Sugar Research Australia

AN ECONOMIC ANALYSIS OF: MOLECULAR ASSAY OF MAJOR SOIL-BORNE PATHOGENS FOR BETTER EXPLOITATION OF COMMERCIAL VARIETIES

Project 2016/047

Chief Investigator
Rob Magarey, Sugar Research Australia

Evaluation completed by AgTrans.

1 Introduction

The following impact assessment has been carried out using the guidelines produced by the Council of Research and Development Corporations (CRRDC, 2018).

2 Background

Pachymetra root rot is an important disease affecting sugarcane production caused by the organism Pachymetra chaunorhiza. The disease impact is generated through a reduction in yields via a weakened root system and increased stool tipping. The impact is greatest in some northern sugarcane growing regions with lesser prevalence in southern regions.

Yield losses of up to 40% in susceptible varieties have been associated with Pachymetra root rot (SRA, 2013a).

As there is variation to the disease across sugarcane clones, the mainstream strategy for reducing impacts is the planting of resistant sugarcane clones rather than the more susceptible clones. Resistance to the disease is taken into account in the sugarcane breeding program and all varieties are screened and rated for resistance before their release. Resistance ratings are available to growers. As sugarcane areas vary in the prevalence of the Pachymetra spores, testing via spore counts is used by sugarcane growers to assist with their choice of clones for new plantings.

Spore counting procedures are undertaken by the Tully SRA laboratory but were labour intensive and costly and the number of field samples that could be assayed was limited. The current labour-intensive assay has been costed at $50/assay. DNA testing processes were considered to have potential in speeding up testing, delivering greater accuracy, and lowering testing costs. Beneficiaries were expected to be the individual sugarcane grower, extension and field service personnel, and the sugarcane breeding program.

Both Pratylenchus zeae and Meloidogyne javanica are plant-parasitic nematode pests, the first a root-lesion nematode (RLN) and the second a root-node nematode (RNN). No test was available for Pratylenchus zeae, but a test had already been developed for Meloidogyne javanica although the test had not been validated. Both nematodes cause significant yield losses in sugarcane, with RLN damage predominant in lighter soils. The use of rotations and improving soil health are the main management control measures used by the industry to combat the pests. Unlike Pachymetra, certain cultural practices (e.g. minimal tillage practices and maintaining trash coverage) and rotations of legume crops can assist control of parasitic nematodes; chemical control is possible but can be cost prohibitive.

The cost of pathogenic nematodes to the Australian sugarcane industry has been estimated as at least $80m per annum via yield losses of 7-10% in sugarcane (Caneconnections, 2019).

Annual losses from Pachymetra root rot and nematode species combined have been estimated at over $200 million (Source: Project 2016/047 proposal).

3 Project objectives

The overall aim of Project SRA 2016/047 was first, to develop PCR-based assays for Pachymetra chaunorhiza and Pratylenchus zeae in sugarcane soils, as well as to validate the existing test for Meloidogyne javanica (a root-node nematode). Second, the project was to incorporate the validated tests into a commercial assay service for sugarcane growers to assist them to manage soil pathogens. The PCR-based tests were to be developed by the South Australian Research and Development Institute (SARDI) in Adelaide. Third, the new tests were to be calibrated against the existing spore count tests to ensure that data obtained using the DNA methods could be used in the existing threshold recommendations upon which sugarcane growers act.

Specific objectives of the project were:

1) To develop/validate qPCR-based assays to detect the three root pathogens in sugarcane soil using SARDI's soil testing procedures.
2) To calibrate the new tests against the traditional assay method.
3) To formulate recommendations for adoption of varieties for Pachymetra management and nematode control based on the new qPCR assays and deliver these to QCANESelect.
4) To develop a strategy for delivery of the qPCR assay results to the sugar industry.
5) To revisit the methods for extending results to industry to ensure the efficient adoption of recommendations.

4 Cost of investment for project 2016/047

Estimates of the total investment by SRA and SARDI are provided in Table 1 for this three year project.

