POSTHARVEST R&D CONCERNING TROPICAL FRUITS

ACIAR Projects 8356 and 8844

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Contents

Abstract

An economic evaluation of two Australian Centre for International Agricultural Research (ACIAR) projects in the area of postharvest technology for tropical fruits was undertaken. This evaluation considered a 30 year time period from the first year of investment and assumed a discount rate of 5 per cent. The estimate of the net present value of the research and development investment was $93 million expressed in 1996/97 terms. The benefit–cost ratio was 38:1 and the internal rate of return estimated at 64 per cent.

If benefits realised by 1996/97 were considered, the net present value was $30 million, the benefit–cost ratio was 13:1, and the internal rate of return was 63 per cent.

Benefits accrued to both Thailand and Australia, with the proportion of benefits attributed 52 per cent to Thailand and 48 per cent to Australia. The commodities to which benefits mostly related were mangoes in the case of Australia, and longans and durians in the case of Thailand. One of the technologies developed in Thailand for longans is now starting to be used in Australia in the developing longan industry.

1. Introduction

This study evaluates the economic impact of two projects supported by the Australian Centre for International Agricultural Research (ACIAR) over the period 1983 to 1991, relating to postharvest handling of tropical and subtropical (hereafter referred to jointly as tropical) fruit crops. The ACIAR projects involved a number of research providers including the Queensland Department of Primary Industries (QDPI), Commonwealth Scientific and Industrial Research Organisation (CSIRO) Divisions of Horticulture and Food Technology, and institutions in Asian countries, principally Thailand. The investment by ACIAR and partner organisations in these projects totalled over A$2 million in nominal dollar terms. The projects addressed issues of wastage and quality deterioration in tropical fruit storage and distribution with emphasis on pre-harvest treatments, storage conditions and the prevention or delay of disease onset and impact.

Benefits accruing to tropical fruit interests in Australia and Thailand from these projects are identified in the following evaluation and a number of these benefits are valued, allowing investment criteria for the overall investment in research and development (R&D) to be estimated. One interesting feature of this study is that one of the benefits accruing to Australian longan producers has been derived from technologies developed earlier in Thailand as a result of support from the ACIAR projects. A second interesting feature is that the total benefits are approximately equally divided between Thailand and Australia.

2. Background

The projects focused on a range of tropical fruit types including mangoes, lychees and longans with some attention given to rambutans, durians and mangosteens. Production of most of these fruit types is minor in Australia except for mangoes. After investment in large plantings in the 1980s in northern Australia, mangoes are now the most abundant tropical fruit crop produced in Australia, with a significant proportion now exported by air to Singapore and Hong Kong. Production of many of the other tropical fruit crops is also expanding in Australia and export markets are being developed.

Production of tropical fruit is far greater in Thailand with mango production, for example, approaching 30 times that of Australia. Exports from Thailand have increased significantly in the past five years, particularly exports of fresh and dried longans and fresh durians. Fresh longan exports now account for 36 per cent of total Thai longan production. Exports of fresh durian have moved steadily from 18 000 tonnes in 1993 to 73 000 tonnes in 1997.

Most tropical fruits are particularly prone to fungal diseases, in particular stem-end rot (SER) and anthracnose. *Alternaria* fungi also affect tropical fruits. Tropical fruits are sensitive to conditions of storage, such as temperature, and these storage conditions interact with the onset and impact of a number of diseases.

Fungal diseases not only impose total losses through spoilage of the fruit but can also downgrade the quality of fruit to a lower priced market. Anti-fungal chemical treatments, some developed as part of the ACIAR investment analysed in the report, have been important in controlling the onset of postharvest disease incidence and impact, but are increasingly coming under scrutiny in line with the chemical-free preference of consumers that has emerged over the past decade. Further, there are interactions between pre-harvest treatment of fruit production, harvesting practices and postharvest storage performance.

Postharvest handling of tropical fruit was an undeveloped area of science in Australia until the 1980s, when the series of ACIAR projects was initiated. As increased production of many of these fruits was anticipated being sold into distant markets, storage and postharvest handling practices were identified as principal factors constraining market development.

