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Economic Evaluation of Investment in the Tea Tree Oil R&D Program

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by

Peter Chudleigh and Sarah Simpson

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Researcher Contact Details

Name: Peter Chudleigh and Sarah Simpson
Address: Agtrans Research, PO Box 385, Toowong Qld 4171

The researchers acknowledge Rachel Gallagher and Alice Peterson for their assistance in the compilation of this report

Phone: 07 3870 9564
Fax: 07 3371 3381
Email: info@agtrans.com.au

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600

PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au.
Web: http://www.rirdc.gov.au

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Foreword

The Tea Tree Oil R&D Program supports the continued development of a profitable and environmentally sustainable Australian tea tree oil industry. The Program is funded by voluntary contributions paid by industry participants and matching funding provided by the Australian Government. The investments made by the Program follow the R&D Plan for the Tea Tree Oil Program 2006-2011.

In May 2008 an Evaluation Framework for RIRDC was finalised. This framework, among other things, sets out a process for reviewing each of RIRDC's programs in the final year of its five year plan. One of the three programs selected for assessment in 2010 was the Tea Tree Oil Program.

A part of each specific program review is to select randomly three independent investments within the program for an impact evaluation through cost benefit analysis. The three economic analyses provide specific case studies that will demonstrate the extent and distribution of benefits that have been, are being, or will be, captured in future. Such information is valuable to not only RIRDC management, but also to the members of the industry (or industries) at which the investment has been targeted.

Another purpose of the economic analyses is to contribute to a process being undertaken for the Council of Rural Research & Development Corporations that aims to demonstrate through examples the outcomes and benefits that have emerged or are likely to emerge from the 15 Rural Research and Development Corporations (RDCs). Valuation of these benefits, along with identification of investment expenditure, is required in order to demonstrate their contribution to Australian rural industry as well as environmental and social benefits to Australia.

The projects evaluated demonstrated a wide range of benefits, a number of which were quantified in value terms. Funding for the three projects analysed totalled $1.64 million (present value terms) and produced aggregate total benefits of $30.21 million (present value terms). The Tea Tree Oil Program share of the total investment was 65%. The analyses found all three investments provided positive returns with Benefit-Cost Ratios ranging from 3:1 to 75:1.

The impact assessments serve the main purpose of providing accountability to government and industry/community stakeholders that research funds have been managed appropriately and are producing positive impacts and benefits to Australia.

This report, an addition to RIRDC's diverse range of over 2,000 research publications, forms part of our Tea Tree Oil R&D Program, which aims to to support the continued development of an environmentally sustainable and profitable Australian tea tree oil industry that has established international leadership in marketing, in value-adding, and in product reliability and production.

Most of our publications are available for viewing, downloading or purchasing online through our website www.rirdc.gov.au.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation

Contents

Executive Summary

What the report is about

This report presents the results of economic analyses of three investments within the Tea Tree Oil R&D Program. The Program is funded by voluntary contributions paid by industry participants, with matching funding provided by the Australian Government up to 0.5 per cent of the industry's gross value of farm production.

Who is the report targeted at?

The information contained in the report is targeted at Program and RIRDC management, those within the tea tree oil industry, and the wider community. Another target audience is the Australian Government and Council of Rural Research and Development Corporations (CRRDC).

Background

In May 2008 an Evaluation Framework for RIRDC was finalised. This framework, among other things, sets out a process for reviewing each of RIRDC's programs in the final year of its five year plan. In the year ending June 2010, three RIRDC programs have been evaluated, and this report addresses the economic evaluation component for the Tea Tree Oil R&D Program.

The Framework contains two major components, a performance review and an impact assessment. This report is the impact assessment and addresses the economic evaluation requirement under the Framework. This report also addresses the reporting requirements for RIRDC under the joint initiative of the CRRDC.

Aims/objectives

The primary purpose of the report is to demonstrate that benefits have accrued from specific investments. Another purpose of the economic analyses is to contribute to a process being undertaken for the CRRDC that aims to demonstrate through examples the outcomes and benefits that have emerged or are likely to emerge from the 15 Rural Research and Development Corporations. Valuation of these benefits, along with identification of investment expenditure, is required in order to demonstrate their contribution to Australian rural industry as well as environmental and social benefits to Australia. The Australian Government is particularly interested in such contributions in order to be assured that public funding of R&D is being used to produce public benefits.

Beneficiaries

The beneficiaries of the report will be RIRDC management, the Australian Government, the CRRDC, the wider Australian community, and those specifically involved with Australian tea tree oil industry.

Methods used

The methods used in the economic analyses followed the instructions in the RIRDC Evaluation Framework, both in terms of project selection and in terms of the analysis process and reporting. The selection process satisfied the random selection process of the CRRDC as well as the evaluation requirements of RIRDC. This entailed the definition of the population of projects in the program, a random sampling process and a filtering process.

Each investment was evaluated by assembling information from the three projects or project groups from original project proposals, final reports, and any progress reports or other relevant publications. Assistance was rendered by Program personnel, project principal investigators, industry personnel and

others. The potential benefits from each investment were identified and described in a triple bottom line context. Some of these benefits were then valued.

The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate investment criteria of Net Present Value and Benefit-Cost Ratio at a discount rate of 5%. The Internal Rate of Return was also estimated from the annual net cash flows. The PVB and PVC are the sums of the discounted streams of benefits and costs. All dollar costs and benefits were expressed in 2009/10 dollar terms and discounted to the first year of the investment being analysed. A 40 year time frame was used in all analyses, with the first year being the initial year of investment in the R&D project. Costs for the R&D project included the cash contributions of the Program (includes both RIRDC and industry investment), as well as any other resources contributed by third parties (e.g. researchers or additional industry funds).

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions. Sensitivity analyses were undertaken in most cases for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Results/key findings

There was a wide range of expected benefits identified in the projects, and a number of these benefits were valued. Funding for the three projects/project groups analysed totalled $1.64 million (present value terms) and produced aggregate total expected benefits of $30.21 million (present value terms). The Program share of the total investment was 65%. The analyses found all three investments provided positive returns with individual Benefit-Cost Ratios ranging from 3:1 to 75:1.

As only three projects/project groups out of a population of 15 project/project groups were analysed, these results can not be used to infer anything about the likely range of results for the population of projects as a whole.

Implications for relevant stakeholders

The positive results in terms of both the number and range of benefits identified and valued demonstrate that the Program is delivering significant impacts and is providing a healthy return on investment. The overall result should be heartening for RIRDC, the tea tree oil industry, and policy personnel responsible for allocation of public funds.

Recommendations

There were no recommendations made.

1. Introduction

In May 2008 an Evaluation Framework for RIRDC was finalised. This framework, among other things, sets out a process for reviewing each of RIRDC's programs in the final year of its five year plan.

These reviews are aimed at serving two broad purposes:

- providing accountability to government and industry/community stakeholders that research funds have been managed appropriately and are producing positive impacts and benefits to Australia
- identifying research areas and processes that may prove fruitful in terms of future investment and ongoing program management

More specific purposes are:

- reporting against the program's five year plan
- identifying lessons learnt from past investment
- reporting to the Council of Rural Research & Development Corporations (CRRDC) on impacts as part of the overall reporting framework of the Research and Development Corporations (RDCs)

In broad terms the Evaluation Framework encompasses a cohesive framework for evaluating research investment at project, program and portfolio levels for both accountability and future investment planning purposes.

The Framework contains two major components, a performance review and an impact assessment. The scope of this report is the impact assessment (or economic evaluation) requirements under the Framework, and the reporting requirements for the CRRDC.

In the year ending June 2010, three RIRDC programs have been evaluated, and this report is the economic evaluation component for the Tea Tree Oil R&D Program.

The impact assessments provide specific case studies that will demonstrate examples of the extent and distribution of benefits that have been, are being, or will be, captured in future. Such information is valuable to not only RIRDC management, but also to the members of the industry (or industries) at which the investment has been targeted.

Section 2 of this report describes the methods used to select the projects for analysis, and how the analyses were undertaken. Section 3 summarises the results of the analyses, and Section 4 presents some findings and conclusions. Details of the three individual analyses are presented in Appendices 1 to 3.

2. Methods

2.1 Project Selection

The RIRDC Evaluation Framework has clear instructions for how projects to be economically evaluated should be selected. The guidelines for project selection were adapted following the completion of the 2009 economic evaluations, and the following are the revised guidelines for project selection.

The selection of projects for impact assessment must be random to satisfy the requirements for the CRRDC. However, as it is important for successful projects to also be chosen the approach to random selection is as follows:

1. *Assuming the Five Year Plan (FYP) has been completed; list all projects that have been completed in the period of the FYP, and also include those that were/are due for completion up to six months after the completion of the FYP. If the FYP has not yet been completed, then all projects that have been completed at the time of the analysis should be included, as well as projects that have had a significant milestone and accomplishment, or are very close to completion.*
2. *Delete postgraduate scholarships, travel grants, general communications and reviews (special extension and some reviews with impact could be retained), conference support, program support and special events.*
3. *Delete projects of low value. The appropriate minimum value of projects to be included in the population will vary by program. This can be determined by the percentage of the total value of the population that is being excluded by setting the minimum value. One method is to list all the projects in descending value, determine the total value, and then determine how many projects at the bottom of the list make up say 2.5% to 5% of the total funding in aggregate. This rule of say 5% of total value could be applied across all programs, which would result in a different minimum value for each program.*
4. *The individual projects in the population should be stratified by program goals. Each project should be allocated to addressing a specific goal, and the total program funds invested in the projects addressing each goal should be summed. Then, if say, 80% of program funds are directed at Goal 1, the stratified sampling process can ensure that two projects from Goal 1 are selected for analysis.*
5. *All projects in the population should be assigned a random number using the random number generator in Windows Excel. The projects are then placed in order from highest random number to lowest and each project is considered in turn until an appropriate sample of three projects is identified. The factors for considering appropriateness are described in points (7) to (8) below.*
6. *In consultation with the Advisory Committee and Program Manager the analyst will discuss the impact of the selected project and the availability of information for undertaking an impact assessment. The assessment should consider not only the individual project selected, but also the project group as a whole if the selected project can be identified as forming part of a set of projects that collectively have contributed to an output or outcome. These can include projects completed prior to the current FYP, or outside of the population. Projects that together contributed to achieving an outcome are assessed as a set to avoid attributing the outcome to only a sub-set of the projects. Following the grouping, this assessment should classify each set as:*
    a. *too early: the projects have follow-on R&D that has yet to come to fruition*
    b. *low: there is little or no indication of outputs being adopted or likely to be adopted, or the project(s) failed to deliver the outputs expected, or other output that was serendipitous*
    c. *medium: there is evidence of adoption but uncertainty about how big the benefits are*

d. *high: there is evidence of adoption and conviction that the benefits have been high and/or good spillovers have been identified.*
e. *difficult to quantify: the project is highly strategic in nature or has some other benefit that is very difficult to value in a quantitative way.*

7. *The previous step should be repeated until there is at least one 'high' project in the full sample, and three that meet the medium or high level.*
8. *Other factors to consider before finalising the sample are that the projects selected are representative of the program goals (as determined by the stratification earlier) and that the individual projects selected are not from the same project grouping (as defined earlier). Projects not meeting the stratification requirements should be excluded and new projects selected and rated in turn until all conditions have been met.*

The first step involved defining the population of projects that were completed over the five years from July 2005 to June 2010 as defined in the RIRDC Clarity project database. The population therefore included projects starting earlier than this time period. Projects involving travel grants, general communications and reviews, conference support, program planning and support and special events were excluded in order to ensure that the population only included R&D projects. The projects were arranged in descending order by value and the bottom 5% in value terms of projects were identified. This bottom 5% of projects were then excluded, which means that projects with a value less than $20,000 of program investment were excluded from the population. This was to ensure that very small projects were not selected, and therefore ensure that higher percentage in value terms of the population was analysed. This resulted in a population of 15 projects, with a total value of $2.13 million (nominal terms). The 15 projects were categorised into goals, and the total percentage of research addressing each goal (in value terms) was identified. Table 2.1 shows the results of this stratification.

Table 2.1: Size and Value of Final Population by Goal

Goal (TTO refers to current program goals, and Old refers to goals under the previous five year program)	No. of projects	Total Value of Projects (Program Investment only) ($)	Percentage
1. TTO-Enhancing production systems to maintain the competitiveness of Australian growers	3	493,380	23.20
2. TTO-Identifying regulatory regimes and market barriers, and enhancing the ability of industry to meet safety standards	3	118,858	5.59
3. TTO- Demonstrating proof of concept/efficacy for innovative applications of tea tree oil	7	850,872	40.01
4. TTO-Fostering communication that increases understanding and thereby encourages greater use of tea tree oil	1	21,700	1.02
5. Old - To establish production systems that are both ecologically sustainable and profitable	1	641,583	30.17
6. Old - To enhance the ability of the industry to provide products that meet appropriate safety and efficacy standards	0	0	0
Total	15	2,126,393	100

Table 2.1 also shows that 40% of the population falls in Goal 3, and 30% into Goal 5 (where there is only one project). It was therefore recommended that one case study should be selected from Goal 3, one case study should be selected from Goal 5, and that the remaining project can be from any Goal. Such a stratification of the sample is consistent with CRRDC guidelines as applied in 2009. This resulted in the breeding program project (DAN-199A) in Goal 5 being forced into the sample.

RIRDC and the TTO R&D Committee confirmed that they were happy with the population definition and proposed stratification.

Agtrans assigned a random number between 0 and 1 to each of the 15 projects using the Excel random number generator. The three projects with the highest random numbers were then identified as the initial sample and sent to the Program Manager for rating as either too early, high, medium, low, or too hard to quantify as per the RIRDC evaluation guidelines. Seven projects were considered and rated before the final sample was determined. Table 2.2 presents the project codes, titles and costs for those projects sampled, and the ratings and comments on each of them that led to the final sample of three projects being selected. The first project randomly selected was identified as being one part of a larger group of projects with a common outcome, and was therefore expanded to include an additional 11 projects, some of which were not in the population.

Table 2.2: Projects/Project Groups Randomly Selected for Analysis

No.	Project Codes and Titles	Cost (Program only, (nominal $)	Rating/comments
1	PRJ-000734 – Preparation of SCCP submission for Tea Tree Oil – Stage 1 (expanded to include an additional 11 projects, some of which had been excluded from the population for being too small)	231,011 (including all 12 projects)	High (SELECTED) and grouped with a number of smaller projects (some of which had previously been excluded from the population). (Goal 2)
2	PRJ-559 (DAN-199A) – Breeding and cloning tea tree for greater profitability.	641,583	High (SELECTED) (Goal 5)
3	PRJ-002403: Microbial adaptation and tolerance to tea tree oil	113,750	Too early - Project not yet complete
4	PRJ-002395: Anticancer activity of *Melaleuca alternifolia* oil	314,784	Too early - The anti-cancer projects have had an impact in terms of additional research on the topic, but obviously nowhere near even the clinical trial stage or cure stage. So there is no impact yet. It is too early for an ex post analysis.
5	PRJ-000009: Anticancer activity of tea tree oil	92,405	Too early - The anti-cancer projects have had an impact in terms of additional research on the topic, but obviously nowhere near even the clinical trial stage or cure stage. So there is no impact yet. It is too early for an ex post analysis.
6	PRJ000005: Effects of tea tree oil on microbial adhesion	118,473	There is some work (product development) which might make use of this knowledge; but it is not a reason for the product being developed and the product stands without this knowledge. In fact, anyone who is developing tea tree products would be interested in this work - but no evidence it has yet been taken up.
7	PRJ-000451 – Effects of tea tree oil on biofilm formation.	85,927	High (SELECTED)

In summary, the final three projects/project groups selected for analysis were:

1. PRJ-000734 – Preparation of SCCP submission for TTO – Stage 1 (including 11 additional projects; the details of these projects are provided in Appendix 1).
2. PRJ-559 (DAN-199A) – Breeding and cloning tea tree for greater profitability.
3. PRJ-000451 – Effects of tea tree oil on biofilm formation.

