16 and 2019/20	Analyst assumption
Total proportion of Australian banana production produced in QLD in 2017/18	94%	https://abgc.org.au/our-industry/key-facts/
Proportion of QLD production quarantined and destroyed in the Tully Valley to prevent spread of Foc TR4	8.0% (20 out of 250 farms)	Based on an estimated 250 banana farming businesses operating in QLD (10 farms + 10 neighbouring properties quarantined as a required buffer from 250 total), Queensland Government, 2016
Probability of Foc TR4 spreading to the rest of the tropical QLD banana industry	5.0% in any year	Analyst estimate
Proportion of QLD production potentially affected by the spread of Foc TR4	35% (50% of the production occurring in the tropics at 70% of total Australian production)	
Time to reach maximum spread and impact	20 years from 2019/20	
Impact cost of Foc TR4 to the Australian banana industry should the disease become widespread	$138 million p.a.	Cook, Taylor, Meldrum, & Drenth, 2015
WITH the investment		
Number of farms affected by Foc TR4 and then quarantined	5 properties between 2015/16 and 2019/20	Jim Pekin, ABGC, pers. comm., 2020
Proportion of QLD production quarantined and destroyed in the Tully Valley to prevent spread of Foc TR4	4.0% (10 out of 250 farms)	Based on an estimated 250 banana farming businesses operating in QLD (5 farms + 5 neighbouring properties quarantined as a required buffer from 250 total), Queensland Government, 2016
Probability of Foc TR4 spreading to the rest of the tropical QLD banana industry	4.0% in any year (reduction of 1.0%)	Analyst estimate – Second year of BA14013 investment given success of the initial Tully *Foc* TR4 quarantine to 2019/20
First year of impact of reduced risk of spread	2016 (year two of BA14013)	
Proportion of QLD production potentially affected by the spread of Foc TR4	35% (50% of the production occurring in the tropics at 70% of total Australian production)	Analyst estimate
Time to reach maximum spread and impact	40 years (from 2019/20 - slows spread by half)	Analyst estimate
Risk Factors		
Probability of output	100%	Based on successful completion of project BA14013

Probability of outcome	80%	Widespread adoption of biosecurity measures and improved understanding of TR4 by growers and government
Probability of impact	50%	Allows for uncertainty regarding the future control methods used to contain and control Foc TR4 in the tropical Australian banana industry (e.g. new technologies, resistant banana varieties)

Results

All costs and benefits were discounted to 2019/20 using a discount rate of 5%. A reinvestment rate of 5% was used for estimating the modified internal rate of return (MIRR). The base analysis used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for the length of the project investment period plus 30 years from the last year of investment (2017/18) as per the CRRDC Impact Assessment Guidelines (CRRDC, 2018).

Investment Criteria

Table 7 shows the investment criteria estimated for different periods of benefit for the total investment. Table 8 shows the investment criteria estimated for different periods for the Hort Innovation only. The present value of benefits (PVB) for Hort Innovation was estimated by multiplying the total PVB by the proportion of Hort Innovation investment in project BA14013 (33.0%).