3. Description of Projects and Their Outputs

The projects included in this evaluation have provided the backbone of postharvest research in tropical fruits in Australia over the period 1983 to 1991 and ACIAR has continued to invest in this area of R&D since 1991. Before this series of projects there had been some work carried out by QDPI in the 1970s and early 1980s, particularly relating to storage conditions and postharvest disease control for mangoes. Very little R&D had been undertaken in relation to other tropical fruits.

Before the first ACIAR project commenced in 1983 there was little commercial production in Australia of any of the tropical fruits included in this study. There were some growers using fungicides for mangoes and there were some recommendations in existence for storage temperatures of mangoes. However, use of these technologies was not widespread and losses in the postharvest chain were significant, particularly for those mangoes that were destined for consumption some time after harvesting. Very sparse information was available for postharvest handling of the other tropical fruits.

The initial ACIAR project arose specifically as a result of high levels of downgrading and wastage in Australia and South-East Asia owing to inadequate postharvest storage and handling knowledge of tropical fruits.

3.1 ACIAR Project 8356 Mango Characteristics in the ASEAN Region

This project referred to mangos as well as some other tropical fruits and was effected over the period 1983 to 1986. Researchers were from QDPI, CSIRO, Kasetsart University (Thailand), and the Thailand Institute of

Scientific and Technological Research (TISTR). Emphasis was on factors affecting performance characteristics of stored fruit including chemical composition, physiological and chemical measurements at different stages of maturity, ethylene production, and ripening under various conditions. Some postharvest diseases and their causes were investigated as well as storage and packing procedures. The project entailed a situation analysis and descriptions of characteristics of fruit and of postharvest problems at that time. This project established a base level of knowledge that led to a number of subsequent projects.

Outputs

The major output from this project was the development of recommended storage conditions for mangoes (time and temperature) as well as the refinement of timing and temperature recommendations for the hot benomyl dip. Recommendations were three minutes at 52°C for anthracnose and seven minutes at 52°C for SER. In addition, spraying with prochloraz for anthracnose was recommended.

Before this project, some Australian growers used postharvest dipping in hot benomyl. Those growers that did use benomyl sometimes incurred heat damage to the mangoes as temperatures used were higher than recommendations emanating from ACIAR Project 8356.

Controlled atmosphere (CA) storage investigations were also carried out but technology was still imperfect at the end of Project 8356. However, significant groundwork was laid during Project 8356, the area further developed in later projects, and CA storage and transport is currently being improved in both Australia and Thailand.

The major output from the R&D investment in Thailand was the use of sulfur dioxide fumigation for longan and lychee. Investigations commenced within this project and some progress was made. The technology was further refined in ACIAR Project 8844. The commercial use of sulfur dioxide for fumigation of longans was developed successfully through the two projects and is currently used in Thailand.

Other significant outputs from this project in Thailand were the development of maturity guidelines for mangosteens, understanding of their postharvest physiology and the assessment of damage during mangosteen handling.

A summary of principal outputs from this project is provided in Table 1.

Table 1. Summary of principal outputs from ACIAR Project 8356.

Country of impact	Fruit	Principal outputs
Australia	Mango	■ Time and temperature refinements for use of hot benomyl dip for anthracnose and stem-end rot.
		■ Prochloraz spray for anthracnose and *Alternaria.*
		■ Storage performance under different temperatures and storageduration.
		■ Controlled atmosphere storage conditions but technology was still imperfect at end of project.
	Lychee	■ Development of maturity guidelines and standards associated with harvesting at the optimal stage of fruit development.
	Rambutan	■ Preliminary information on storage performance under different temperatures and storage duration.
Thailand	Mango	■ Dipping in hot benomyl for disease control.
	Longan	■ Initial technology for sulfur dioxide fumigation.
	Lychee	■ Technology for sulfur dioxide fumigation.
	Mangosteen	■ Maturity guideline development and recommendations for postharvest handling

Project 8356 resulted in recommendations for postharvest treatment of mangoes for export and these were endorsed by the Committee of Direction for Fruit Marketing, now called the Queensland Fruit and Vegetable Growers' Association (QFVGA). This stimulated interest in export and was a factor influencing the increased planting of mangoes in Queensland in the mid-1980s.