The three selected investments making up the final sample analysed had a total nominal value of $0.96 million (including all 12 projects in the SCCP submission cluster of projects). The total nominal value of the seven investments randomly selected in order to reach a final sample with the required number of medium and high rated projects was $1.60 million. The total value of the population (15 projects as well as additional 11 projects eventually grouped with PRJ000734) was $2.22 million (nominal terms). Therefore, the sample of three projects represents 43.2% of the population in value terms, and 72.1% of the population was considered before reaching the final sample meeting the high/medium requirements.

2.2 Individual Analyses

Each investment was evaluated through the following steps:

1. Information from the original project proposals, final reports, and any progress reports or other relevant reports and material was assembled with assistance from Program personnel, Principal Investigators and others.

2. A presentation was made to the Tea Tree Oil R&D Committee in order to aid understanding of the process that was to follow, and to gain basic information and contact details on each of the projects.

3. An initial description of the project background, objectives, activities, costs, outputs, and outcomes and benefits was drafted. Additional information needs were identified.

4. Telephone contact was made with Principal Investigators and the draft sent to that person or persons for perusal and comment, together with specific information requests.

5. Further information was assembled where appropriate from industry personnel and others associated with the industry, and the quantitative analysis undertaken.

6. Drafts were passed by industry personnel for comment.

The potential benefits from each investment were identified and described in a triple bottom line context. Some of these benefits were then valued.

The factors that drive the investment criteria for R&D include:

C The cost of the R&D.

K The magnitude of the net benefit per unit of production affected; this net benefit per unit also takes into account the costs of implementation.

Q The quantity of production affected by the R&D, in turn a function of the size of the target audience or area, and the level of initial and maximum adoption ultimately expected, and level of adoption in the intervening years.

D The discount rate.

T_1 The time elapsed between the R&D investment and commencement of the accrual of benefits.

T_2 The time taken from first adoption to maximum adoption.

A An attribution factor can apply when the specific project or investment being considered is only one of several pieces of research or activity that have contributed to the outcome being valued.

P Probability of an R&D output, commercialisation etc. occurring. Can be applied when the research is not complete or when some further investment is required before the outputs of the research are translated into adoptable outcomes and extended to the industry.

Defining the 'without R&D' scenario to assist with defining and quantifying benefits is often one of the more difficult assumptions to make in investment analyses. The 'without' scenario (referred to here as counterfactual) usually lies somewhere between the status quo or business as usual case and the more extreme positions that the research would have happened anyway but at a later time; or the benefit would have been delivered anyway through another mechanism. The important issue is that the definition of the counterfactual scenario is made as consistently as possible between analyses.

The Present Value of Benefits (PVB) and Present Value of Costs (PVC) were used to estimate investment criteria of Net Present Value and Benefit-Cost Ratio at a discount rate of 5%. The Internal Rate of Return was also estimated from the annual net cash flows. The PVB and PVC are the sums of the discounted streams of benefits and costs. The discounting is used to allow for the time value of money. All dollar costs and benefits were expressed in 2009/10 dollar terms and discounted to the first year of the investment being analysed. A 40 year time frame was used in all analyses, with the first year being the initial year of investment in the R&D project. Costs for the R&D project included the cash contributions of the Program (RIRDC and industry investment), as well as any other resources contributed by third parties (e.g. researchers or additional industry contributions).

Analyses were undertaken for total benefits that included future expected benefits. A degree of conservatism was used when finalising assumptions. Sensitivity analyses were undertaken in most cases for those variables where there was greatest uncertainty or for those that were thought to be key drivers of the investment criteria.

Some identified benefits were not quantified mainly due to:

- A suspected, weak or uncertain relationship between the research investment and the identified R&D outcomes and associated benefits.
- The magnitude of the value of the benefit was thought to be only minor.

3. Results

The results for each of the three project evaluations are reported in Appendices 1 to 3. The following provides a summary of results of the three evaluations.

3.1 Qualitative Results

Table 3.1 identifies the benefits from each of the three case studies. Each benefit is categorised as economic, environmental or social. Not all of the case studies demonstrated benefits from each category.

Table 3.1: Summary of Benefits for Three Investments

Project	Benefits
SCCP submission	Economic • Avoided loss of sale of tea tree oil to European consumer goods market. • Avoided loss of sale of tea tree oil to other export markets. Environmental • Nil Social • Potentially improved health outcomes for users of TTO, through improved understanding of the appropriate use and storage of tea tree oil (for example information on the toxicity, shelf life and skin irritant factors). • Reduced impact on regional communities where the TTO industry is concentrated
Breeding Program (Phase 3)	Economic • Increased profits per kg of oil produced (due to yield increases). • Increase in area of land planted to tea tree. Environmental • Nil Social • Reduced impact on regional communities where TTO industry is concentrated. • Public health benefits through the continued availability and affordability of tea tree oil for therapeutic and cosmetic uses
Biofilm	Economic • Potential for reduced costs associated with controlling or preventing biofilms in a number of applications including air conditioning cooling towers, food processing and human health. • Potential for reduced economic impacts of biofilms in a number of applications including air conditioning cooling towers, food processing and human health. • Increased profit in the tea tree oil producing and Australian manufacturing industry due to increased demand. Environmental • Availability of a management option which is environmentally sustainable to produce and readily biodegradable. Social • Potential improved prevention or treatment of disease, built-environment infections and food poisoning incidents, leading to improvements in the quality of life.

3.2 Quantitative Results

The investment criteria calculated for each research area were the Net Present Value (NPV), the Benefit-Cost Ratio (B/C Ratio) and the Internal Rate of Return (IRR). The NPV is the difference between the Present Value of Benefits (PVB) and the Present Value of Costs (PVC). Present values are the sum of discounted streams of benefits and/or costs. The B/C Ratio is the ratio of the PVB to the PVC. The IRR is the discount rate that would equate the PVB and the PVC, thus making the NPV zero and the B/C Ratio 1:1. Investment criteria were estimated for both the total investment and for the Program (RIRDC and industry) investment.

Table 3.2 presents the investment criteria for the total investments in each of the three case studies analysed at a 5% discount rate.

Table 3.2: Investment Criteria for Total Investments for Three Case Studies

(discount rate = 5%)

Investment	PVB ($m)	PVC ($m)	NPV ($m)	B/C Ratio	IRR (%)
SCCP Submission	23.82	0.32	23.50	74.6	591
Breeding Program (Phase 3)	6.05	1.19	4.86	5.1	19.6
Biofilm	0.34	0.13	0.21	2.6	13.1

Table 3.3 presents the investment criteria for only the cash investment by the Tea Tree Oil R&D Program only in each of the three case studies (at a 5% discount rate). The Program is funded through equal contributions from RIRDC and industry.

Table 3.3: Investment Criteria for Program Investment for Three Case Studies

(discount rate = 5%)

Investment	PVB ($m)	PVC ($m)	NPV ($m)	B/C Ratio	IRR (%)
SCCP Submission	18.68	0.25	18.43	74.9	663
Breeding Program (Phase 3)	3.51	0.69	2.82	5.1	19.6
Biofilm	0.31	0.12	0.19	2.6	13.1

Funding for the three investments analysed was $1.64 million (present value terms) and produced aggregate total expected benefits of $30.21 million (present value terms). The Program share of the total investment was 65%. The analyses found all three investments provided positive returns with individual benefit cost ratios ranging from about 3:1 to 75 to 1.

The results produced are highly dependent on the assumptions made in each analysis, many 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 each investment analysis (Table 3.4). 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 significant uncertainties in assumptions made

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

Table 3.4: Confidence in Analysis for Three Case Studies

Case Study	Coverage of Benefits	Confidence in Assumptions
SCCP Submission	Medium	High
Breeding Program (Phase 3)	High	High
Biofilm	Low	Low

3.3 Previous Economic Evaluations of Investments in the Tea Tree Oil R&D Program

Two tea tree oil program investments were previously analysed and included in two publications. The first was an analysis of project DAN-61A: The insect fauna of *Melaleuca alternifolia* (tea tree) with emphasis on three known pest species. A cost-benefit analysis was carried out on the project and included in the publication "Gains in Shaping the Future: Returns from Research Funded by RIRDC" (Fearn, 1994). The analysis used a 30 year time-frame and was carried out in 1992/93 dollar terms. The investment criteria at a discount rate of 5% are shown in Table 3.5. The second cost-benefit analysis on a tea tree oil R&D investment was carried out by Agtrans Research in 1998, and included in the publication "Benefit-cost analysis of RIRDC's Emerging Industries Program" (Centre for International Economics, 1998). The evaluation was of three breeding projects funded between 1992 and 1996 (CSF43A, ANU11A and DAN87A). The analysis used a 30 year time frame and results reported in 1998 dollar terms. The investment criteria at a discount rate of 5% are shown in Table 3.5 The costs for both investments include the total contributions from all investors.

Table 3.5: Investment Criteria for Two Investments Analysed in 1994 and 1998

Investment	PVB ($m)	PVC ($m)	NPV ($m)	B/C Ratio	IRR (%)
DAN-61A: The insect fauna of *Melaleuca alternifolia* (tea tree) with emphasis on three known pest species	2.46	0.07	2.40	37.8	89
Breeding projects (CSF43A, ANU11A and DAN87A)	Not provided	Not provided	19.0	14	23

Source: Fearn, 1994 and Centre for International Economics, 1998

The investment criteria for the two investments carried out in 1994 and 1998 are not dissimilar in their range from the three investments carried out in the current analysis, however, it is not appropriate to compare the results of the current 2010 evaluations with those of the earlier analyses, due to the small sample in both the previous analyses and the current analysis.

4. Findings and Conclusions

4.1 Summary of Findings

SCCP Submission

The cluster of projects analysed in this evaluation were successful in developing data and information to be included in a dossier submitted to the SCCP in order to demonstrate the safety of tea tree oil for use in consumer products. Addressing this significant risk to the industry has resulted in the retention of a significant market for tea tree oil, and reduced the likelihood of losing other markets as well.

The results of the analysis demonstrate, that given the assumptions made, the benefits from this research have been significant, with a benefit-cost ratio of 74.6 to 1, and a net present value of $23.5 million when benefits are considered over 40 years, at a discount rate of 5%. The very high benefit-cost ratio is partly a function of the low cost at which the research was carried out, and the very high proportion of the total tea tree oil market that was protected by undertaking the research.

Breeding Program (Phase 3)

The tea tree oil breeding program has been ongoing since 1993, and over that time has resulted in significant improvements to the oil yields of tea tree plants. This analysis considered the third phase of the breeding program (2001 to 2006). This phase of the program resulted in the breeding of several new varieties, as well as allowing seed from previously developed varieties to continue to be produced and sold. The availability of seed from the breeding program has allowed the industry to expand, and increased the profits for tea tree growers through increasing oil yield without significantly increasing production costs.

Based on a series of assumptions regarding the potential benefits, this phase of the breeding program had a total investment (present value) of $1.2 million resulting in a total benefit (present value) of $6.1 million, and therefore an estimated net present value of $4.9 million and a benefit cost ratio of 5 to 1.

Biofilm

This project was exploratory in nature, and its major output was scientific knowledge. This scientific knowledge will potentially be of value in providing greater confidence in the development of a range of applications for the prevention and control of biofilm development in a range of situations. At this stage, there are no tea tree oil products marketed for this purpose, and the likely timing of the development of such products is uncertain.

Also uncertain is the nature of the benefit that will accrue from the development of such products, in terms of whether they will result in cost reductions, or improved control. Such factors are likely to influence the potential market penetration of any tea tree oil products developed.

Despite the many uncertainties in this area, a probabilistic cost-benefit analysis has been undertaken that seeks to identify the potential benefits from this research project, given a certain set of assumptions. The analysis showed that for the research investment of $0.13 million (present value terms) the expected gross benefit was $0.34 million (present value terms), resulting in an expected net present value of $0.21 million and an expected benefit cost ratio of 2.6 to 1.

Scientifically, this was a successful project. The relatively low benefit-cost ratio is a result of a number of factors including the long time period until benefits will be realised, the uncertainties

surrounding the potential size and nature of the impact that any eventual tea tree oil product might have, and the low level of attribution (via the speeding up of product development) of any eventual benefit that can be attributed back to this single piece of research.

Public versus Private Benefits

All three projects have captured both public and private benefits. There will be private benefits to the tea tree oil industry through the retention of a key market, increased yields, and increased demand for tea tree oil through the opening up of a potential new market.

Public benefits identified from the three projects include:

- the reduced likelihood of irritant or allergic reactions to tea tree oil through inappropriate use of tea tree oil products
- lowering of regional impacts from avoiding a loss of a substantial market. In some areas of Northern NSW, tea tree oil is one of the few cropping options
- public health benefits due to the ongoing viability of the tea tree oil industry, and therefore the availability and affordability of tea tree oil for therapeutic and cosmetic uses
- reduced human health impacts due to the reduced impact of biofilms, as often these costs are borne by society.
- the availability of a product that is environmentally sustainable to produce and readily biodegradable.

It should be noted that the public and private benefits summarised here only relate to the three case studies analysed. Other projects funded by the Tea Tree Oil R&D Program would also contribute significantly to public benefits, including public health benefits through the identification and development of new therapeutic uses for tea tree oil.

Distribution of benefits along the supply chain

For all three projects, benefits to the tea tree oil industry will be distributed along the tea tree oil supply chain, and distributed along that chain, from producers through to product formulators and the consumer (who are mostly overseas) in accordance with the various supply and demand elasticities.

Benefits to other primary industries

The industry benefits from all three projects are mostly restricted to the tea tree oil industry. However, for the breeding project, there may be some benefits to other industries with respect to improved knowledge for breeding (particularly for other essential oil crops). For the project on understanding biofilm formation, there is the potential for some indirect spin-off benefits to other primary industries where food is processed through processing plants that may adopt tea tree oil based product for biofilm control. The SCCP cluster of projects has provided improved knowledge that can be utilised by other industries with respect to how to prepare a submission to the SCCP and other regulatory agencies.

Match with national priorities

The Australian Government's national and rural R&D priorities are reproduced in Table 4.1.

Table 4.1: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

All three projects address National Priority 3, and both the SCCP submission cluster and the Biofilm project address National Priority 2. The Biofilm project also addressed National Priority 1.

The breeding program and the Biofilm project both addressed Rural Research Priority 1, while the SCCP cluster and the Biofilm project both addressed Rural Research Priority 2. The Breeding program and the biofilm project both also contributed to the supporting priorities.

Additionality

If the government's contribution to the Tea Tree Oil R&D Program was reduced by half, then it is likely that the SCCP cluster of projects would still have been funded due to the high priority issue it was addressing. The breeding program may not have been funded as there may not have been enough resources to fund a breeding program, which is relatively high cost. However, for the biofilm project, it may have been funded at a reduced level or over a longer period.