TABLE 1: THE COSTS OF THE INVESTMENT IN PROJECT 2016/047 (NOMINAL $)

YEAR ENDED JUNE	SRA	SARDI	TOTAL
2017	223,692	28,028	251,720
2018	190,298	28,714	219,012
2019	32,012	0	32,012
Total	446,002	56,742	502,744

4.1 Program management and extension costs

The costs of administration and management of the investment are assumed to be included in the figures appearing in Table1.

5 Activities and outputs

- Provisional assays (TaqMan qPCR assays) were developed that target the Internal Transcribed Spacer (ITS) for each of the first two target pathogens (Pachymetra chaunorhiza and Pratylenchus zeae). Related species were also included to ensure assay specificity for the targeted pathogens. It was concluded that both tests were sensitive and specific to the pathogens. The tests were therefore ready to be validated in soil samples.
- As a precursor to soil testing, some productivity service groups were contacted to supply soil samples containing the pathogens.
- It was determined with confidence that the two DNA assays do not detect non-target organisms in non-infested soil samples.
- Results of the three DNA assays were consistent with the existing methods of assessment (traditional counting methods) with correlations between the two methods of between 0.9 and 1.
- Existing pathogen thresholds were converted to DNA equivalent thresholds.
- The DNA tests can effectively detect the nematodes at economic threshold levels and can therefore accommodate the standard existing varietal resistance recommendations.

- After the calibration experiments were completed, the SARDI assay laboratory in Adelaide tested samples sent by SRA staff and the laboratory provided quantitative DNA results.
- The tests were declared ready for assaying selected soil samples for management purposes, once extension and training on soil sampling had been effected.
- A framework was developed for delivering the innovation to the sugarcane industry, including soil sampling, relating crop and farm information to the sample, dispatch of the sample, interpretation and communication of results, pricing structures and data storage. The framework involved:
    - SARDI being contracted to assay samples for the three pathogens and to communicate results to the SRA laboratory in Tully.
    - The SRA laboratory to utilise existing reporting services, databases and industry contacts to provide results to researchers and growers.
    - A new pricing structure to be introduced that delivered to industry the economies provided through multiple assays of an individual soil sample; a cost of $75 per DNA test covering all three organisms was initially set; this cost was below the price paid by growers for the manual tests.
- Testing for free living beneficial nematodes has been complicated by the change to DNA testing as the DNA assays at SARDI do not align with species in sugarcane soils. This issue is being addressed over time.

5.1 Other communications

- A paper addressing the validation of the Pachymetra root rot test was presented at the 39th conference of ASSCT in Cairns in May 2017.
- Early awareness of the tests was provided through the SRA soil health masterclasses attended by leading growers and technicians.

6 Outcomes

Once implemented, the project outputs and findings as incorporated into the new framework are enabling lower cost and more efficient testing of the designated soil pathogen and nematode pests by the sugarcane industry.

For example, previous testing via spore counts (spores per kg soil) was used to assess the potential severity of the disease impact in sugarcane paddocks (SRA, 2013a). Where counts were medium to high, the more resistant varieties could be considered for new planting. The same considerations will be conveyed with the DNA tests.

The extension of the pathogen testing platform with the newly developed tests will also could be strengthened by other diagnostic tests becoming available. These include root biomass diagnostics (YCS program) developed by CSIRO and potentially other future assays for beneficial organisms (free living nematodes, nematode trapping fungi and mycorrhizal fungi) that are indicators that contribute to the maintenance of soil health.

Also, there are a number of other SRA projects that will benefit from access to the testing technology, including the new soil health project (2017/005) to benchmark root biomass and soil pathogens/ disease suppressive organisms and a project on marginal soils and amelioration strategies to assess root biomass (2015/007).

7 Impacts

The principal impacts of SRA Project 2016/047 will be a lower cost per test for Pachymetra on its own, a lower cost for nematode testing on its own and a lower cost per soil sample if tests for nematodes and Pachymetra are both required.

In addition, the DNA testing advance will create not only cost reductions for those who currently require soil tests but also a more efficient testing platform for both Pachymetra and nematodes potentially stimulating increased soil testing to be carried out by sugarcane growers who may not currently regularly participate in soil testing for pathogens and pest management purposes.

A summary of the principal types of potential impacts associated with the outcomes of the project is shown in Table 2.