After ACIAR Project 8356, continuing projects funded by QFVGA ran from 1987 to 1990. The QFVGA projects arose because of the increased problem of SER once anthracnose was controlled by chemicals and the need to maintain fruit quality. Changes in the fungal population favoured those SER fungi which were less effectively controlled by the chemicals. The QFVGA projects were concerned with:

- further refining fungicide treatments with benomyl and prochloraz in relation to postharvest storage,
- initiating R&D on desapping methods,
- initiating R&D on method of infection, and
- assessing whether infection levels of SER could be predicted.

The QFVGA projects led into ACIAR Project 8844. Hence, some of the outputs and benefits from the QFVGA projects are included with those of Project 8844, asdescribed in the next subsection. Particular contributions from the QFVGA projects included the generation of knowledge on the method of infection of SER and the development of alternative desapping methods.

3.2 ACIAR Project 8844 Postharvest Handling Technology: Tropical Tree Fruits

ACIAR Project 8844 ran from 1988 to 1991. The joint researchers were QDPI, Horticultural Research Institute, Rattanpruk, Maliwan (Department of Agriculture), Kasetsart University, TISTR and Chiang Mai University in Thailand. This project emanated from ACIAR Project 8356 and requests from the Thai government. Interest in tropical fruit exports from Thailand was increasing and the Thai government was keen to pursue improvements and remove technical constraints.

The project had two components, a physiology component and a disease component. The physiology component had objectives to:

- establish commercially applicable harvesting indices for use in regulating market quality and ensuring maximum storage potential,
- further refine CA storage recommendations for mangoes, and
- define optimum cool storage and CA storage regimes for the five other crops (lychees, longans, mangosteens, rambutans and durian).

The disease component had objectives to investigate:

- the identity of organisms and their relative importance,
- infection mechanisms of the organisms,
- the effects of the environment and fruit maturity on disease development,
- disease control measures,

- the establishment of permanent reference cultural and plant disease herbaria in Thailand to allow future monitoring of changes in pathogen importance and fungicide tolerance,
- alternatives to sulfur dioxide fumigation for postharvest disease control in lychee, longan, rambutan, mangosteen and durian,
- present fumigation technology for use with lychee, longan and rambutan including devising measures to limit loss of skin colour in lychee and rambutan in storage,
- improved commercial control measures against SER as current technology was only about 80 per cent effective,
- control measures against *Alternaria*, a significant problem in storage, and
- the susceptibility of Thai varieties of mangoes to sapburn, identify the specific chemicals involved and recommend practices to limit damage.

Investigations included some replicated studies, some complementary and some joint work in both Australia and Thailand, taking advantage of complementary cropping seasons.

A further objective of Project 8844 was to improve the level of research facilities and expertise in Thailand.

Outputs

The principal outputs relevant to Australian production of mangoes were:

- The finding that washing with detergent immediately after desapping could control sapburn; refinements to detergent washing to avoid skin browning were made in a later project funded by the Horticultural Research and Development Corporation (HRDC).
- The refinement of storage temperature conditions for mangoes (if outside 18–22 degrees then increased deterioration of flavour and colour resulted).
- New knowledge of carbon dioxide and oxygen conditions for CA storage for mangoes.

- New knowledge of how infection with SER developed in mangoes. This led to the avoiding contact of mangoes with soil when bleeding. Findings regarding this method of infection were significant in terms of future research.

The finding that washing mangoes with detergent was effective in minimising the impact of sapburn was taken up by the Australian industry and various methods of washing were further developed by industry. Harvest aids including some form of washing are now incorporated into the field harvesting system, thus saving considerable labour in harvesting. Other washing systems have been incorporated into the packing sheds where desapping takes place.

The principal outputs for Australian lychee production were recommendations on maturity standards and storage temperatures. A project funded by the Rural Industries Research and Development Corporation (RIRDC) followed this ACIAR project and pursued lychee postharvest work. The overall impact on lychees in Australia was quite significant. There were also significant findings for rambutans including optimal temperature storage conditions, packaging and changed atmospheric conditions. Also, the research showed that sulfur dioxide fumigation could not be used for rambutans because of the damage it caused to the peel.