If the Program did not exist at all, then the SCCP cluster of projects would most likely still have been undertaken by industry, but the timing may have been delayed while funding was sought from private sources. Also, the outcomes may not have been as effective without the coordinating role played by RIRDC. The breeding program would not have been funded, as the industry and RIRDC would not have had the resources to fund the breeding program given the size of the industry. The biofilm project is unlikely to have been funded by industry alone, due to the strategic nature of the research.

It is evident that the public benefits of investment in the Tea Tree Oil R&D Program would not have been captured with any reduction in the public funding of RIRDC.

4.2 Conclusions

The current analyses of three Tea Tree Oil R&D program investments have resulted in Benefit-Cost Ratios in a wide range of 2.6:1 to 75:1. However, as only three investments out of a population of 15 projects were analysed, these results cannot be used to infer anything about the likely range of results for the population of projects as a whole.

The principal benefits identified were economic and social in nature with some limited environmental benefits. Of the subset of benefits identified that were valued, most were economic in nature and economic benefits accrued both to the tea tree oil industry and to society in general. Tea Tree Oil producers would benefit in the main but some private benefits would be passed along the supply chain.

There were also a range of public benefits identified that were not quantified, relating largely to the regional and health benefits that flow from the continued viability of the tea tree oil industry.

Both the qualitative and quantitative results for the impact evaluations demonstrate that, at least for these three randomly selected projects/project groups, the investments have provided confidence in the investments that are being made by the Tea Tree Oil R&D Program.

References

Fearn, M. (1994) “Gains in Shaping the Future: Returns from Research Funded by RIRDC” RIRDC Occasional Paper No 94/4.

Centre for International Economics (1998) “Benefit-cost analysis of RIRDC’s Emerging Industries Program” RIRDC Publication No. 98/104.

Appendix 1: Impact Assessment of Investment in SCCP Submission for Tea Tree Oil

Background

Approximately 50% of Australia's annual production of tea tree oil (TTO) is imported into Europe, and about 40% to North America (ATTIA, 2007). The Scientific Committee on Consumer Products (SCCP) was set up by the European Commission to provide scientific advice on the safety of consumer products (defined as non-food products intended for the consumer). This includes addressing questions in relation to the "safety and allergenic properties of cosmetic products and ingredients with respect to their impact on consumer health, toys, textiles, clothing, personal care products, domestic products such as detergents and consumer services such as tattooing" (EU SCCP website).

The products regulated by the SCCP in which TTO is used, are cosmetics and personal care products. Specifically the cosmetics to which tea tree oil is added and typical concentrations in the formulation are moisturisers (1.25%), body lotions (1.25%), shampoos and conditioners, mouth washes (0.2%), face cleansing washes (0.7%), soaps (2%), foot sprays (2%), foot powders (1%), shaving products (2%), post-waxing treatments (1.25%) and deodorants (2%). Tea Tree Oil is also sold over the counter as neat oil or in 10-15% tea tree oil solutions (ATTIA, 2007).

In December 2004, the SCCP adopted a scientific opinion on tea tree oil. The opinion concluded that "a complete dossier of a representative standardised material to all relevant toxicological endpoints is required by the end of 2005; an opinion based on the information available at that time will be given." This finding did receive some negative media coverage overseas, including headlines such as "tea tree oil – unsafe and unstable" (Ian Southwell's proposal for DAN-241A). A number of projects were funded by the Tea Tree Oil R&D Program in order to prepare a safety dossier to respond to the 2005 SCCP opinion. The economic impact of the investment in this cluster of projects is evaluated in this analysis.

The Projects

Eleven projects were funded by the Tea Tree Oil R&D Program to prepare the Tea Tree Oil Safety Dossier, and these eleven projects are included in this analysis. Table 1 presents the Project Number, Project Title, Research Organisation, Principal Investigator and Period of Research for each of these 11 projects.

Table 1: Summary of Project Details

Project Number	Project Title	Other Details
CTM-1A	Communication of the Tea Tree Oil Safety Dossier	Research Organisation: Coretext Communications Period: Jun 2007 to Nov 2007 Principal Investigator: Penny Fannin
DAN-241A	Quality assurance for tea tree oil safety investigative samples	Research Organisations: NSW Department of Primary Industries and Southern Cross University Period: Sep 2005 to Feb 2006 Principal Investigator: Ian Southwell and David Leach
ISO-2A	p-Cymene and organic peroxides, indicators of oxidation in tea tree oil	Research Organisation: NSW Department of Primary Industries Period: Jun 2006 to Jun 2006 Principal Investigator: Ian Southwell
MSO-56-55	Review of the SCCP Safety Dossier for Tea Tree Oil	Research Organisation: EVIC FRANCE Period: Apr 2006 to Jun 2006 Principal Investigator: Philippe Masson
MS0-67-22	Review of SCCP Safety Dossier for Tea Tree Oil	Research Organisation: University of California, San Francisco Period: July 2006 to June 2007 Principal Investigator: Howard Maibach
MOT-1A	Literature Review of Tea Tree Oil for SCCP	Research Organisation: Mercalli Overseas Trading Enterprises Ltd Period: Sep 2005 to Jun 2006 Principal Investigator: Jesper Bo Nielsen
UQ-124A	In-vitro human skin penetration of topically applied tea tree oil	Research Organisation: University of Queensland Period: Oct 2005 to Apr 2006 Principal Investigator: Sheree Cross
UWA-89A	Compilation of toxicity data for tea tree oil components	Research Organisation: University of Western Australia Period: Jul 2005 to Oct 2005 Principal Investigator: Thomas Riley
PRJ-819 (GUI-1A)	Skin sensitisation: local lymph node assay	Research Organisation: P. Guinane Pty Ltd Period: Mar 2006 to Jun 2006 Principal Investigator: Patricia Bolster
PRJ-648 (USC-9A)	Stability testing of tea tree oil	Research Organisation: Southern Cross University Period: Feb 2006 to Mar 2007 Principal Investigator: David Leach
PRJ-734 (CIN-1A)	Preparation of SCCP submission for TTO – Stage 1	Research Organisation: Cintox pty Ltd Period: Jul 2005 to Dec 2005 Principal Investigator: John Issa
PRJ-767 (SCF-1A)	Allergy to tea tree oil: qualitative aspects and risk assessment	Research Organisation: Skin & Cancer Foundation Australia Period: Jun 2006 to Nov 2006 Principal Investigator: Rosemary Nixon

Project Objectives

Table 2 presents the objectives for each of the projects.

Table 2: Summary of Project Objectives

Project	Objectives
CTM-1A Communication	• To promote tea tree oil as a safe and effective product.
DAN-241A Quality assurance for samples	• To determine the peroxide index of a range of fresh and aged commercial tea tree oil samples. • To select three samples suitable for safety package regulatory testing that can be categorised as fresh, mildly oxidised and oxidised. • To define the quality of the selected three samples of tea tree oil by determining the chemical composition by Gas chromatography – Mass spectrometry (GCMS) and comparison with ISO 4730.
ISO-2A Indicators of oxidation	• To use both p-Cymene content and peroxide value determinations as selection criteria for choosing three tea tree oils which were (i) unoxidised, (ii) partially oxidised and (iii) significantly oxidised. • To determine the percentage composition of the major components in these oils using gas chromatography. • To determine the physico-chemical constants specified as mandatory for both the international and Australian standards (relative density; refractive index; optical rotation; solubility in ethanol and chromatographic profile). • To determine the components present at > 0.1% in all three oils using Gas Chromatography – Flame Ionising Detection (GCFID) and GCMS.
MS0-56-55 Review of dossier	• To provide a review of the draft SCCP safety dossier for tea tree oil.
MS0-67-22 Review of dossier	• To provide a review of the draft SCCP safety dossier for tea tree oil
MOT-1A Literature review	• To provide a review of available literature as a component of the response to the SCCP opinion of December 2004.
UQ-124A Skin penetration	• To determine the in-vitro human skin penetration of tea tree oil over a 24 hour application period of: o A pure 100% oil standard preparation, and o A 20% tea tree oil in a commercial formulation as representative of an 'in use' low concentration preparation.
UWA-89A Toxicity data	• To extract and compile data on the toxicology of the 15 major components of tea tree oil.
PRJ-819 (GUI-1A) Skin sensitisation	• To undertake a lymph node assay in mice (OECD429) to identify the contact allergenic potential of tea tree oil in order to provide a rational basis for risk assessment to the sensitising potential of tea tree oil to humans.
PRJ-648 (USC-9A) Stability testing	• To determine the changes in tea tree oil composition and peroxide value over 12 months under simulated in-use conditions. The proposed study protocol is based on principles outlined by the European Agency for the Evaluation of Medicinal Products (EMEA) in 'Guidance on In-Use Stability of Human Medicinal Products'.
PRJ-734 (CIN-1A)	• To prepare a safety dossier on tea tree oil for submission to the Scientific Committee on Consumer Products (SCCP) in conjunction with the tea tree oil

Preparation of submission	industry.
PRJ-767 (SCF-1A) Allergy testing	• To evaluate the safety profile of current exposure to tea tree oil in relation to allergic contact dermatitis. • To determine a safe dilution which will not elicit a reaction in subjects allergic to tea tree oil.

Project Costs

Estimates of the annual total investment in each of the projects by the Tea Tree Oil R&D Program are provided in Table 3. The Program is funded equally by RIRDC and the tea tree oil industry.

Table 3: Estimate of Investment in SCCP Submission (and associated projects) for Tea Tree Oil R&D Program (nominal $; including RIRDC and industry contributions)

Year ending June	2006	2007	2008	Total
CTM-1A	0	10,450	11,250	21,700
DAN-241A	1,509	0	0	1,509
ISO-2A	3,400	0	0	3,400
MS0-56-55	8,129			8,129
MS0-67-22	0	16,938	0	16,938
MOT-1A	15,000	0	0	15,000
UQ-124A	17,250	0	0	17,250
UWA-89A	15,575	0	0	15,575
PRJ-819 (GUI-1A)	21,848	15,292	0	37,140
PRJ-648 (USC-9A)	6,325	6,327	0	12,563
PRJ-734 (CIN-1A)	35,608	10,000	0	45,608
PRJ-767 (SCF-1A)	13,100	23,010	0	36,110
Total	137,744	82,017	11,250	231,011

There was also one project (UWA-89A – toxicity data) that had some contribution from a source other than the Program ($2,991). There was also a significant in-kind contribution from a number of industry members who met regularly during the course of the projects to discuss, formulate and devise responses to each of the step-wise decisions and projects being undertaken. This in-kind contribution has been valued at $60,000 and therefore the total investment in the cluster of projects was $294,002, with the Tea Tree Oil R&D Program contributing 78.6% of the total investment in this cluster.

Project Description

Following the release of the opinion of the SCCP in late 2004, the Tea Tree Industry (through ATTIA and the Tea Tree Oil R&D Committee), made the decision to pursue the submission of a dossier of safety information for tea tree that would address the concerns the SCCP raised when forming their opinion.

A number of projects were funded in order to be able to prepare a dossier that met the data needs identified by the SCCP. These included literature reviews, as well as a number of tests on the chemical composition, toxicity, degradation and sensitivity factors associated with tea tree oil use on human skin (both neat and diluted). The dossier was then prepared, and experts engaged in order to

review the dossier before it was submitted to the SCCP. In addition, a communications project was established to ensure that the information contained in the dossier was also available in a 'plain English' format, and that this information was promoted to a range of interested parties.

Outputs

Table 4 presents a summary of the outputs for each of the projects included in the cluster.

Table 4: Summary of Project Outputs

Project	Outputs
CTM-1A Communication	• Development of a comprehensive and targeted media contact list. • Preparation of a full-colour brochure that summarises the efficacy and safety data contained in the tea tree oil safety dossier. • Articles in RIRDC's Tea Tree Industry Research newsletter. • Media releases written and disseminated. Three media releases associated with the dossier were distributed in December 2007 and March 2008 (2 releases).
DAN-241A Quality assurance for samples	• Eleven commercial TTO samples were screened and three samples were selected for further investigation using peroxide index determination (one fresh, one oxidised and one mildly oxidised). • The three samples were thoroughly defined by Gas chromatography (GC), Gas Chromatography – Mass Spectrometry (GCMS) and physical constants. • These definitions were used to determine the status of the oil with respect to the International Organisation for Standardisation (ISO) standard for TTO before being recommended for dermal penetration and other safety parameter investigations for the SCCP dossier. • The results of the study found it could be suggested that oxidised TTOs are usually, but not always, seen to be associated with high peroxide values and high p-Cymene contents. Detailed results were provided in the final report. • A final report summarising the findings was produced.
ISO-2A Indicators of oxidation	• This project was essentially an extension to project DAN—241A and the final reports were combined. The main output of this part of the project was to clearly relate an increase in p-cymene to increasing oxidation levels rather than relying on a peroxide test which had been demonstrated as unreliable in DAN-241A.
MS0-56-55 Review of dossier	• A review of draft safety dossier for TTO was prepared, which provided comment on: o Conformance to the SCCP o Testing strategy in place o Data gaps and need for additional studies o Review of scientific arguments o Provide strategic advice for pre-submission and post-SCCP-opinion
MS0-67-22	• A review of the draft safety dossier for TTO (handwritten comments).
MOT-1A Literature review	• A literature review was prepared and submitted as a final report to RIRDC. It formed a supplement to a previous literature review carried out in 2003 by the same author. • The literature review was focused on the toxicity of individual tea tree oil components including potential products formed due to oxidation of the oil.

	• The review summarises the toxicity profiles of the 14 individual constituents of TTO with an expected concentration in newly refined TTO above 0.5% and five known oxidative degradation products from TTO.
UQ-124A Skin penetration	• The project produced a final report and information was provided on which components of TTO are absorbed through human skin. • Fifteen separate TTO components were analysed, and information is provided regarding their absorption across the skin and retention within the skin following a 24 hour application period. • The data showed that under normal 'in use' conditions, a total of 3% of applied TTO components can be found either permeating the skin into receptor fluid, or retained within the epidermis in 24 hours.
UWA-89A Toxicity data	• A final report that collated and summarised a wide range of data and scientific publications that relate to the toxicity of the major components of tea tree oil. • Data describing the toxicity of the 15 TTO components identified in the ISO4730 standard was obtained by conducting a rigorous search of literature and toxicology databases. A search was also conducted for the major degradation products of these components. • The report provides: o A list of TTO papers that have been published since the previous compilation and review of TTO data (UWA 75A) o A brief summary of literature relating to the toxicity of TTO components o A list of publications categorised by component and toxicology parameter o A library of over 400 component toxicology citations constructed using the Endnote program o A library of over 120 TTO citations constructed • Research publications and reports relating to TTO component toxicity were collected.
PRJ-819 (GUI-1A) Skin sensitisation	• A number of local lymph node assay (LLNA) tests were undertaken in mice in accredited laboratories in Europe and the USA to identify the contact allergenic potential of TTO. • The key finding was that topical applications at 25% and 50% in PEG 400 resulted in a stimulation index greater than three which classifies TTO as an extremely weak sensitiser at those concentrations. • Oxidised TTO was shown by the study to have a much greater propensity to cause skin sensitisation, and the use of oxidised TTO should be avoided. However when used and stored properly, TTO is not expected to pose a risk to human health.
PRJ-648 (USC-9A) Stability testing	• Oil was tested to determine the changes in TTO composition and peroxide value over 12 months under simulated in-use conditions. Results indicated that samples remained relatively stable over the 12 month test period, and that there was a gradual increase in peroxide value over the 12 month period from 2 to 9 meqO_2/kg. • The major components of TTO remained stable for 6 months after which time downward trends in α-terpinene and γ-terpinene and an upward trend in p-cymene were observed. • There was no significant change in minor TTO components over the 12 month period. • At the end of the 12 month storage period both batches of TTO still conformed to monograph specifications for TTO.