Table 7: Investment Criteria for Total Investment in Project BA14013

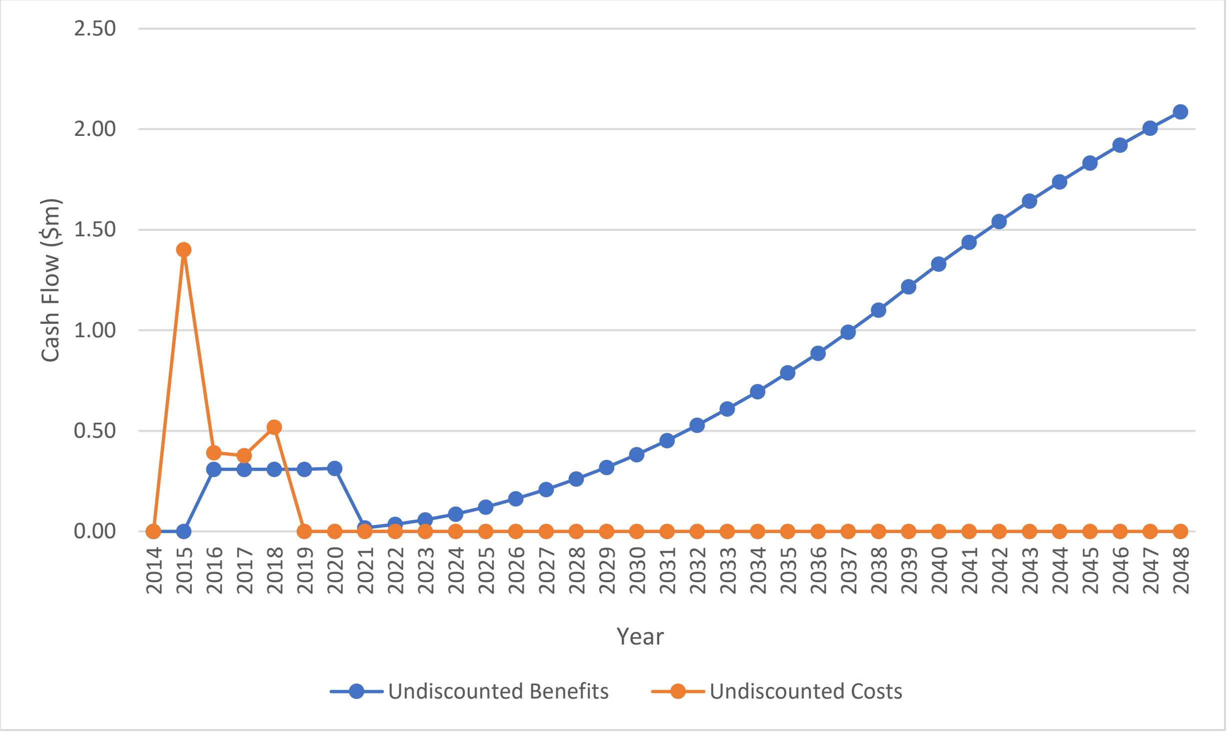
Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	1.07	1.81	2.42	3.74	5.77	8.33	11.02
Present Value of Costs ($m)	3.27	3.27	3.27	3.27	3.27	3.27	3.27
Net Present Value ($m)	-2.20	-1.46	-0.85	0.47	2.50	5.06	7.75
Benefit-Cost Ratio	0.33	0.55	0.74	1.14	1.76	2.55	3.37
Internal Rate of Return (%)	negative	negative	negative	6.81	10.62	12.50	13.43
MIRR (%)	negative	negative	negative	6.58	9.52	10.59	10.81

Table 8: Investment Criteria for Hort Innovation Investment in Project BA14013

Investment Criteria	**Years after Last Year of Investment**						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present Value of Benefits ($m)	0.35	0.60	0.80	1.23	1.90	2.75	3.63
Present Value of Costs ($m)	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Net Present Value ($m)	-0.73	-0.48	-0.28	0.15	0.82	1.67	2.55
Benefit-Cost Ratio	0.33	0.55	0.74	1.14	1.76	2.55	3.37
Internal Rate of Return (%)	negative	negative	negative	6.80	10.62	12.50	13.42
MIRR (%)	negative	negative	negative	6.57	9.52	10.59	10.81

The annual undiscounted benefit and cost cash flows for the total investment for the duration of BA14013 investment plus 30 years from the last year of investment are shown in Figure 2.

Figure 2: Annual Cash Flow of Undiscounted Total Benefits and Total Investment Costs



Sensitivity Analyses

A sensitivity analysis was carried out on the discount rate. The analysis was performed for the total investment and with benefits taken over the life of the investment plus 30 years from the last year of investment. All other parameters were held at their base values. Table 9 present the results. The results were moderately sensitive to the discount rate. This was largely because the benefits occur into the long-term future where cash flows are subjected to more significant relative discounting.