The principal outputs relevant to Thailand included:

- Refinement of sulfur dioxide fumigation of longans including documentation of sulfur dioxide residue samples. As a result of this project, Thai practices are now well developed for export longans and commercial use of the refined technology is widespread.
- Maturity standards were developed and sulfur dioxide fumigation of lychees was refined.
- Waxing of durians reduced fruit splitting which was resulting in some exports (for example, to Hong Kong) being totally rejected.
- Mango storage recommendations, and disease control treatments for mangoes, were developed.

One of the above outputs, the sulfur dioxide fumigation technology for longans, has subsequently been used by the Australian longan industry. QDPI officers visited Thailand in 1994 to assess the technology. There was still development required in Australia including registration, but overall this further development cost QDPI and the Australian industry only about $20 000.

A summary of the principal outputs from Project 8844 is given in Table 2.

Table 2. Summary of principal outputs from ACIAR Project 8844.

Country of impact	Fruit	Principal outputs
Australia	Mango	■ Detergent washing to minimise sapburn impact. ■ Storage conditions including temperature and CA, all leading to quality assurance protocols. ■ Determination of stem-end rot pathogen infection method. ■ Avoidance of soil contact when desapping or bleeding.
	Lychee	■ Maturity work completed; refined storage temperature recommendations and some packaging findings.
	Rambutan	■ Findings regarding temperature storage, packaging and atmosphere conditions, and an assessment of sulfur dioxide fumigation.
	Longan	■ Preliminary information produced on storage conditions.
Thailand	Mango	■ Optimal cool storage temperature and disease control treatments.
	Longan	■ Optimal conditions for sulfur dioxide fumigation and scaling up to commercial conditions including technology transfer.
	Lychee	■ Maturity standards and optimal conditions for sulfur dioxide fumigation. Colour manipulation and sulfur dioxide pads for lychees were important but not adopted due to off-flavours and non-uniform bleaching.
	Durian	■ Waxing treatment that delayed ripening and cracking of fruit.

4. Benefits Arising from Projects

Benefits from the projects described flowed principally to Thailand and Australia. The Philippines may have received some direct benefits from Project 8356. No other Asian countries directly benefited although the Philippines and Malaysia, being involved in Project 8356, may have benefited more via spillovers than other tropical fruit producing countries around the world. Subsequently the technology was also introduced to other Association of South-East Asian Nations (ASEAN) countries under the Australian Agency for International Development's (AusAID's) ASEAN–Australia Economic Cooperation Program (AAECP).

There are two principal ways in which fruit can be devalued during postharvest distribution. Fruit apparently sound and unblemished when leaving the farm can be spoiled to the stage where it is discarded completely (hereafter termed wastage) due to inadequate storage, handling or disease in the transporting, wholesaling or retailing operations. Fruit can also be subjected to a quality downgrading. Both disease and chilling injury can contribute to wastage as well as downgrading.

In the case of downgrading, a price fall in the market chain for the particular fruit affected will result. This price fall can be incurred either by the entity holding the fruit at the time or may be passed back to the grower. Different groups of consumers may gain and lose. Those consumers who can only afford to purchase downgraded fruit may benefit as they now have the luxury of having fruit to purchase, albeit second grade, but at a lower price. The quantity of high grade fruit potentially on offer will fall and the price may rise as a result so those consumers seeking high grade fruit may face higher prices than otherwise.

In the case of wastage, the price to consumers may be kept higher due to the lower supply and the price to growers may rise. On the other hand, demand may be lower due to the known wastage rate and hence the price lower. Nevertheless, costs will have been incurred in producing, harvesting, packaging and marketing the fruit so wastage constitutes a loss to society. The incidence of loss will depend on the payment systems and who takes the risk with respect to postharvest losses.

Identifying the weak linkages in the market chain and establishing where, and under what circumstances, spoilage occurs would be an important issue to address in order for improvements to be made. It appears there is little knowledge available in this area. In addition, identification of who gains and who loses from both postharvest wastage and downgrading would be important information to stimulate improvement.

In Asian countries the loss through downgrading and wastage may be less than in Australia. In the past there has been possibly more local processing in Asian countries and a larger market for downgraded fruit. However, the difference between Australia and Asian countries in this regard is probably narrowing.