	• The study confirmed that neat TTO is stable for 12 months and therefore presents no additional health hazards.
PRJ-734 (CIN-1A) Preparation of submission	• Preparation of the dossier for submission to the SCCP. This involved the compilation of all existing information, and new information and data developed through investment by RIRDC. • It includes a comprehensive review of the available scientific literature on the toxicity of TTO and its main constituents, as well as information from additional new studies conducted in response to the earlier SCCP request.
PRJ-767 (SCF-1A) Allergy testing	• Seventeen volunteers known to be allergic to TTO participated in the study with patch testing and repeat open application testing (ROAT). • A significant relationship was found between the dose of TTO applied and the likelihood of a skin reaction. It was found that only 7% (1/14) of sensitised individuals reacted to 2% non-oxidised TTO on ROAT. • The issue of how much oxidation of products might contribute to allergic reactions attributed to TTO was unresolved. • It was determined that the study did not have enough statistical power, due to significant difficulties in locating subjects throughout Australia who were known to be sensitised to Tea Tree Oil.

Outcomes

Table 5 presents a summary of the outcomes for each project in the cluster.

Table 5: Summary of Project Outcomes

Project	Outcomes
CTM-1A Communication	• A concise summary of the TTO safety dossier in print and on the web, that is accessible by consumers, politicians and regulators. • Distribution of information to industry stakeholders and others regarding the effectiveness and safety of Australian Tea Tree Oil in an easy to read plain English format. This document was distributed to the Australian industry who sent it on to their own customers, including international customers. • Publication of balanced reports on the health benefits and safety of TTO has occurred in mainstream, trade and natural health media.
DAN-241A Quality assurance for samples	• The findings were incorporated into the TTO safety dossier and into the communications brochure.
ISO-2A Indicators of oxidation	• The findings were incorporated into the TTO safety dossier. • The p-Cymene protocol developed as part of this project is the basis of the quality monitoring system used in the ATTIA code of practice, and is the most important marker relied upon to determine oil quality (once t-4-ol and cineole are established).
MS0-56-55 Review of dossier	• This review contributed to improvements to the safety dossier that was eventually submitted to the SCCP.
MS0-67-22 Review of dossier	• This review contributed to improvements to the safety dossier that was eventually submitted to the SCCP.
MOT-1A Literature review	• The literature review was a component of the safety dossier.
UQ-124A	• The findings were incorporated into the TTO safety dossier and into the

Skin penetration	communications brochure. • A paper based on the dossier was accepted for publication in European Journal of Pharmaceutics and Biopharmaceutics. The paper was titled "Human skin penetration of the major components of Australian TTO applied in its pure form and as a 20% solution in vitro" (May 2008 69(1) pp 214-222).
UWA-89A Toxicity data	• The findings were incorporated into the TTO safety dossier. • The compilation of the data was in a format to make it suitable for evaluation by a toxicologist.
PRJ-819 (GUI-1A) Skin sensitisation	• The findings were incorporated into the TTO safety dossier and into the communications brochure.
PRJ-648 (USC-9A) Stability testing	• The findings were incorporated into the TTO safety dossier and into the communications brochure.
PRJ-734 (CIN-1A) Preparation of submission	• The dossier was completed and submitted to the SCCP in April 2007. • A response to the dossier was provided by the SCCP, and the opinion was adopted at its 18th plenary of 16 December 2008.
PRJ-767 (SCF-1A) Allergy testing	• This study was not completed in time, and did not have enough statistical significance, to be included in the safety dossier submitted to the SCCP.

Summary of Overall Outcomes

Together, this cluster of projects has contributed to the overall outcome of completing the dossier and submitting it to the SCCP in March 2007. An opinion on tea tree oil was then adopted by the SCCP at its 18th Plenary of 16 December 2008. The conclusion of the opinion on the safety of TTO as used in cosmetic preparations was:

> *The cosmetic function of Tea Tree Oil needs to be indicated, as no clear cosmetic function was given by the applicant and several non-cosmetic applications are known.*
>
> *When exposed to air and heat, Tea Tree Oil is prone to oxidation, yielding epoxides and further oxidation products which are considered to contribute to the skin sensitising potential of Tea Tree Oil. It is important to consider that certain formulations tend to reduce stability. According to the Code of Practice and the Guidance document introduced by the Australian Tea Tree Oil Association, safe processing and storage may be achieved which can be controlled by the p-cymene content.*
>
> *Tea Tree Oil is a skin sensitiser. Skin sensitisation may also be enhanced by irritancy. Neat Tea Tree Oil and certain formulations at concentrations of 5% or more can induce skin and eye irritation.*
>
> *Based on clinical data, the current use levels of TTO are shown to induce contact allergy.*
>
> *Methyleugenol was reported as a minor constituent of Tea Tree Oil; the content should be indicated. According to the opinion SCCNFP/0373/00 on methyleugenol in fragrances the content in finished leave-on products should not exceed 0.0002% (2 ppm) and in rinse-off products 0.001% (10 ppm).*
>
> *Following topical application of Tea Tree Oil and Tea Tree Oil containing products, percutaneous absorption of some constituents may occur, leading to a considerable systemic exposure, especially from neat oil, body lotion and foot spray/powder. Because of inadequate dermal absorption studies available, the magnitude of systemic exposure to Tea Tree Oil from cosmetic products is uncertain. Only worst case estimations for NOAELS for general systemic and reproductive toxicity can be made. A Margin of Safety has not been calculated and the safety of Tea Tree Oil cannot be assessed.*

Should there be reliable data on percutaneous absorption covering relevant concentrations and cosmetic formulations, a reassessment of the safety of Tea Tree Oil is envisaged by the SCCP.

This ruling does not initially seem positive and the facts contained in it are challenged by ATTIA. However, commercially it has made no difference to the purchase/sale of oil or its product formulation when compared to the situation prior to the ruling. Without the submission of the dossier to the SCCP, there was a very high likelihood that use of TTO in consumer products in Europe would have been severely or totally restricted. Therefore the overall outcome has been the retention of this extremely important market for Australian tea tree oil.

As noted above, the information developed for use in the dossier was also summarised in a plain English publication that was communicated widely within Australia. This had the intention of developing an increased understanding by consumers and regulators that TTO produced in line with ATTIA guidelines does not pose a health risk. It also sought to increase understanding of the health benefits and safety profile of TTO. Other intended goals of this communication were:

- Politicians and regulators accept that restrictions or conditions on the use of TTO are not warranted

- Consumers, health professionals and retailers have good, accurate information and maintain confidence in TTO products.

In addition to the SCCP, the data and information collated will also be of value to responding to concerns by other regulatory organisations in other markets (e.g. therapeutics, North American markets etc). Seven of the projects (DAN-241A, ISO-2A, MOT-1A, UQ-124A, UWA-89A, PRJ-819 and PRJ-648) were used by ATTIA in the preparation of a dossier for submission to the European Medicines Agency (EMEA) to apply for a herbal monograph for tea tree oil in the European Union. The results of these projects were also used by contributors to the original dossier when preparing "personal" dossiers (i.e. their own commercial dossiers).

Benefits

The most significant benefit from this cluster of research is the avoidance of increased restrictions on the use of TTO in consumer products in Europe (exports to Europe account for 50% of Australia's TTO market). In addition, such restrictions by the EU may have led to other markets considering their own regulations with respect to TTO, and other restrictions and loss of markets may have flowed from this.

The improved information and data available on TTO as a result of the dossier may have also contributed to an improved understanding of TTO by regulators and product developers across a range of product types and markets. The information developed as part of the dossier has been used for a range of other dossiers for other markets. Also, the information could lead to increased sales of TTO for inclusion in a new range of products.

The availability of improved information on toxicity etc may also lead to some safety improvements in the use of TTO as awareness of potential issues by product formulators increases. However there is no information available to determine if this is the case due to the commercial in confidence associated with product formulation.

Summary of Benefits

A summary of the principal types of benefits associated with the outcomes of the cluster of projects is shown in Table 6.

Table 6: Categories of Benefits from the Investment

Economic • Avoided loss of sale of tea tree oil to European consumer goods market. • Avoided loss of sale of tea tree oil to other export markets.
Environmental • Nil
Social • Potentially improved health outcomes for users of TTO, through improved understanding of the appropriate use and storage of tea tree oil (for example information on the toxicity, shelf life and skin irritant factors). • Reduced impact on regional communities where the TTO industry is concentrated.

Public versus Private Benefits

The benefits from this research will be both public and private in nature, and will accrue both to the TTO industry and society as a whole. There will be public benefits in the form of reduced likelihood of irritant or allergic reactions to tea tree oil through inappropriate use and some lowering of regional impacts. In some areas of Northern NSW, tea tree oil is one of the few cropping options and therefore its continued viability contributes significantly to regional incomes and stability.

Distribution of Benefits

The private sector benefits will be distributed along the TTO supply chain, and distributed along that chain in accordance with the various supply and demand elasticities.

Benefits to Other Primary Industries

There will be limited spin-off benefits to other primary industries. However, the cluster of projects has provided improved knowledge that can be utilised by other industries with respect to how to prepare a submission to the SCCP and other regulatory agencies.

Match with National Priorities

The Australian Government's National and Rural R&D Priorities are reproduced in Table 7.

Table 7: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The project investment will contribute to National Research Priority 2 and 3 and Rural Research Priority 2.

Quantification of Benefits

Benefits Valued

The benefit valued is the avoidance of the lost market for use of tea tree oil in consumer products in Europe. Benefits not valued include the potential benefits regarding potential impacts on non-European markets, the social benefit of improved use of TTO in formulations, the lowered regional impact, and any reduced future investment in TTO production.

Approximately 50% of Australia's tea tree oil production is exported to Europe. In 2005 and 2006, Australia's level of production was just over 500 tonnes per annum. For the purposes of this analysis, it is assumed that the average production in the future is expected to also average 500 tonnes per annum, and therefore the annual volume of tea tree oil exported to Europe is 250 tonnes. Of this, 80% is used for the types of consumer products targeted by the SCCP ruling. It is assumed that the farm-gate value of TTO will average $35/kg (average price from January 2006 to March 2010), and therefore the farm-gate value of oil exported to Europe for consumer products is $7 million per annum. The farm-gate price is used as formulation and manufacturing is largely undertaken in Europe.

Since the submission to the SCCP, and the subsequent adoption of a decision, it is assumed the probability of TTO being severely restricted (or even banned) for use in consumer products in Europe is 0% per annum. This cluster of projects and the preparation of this dossier were the key factor in reducing this probability, and the vast majority of the information included in the dossier came from the work funded as part of this cluster. Therefore, it is assumed that 100% of the estimated benefit can be attributed to this cluster of research projects.

The Counterfactual Situation (Without the Investment)

Without the research, and the subsequent submission to the SCCP in 2007, it is assumed that the use of TTO in these products in Europe would have been severely restricted (or banned), and that this restriction would have applied from the year ending June 2007. It is recognised that this is earlier than when the dossier was submitted and the SCCP decision was made, however if the SCCP had not known the Australian industry was working towards the preparation of the dossier, the decision to restrict TTO would have come earlier.

In the event that the investment in this cluster had not been made, the value of any profits from the sale of TTO to this market would have been lost. The profits are assumed to equal 25% of the farm-gate value.

Determining what may have happened to the industry if sales to Europe for use in consumer products was severely curtailed is difficult due to the uncertain nature of how the market and the industry would react to the significant decrease in demand for oil. Such a change in demand would have impacts on the price for tea tree oil, and the quantity of oil that the industry would be prepared to supply at any reduced price. It is recognised that in many cases where a market is lost, some proportion of this lost market may be captured by increased sales to other markets, or for use in other products. However, in this case it is argued that if the EU authorities had declared that the use of TTO should be severely restricted because it was unsafe for human use, then it is quite likely other international markets (e.g. USA) could have followed and therefore the chances of their being an alternative market for this oil at an equivalent price would be low. As the most likely outcome without the SCCP would have been severe restriction rather than outright banning, there may still have been some small level of sales into Europe. In addition, some other low value markets may have been found for some of the oil. Therefore, it is assumed that 20% of the oil that was being sold into Europe for consumer products would find an alternative market, at the average price of $35/kg oil. The value from the potential loss of sales to non-European markets is not quantified, due to uncertainty over the impact of any European restriction on other markets.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 8.

Table 8: Summary of Assumptions

Variable	Assumption	Source
Average annual volume of TTO exported to Europe	250 tonnes per annum (50% of Australian production)	Tea Tree Oil R&D Plan 2006-2011
Proportion of European market used in consumer products	80%	Consultant estimate in conjunction with ATTIA
Average annual farmgate value of TTO exports to Europe	$7 million (using a farmgate price of $35/kg)	Average monthly price from January 2006 to March 2010 (ATTIA)
Proportion of farmgate price that is operating profit	25%	Consultant estimate after discussions with ATTIA
Probability of loss of European market without research	100%	Consultant estimate in conjunction with ATTIA

Probability of loss of European market with research	0%	Consultant estimate
Proportion of lost market that would have been captured through sales to another market at the same price	20%	Consultant estimate in conjunction with ATTIA
Attribution to this project	100%	Consultant estimate in conjunction with ATTIA
First year of benefits	2006/07	Year SCCP decision was made

Results

Overall return on investment

All past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the first year of investment (2005/06) using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for 40 years including the first year of investment. Investment criteria were estimated for both total investment and for the Program investment alone (includes investment from RIRDC and the industry). The investment criteria are reported in Table 9.

Table 9: Investment Criteria for Total Investment and Program Investment

(discount rate 5%)

Criterion	Program Investment only (includes RIRDC and industry)	Total Investment
Present value of benefits ($m)	18.68	23.82
Present value of costs ($m)	0.25	0.32
Net present value ($m)	18.43	23.50
Benefit cost ratio	74.9	74.56
Internal rate of return (%)	663	591

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 10 to 12. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 10) with benefits taken over the 40 year period. All other parameters were held at their base values.

Table 10 shows that the investment criteria are highly sensitive to the discount rate. This is partly as the benefits start to accrue during the life of the research investment, and also due to the short period and low level of investment costs.

Table 10: Sensitivity to Discount Rate

(All Investment, 40 years)

Criterion	Discount Rate		
	0%	5% (Base)	10%
Present value of benefits ($m)	54.60	23.82	13.66
Present value of costs ($m)	0.32	0.32	0.31
Net present value ($m)	54.28	23.50	13.35
Benefit cost ratio	168.1	74.56	43.4

Table 11 shows the sensitivity of the investment criteria to the assumption of the probability of a severe restriction occurring in the 'with' research scenario. The base assumption is 0% probability per annum.

Table 11: Sensitivity to Assumed Probability of Loss of European Market with Research

(All Investment, 5% discount rate; 40 years)

Criterion	Assumed probability of loss of market with research		
	0% (Base)	10%	25%
Present value of benefits ($m)	23.82	21.44	17.87
Present value of costs ($m)	0.32	0.32	0.32
Net present value ($m)	23.50	21.12	17.55
Benefit cost ratio	74.56	67.1	55.9
Internal rate of return (%)	591	529	436

Table 12 shows the sensitivity of the investment criteria to the assumption of the proportion of the lost market that could be sold to an alternative market for the same price. The base assumption is 20%.