TABLE 2: CATEGORIES OF PRINCIPAL POTENTIAL IMPACTS FROM THE INVESTMENT IN 2016/047

ECONOMIC • Greater confidence in DNA testing for the three designated pests. • Testing cost reduction for growers and researchers for assessment of Pachymetra severity and nematode presence. • More efficient testing process/platform so removing any constraints on testing throughput at the SRA Tully laboratory. • The three primary impacts described above will together stimulate increased adoption by growers of testing for the pathogen/pests that will improve management and reduce damage costs. • The enhanced use of testing for Pachymetra resistance due to removal of throughput constraints will improve the efficiency of sugarcane varietal development.
ENVIRONMENTAL • The extent of chemical treatment for nematodes is already small so any reduced chemical use, and hence reduced chemical export, is likely to be minor. • Some soil loss to the environment may be minimised from an increase in use of appropriate Pachymetra-resistant varieties leading to a decrease in disrupted soil due to reduced Pachymetra damage.
SOCIAL • Spillover impacts to sugarcane regional communities from increased productivity and profitability of sugarcane production and processing. • Capability enhancement for other soil health research and management activities in the sugar cane industry.

7.1 Public versus private impacts

The key potential impacts will be both private and public. The future principal private impacts of lowered costs and increased efficiency that will potentially accrue to growers, farm productivity groups via decreased testing costs for the pathogen and nematodes. These primary impacts are expected to lead to reduced yield losses and increased factory throughputs. More efficient and timely testing is expected also to impact on the sugarcane breeding program via enhanced varietal development.

Public impacts will potentially include the spillover regional impacts from the private sector profitability gains and the capability enhancement that can impact on other soil health issues.

7.2 Distribution of impacts along the supply chain

Potential future impacts associated with this project will most likely accrue to sugarcane producers in the first instance via reduced testing costs, improved management of Pachymetra and nematodes, and varietal improvements. If the yield losses from the pathogens are reduced significantly by increased and more efficient testing, sugarcane some factories could benefit from increased sugarcane throughput.

7.3 Impacts on other primary industries

There are not likely to be any direct impacts to other agricultural industries from the investment.

7.4 Match with national, state and SRA priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table 3.The investment contributes primarily to Rural RD&E Priorities 1, 3 and 4 and to Science and Research Priority 1.

TABLE 3: AUSTRALIAN GOVERNMENT RESEARCH PRIORITIES

AUSTRALIAN GOVERNMENT	
RURAL RD&E PRIORITIES (EST. 2015)	**SCIENCE AND RESEARCH PRIORITIES (EST. 2015)**
1) Advanced technology 2) Biosecurity 3) Soil, water and managing natural resources 4) Adoption of R&D	1) Food 2) Soil and Water 3) Transport 4) Cybersecurity 5) Energy and Resources 6) Manufacturing 7) Environmental Change 8) Health

Sources: DAWR (2015) and OCS (2016)

7.5 SRA Key Focus Areas

SRA's key focus areas are presented in Table 4. Project 2016/047 addressed KFAs 1, 2, and 3.

TABLE 4: SRA STRATEGIC FOCUS AREAS AND DESIRED OUTCOMES

KEY FOCUS AREA (KFA)	OUTCOMES
1) Optimally adapted varieties, plant breeding and release	Increased sugarcane yield and commercial cane sugar (CCS)
2) Soil health, nutrient management and environmental sustainability	Better soil health, reduced nutrient losses and improved water quality
3) Pest, disease and weed management	Reduced or avoided yield losses and/or added input costs
4) Farming systems and harvesting	Improved farm input-output efficiencies and profitability
5) Milling efficiency and technology	Optimised production, improved capital utilisation and waste minimisation
6) Product diversification and value adding	Diversified revenue streams and product innovation
7) Knowledge and technology transfer and adoption	Accelerated adoption of new technology and practice change
8) Collaboration and capability development	Enhanced industry and research capability and capacity
9) Organisational effectiveness	Increased investor satisfaction and returns on investment

Source: SRA Strategic Plan (2018)

8 Valuation of impacts

8.1 Impacts valued

The project has validated alternative testing methods for Pachymetra and for the two nematode pests. The use of the new tests has reduced the current testing costs incurred by growers for these pathogens/pests. The new tests are also more rapid allowing a quicker turnaround as well as allowing more tests to be carried out compared to the existing more labour intensive methods (e.g. counting spores) that can constrain throughput at the SRA laboratory. Further, these two impacts together (cost reduction and efficiency) may entice more growers to adopt testing, so improving varietal choice to combat Pachymetra and choice of appropriate cultural practices to manage nematodes.