In both Australia and Asian countries, more fruit is probably subject to quality loss due to postharvest deterioration than is subject to complete wastage, although the wastage is probably a more visible loss and the loss in dollar terms is probably more significant. Sapburn and browning in mangoes, for example, is associated more with quality loss than wastage; disease may be more associated with wastage, while lack of maturity indices guidelines, or regulations and poor storage recommendations can be associated with both quality loss and wastage.

A high proportion of fruit in Thailand is sold within a few days of harvest. However, a significant and increasing proportion of fruit does travel from rural areas to cities for consumption or export, and in these cases distribution systems can be slow, and highly controlled storage systems are not particularly evident.

4.1 Estimating the Benefits

The benefits from the projects evaluated are valued in this study through valuing the wastage that is avoided through use of the various technologies, less the estimated cost of implementing the technologies. This method has been used in other studies as reviewed in Lubulwa and Davis (1993).

The distribution of these benefits to producers and consumers will vary with the elasticities of supply and demand for each fruit in each country. In Thailand, a significant proportion of the fruit to which the technology applies has been exported. In that regard it is likely that the demand elasticity is quite high for fruit that is subject to the technologies, so the Thai producers have probably gained most from much of the technology. Thai consumers could actually lose due to potentially higher prices for some fruits because of the export pull, but this is difficult to quantify. However, exports still only make up less than 10 per cent of production for most tropical fruits, except for longans and lychees which are higher. Also, a cursory inspection of the price series in Table 6 does not suggest that Thai consumers have been affected to any large extent.

In Australia reduced wastage would increase the quantity of fruit on the Australian market, particularly for mangoes where only a very small proportion of production is exported and the technologies are applied to fruit destined for the domestic market as well as export. Inspection of the price series in Table 7 suggests that there may have been a price fall in real terms over the past decade for some tropical fruits. However, the relative causes of any price changes are difficult to quantify and may differ from fruit to fruit. Improved quality and storage times for fruits may in fact have shifted the demand curve for fruit outwards. On balance, it is likely that both Australian producers and consumers would benefit from reduced wastage due to the technologies developed in the ACIAR projects.

4.2 Information Sources

The data and assumptions used in estimating the benefits from these three projects have been largely derived from official statistical sources and from principal investigators for these projects. Focus has been on the following parameters:

- the tonnages of each fruit produced and the proportion of production to which the technology applies,
- the farm gate unit value of each fruit,
- the magnitude of the loss avoided for each fruit type as a result of the new technology,
- the maximum level of adoption of the technology, taking into account the proportion of each fruit type to which the new technology would potentially apply,
- the year in which first adoption would have occurred,
- the number of years from first adoption to maximum adoption, and
- any additional costs of implementing the technology.

The variables and their values for estimating both Australian and Thai benefits used in the quantitative analysis are shown in Table 3 for Project 8356 and Table 4 for Project 8844. The assumptions used for estimating benefits accruing to the Australian longan industry are shown in Table 5. The development of the sulfur dioxide technology increasingly being used in Australia for longans is related to both ACIAR projects. This technology was developed in Thailand under the ACIAR projects and subsequently adapted and modified by QDPI and Australian longan producers. Hence, the benefit to Australian longan producers is considered a benefit from the ACIAR projects, although it was not directly developed in either ACIAR project reported here.

Table 3. Information used in quantifying benefits from ACIAR Project 8356.

Country of impact	Fruit	Outputs contributing to benefits	Year of first adoption	Time to max. adoption (years)	Level of max. adoption (%)	Wastage before project (%)	Wastage after project (%)	Cost of intervention
Australia	Mango	Table 1 A B C	1987	2	76[a]	20	10	0.02 A$/kg
	Lychee	Table 1 E	1987	2	76[a]	40	30	0[b]
Thailand	Mango	Table 1 G	1989	4	0.5	30	20	0.5 baht/kg
	Longan	Table 1 H	1989	4	10	40	35	1 baht/kg
	Mangosteen	Table 1 J	1988	4	0.5	20	10	0

[a]Based on the estimates that the technology is potentially applicable to 95% of fruit produced and a maximum adoption level of 80% of production of fruit to which the technology is potentially applicable. [b]There may be some cost in application if maturity tests are by private laboratories

Table 4. Information used in quantifying benefits from Project 8844 and QFVGA Project.