Table 12: Sensitivity to Assumed Proportion of Lost Market Sold to Other Markets at the Same Price

(All Investment, 5% discount rate; 40 years)

Criterion	Assumed Proportion of Lost Market Captured		
	0%	20% (base)	50%
Present value of benefits ($m)	29.78	23.82	14.89
Present value of costs ($m)	0.32	0.32	0.32
Net present value ($m)	29.46	23.50	14.57
Benefit cost ratio	93.2	74.56	46.6
Internal rate of return (%)	747	591	359

Confidence rating

The results produced are highly dependent on the assumptions made in each analysis, many 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 13). 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 significant uncertainties in assumptions made

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

Table 13: Confidence in Analysis

Coverage of Benefits	Confidence in Assumptions
Medium	High

Conclusions

The cluster of projects analysed in this evaluation were successful in developing data and information to be included in a dossier submitted to the SCCP in order to demonstrate the safety of tea tree oil for use in consumer products. Addressing this significant risk to the industry has resulted in the retention of a significant market for tea tree oil, and reduced the likelihood of losing other markets as well.

The results of the analysis demonstrate, that given the assumptions made, the benefits from this research have been significant, with a benefit-cost ratio of 74.6 to 1, and a net present value of $23.5 million when benefits are considered over 40 years, at a discount rate of 5%. The very high benefit-cost ratio is partly a function of the low cost at which the research was carried out, and the very high proportion of the total tea tree oil market that was protected by undertaking the research.

Acknowledgments

Patricia Bolster, ATTIA

Annex 1: Results for CRRDC Process

As for the results presented earlier, all past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the year of analysis (2009/10) using a discount rate of 5%. These results are shown in Table A.1 and A.2 and reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone (includes both RIRDC and industry contributions).

Table A.1: Investment Criteria for Total Investment and Total Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($m)	3.16	9.85	15.08	19.19	22.40	26.89
Present value of costs ($m)	0.39	0.39	0.39	0.39	0.39	0.39
Net present value ($m)	2.78	9.46	14.69	18.80	22.01	26.50
Benefit cost ratio	8.2	25.4	38.8	49.4	57.7	69.2
Internal rate of return (%)	578	591	591	591	591	591

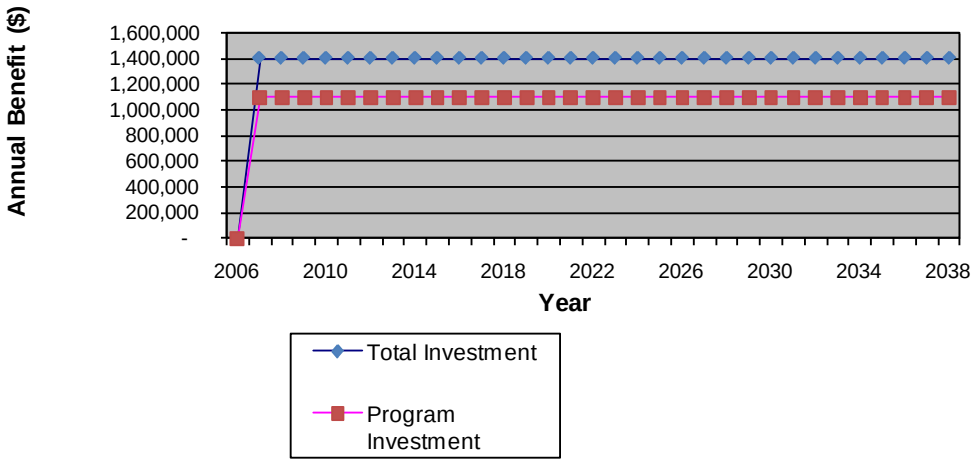
Table A.2: Investment Criteria for Program Investment and Program Benefits

(includes both RIRDC and industry contributions; discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($m)	2.48	7.22	11.82	15.04	17.56	21.08
Present value of costs ($m)	0.30	0.30	0.30	0.30	0.30	0.30
Net present value ($m)	2.18	7.42	11.52	14.74	17.26	20.78
Benefit cost ratio	8.2	25.5	39.0	49.6	57.9	69.6
Internal rate of return (%)	651	664	664	664	664	664

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the Program investment.

Figure 1: Annual Benefits



Appendix 2: Impact Assessment of Investment in Breeding and Cloning Tea Tree for Greater Profitability (DAN-199A)

Background

Australian Tea Tree Oil (TTO), sourced principally by steam distillation of the foliage of *Melaleuca alternifolia,* is a powerful antimicrobial (both antibacterial and antifungal properties) that is relatively safe for topical applications. TTO is used in cosmetics, personal health care, animal care products and other household products.

Production of TTO in Australia of about 500 tonnes of tea tree oil annually involves 300 growers and distillers (20% of producers account for 80% of oil production), and a plantation resource in excess of 4,000 hectares. With more than 60% of production for export, tea tree oil is a significant part of Australia's essential oil industry and remains a valuable rural industry particularly in the principal production centres of northern New South Wales and Northern Queensland.

The establishment of Australian tea tree plantations increased rapidly during the 1990s as demand and price for tea tree oil increased. Seed used to establish the early plantations were simply sourced from natural stands with only rudimentary selection of seed trees. The average plantation production of 148 kg oil/ha had long been considered below potential. The Australian Tea Tree Industry Association (ATTIA) together with the Rural Industries Research & Development Corporation (RIRDC) recognised that a breeding project was a way to provide progressive economic gain in oil yield and oil quality. These funding bodies have supported the breeding project since May 1993.

TheTea Tree Oil Breeding Program provides research and development for the industry to develop further growth in demand for the product. The project being analysed in this investment analysis (DAN-199A) is the third phase of the breeding program (July 2001 to June 2006), and is related to previous breeding projects that ran from 1993 to 1996 and 1996 to 2001 respectively.

The Project

The Tea Tree Oil Breeding Program was funded with the aim to improve the profitability of the industry through production and distribution of highly improved seed from a recurrent breeding program. This was aimed at meeting the long term strategy of the tea tree oil R&D program of enhancing production systems to maintain the competitiveness of Australian growers.

Project Objectives

The objectives of the third phase of the breeding program (2001- 2006) were:

- To release improved seed with the capacity to increase yields by 60%
- To quantify gains for the three released seedlots
- To ensure that oil quality maximises market access
- To develop the second generation seedling seed orchard
- To select, field test and make available high yielding clones

Project Costs

Table 1 presents the investment in the program by the Program and others.

Table 1: Estimate of Investment in Breeding and Cloning Tea Tree for Greater Profitability (nominal $)

Year ending June	Program (RIRDC and industry)	Others (research providers and additional industry contributions)(a)	Total
2002	124,077	89,698	213,775
2003	123,024	93,840	216,864
2004	130,334	94,191	224,525
2005	129,195	93,487	222,682
2006	134,953	93,335	228,288
Total	641,583	455,551	1,106,134

(a) includes cash and in-kind contributions from NSW Agriculture, CSIRO Forestry and Forest Products, and tea tree oil industry

Project Description

The third phase of the breeding program (2001 to 2006) was implemented as a continuation from the previous two phases 1993 to 1996 and 1996 to 2003. A breeding committee was created as part of the initial implementation of the breeding strategy, and was continued as part of this project. The committee contained representatives from RIRDC, the Australian Tea Tree Industry Association (ATTIA) and NSW DPI. The committee met annually and reviewed progress of the breeding strategy, ratified plans for each stage of the project and developed strategies for commercialisation of project outputs of seed and cuttings.

Determinants of the breeding strategy adopted were carried on from the previous projects. The traits and other considerations that were important in this second generation of breeding were:

- Oil traits (oil concentration and oil composition): these traits are highly heritable, relatively stable across sites and able to be determined reliably at a young age (approximately 18 months).
- Growth traits: these traits are only moderately inherited but sufficiently so to allow improvements in biomass production to be made in each generation of breeding.
- Genetic correlations between oil and growth traits are neutral.
- Flowering and seeding: the time to the first major flowering of orchard trees varies markedly between sites; also substantial year to year variation in abundance and timing of peak flowering to seed maturity is 16 to 18 months.
- Seed (rather than clones) was to be the main means of deployment of improved varieties from the breeding program.
- Controlled crossing is a technique that was successful using conventional techniques first developed for eucalypts. However, the method is time consuming and costly, and mainly of

use in developing an elite nucleus population for selection of clonal candidates and as a research plot.

- Vegetative propagation and the use of clonal plantations is relatively easy for *M.alternifolia* as it is relatively easy to propagate vegetatively by stem cutting and clones can be selected that root readily in the nursery, grow vigorously and give superior oil traits for deployment in clonal plantations.
- Genetic resources for the second generation of breeding were considered adequate with a total of 99 seedlots and a wide range of other natural and manipulated sources.

The following features were used by the researchers to identify ideal plants for use in commercial plantations:

- A large leaf biomass as a seedling and when coppiced
- High leaf oil concentration
- An oil quality compliant with industry needs (1,8-cineole < 4% and terpinene-4-ol >36%)
- Broad adaptability to different growing conditions
- Resistance to pests and diseases

A multi-trait selection index for tea tree was used to improve efficiency of individual tree selection in breeding project trials. A number of plantation owners played an important role in providing sites for orchards, land for progeny and genetic gain trials and maintenance of project plantings.

Outputs

The major output from this investment was the development and release of improved varieties of tea tree that have significantly higher oil yields than the previously best available provenance. It also continued the maintenance and production of varieties of improved seed that had been developed as part of the earlier phases of the breeding program. Table 2 presents the volumes of release of seed for each of five varieties over time. The table demonstrates that prior to the commencement of the third phase of the program (2001) there had been sales of three varieties (ATTIA 1, ATTIA 2A and ATTIA 2 B). However, the major releases of ATTIA 2B occurred during the third phase of the program (2001 to 2006).

Despite the release of ATTIA 2B prior to this project, without the third phase being funded the further maintenance and development of the orchards from which that seed was produced would not have continued, and no further sales would have occurred. This is because the orchards were on private land, and relied on the funding from this breeding program for their operation and maintenance. Two more varieties (ATTIA 3A and 3B) were released after the completion of the third phase of the program. Work during the third phase of the program did contribute to the yield improvements in those varieties. The improvements in yield are expressed as yield gains compared to unimproved seed. That is, in a given year if the unimproved seed was expected to produce a given yield, then the improved seed would yield a certain percentage more per hectare. It is therefore a relative improvement, not a fixed yield that can be defined. For the purposes of this study, it is assumed that the average yield of unimproved seed is 148 kg/ha. The yield improvements for the varieties in Table 2 are 39% for ATTIA 1, 33% for ATTIA 2A, and 69% for ATTIA 2B. The expected yield improvements for ATTIA 3A and 3B are not yet able to be reported, as yield trials are still ongoing. However for the purposes of this analysis, it is assumed that the yield improvements for ATTIA 3A and 3B are the same as for ATTIA 2B (69% improvement).

Table 2: Volumes of ATTIA seed sold (grams)

Year	ATTIA 1 (yield 39%[a])	ATTIA 2A (yield 33%[a])	ATTIA 2B (yield 69%[a])	ATTIA 3A (yield 69%[ab])	ATTIA 3B (yield 69%[ab])	Total
1997	1,500	0	0	0	0	1,500
1998	2,700	0	0	0	0	2,700
1999	2,485	0	0	0	0	2,485
2000	0	12.5	12.5	0	0	25
2001	0	10	20	0	0	30
2002	50	35.3	0	0	0	85.3
2003	0	0	40.5	0	0	40.5
2004	0	0	325.5	0	0	325.5
2005	0	0	81	0	0	81
2006	0	0	364	0	0	364
2007	0	0	210.5	68	0	278.5
2008	0	0	49	1,339	0	1,388
2009	0	0	0	106.8	695.1	801.9
2010	0	0	0	150.7	377	527.7
Total	6,735	57.8	1,103	1,664.5	1072.1	10,632.9

(a) percentage increase in yield over unimproved seed (assumed to be 148 kg oil/ha)
(b) actual data not yet available from yield trials, however is assumed yield gain will be at least same as for ATTIA 2B

Other outputs from the investment include:

- A final report that reports the findings of the project and is publicly available on the RIRDC website.
- An in-depth understanding of the floral biology of *M. alternifolia,* potentially leading to better placement and design criteria for seed orchards. More efficient control of pollination practices was also developed.
- Information gathered gave a potential to employ artificially produced inter-specific hybrids between *M. alternifolia* and *M. dissitiflora* and also *M. linariifolia* to extend the planting range of tea tree to drier and colder sites.
- A grounded base of information for further breeding projects. This includes the continuation of the breeding program to phase four (2006 to 2009).

Outcomes

Releasing highly improved germplasm has assisted with the long term economic viability of the Australian tea tree industry. During the early stage of this third phase of the program, oil prices were very low (<$20/kg oil) and therefore being able to reduce production costs per kg of oil produced was of great importance for those intending to remain in the industry.

Sales of seed released by the program have increased as the oil price has increased over recent years and there has been a demand for seed for new plantings, and for replacement of old plantings. The breeding program has continued beyond 2006, and the varieties 3A and 3B were released during the period of this later phase of the program.

Benefits

The most significant benefit from this research is an increase in producer's profits per kg of tea tree oil. This is a result of the significant increases in yield available as a result of the improved varieties developed and released by the program. While additional establishment costs are required from changing the variety, the annual operating costs do not change with the increase in oil yield (with the exception of biomass harvesting costs which are a function of biomass yield, in turn related to oil

yield). It is likely to have also led to plantings of tea tree across a greater area than would have occurred if the higher yielding varieties were not available.

There are also some additional potential benefits due to the improved knowledge regarding tea tree oil characteristics generated as a result of the breeding program including small improvements in quality (oil composition) and increased understanding of the oil and how it can be used in formulations.

Due to the low prices being experienced by industry at the time of funding, it is possible that without this program and the prospects of higher future yields from the higher yielding seed, many growers would have left the industry, with subsequent economic and social impacts for the communities where tea tree is grown. In addition, there may have been difficulties with re-establishing the industry when prices improved.

Summary of Benefits

A summary of the principal types of benefits associated with the outcomes of the project is shown in Table 3. It shows that the majority of the benefits are economic in nature.

Table 3: Categories of Benefits from the Investment

Economic • Increased profits per kg of oil produced (due to yield increases). • Increase in area of land planted to tea tree.
Environmental • Nil
Social • Reduced impact on regional communities where TTO industry is concentrated. • Public health benefits through the continued availability and affordability of tea tree oil for therapeutic and cosmetic uses

Public versus Private Benefits

The benefits from this research will be both public and private in nature, and will accrue both to the TTO industry and society as a whole. There will be public benefits in the form of a reduced impact on regional communities where the TTO industry is concentrated. For example, in some areas of Northern NSW, tea tree oil is one of the few cropping options and therefore its continued viability contributes significantly to regional incomes and stability. Also, the continued viability of the tea tree oil industry ensures the continued availability and affordability of tea tree oil for therapeutic and cosmetic uses.

Distribution of Benefits Along the Supply Chain

The benefits from this research (higher profitability of growers) will be distributed along the supply chain, from producers through to product formulators and the consumer (who are mostly overseas).