The two impacts valued in this evaluation are the lowered testing costs and the increase in testing leading to improved pest management, in turn leading to a reduction in annual damage costs to the industry.

Current assumptions for valuing the two impacts are provided in Table 5.

TABLE 5: SUMMARY OF ASSUMPTIONS

VARIABLE	ASSUMPTION	SOURCE
GENERAL ASSUMPTIONS		
Existing damage from Pachymetra and nematodes	$200 million p.a.	Project proposal for SRA Project 2016/047
Attribution of following impacts to Project 2016/047	100%	Agtrans Research
IMPACT 1: REDUCED TESTING COSTS		
Existing cost of spore testing for Pachymetra or for nematodes alone	$50 per test/count	SRA information Sheet IS13121 (2013b) for Pachymetra
DNA test for Pachymetra or for nematodes alone	$40 per test/count	Agtrans Research, guess
Current number of spore or count tests	10,000 p.a.	Agtrans Research, guess
First year of benefits	2022	Agtrans Research, guess
RISK FACTORS FOR IMPACT 1		
Probability of outcome of test cost saving	100%	Agtrans Research
Probability of impact	90%	
IMPACT 2: INCREASED TESTING LEADING TO IMPROVED PATHOGEN/PEST MANAGEMENT AND REDUCED DAMAGE COSTS		
Maximum increase in grower testing	10%	Agtrans Research
Maximum number of new tests	1,000 p.a.	
Cost of new DNA testing to growers	$40 per test equivalent	
Impact of increased testing on annual pathogen/pest damage costs	0.075% reduction in damage costs	
First year of benefit	2022	
Year of maximum benefit	2026	
RISK FACTORS FOR IMPACT 2		
Probability of outcome	75%	Agtrans Research
Probability of impact	75%	

8.2 Impacts identified but not valued

The increased confidence in the new testing processes is assumed to be included as a factor in the two impacts already valued, as is the removal of constraints on test throughput.

Impacts identified but not valued for Project SRA 2016/047 included:

- Improved efficiency of sugarcane varietal development due to enhanced testing for Pachymetra resistance.
- Spillover impacts to sugarcane regional communities from increased productivity and profitability of sugarcane production and processing.
- Capability enhancement for other soil health research and management activities in the sugar cane industry.

The varietal development enhancement due to the DNA testing was not valued due to the difficult assumptions required on the increased number of tests likely and the associated impact on the varietal performance that could be delivered.

The spillover impacts and capability enhancements potentially associated with the project were not valued due to the lack of information readily available.

9 Results

All past costs and benefits were expressed in 2018/19-dollar terms using the Implicit Price Deflator for GDP. All benefits after 2018/19 were expressed in 2018/19-dollar terms. All costs and benefits were discounted to 2018/19 using a discount rate of 5%. A Re-investment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for a period of 30 years after the last year of investment (2018/19).

The investment criteria are reported for the total investment and the SRA investment in Tables 6 and 7.

TABLE 6: INVESTMENT CRITERIA FOR TOTAL INVESTMENT AND TOTAL BENEFITS (DISCOUNT RATE 5%)