Country of impact	Fruit	Outputs contributing to benefits	Year of first adoption	Time to max. adoption (years)	Level of max. adoption (%)	Wastage before project (%)	Wastage after project (%)	Cost of intervention
Australia	Mango	Table 2 A B C	1991	5	76[a]	10	7	0[b]
	Lychee	Table 2 D	1992	2	76[a]	30	20	0
	Rambutan	Table 2 E	1992	2	76[a]	40	30	0
Thailand	Mango	Table 2 G	1993	4	0.5	20	15	0
	Longan	Table 2 H	1993	4	10	35	20	1 baht/kg
	Lychee	Table 2 I	1993	4	3	20	10	0
	Durian	Table 2 J	1993	4	3	30	20	0.25 baht/kg

[a]Based on the estimates that the technology is potentially applicable to 95% fruit produced and a maximum adoption level of 80% of production of fruit to which the technology is potentially applicable. [b]The net cost to the industry has been minimal; if stems are left on in field and desapping effected in packing shed with detergent washing, then additional costs may be incurred. In this case, additional capital costs in the shed are minimal as only simple modifications to the packing line were used (such as hoses and pumps). If stems are broken off in field and a sheeting system used with detergent spray (harvest aid used), the costs will actually be lowered due to higher labour picking productivity.

Table 5. Assumptions of benefits to Australia from sulfur dioxide fumigation of longans.

Year	Production affected (tonnes additional exports)	Additional unit revenue ($ per tonne to producer)	Additional cost (A$ per kg)
1999	100	1000	0.13
2000	300	1000	0.13
2001	500	1000	0.13
2002 and on	500	1000	0.13

Price and production data for tropical fruit production in Thailand produced by the Thai Office of Agricultural Economics, DOA, was obtained and is presented in Table 6. Data for production and prices for Australian tropical fruit were sourced from the Australian Bureau of Statistics, QDPI and Market Information Services at Brisbane Market and are presented in Table 7. Data were not available for all years and for all fruits.

Table 6. Production (t) and price data for tropical fruit production in Thailand.

Year	Mango		Longan		Lychee		Mangosteen		Durian	
	(t)	(baht/kg)	(t)	(baht/kg)	(t)	(baht/kg)	(t)	(baht/kg)	(t)	(baht/kg)
1988	422 314	15.60	97 990	11.53	18 660	30.21	67 423	15.35	444 415	35.95
1989	440 418	15.60	44 661	28.00	23 263	14.77	77 349	15.35	486 644	34.02
1990	481 102	14.95	145 869	7.46	21 270	31.85	90 119	15.14	465 315	28.63
1991	481 893	16.20	81 842	25.63	24 358	32.13	90 263	16.79	539 190	26.90
1992	587 206	14.63	14 5047	22.86	46 280	26.06	90 940	17.59	711 371	26.16
1993	601 838	14.81	92 742	11.49	45 009	17.61	104 096	20.38	749 286	24.05
1994	602 886	15.01	193 079	7.72	46 779	26.20	110 204	21.44	772 670	19.26
1995	631 186	15.20	143 592	18.87	42 856	24.18	128 279	22.67	849 940	21.70
1996	702 069	14.33	236 428	16.17	55 639	25.87	114 193	21.50	917 689	21.52
1997	780 719	16.05	227 979	23.90	37 657	34.12	114 193	21.50	916 023	30.84
1998	876 842	15.19	251 999	19.65	15 274	28.06	114 193	21.50	951 683	24.69
1999	786 543	15.19	238 802	19.65	36 190	28.06	114 193	21.50	928 465	24.69
To 2012	786 543	15.19	238 802	19.65	36 190	28.06	114 193	21.50	928 465	24.69

Note: The last year of official data varies for each fruit; after the last year of data, an average for the last three years has been used for future years.

Table 7. Production (t) and price data for tropical fruit production in Australia.