Benefits to Other Primary Industries

There may be some benefits to other essential oil industries with respect to improved knowledge for breeding for increasing oil yield.

Match with National Priorities

The Australian Government's National and Rural R&D Priorities are reproduced in Table 4.

Table 4: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The project investment will potentially indirectly contribute to National Research Priority 3. The focus of the project with regards to the Rural Research Priorities is on Rural Research Priority 1 as well as the supporting priorities.

Quantification of Benefits

The benefits from this research are quantified by estimating the difference in the profits of tea tree producers as a result of the yield increases experienced due to the availability of the improved seed, and comparing it to the situation if the seed had not been available.

The Counterfactual Situation (Without the Investment)

Without the research investment, it is assumed that the breeding program would have ceased entirely after Phase 2 and the seed orchards would have been removed as they were located on private land (Richard Davis, pers. comm., 2010). There was no stock of seed at this time, and therefore all sales of seed would have stopped, and seed supply for any new plantings would have reverted to bush collection or collection off existing plantations. It is assumed however that yields would not entirely revert to unimproved seed levels, as a lot had been learnt about seed collection through the earlier Phases of the program. Instead, it is assumed that yields from any new plantings would have been maintained at the level of yield equivalent to that being achieved by the ATTIA 1 variety. In addition, there would have been little to no new investment, and possibly some producers would have exited the industry. Of the total area planted to the new seed varieties in Table 2, it is assumed that only 75% of that area would have been planted to tea tree oil using the already existing varieties (that is, it is expansion that would not have occurred to the same extent without the availability of the new varieties). It is assumed that the seed (yielding equivalent to ATTIA 1) would have been valued at $50/gram (cost to growers of collecting seed).

With the Investment

With the investment, releases of ATTIA 2B seed became possible and further developments were made in the development of two further varieties (ATTIA 3A and 3B).

The benefits from actual sales of seed for these three varieties are quantified (see Table 2 earlier for volumes of seed sold) in terms of the future cost reduction (reduced costs per kg of oil produced). It is assumed that there is no yield of tea tree oil in the year of planting, and that in year 2 the yield is only 50% of the expected maximum yield, and in year 3 it is only 75% of the expected maximum yield. It is assumed that the tea tree plant only has an effective life of 20 years, and that after this time the yield starts to decline to the point that trees may have to be replaced. Therefore, benefits are only assumed to continue for 20 years after planting.

It is assumed that 25% of the area that has been planted to ATTIA 2B, 3A and 3B seed would not have been planted to tea tree at all if the improved yielding seed were not available. It is assumed that any increase in supply due to the availability of the higher yielding varieties is able to be absorbed by the market without any significant impacts on price. The assumed price for tea tree oil over the period of the analysis is $35 per kg of oil, which is based on the monthly average price from January 2006 to March 2010.

A complication when attempting to value the benefits of a breeding program is to appropriately attribute the benefits to the different periods of investment that have occurred in the life of the entire program. As noted above, no new releases would have occurred without this third phase of the program. However, the contribution of the earlier phases of the program to the increased oil yield within the ATTIA 2B variety must be recognised. It is therefore assumed that only 50% of the benefit from the release of this variety is attributable to this third phase of the program. Further, it is assumed that only 50% of the benefits from the release of ATTIA 3A and 3B varieties are attributable to the investment in this phase of the program. Also, the genetic capital at the beginning of Phase 3 is assumed the same as the genetic capital at the end of the Phase.

It is further assumed that some continued sale of a variety yielding the equivalent of the ATTIA 3B variety continues in the future at a rate of 200 grams per annum, and at a cost of $150/gram. This volume of seed equates to approximately 25 hectares of tea tree, which is a reasonable area for assuming that the seed is being used to replace older plantings, and not for expansion in the industry. The availability of the improved seed will only continue at this rate if the breeding program continues into the future (either through continued support from the TTO R&D Program, or through some other support). It is assumed there is a 50% probability of this occurring. As for the sales to date, it is assumed that without the availability of this higher yielding seed that 75% of the area would have been planted using a variety yielding similar to ATTIA 1, and that 25% would not have been planted at all. It is further assumed that 25% of the benefits from these future plantings can be attributed to this current research.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 5.

Table 5: Summary of Assumptions

Variable	Assumptions	Source
General assumptions		
Grams of seed per hectare	8g/hectare	John Doran pers comm., 1997
Establishment costs per hectare (excluding seed cost)	$2,000	John Doran pers comm. 1997 and Robert Dyason pers comm. 2010

Operating costs per hectare in non-mature yield year	$2,000 per hectare	John Doran pers comm. 1997 and Robert Dyason pers comm. 2010
Operating costs per hectare in mature yield year	$2,500 per hectare	John Doran pers comm. 1997 and Robert Dyason pers comm. 2010
Proportion of mature yield in year 1	0.5	John Doran pers comm., 1997
Proportion of mature yield in year 2	0.75	John Doran pers comm., 1997
Life of tea tree plants	20 years	John Doran pers comm. 1997 and Robert Dyason pers comm. 2010
Farm-gate price of oil	$35/kg	ATTIA data
With research		
Volume of seed sold up to 2010	See Table 2	Gary Baker, pers comm., 2010
Volume of seed sold post 2010	200g/annum	Consultant estimate
Yield for varieties of tea tree oil planted with research	ATTIA 2B – 250 kg/ha ATTIA 3A – 250 kg/ha ATTIA 3B – 250 kg/ha	Gary Baker, pers comm., 2010
Yield for tea tree planted post 2010 with research	250 kg/ha	Consultant estimate
Price of seed sold (weighted averages)	ATTIA 2B – $79/g seed ATTIA 3A – $91/g seed ATTIA 3B – $145/g seed	Gary Baker, pers comm., 2010
Price of seed sold post 2010	$150/g seed	Consultant estimate
Attribution of benefits from ATTIA 2B to this investment	50%	Consultant estimate
Attribution of benefits from ATTIA 3A and 3B to this investment	50%	Consultant estimate
Attribution of benefits from post 2010 plantings to this investment	25%	Consultant estimate
Without research		
Proportion of volume of ATTIA 2B, 3A or 3B seed that would instead have been planted with varieties yielding equivalent to ATTIA 1	75%	Consultant estimate
Proportion of volume of ATTIA 2B, 3A or 3B seed that would not have been planted to tea tree at all without this research	25%	Consultant estimate
Yield for variety of tea tree oil planted without research	206 kg/ha (equivalent to ATTIA 1)	Consultant estimate
Price of seed sold in without scenario	$50 per gram of seed	Consultant estimate

Results

Overall return on investment

All past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the first year of investment (2009/10) using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for 40 years including the first year of investment. Investment criteria were estimated for both total investment and for the Program investment alone (includes investment from RIRDC and the industry). The investment criteria are reported in Table 6.

Table 6: Investment Criteria for Total Investment and Program Investment

(Discount rate 5%)

Criterion	Program Investment only (includes RIRDC and industry)	Total Investment
Present value of benefits (m$)	3.51	6.05
Present value of costs (m$)	0.69	1.19
Net present value (m$)	2.82	4.86
Benefit cost ratio	5.1	5.1
Internal rate of return (%)	19.6	19.6

Distribution of benefits

Forth-six per cent of the present value of benefits is due to the benefits from the area of land that has been planted with a higher yielding variety compared to planting with the lower yielding variety. The remainder of the benefits (54%) flow from the expansion in the area planted that has occurred due to increased confidence as a result of availability of the higher yielding varieties. Eight-seven per cent of the present value of benefits is due to the benefits from the plantings that have occurred from the actual sales of seed up to 2010. Only 13% of the total benefits are due to the future assumed plantings. This is due to the small areas assumed, the lower level of attribution to this research, and the risk that this benefit may not be achieved.

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 7 to 10. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 7) with benefits taken over the 40 year period. All other parameters were held at their base values.

Table 7 shows there is considerable sensitivity of the investment criteria to the discount rate.

Table 7: Sensitivity to Discount Rate

(All Investment, 40 years)

Criterion	Discount Rate		
	0%	5% (Base)	10%
Present value of benefits (m$)	14.29	6.05	2.93
Present value of costs (m$)	1.31	1.19	1.09
Net present value (m$)	12.98	4.86	1.83
Benefit cost ratio	10.9	5.1	2.7

Table 8 shows the sensitivity of the investment criteria to the assumption of the assumed base yield of unimproved seed from which the yield improvements are measured. The base scenario assumes this is 148 kg oil per hectare.

Table 8: Sensitivity to Base Yield Assumption

(All Investment, 5% discount rate; 40 years)

Criterion	Base Yield		
	100 kg/ha	148 kg/ha	175 kg/ha
Present value of benefits (m$)	3.49	6.05	7.89
Present value of costs (m$)	1.19	1.19	1.19
Net present value (m$)	2.29	4.86	6.30
Benefit cost ratio	2.9	5.1	6.3
Internal rate of return (%)	13.6	19.6	22.3

Table 9 shows the sensitivity of the investment criteria to the assumption of the yield achieved in the without scenario. The base scenario assumes that this is 206 kg/ha (equivalent to ATTIA 1 yield). The analysis shows that if the yields actually revert to the unimproved seed yield levels of 148 kg/ha, then the B/C Ratio increases to 8 to 1.

Table 9: Sensitivity to Yield Without Research

(All Investment, 5% discount rate; 40 years)

Criterion	Yield Without Research	
	206 kg/ha	148kg/ha
Present value of benefits (m$)	6.05	9.62
Present value of costs (m$)	1.19	1.19
Net present value (m$)	4.86	8.42
Benefit cost ratio	5.1	8.1
Internal rate of return (%)	19.6	25.7

Table 10 shows the sensitivity of the investment criteria to the proportion of the area planted to the improved varieties of seed, that it is assumed is entirely new plantings (that is, the area of expansion due to this project). The base scenario assumes this is 25%.

Table 10: Sensitivity to Proportion of Planted Area that is New Plantings

(All Investment, 5% discount rate; 40 years)

Criterion	Proportion of Planted Area that is New Plantings		
	0%	25%	50%
Present value of benefits (m$)	3.56	6.05	8.54
Present value of costs (m$)	1.19	1.19	1.19
Net present value (m$)	2.37	4.86	7.34
Benefit cost ratio	3.0	5.1	7.2
Internal rate of return (%)	14.4	19.6	23.1

Confidence rating

The results produced are highly dependent on the assumptions made in each analysis, many 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 (Table11). 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 significant uncertainties in assumptions made

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

A confidence rating has been developed for the investment analysis using a standard format

Table 11: Confidence in Analysis of Tea Tree Breeding Program Project

Coverage of Benefits	Confidence in Assumptions
High	High

Conclusions

The tea tree oil breeding program has been ongoing since 1993, and over that time has resulted in significant improvements to the oil yields of tea tree plants. This analysis considers the third phase of the breeding program (2001 to 2006). This phase of the program resulted in the breeding of several new varieties, as well as allowing seed from previously developed varieties to continue to be produced and sold. The availability of seed from the breeding program has allowed the industry to expand, and increased the profits for tea tree growers through increasing oil yield without significantly increasing production costs.

Based on a series of assumptions regarding the potential benefits, this phase of the breeding program had a total investment (present value) of $1.2 million resulting in a total benefit (present value) of $6.1 million, and therefore an estimated net present value of $4.9 million and a benefit cost ratio of 5 to 1.

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Gary Baker, NSW Department of Industry and Investment (Primary Industries)

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Richard Davis, G.R. Davis Pty Ltd

Robert Dyason, tea tree oil producer

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RIRDC (2010) 'Tea Tree Oil', RIRDC,
< http://www.rirdc.gov.au/RIRDC/programs/new-rural-industries/tea-tree-oil/tea-tree-oil_home.cfm >

Annex 1: Results for CRRDC Process

As for the results presented earlier, all past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the year of analysis (2009/10) using a discount rate of 5%. These results are shown in Table A.1 and A.2 and reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone (includes both RIRDC and industry contributions).

Table A.1: Investment Criteria for Total Investment and Total Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($m)	0.02	1.22	3.92	6.20	7.95	8.79
Present value of costs ($m)	1.76	1.76	1.76	1.76	1.76	1.76
Net present value ($m)	-1.74	-0.55	2.16	4.43	6.19	7.03
Benefit cost ratio	0.01	0.7	2.2	3.5	4.5	5.0
Internal rate of return (%)	negative	negative	15.1	18.4	19.4	19.6

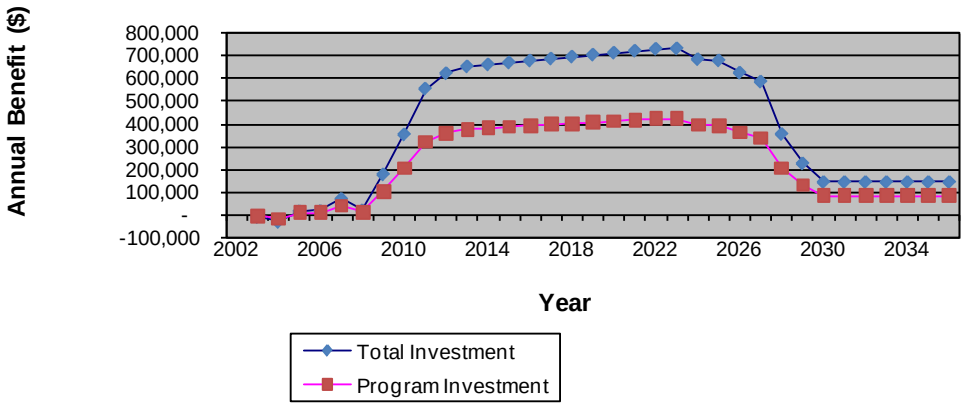
Table A.2: Investment Criteria for Program Investment and Program Benefits

(includes both RIRDC and industry contributions; discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($)	0.01	0.70	2.27	3.59	4.61	5.09
Present value of costs ($)	1.02	1.02	1.02	1.02	1.02	1.02
Net present value ($)	-1.01	-0.32	1.25	2.57	3.59	4.07
Benefit cost ratio	0.01	0.7	2.2	3.5	4.5	5.0
Internal rate of return (%)	negative	negative	15.1	18.4	19.4	19.6

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the Program investment.

Figure 1: Annual Benefits



Appendix 3: Effects of Tea Tree Oil on Biofilm Formation (PRJ-451)

Background

Tea tree or melaleuca oil is a clear essential oil taken from the leaves of *melaleuca alternifolia,* which is native to the north eastern coast of New South Wales. Tea tree oil has a well-characterised spectrum of antimicrobial activity against a variety of bacteria, fungi and viruses. It is well recognised that the majority of bacteria and fungi grow in matrix-enclosed communities called 'biofilms', commonly referred to as 'slime'. Biofilms occur wherever there is sufficient water, nutrients and microorganisms fixed to an available surface, including food manufacturing equipment, sewage treatment plants, air conditioning units and medical equipment such as endoscopes. Biofilm formation is becoming recognised as a key step in many infections and thus prevention of the formation process as well as the destruction of already formed biofilms are a means to controlling disease. Biofilms have been implicated in many types of infections including in wounds, as well as in devices such as catheters and pacemakers. These biofilms can pose significant risks to health. In industrial and commercial settings, biofilms formation can ruin production lines, and contribute to the spoilage or contamination of food, significantly contributing to production time and costs.

Moreover, biofilms have the ability to change according to the susceptibility of their microorganisms to antibiotics and biocides. Since they are highly resistant, biofilms are often difficult to prevent as well as to eradicate.