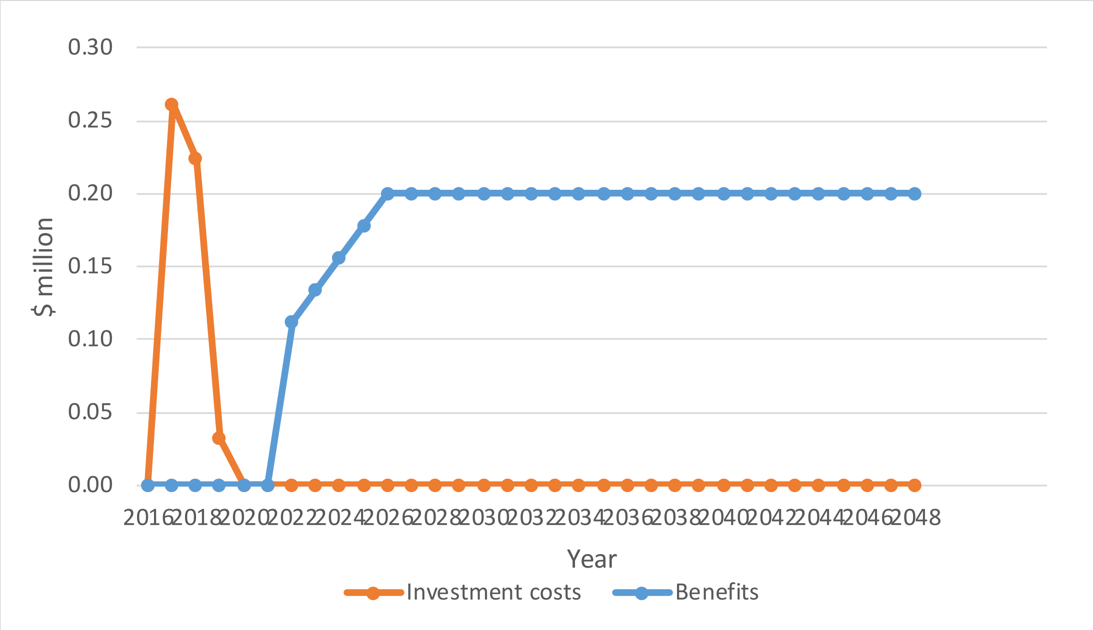
INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.33	0.99	1.52	1.94	2.27	2.52
Present value of costs ($m)	0.56	0.56	0.56	0.56	0.56	0.56	0.56
Net present value ($m)	-0.56	-0.23	0.44	0.97	1.38	1.71	1.97
Benefit–cost ratio	0.00	0.59	1.79	2.74	3.49	4.08	4.54
Internal rate of return (%)	negative	negative	12.9	16.5	17.7	18.1	18.3
Modified internal rate of return (%)	negative	negative	11.3	12.3	11.8	11.1	10.4

TABLE 7: INVESTMENT CRITERIA FOR SRA INVESTMENT AND SRA BENEFITS (DISCOUNT RATE 5%)

INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.29	0.88	1.35	1.72	2.01	2.24
Present value of costs ($m)	0.49	0.49	0.49	0.49	0.49	0.49	0.49
Net present value ($m)	-0.49	-0.20	0.39	0.86	1.23	1.52	1.74
Benefit–cost ratio	0.00	0.59	1.79	2.74	3.50	4.08	4.54
Internal rate of return (%)	negative	negative	13.0	16.6	17.7	18.1	18.3
Modified internal rate of return (%)	negative	negative	11.3	12.3	11.8	11.1	10.4

The annual cash flow of undiscounted benefits and costs for the total investment are shown in Figure 1.

FIGURE 1: UNDISCOUNTED CASH FLOW OF BENEFITS AND COSTS



9.1 Source of benefits

The relative contributions of the two sources of benefits are provided in Table 8. Given the assumptions made, there was not a large difference between the contributions from each source.

TABLE 8: CONTRIBUTION TO PRESENT VALUE OF BENEFITS (PVB) FROM EACH SOURCE

SOURCE OF BENEFIT	CONTRIBUTION TO PVB ($M)	CONTRIBUTION TO PVB (%)
Saved testing costs ($m)	1.22	48.2
Increased use of testing ($m)	1.31	51.8
Total	2.52	100.0

9.2 Sensitivity analyses

Sensitivity analyses were carried out for several variables and results are reported in Tables 9 to 10. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 9) with benefits taken over the 30-year period. All other parameters were held at their base values.

Table 9 shows there is only a moderate sensitivity to the discount rate, largely due to short period of time between the investment and when benefits commence being delivered.