Year	Mango		Longan		Lychee	
	(t)	$	(t)	$	(t)	$
1987	11 000	1 770	300	4 150	na	na
1988	12 000	1 770	300	4 150	na	na
1989	13 000	2 320	500	4 750	na	na
1990	14 000	1 480	1 200	3 120	na	na
1991	16 000	1 620	1 200	3 960	na	na
1992	17 252	1 180	1 200	2 580	72	8 809
1993	22 369	1 358	1 500	3 357	121	10 988
1994	19 440	1 664	1 000	5 478	139	11 926
1995	29 603	1 359	2 000	3 937	150	10 093
1996	27 236	1 474	2 500	3 730	150	11 298
1997	25 428	1 311	1 833	5 008	150	6 671
1998	25 428	1 312	1 833	4 225	160	9 354
1999	25 428	1 366	1 833	4 225	170	9 354
To 2012	25 428	1 366	1 833	4 225	170	9 354

Note: na = not available

5. Cost of Projects

The cost of the two principal projects for each year in which they were supported is shown in Table 8. The costs reported include costs for all agencies involved. To these costs have been added estimates of costs associated with other projects implicit in the derivation of the estimated benefits, including the QFVGA project.

Table 8. Cost of ACIAR's tropical fruit projects.

Year ending 30 June	ACIAR project costs (A$ nominal)	Other project costs (A$ nominal)	Total project costs (A$ nominal)
1983	77 643		77 643
1984	168 623		168 623
1985	390 941		390 941
1986	176 991		176 991
1987	0		0
1988	553 080	8 000[a]	561 080
1989	425 869	16 000[a]	441 869
1990	249 646	16 000[a]	265 646
1991	0	0	
1992	0	0	
1993	0	0	
1994	0	43 333[b]	43 333
1995	0	63 333[b] [c]	63 333
1996	0	43 333[b]	43 333

[a]Contribution from the Queensland Fruit and Vegetable Growers' Association to maintain project plus assumed equal contribution from Queensland Department of Primary Industries (QDPI). [b]Horticultural Research and Development Corporation/QDPI project on browning and detergent washing in mangoes. [c]Resources provided by QDPI to register and adapt sulfur dioxide fumigation technology for Australian longans ($20,000).

6. The Investment Analysis

6.1 Method

The investment analysis was carried out over a period of 30 years with the first year taken as the year of the initial R&D investment in 1982/83. Costs of R&D were as shown in Table 8. Costs were translated into 1996/97 dollar terms using adjustment factors for inflation.

Benefits were estimated for each year using the data and estimates provided in Tables 3 to 7. All benefits estimated were expressed in 1996/97 dollar terms. Benefits accruing to Thailand were expressed in Thai baht and then converted to Australian dollars using a fixed exchange rate of 19.57 baht to one Australian dollar.

The benefit and cost streams were discounted to the year ended 30 June 1983, the start year for the project using a discount rate of 5 per cent. Investment criteria including net present value (NPV), the benefit–cost ratio (BCR) and the internal rate of return (IRR) were estimated.

6.2 Results

The resulting cash flows are shown in Table 9.

The NPV of the investment by ACIAR and others in post harvest technology of tropical fruits was estimated at A$93.3 million as of 1982/83 expressed in 1996/97 dollar terms and using a discount rate of 5%. The BCR was 38:1 and the IRR was 64%.

The relevant fruit and country contributions to the present value of benefits are shown in Table 10.

Table 10. Source of benefits by country and by tropical fruit type.

Source of benefits	Present Value of Benefits (A$ million)	Present Value of Benefits (%)
Australia		
Mango	32.4	34
Lychee	10.4	11
Rambutan	1.0	1
Longan	1.8	2
Sub-total	45.6	48
Thailand		
Mango	2.9	3
Lychees	1.1	1
Longans	23.4	24
Mangosteen	0.6	1
Durian	22.2	23
Sub-total	50.2	52
Total	95.8	100

The NPV is $30.4 million when benefits are considered only up to and including the 1996/97 year, with a BCR of 13:1 and an IRR of 63%. The predominant benefits for Thailand came from Project 8844 (longans and durians) while the predominant benefits for Australia emanated from Project 8356 (mangoes).