Despite the need for safe and effective means for preventing or removing biofilms there have not been any previous studies into the effects of tea tree oil on biofilms. Plant essential oils and their products often have potentially useful anti-biofilm agents. As they are naturally derived, many are considered safe to ingest, within specified limits, making them attractive as control agents for biofilms present in food manufacturing equipment or in pharmaceuticals.

The project targeted manufacturers and marketers of tea tree oil products, attempting to understand the mechanism by which tea tree oil could potentially control microorganisms and biofilm formation.

The Project

Project Objectives

The study aimed to:

1. examine the effect of tea tree oil on the formation of biofilm;
2. investigate the effects of tea tree oil on existing biofilm;
3. investigate the mechanism by which biofilm formation is influenced by tea tree oil and;
4. explore potential medical and industrial applications of biofilm inhibition by tea tree oil.

Project Costs

Estimates of the investment by RIRDC and the Australian Tea Tree Industry Association (ATTIA) that make up the funding of the Tea tree oil R&D Program (the Program) are provided in Table 1.

These Program funds were combined with some funding provided by researchers and others to provide the total funding for the project.

Table 1: Summary of Project Costs (nominal $)

Year ending June	Program (includes RIRDC and industry)	Other investors	Total
2006	42,137	5,600	47,737
2007	32,842	5,821	38,663
2008	43,494	0	43,494
Total	118,473	11,421	129,894

Project Description

In order to determine the effect of tea tree oil on biofilm formation, ten isolates of *Pseudomonas aeruginosa*, *Staphylococcus epidermidis* and *Candida alibicans* as well as nine isolates of *Vibrio hjarveyi* were used in a series of experiments. The tea tree oil (batch #1216) was provided by Gelair Pty Ltd. Its composition was ascertained in the report.

To determine the ability of tea tree oil to destroy or inactivate pre-formed biofilm, the clinical isolate *S. epidermidis* 4513735E and the reference isolates *P. Aeruginosa* NCTC 10662 and *S. Maltophilia* ATCC 13637 were used in a second set of experiments.

The 96 trays of test microorganisms were inoculated in appropriate growth mediums. For example, *C. albicans* was grown in a yeast extract at 35ºC. Cells were collected, washed in a saline solution and the 96 trays were incubated in conditions conducive to biofilm formation. In some experiments, tea tree oil was added at the same time as the microorganisms in order to assess the effect on biofilm formation. In other experiments, biofilms were allowed to form and then treated with tea tree oil. For all experiments, the amount and variability of the biofims were measured. A two tailed, paired t-test was used to compare values at each tea tree oil concentration to the inoculated well without tea tree oil (control). Significance was set at $p<0.05$.

The effect of tea tree oil on the formation of biofilm were analysed by incubating organisms for up to 24 hours with a concentration of tea tree oil ranging from 1 to 0.016%. The results were quantified using two methods. Firstly, the study used crystal violet staining. This stains all biological material and does not distinguish between living and dead cells. The second method was the reduction of tetrazolium salt (or XTT) which is initially colourless but forms an orange soluble dye that can be quantified spectrophotometrically.

The ability of tea tree oil to eradicate pre-formed biofilm was investigated using one isolate each of *S. Epidermidis, S. Maltophilia,* and *P. Aeruginosa.* Biofilms were treated with tea tree oil for 24 hours, which was then discarded and replaced with a neutralising agent. Once the neutraliser was discarded, the tray was re-incubated for 6 hours to allow regrowth of viable organisms. The average and standard deviation was found comparing the trays to a sterile control tray.

The third objective of this study was to investigate potential mechanisms by which tea tree oil may inhibit biofilm formation. This was investigated by determining whether reductions in biofilm formation occurred as a by-product of reduced growth or as a separate, specific effect.

The final objective of the study was to explore potential medical and industrial applications for biofilm inhibition. Since tea tree oil was found to have effects on forming and already formed biofilm, applications were considered for both purposes.

Outputs

The main output of this research was a report highlighting the study's results, with the scientific findings within that report forming a significant output in themselves. The report made recommendations concerning what areas of the study should be investigated further.

The data showed a trend of decreased biofilm formation in the presence of tea tree oil, by XTT reduction. Biofilm was inhibited for 6 out of the 10 isolates at the lowest test concentration of 0.016%. However, in some of the test results the lowest concentration of tea tree oil did not provide results dramatically different from the control tray. According to the final report for the project (Hammer *et al*., 2008) this could suggest that the impact on the inhibition of biofilm may be a function of reduced growth rather than a specific inhibition of biofilm. For some tests with *S. Epidermidis* the tea tree oil actually appeared to increase biofilm formation. Such increases were quite significant for two of the ten isolates and Hammer *et al*. (2008) state that similar observations have been previously reported in the literature. Reasons for this result were that bacteria are able to respond to environmental conditions such as a lack of nutrients, and thus extra growth may be a stress response. It was noted however that the overall metabolic activity of the biofilms was decreased. The final report for the project notes that it is possible that the components of tea tree oil increased biofilm growth by altering characteristics such as density, depth or strength. The study did not measure these factors.

With the already formed *S. Maltophilia* and *S. Epidermidis* biofilms, the study showed reduced viability following treatment with tea tree oil. In the various biofilms, some experienced a reduced amount of cells, whereas some had no viable organisms at all. One observation made by the study was that when a biofilm was measured by crystal violet light, most reductions were generally not large in contrast to the reductions measured by the regrowth method. Hence, the data showed that tea tree oil may not alter the structure or matrix of the biofilm, but it can adversely affect the organisms' ability to grow.

Moreover, the concentrations of tea tree oil required to inhibit the formation of, cause the destruction of and inactivate the organisms of the biofilm were all similar to those that could inhibit the growth of free living planktonic microorganisms.

With respect to the third objective, the experiments with *V. Harveyi* strongly suggested that the reductions in biofilm were a function of reduced growth, thus suggesting that it was unlikely that biofilm was specifically being inhibited. This does not, however, rule out that tea tree oil has anti-biofilm effect. There are several stages associated with biofilm formation that tea tree oil may interfere with and the possibility that tea tree oil may interfere with quorum sensing is yet to be investigated.

Several opportunities for potential medical and industrial applications of biofilm inhibition were explored. With regard to human disease and infection, the role of biofilm is in bacterial infections, particularly chronic infections of the ear, throat and respiratory tract. In addition, wounds such as venous leg ulcers may be due to the presence of biofilm. Tea tree oil has the ability to kill the organisms within such wounds.

In an industrial setting, biofilm is a very common problem, as it can form on the inside of pipes causing clogging and on food manufacturing facilities resulting in the contamination of food products, which has the potential to cause illness.

Outcomes

Given the diverse range of situations and environments in which biofilms occur and the need for it to be removed, there is a large potential for tea tree oil products to be developed in this area with appropriate product development. Likely potential applications for tea tree oil with respect to biofilm management and removal are in the areas of healthcare, food manufacturing and air conditioning systems. There are currently no products containing tea tree oil that are specifically marketed at, and tested for, preventing or controlling biofilms.

Air Conditioning Systems

Tea Tree oil is already marketed for use in air conditioning systems to control mould and bacteria which themselves form biofilm in air conditioning ducts, in carpets, on walls etc. In this market sector, tea tree oil products present as cost effective because other treatments in air conditioning ductwork is essentially cosmetic (ie physical clean without addressing the actual source of infection). Tea tree also markets itself as being safer and better smelling than the alternative treatments such as Ozone or other chemical treatments.

However, this project has demonstrated that there is also the potential for the development of a product to be used in air conditioning cooling towers as an extension of the other air conditioning applications. This would mean that the one product could be used throughout the entire air conditioning system, rather than requiring a specific separate product for use in the cooling tower, as is currently the case. Biofilms in air conditioning cooling towers are a concern, as lack of control of such biofilms can greatly increase the risk of outbreaks of bacterial problems such as legionella, which leads to legionnaire's disease.

Food Processing

Biofilms are a significant problem in food manufacturing, in that they develop on equipment used in food processing and manufacturing, such as conveyor belts and other equipment. The presence of biofilms greatly increases the risks of food contamination with bacteria such as salmonella and listeria. There are currently a number of methods available for controlling biofilm in food processing, and tea tree oil could provide an alternative to these other products. At this stage to the knowledge of the authors there is no tea tree oil product being developed for such a market, however this project has demonstrated that the potential for such product development would be there.

Medical Applications

Biofilms are also a concern in many medical circumstances, and contribute to a number of difficult to treat infections including staph. There is the potential for the use of tea tree oil in a number of applications to aid with infection management through addressing biofilm. This may include in catheters etc, and in some other medical equipment such as dialysis equipment. The potential for the development of a tea tree product for such applications is probably more limited than for the industrial applications (air conditioning and food processing). This is because medical applications are very expensive to test and establish and lead times can be more than a decade.

Benefits

Economic

The benefits of the use of tea tree oil with respect to biofilm prevention or control is still uncertain. It has the potential to either decrease control costs or decrease impacts of biofilm in a variety of

industries if applications and products are developed for those industries. In addition, the opening up of new markets for tea tree oil will provide benefits to the tea tree industry itself, through potential increases in demand for tea tree oil. Significant potential markets for a tea tree oil product in this area include air conditioning cooling towers and food processing. There are potential benefits from health applications but these are not discussed in detail. This is because the likelihood of product development in this area is uncertain due to long-lead times in research, high costs of research and development, and increased barriers to commercialising a product in the human health areas.

Cooling Towers

The purpose of cooling towers is to cool water and dissipate heat to the environment. They are normally associated with air conditioning, refrigeration systems and other large plants. The combination of elevated water temperatures, high humidity and large surface areas in cooling towers provide ideal conditions for the growth of microorganisms. The microorganisms that are present in cooling towers can be either in the form of microbial flora in the planktonic phase, or microbial flora in biofilm. The range of microorganisms found within cooling towers includes bacteria, algae, fungi, protozoa and viruses (Critchley and Bentham, 2006). One of the commonly isolated microorganisms from cooling towers are *Legionellae* which have significant implications for public health, as they have the potential to cause Legionnaire's disease. Legionnaires' disease is a severe pneumonia that can result in multi-organ failure, and that was first described in the USA in 1976. *Legionellae* also cause a less serious infection, Pontiac fever that has a significantly higher attack rate than Legionnaires' disease but is not fatal. The largest Legionnaires' disease outbreak in Australia was in April 2000 when 125 cases, 95 hospitalisations and 4 deaths occurred as a result of microbial contamination of the Melbourne Aquarium's cooling towers. In 2007 there were 307 notifications of legionellosis in Australia, which was down from 350 cases in 2006 (NNDSSA Annual Report Writing Group, 2007). This order of cases provides a national rate of about 1.5 cases per 100,000 population. In 2007, there were 5 deaths from *Legionellae* species, and in 2006 there were 9 deaths. However, not all of these cases are as a result of air conditioning cooling towers as *Legionellae* species are also a problem in spas, showers, fountains, eyewash stations, reticulated water supplies of hospitals and other large buildings, and environmental soils including potting mix. In 2007, there were two large outbreaks of Legionnaire's disease due to contaminated cooling towers. The first was a cluster of six cases in Sydney, and the second was a cluster of 9 cases in Melbourne.

There are a wide variety of methods and products available to control the growth of microorganisms in cooling towers. These products and methods vary in their effectiveness and cost. Australian governments also have regulations surrounding the control of microorgansisms in cooling towers that require regular inspections and testing. The nature of the benefit from the development of a product that uses tea tree oil to control the development of biofilms in air conditioning cooling towers is not yet clear. It has the potential to either be more effective at reducing the risk and impact of microorganisms on public health, or to provide a lower cost control method than those currently available. There may be other benefits of its use such as improved smell over competing products, and being sourced from a sustainably grown natural product that is biodegradable.

Food Processing

Biofilm development and subsequent microbial attachment is a source of contamination in food processing environments. It can lead to issues such as food spoilage as well as disease transmission related to foodborne pathogens such as *Listeria monocytogenes*. Brooks and Flint (2008) indicate that microbiological contamination costs the Australian food industry millions of dollars annually in terms of lost or downgraded product, as well as in food poisoning. Biofilms are formed on surfaces in processing plants, and microbial adhesion then occurs. The biofilm formation is what facilitates the transmission of pathogens, and they form a reservoir of contamination that persists where cleaning of manufacturing equipment is ineffective. Biofilms in these environments are becoming increasingly resistant to cleaning and disinfection processes. Biofilms form on the processing surfaces, as well as on the food itself. They lead not only to food spoilage and food poisoning, but also limit the life of

manufacturing plants themselves. Examples of biofilms related to food poisoning identified by Brooks and Flint (2008) include Salmonella and *L. monocytogene*. The increase in the consumption of minimally processed products (such as fresh fruit and vegetables that travel through processing or packaging plants) has led to an increase in the food poisoning incidents traced to the equipment used in the production of these minimally processed foods.

Brooks and Flint (2008) identified a number of control measures that are currently used for controlling biofilm development in food processing including improved cleaning, temperature cycling, biofilm disruption, electrical methods, the use of bacteriophage as a control agent, substrate properties and surface modification, molecular brush and active surfaces.

The development of a tea tree oil product suitable for controlling biofilm in food processing environments will serve as an alternative measure to assist with the above measures. As with air conditioning cooling towers, it is not known yet whether the benefits of the product would be in the form of reduced control costs, or reduced impacts (through reduced food poisoning incidents, reduced spoilage, or longer life of manufacturing equipment).

Tea Tree Oil Industry

There is the potential for increased demand for tea tree oil as a result of any new products and markets developed. However, the magnitude of these benefits will depend on the development cost, the efficacy of the new product, the cost of the new product to users, and its level of penetration into target markets.

Environmental

Biofilm present in industrial settings is commonly removed by a range of methods, some of which are toxic chemicals that pose the risk of contaminating the surrounding environment. Tea tree oil is also a very complex and toxic chemical substance. However, it is more socially acceptable, environmentally sustainable to produce and readily biodegradeable.

Social

Infectious disease is a significant social burden and biofilm is a factor in many infections. Biofilm is formed on surfaces such as teeth (dental plaque), catheters, heart valves, joints, and it is also a recognised factor in the formation of many infections, including the persistence of cystic fibrosis pneumonia. If tea tree oil proves to be a successful treatment for biofilm, it will obviously have significant impacts on the treatment or prevention of infections, and therefore result in improvements in the quality of life for those vulnerable to such disease. There will also be public health benefits as a result of the potentially reduced incidence of food-borne diseases, and health problems caused by air conditioning cooling towers.

Summary of Benefits

Table 2 presents in a triple bottom line format the potential benefits from the investment.

Table 2: Categories of Benefits from the Investment

Economic 1. Potential for reduced costs associated with controlling or preventing biofilms in a number of applications including air conditioning cooling towers, food processing and human health. 2. Potential for reduced economic impacts of biofilms in a number of applications including air conditioning cooling towers, food processing and human health. 3. Increased profit in the tea tree oil producing and Australian manufacturing industry due to increased demand.
Environmental 4. Availability of a management option which is environmentally sustainable to produce and readily biodegradable.
Social 5. Potential improved prevention or treatment of disease, built-environment infections and food poisoning incidents, leading to improvements in the quality of life.