TABLE 9: SENSITIVITY TO DISCOUNT RATE (TOTAL INVESTMENT, 30 YEARS)

CRITERION	DISCOUNT RATE		
	0%	BASE (5%)	10%
Present value of benefits ($m)	5.38	2.52	1.39
Present value of costs ($m)	0.52	0.56	0.59
Net present value ($m)	4.86	1.97	0.79
Benefit-cost ratio	10.40	4.54	2.33

Table 10 provides a sensitivity analysis for several key assumptions behind each impact. Results show that while the investment criteria for the pessimistic assumptions fall considerably from the base, they are still positive.

TABLE 10: INVESTMENT CRITERIA CHANGES FOR OPTIMISTIC AND PESSIMISTIC SCENARIOS (TOTAL INVESTMENT, 5% DISCOUNT RATE, 30 YEARS)

CRITERION	SENSITIVITY TO OPTIMISTIC AND PESSIMISTIC SCENARIOS FOR SAVED TESTING COSTS AND INCREASED USE OF TESTING		
	PESSIMISTIC $5 PER TEST SAVED AND 0.05% IMPACT ON TOTAL DAMAGE COSTS FOR NEW TESTING	BASE $10 PER INDIVIDUAL TEST SAVED AND 0.075% IMPACT ON TOTAL DAMAGE COSTS FOR NEW TESTING	OPTIMISTIC $15 PER TEST SAVED AND 0.10% IMPACT ON TOTAL DAMAGE COSTS
Present value of benefits ($m)	1.26	2.52	3.78
Present value of costs ($m)	0.56	0.56	0.56
Net present value ($m)	0.71	1.97	3.23
Benefit-cost ratio	2.27	4.54	6.81

10 Conclusions

Given the assumptions made on the value of impacts, the investment criteria estimated for total investment in the project of $0.56 million (present value of costs) were positive with an expected present value of benefits of $2.52 million, an expected net present value estimated at $1.97 million and an expected benefit-cost ratio of 4.54 to 1. All investment criteria were estimated using a discount rate of 5% and with benefits estimated over 30 years from the final year of investment. The internal rate of return was estimated at 18.3% and the modified internal rate of return at 10.4%.

As several impacts identified were not valued, particularly the potential impact on the sugarcane breeding program, the magnitude of the investment criteria reported are likely to be underestimated.

11 Acknowledgments

Harjeet Khanna, General Manager, Research Funding Unit, Sugar Research Australia

12 References

CaneConnection (2019) Helping nematode challenge through varieties, pp14-15 Accessed at https://sugarresearch.com.au/wp-content/uploads/2019/02/CaneConnection-Autumn-2019_Web.pdf

Council of Rural Research and Development Corporations. (2018). Cross-RDC Impact Assessment Program: Guidelines. Canberra: Council of Research and Development Corporations. Retrieved from http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA- Guidelines-V.2.pdf

Department of Agriculture and Water Resources (DAWR) (2015). Agricultural Competitiveness White Paper. Canberra: Commonwealth of Australia. Retrieved from http://agwhitepaper.agriculture.gov.au/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf

Office of the Chief Scientist (OCS) (2016). Strategic Science and Research Priorities. Canberra: Commonwealth of Australia. Retrieved from http://www.chiefscientist.gov.au/wp-content/uploads/STRATEGIC-SCIENCE-AND-RESEARCH-PRIORITIES_181214web.pdf

SRA (2013a) Pachymetra Root Rot, Information Sheet IS 1 3005. https://sugarresearch.com.au/wp-content/uploads/2017/02/Pachymetra-root-rot-IS13005.pdf

SRA (2013b) Sampling Procedures and the transport of samples for testing or assays http://sugarresearch.com.au/wp-content/uploads/2017/02/Sampling-procedures-and-transport-procedures-for-testing-or-assays-IS13121.pdf

SRA (2017) SRA Strategic Plan 2017/18 − 2021/22 Accessed August 2018 at: https://sugarresearch.com.au/wp-content/uploads/2017/09/Strategic-Plan-2017-_FINAL.pdf

SRA (undated) Nematodes in sugarcane, Information sheet IS 1. Accessed at; 3040http://sugarresearch.com.au/wp-content/uploads/2017/02/NutriCalc-A3-IS13040.pdf