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

Investment Criteria	**Discount rate**		
	0%	**5% (base)**	**10%**
Present Value of Benefits ($m)	26.00	11.02	5.94
Present Value of Costs ($m)	2.69	3.27	3.96
Net Present Value ($m)	23.31	7.75	1.99
Benefit-cost ratio	9.68	3.37	1.50

A sensitivity analysis was then undertaken for the assumed reduction in the risk of spread of *Foc* TR4. The results are presented in Table 10 and show a moderate to low sensitivity to the assumed reduction in risk due to the investment in BA14013. This was largely because of the long timeframes assumed for the spread of Foc TR4 to reach maximum impact were the main driver of the investment criteria (the difference between the 40-year timeframe in the with scenario versus the 20-year timeframe in the without case).

Table 10: Sensitivity to Reduction in Risk of Spread of *Foc* TR4
(Total investment, 30 years)

Investment Criteria	**Reduced risk of *Foc* TR4 spread**		
	0.5%	**1.0% (base)**	**2.0%**
Present Value of Benefits ($m)	10.20	11.02	12.65
Present Value of Costs ($m)	3.27	3.27	3.27
Net Present Value ($m)	6.93	7.75	9.37
Benefit-cost ratio	3.12	3.37	3.87

Confidence Rating

The results produced are highly dependent on the assumptions made, some of which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 11). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made

Table 11: Confidence in Analysis of Project

Coverage of Benefits	**Confidence in Assumptions**
Medium-High	Medium-Low

Coverage of benefits was assessed as Medium-High – the primary and most important economic impact was valued; however, a number of potential economic and social benefits were not able to be valued within the scope of the current assessment.

Confidence in assumptions was rated as Medium-Low. Data used in the analysis were mostly drawn from published and/or credible sources such as Hort Innovation, published scientific journal articles, ABGC and the ABS. However, a number of key assumptions, particularly those associated with the magnitude of the estimated impact, were analyst assumptions and therefore were uncertain.

Conclusion

The investment in project BA14013 has provided new science, information and practices to address the priority needs for robust, science-based biosecurity measures to contain *Fusarium wilt* TR4 and prevent further spread, as well as to investigate measures for detecting and managing new incursions. The project also produced outputs that were used to provide input to the development of content and process for the ABGC Biosecurity Extension project workshops and activities and BQ's development of the Panama disease Standards and Guidelines. Key project findings have been integrated into on-farm biosecurity practices in the Australian banana industry.

BA14013 is likely to have contributed to maintained productivity through avoided production losses for some Australian banana growers through the project's contribution to a reduced risk and rate of spread of *Fusarium wilt* TR4 in north Qld associated with.

Total funding from all sources for the project was $3.27 million (present value terms). The investment produced estimated total expected benefits of $11.02 million (present value terms). This produced an estimated net present value of $7.75 million, a benefit-cost ratio of 3.37 to 1, an internal rate of return (IRR) of 13.43% and a modified IRR of 10.81% over 30-years at a discount rate of 5% and a reinvestment rate of 5%.

Several other economic and social impacts were identified but not valued as part of the current assessment. Thus, given the impacts not valued, combined with conservative assumptions made for the principal economic impacts valued, it is reasonable to conclude that the investment criteria reported may be an underestimate of the actual performance of the BA14013 investment.

Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are re-invested at the rate of the cost of capital (the re-investment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.

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Abbreviations

ABGC	Australian Banana Growers' Council
ABS	Australian Bureau of Statistics
AL	Almond
BA	Banana
BMP	Best Management Practice
BQ	Biosecurity Queensland
CRC	Cooperative Research Centre
CRRDC	Council of Rural Research and Development Corporations
CT	Citrus
DAF	Department of Agriculture and Fisheries (Queensland)
Foc	Fusarium Wilt (also known as Panama Disease)
Hort Innovation	Horticulture Innovation Australia Ltd
IRR	Internal Rate of Return
MIRR	Modified Internal Rate of Return
NSW	New South Wales
NT	Northern Territory
PCR	Polymerase Chain Reaction
PVB	Present Value of Benefits
QLD	Queensland
R&D	Research and Development
R1	Race 1
R2	Race 2
R3	Race 3
R4	Race 4
RD&E	Research, Development and Extension
RDC	Research and Development Corporation
SARDI	South Australian Research and Development Institute
SIP	Strategic Investment Plan
SR4	Sub-Tropical Race 4
TR4	Tropical Race 4
VN	Onion
WA	Western Australia