Public versus Private Benefits

The benefits from this research will be both public and private in nature. Some of the economic benefits will accrue to private industry in terms of saved control costs. The tea tree oil industry itself will also benefit from increased demand. Any benefits that result in reduced impacts of biofilms in terms of reduced human health impacts will be public in nature as often these costs are borne by society. There may be some additional public benefits in the form of the availability of a product that is environmentally sustainable to produce and readily biodegradable.

Distribution of Benefits

The private sector benefits will be distributed along the tea tree oil supply chain, and distributed along that chain in accordance with the various supply and demand elasticities. Other benefits will fall to the industries associated with applications of tea tree oil that may eventuate (e.g. food processing, air conditioning maintenance).

Benefits to Other Primary Industries

There is the potential for some indirect spin-off benefits to other primary industries where food is processed through processing plants that may adopt tea tree oil based product for biofilm control.

Match with National Priorities

The Australian Government's National and Rural R&D Priorities are reproduced in Table 3.

Table 3: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The project investment will contribute to National Research Priority 1, 2 and 3 and Rural Research Priorities 1 and 2. There will also be a contribution to the supporting priorities.

Quantification of Benefits

Benefits Valued

There are currently many uncertainties with respect to the development of products using tea tree oil to control or prevent biofilm formation. There are a number of possibilities for development of products and applications across a number of industries. There are currently no products developed to a commercial stage, and very few products in any serious stage of development. However, this project has demonstrated that the potential is there for tea tree oil to control or prevent biofilm formation, and therefore has increased the likelihood that such products will be developed and successfully marketed in the future.

Due to the uncertainties involved, this analysis takes a probabilistic approach to estimating the potential benefits from this project. Benefits are valued from the potential use of tea tree oil in two areas – air conditioning cooling towers and food processing. Any potential increase in the volume or value of tea tree oil demanded as a result of the development of such applications is also not quantified, due to uncertainties regarding the volumes that might be demanded.

It is uncertain whether the potential benefits from tea tree oil will come from it being a more cost-effective product than the currently used alternatives, or whether it will be more effective overall, and therefore reduce the impact of biofilm compared to alternatives. As information is more readily available on the magnitude of impacts from biofilm, than on the costs of controlling biofilm (and the costs of the varying competing products), this analysis is based on the tea tree oil being more effective at controlling or preventing biofilm than competing products. It is recognised however that this may not be the case, and that in reality, any product developed may not be more effective, it may just be lower cost to produce, lower cost to apply, or have some other qualities that make it preferential to the competitor such as smell or being perceived as a relatively 'green' product. The assumptions in this

analysis therefore are only acting as proxies for the expected magnitude of potential benefits. More detailed information on the specific sizes of the potential markets for such a product, and the nature of the competing products (in terms of effectiveness, volume and value) has not been sought for this analysis, as to do so would take considerable effort and would be a market analysis exercise in itself.

The benefits not valued quantitatively include the increased demand for tea tree oil, the environmental and social benefits as defined earlier, and potential other uses of tea tree oil for inhibiting biofilm that may be developed in the future for a range of industries and applications.

Air conditioning cooling towers

A study by Lock et al (2008) sought to calculate the public health and economic costs of investigating a suspected outbreak of Legionnaires' disease in South East London in 2005. The study found that the overall estimated costs were 455, 856 pounds (approximately $800,000 Australian dollars), of which 14% was spent on investigation and control of the outbreak, and 86% was spent on the hospital treatment of the patients. However, this figure can be considered an underestimate as the investigation and control costs referred to staff time only, and did not include overhead or indirect costs, or opportunity costs for the organisations involved. In addition, the estimated hospital treatment costs did not include the indirect social, health and economic costs to the patients, their families and employers of the acute illness or its long-term effects and these would be significant. This analysis therefore assumes and multiplier of 5 be applied to the estimated basic cost, to account for some of these other indirect costs. This leads to the estimate of the cost of an outbreak of $4,000,000. As noted above, there were two air conditioning cooling tower related outbreaks in Australia in 2007, and it is therefore assumed that the number of outbreaks investigated per year (including those that are not confirmed as outbreaks) is 3. The current annual cost of legionnaire's disease to Australia defined in this way is therefore assumed to be $12 million.

It is assumed that a tea tree oil product suitable for use in air conditioning cooling towers for inhibiting biofilm development is developed and commercially available in the year 2015. It is assumed that the cost of this product is comparable to the other products and methods currently used, but that it is more effective, and therefore results in a reduction of the impact of these legionnaire's disease outbreaks of 10% annually. It is further assumed that this tea tree oil product will capture 10% of the market for maintenance of air conditioning cooling towers after 5 years.

Food processing

The OzFoodNet Working Group (2007) produces an annual report on the incidence and causes of diseases potentially transmitted by food in Australia. In 2007, there were 27, 332 notifications of 8 diseases or conditions commonly transmitted by food. It is estimated however that there are actually 5.4 million cases of foodborne disease annually in Australia, costing an estimated $1.2 billion dollars per year. Of the 27,332 actual notifications received, the majority of these were found to be spread person-to-person. Only 8.4% of these incidents were actually found to be as a direct result of contaminated food. Of the 8.4%, only 6% were found to relate to primary production processing environments such as fruit and vegetables contaminated with salmonella. The remainder were from restaurants, private residences, take-aways and institutions (such as nursing homes). Applying the two percentages above to the $1.2 billion annual cost of foodborne diseases, leads to the estimate that the cost of foodborne diseases from primary production processing is approximately $6 million. The focus is on primary production processing environments; at it is this environment that will most likely be the adopters of tea tree oil as a biofilm control agent, as compared to environments where food is prepared for serving (e.g. restaurants, residences).

It is assumed that a tea tree oil product suitable for use in food processing systems for the prevention of biofilm development is developed and commercially available in the year 2018. This is assumed later than for the air conditioning use as there is currently less ongoing interest in developing such a product, and therefore potentially longer timeframes to product development. It is assumed that the

cost of this product is comparable to the other products and methods currently used, but that it is more effective, and therefore results in a reduction of the negative impacts of biofilms in food processing of 10% annually. It is further assumed that this tea tree oil product will capture 10% of the market after 5 years.

The Counterfactual Situation (Without the Investment)

Without this research project, it is assumed that such tea tree oil products for inhibiting biofilm would still be developed at some point in the future. This is because the anti-microbial properties of tea tree oil were already known, and biofilm is becoming an increasingly significant problem. It is therefore assumed that at some point in the future research and development would have been undertaken (most likely in the private sector) to assess the possibilities of the use of tea tree oil for these purposes. It is assumed therefore that without this project, the assumed benefits would have been delayed by 5 years, from when they will occur with the research having been carried out.

In both the with and without scenarios, it is assumed there is a 75% chance of such a product being developed in the timeframes assumed. It is also assumed that the costs of commercially developing any product are the same in both scenarios.

Summary of Assumptions

A summary of the key assumptions made is shown in Table 4.

Table 4: Summary of Assumptions

Variable	Assumption	Source
Air conditioning cooling towers		
Total annual cost of legionnaires outbreaks in Australia	$12 million	Adapted from Lock et al
Reduction in impact of Legionnaires outbreaks due to tea tree oil product	10%	Consultant estimate
Extent of market adopting tea tree product at maximum adoption	10%	Consultant estimate
Year of first adoption with research	2015	Consultant estimate
No. of years to maximum adoption	5 years	Consultant estimate
Year of first adoption without research	2020	Consultant estimate
Probability of product development both with and without research	75%	Consultant estimate
Food processing		
Total annual cost of legionnaires outbreaks in Australia	$6 million	Adapted from OzFoodNet, 2007
Reduction in impact of Legionnaires outbreaks due to tea tree oil product	10%	Consultant estimate
Extent of market adopting tea tree product at maximum adoption	10%	Consultant estimate
Year of first adoption with research	2018	Consultant estimate

No. of years to maximum adoption	5 years	Consultant estimate
Year of first adoption without research	2023	Consultant estimate
Probability of product development both with and without research	75%	Consultant estimate

Results

Overall return on investment

All past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the first year of investment (2005/06) using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for 40 years including the first year of investment. Investment criteria were estimated for both total investment and for the Program investment alone (includes investment from RIRDC and the industry). The investment criteria are reported in Table 5.

Table 5: Investment Criteria for Total Investment and Program Investment

(discount rate 5%)

Criterion	Program Investment only (includes RIRDC and industry)	Total Investment
Present value of benefits (m$)	0.31	0.34
Present value of costs (m$)	0.12	0.13
Net present value (m$)	0.19	0.21
Benefit cost ratio	2.6	2.6
Internal rate of return (%)	13.1	13.1

Distribution of benefits

Sensitivity Analyses

Sensitivity analyses were carried out on a range of variables and results are reported in Tables 6 to 8. All sensitivity analyses were performed on the total investment only using a 5% discount rate (with the exception of Table 6) with benefits taken over the 40 year period. All other parameters were held at their base values.

Table 6 shows the sensitivity of the investment criteria to the discount rate.

Table 6: Sensitivity to Discount Rate

(All Investment, 40 years)

Criterion	Discount Rate		
	0%	5% (Base)	10%
Present value of benefits (m$)	0.68	0.34	0.18
Present value of costs (m$)	0.14	0.13	0.13
Net present value (m$)	0.53	0.21	0.05
Benefit cost ratio	4.8	2.6	1.4

Table 7 shows the sensitivity of the investment criteria to the assumption of the reduction in biofilm impact due to the tea tree oil product.

Table 7: Sensitivity to Reduction of Impact of Biofilm due to Tea Tree Oil

(All Investment, 5% discount rate; 40 years)

Criterion	Assumed Reduction of Impact		
	5%	10% (base)	20%
Present value of benefits (m$)	0.17	0.34	0.69
Present value of costs (m$)	0.13	0.13	0.13
Net present value (m$)	0.04	0.21	0.55
Benefit cost ratio	1.3	2.6	5.1
Internal rate of return (%)	7.0	13.1	19.7

Table 8 shows the sensitivity of the investment criteria to the assumption of the year in which benefits would have commenced without the research. The base analysis assumes that the benefits in the 'without research' scenario commence five years after the assumed first year of benefits in the 'with research' scenario.

Table 8: Sensitivity to Difference in Years Benefits Commence Between With and Without Research Scenarios

(All Investment, 5% discount rate; 40 years)

Criterion	Assumed Number of Years Benefits Delayed in Without Scenario		
	2 years	5 years (base)	10 years
Present value of benefits (m$)	0.15	0.34	0.61
Present value of costs (m$)	0.13	0.13	0.13
Net present value (m$)	0.01	0.21	0.48
Benefit cost ratio	1.1	2.6	4.6
Internal rate of return (%)	5.8	13.1	16.6

Confidence rating

The results produced are highly dependent on the assumptions made in each analysis, many 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 9). 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 significant uncertainties in assumptions made

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

Table 9: Confidence in Analysis

Coverage of Benefits	Confidence in Assumptions
Low	Low

Conclusions

This project was exploratory in nature, and its major output was scientific knowledge. This scientific knowledge will potentially be of value in providing greater confidence in the development of a range of applications for the prevention and control of biofilm development in a range of situations. At this stage, there are no tea tree oil products marketed for this purpose, and the likely timing of the development of such products is uncertain.

Also uncertain is the nature of the benefit that will accrue from the development of such products, in terms of whether they will result in cost reductions, or improved control. Such factors are likely to influence the potential market penetration of any tea tree oil products developed.

Despite the many uncertainties in this area, a probabilistic cost-benefit analysis has been undertaken that seeks to identify the potential benefits from this research project, given a certain set of assumptions. The analysis showed that for the research investment of $0.13 million (present value terms) the expected gross benefit was $0.34 million (present value terms), resulting in an expected net present value of $0.21 million and an expected benefit cost ratio of 2.6 to 1.

Scientifically, this was a successful project. The relatively low benefit-cost ratio is a result of a number of factors including the long time period until benefits will be realised, the uncertainties surrounding the potential size and nature of the impact that any eventual tea tree oil product might have, and the low level of attribution (via the speeding up of product development) of any eventual benefit that can be attributed back to this single piece of research.

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Annex 1: Results for CRRDC Process

As for the results presented earlier, all past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the year of analysis (2009/10) using a discount rate of 5%. These results are shown in Table A.1 and A.2 and reported for different periods of benefits with year 0 being the last year of investment. All analyses ran for a maximum period of 30 years from year 0. Investment criteria were estimated for both total investment and for the Program investment alone (includes both RIRDC and industry contributions).

Table A.1: Investment Criteria for Total Investment and Total Benefits

(discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($m)	0.00	0.00	0.13	0.39	0.42	0.42
Present value of costs ($m)	0.16	0.16	0.16	0.16	0.16	0.16
Net present value ($m)	-0.16	-0.16	-0.03	0.23	0.25	0.25
Benefit cost ratio	-	-	0.8	2.4	2.6	2.6
Internal rate of return (%)	-	-	3.0	12.7	13.1	13.1

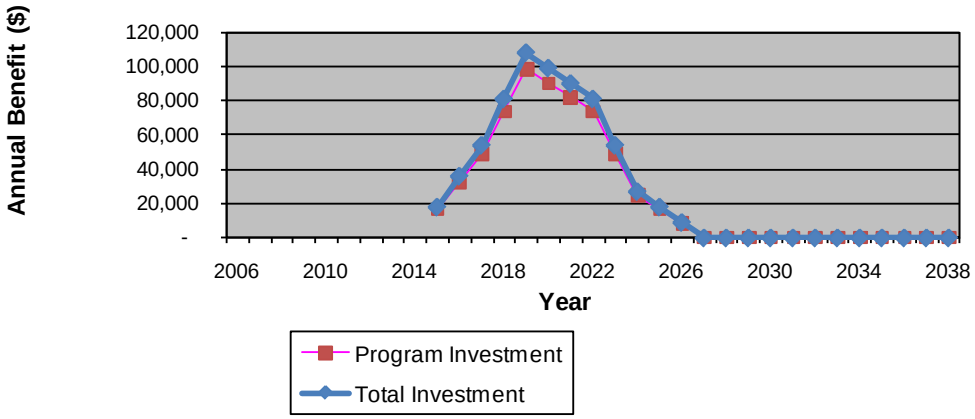
Table A.2: Investment Criteria for Program Investment and Program Benefits

(includes both RIRDC and industry contributions; discount rate 5%)

	0 years	5 years	10 years	15 years	20 years	30 years
Present value of benefits ($m)	0.00	0.00	0.12	0.36	0.38	0.38
Present value of costs ($m)	0.15	0.15	0.15	0.15	0.15	0.15
Net present value ($m)	-0.15	-0.15	-0.03	0.21	0.23	0.23
Benefit cost ratio	-	-	0.8	2.4	2.6	2.6
Internal rate of return (%)	-	-	3.0	12.7	13.1	13.1

The flow of annual benefits is shown in Figure A.1 for both the total investment and for the Program investment.

Figure 1: Annual Benefits



Economic Evaluation of Investment in the Tea Tree Oil R&D Program

by Peter Chudleigh and Sarah Simpson

Publication No. 10/212

This report presents the results of economic analyses of three investments within the Tea Tree Oil R&D Program. The Program is funded by voluntary contributions paid by industry participants, with matching funding provided by the Australian Government up to 0.5 per cent of the industry's gross value of farm production.

The information contained in the report is targeted at Program and RIRDC management, those within the tea tree oil industry, and the wider community. Another target audience is the Australian Government and Council of Rural Research and Development Corporations (CRRDC).

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PO Box 4776
Kingston ACT 2604

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