Table 9. Cash flows for estimating investment criteria

Year	Year ending 30/6	Thai benefits (000 baht)	Thai benefits A$ nom	Adjust. factor	Thai benefits 1996-97 A$	Discount factor	Discounted Thai benefits 1996-97 A$	Aust. benefits A$ nom	Aust. benefits 1996-97 A$	Discounted Aust. benefits 1996-97 A$	Total disc benefits 1996-97 A$	R&D costs A$ nom	Other R&D costs A$ nom	Total R&D costs A$ nom	Total R&D costs 1996-97 A$	Total disc R&D costs 1996-97 A$
1	1983	0	0	1.8684	0	1.0000	0	0	0	0	0	77643	0	77643	145068	145068
2	1984	0	0	1.7498	0	0.9091	0	0	0	0	0	168623	0	168623	295056	268233
3	1985	0	0	1.6518	0	0.8264	0	0	0	0	0	390941	0	390941	645756	533683
4	1986	0	0	1.5377	0	0.7513	0	0	0	0	0	176991	0	176991	272159	204477
5	1987	0	0	1.4322	0	0.6830	0	703570	1007653	688241	688241	0	0	0	0	0
6	1988	129	6611	1.3366	8836	0.6209	5486	1526460	2040266	1266845	1272331	553080	8000	561080	749939	465653
7	1989	1327	67807	1.2297	83383	0.5645	47067	2275060	2797641	1579196	1626263	425869	16000	441869	543366	306716
8	1990	–2865	–146377	1.1561	–169227	0.5132	–86840	1646464	1903477	976785	889945	249646	16000	265646	307113	157598
9	1991	4510	230434	1.1093	255621	0.4665	119249	2206067	2447190	1141632	1260881	0	0	0	0	0
10	1992	5701	291333	1.0889	317232	0.4241	134538	1847634	2011888	853237	987774	0	0	0	0	0
11	1993	17324	885257	1.0753	951916	0.3855	367005	3250651	3495425	1347638	1714643	0	0	0	0	0
12	1994	25918	1324351	1.0666	1412553	0.3505	495091	3711645	3958840	1387549	1882641	0	43333	43333	46218	16199
13	1995	75192	3842231	1.0556	4055859	0.3186	1292322	4836714	5105635	1626813	2919134	0	63333	63333	66854	21302
14	1996	116517	5953868	1.0255	6105691	0.2897	1768601	5098621	5228636	1514550	3283151	0	43333	43333	44437	12872
15	1997	176584	9023219	1	9023219	0.2633	2376096	4378523	4378523	1153002	3529098	0	0	0	0	0
16	1998	147475	7535791	1	7535791	0.2394	1804009	4200535	4200535	1005575	2809583	0	0	0	0	0
17	1999	143021	7308201	1	7308201	0.2176	1590477	4429461	4429461	963980	2554457	0	0	0	0	0
18	2000	143021	7308201	1	7308201	0.1978	1445889	4610570	4610570	912177	2358065	0	0	0	0	0
19	2001	143021	7308201	1	7308201	0.1799	1314444	4791679	4791679	861826	2176270	0	0	0	0	0
20	2002	143021	7308201	1	7308201	0.1635	1194949	4798788	4798788	784640	1979589	0	0	0	0	0
21	2003	143021	7308201	1	7308201	0.1486	1086318	4798788	4798788	713309	1799627	0	0	0	0	0
22	2004	143021	7308201	1	7308201	0.1351	987561	4798788	4798788	648463	1636024	0	0	0	0	0
23	2005	143021	7308201	1	7308201	0.1228	897783	4798788	4798788	589512	1487295	0	0	0	0	0
24	2006	143021	7308201	1	7308201	0.1117	816166	4798788	4798788	535920	1352086	0	0	0	0	0
25	2007	143021	7308201	1	7308201	0.1015	741969	4798788	4798788	487200	1229169	0	0	0	0	0
26	2008	143021	7308201	1	7308201	0.0923	674518	4798788	4798788	442909	1117427	0	0	0	0	0
27	2009	143021	7308201	1	7308201	0.0839	613198	4798788	4798788	402644	1015842	0	0	0	0	0
28	2010	143021	7308201	1	7308201	0.0763	557453	4798788	4798788	366040	923493	0	0	0	0	0
29	2011	143021	7308201	1	7308201	0.0693	506775	4798788	4798788	332764	839539	0	0	0	0	0
30	2012	143021	7308201	1	7308201	0.0630	460705	4798788	4798788	302513	763217	0	0	0	0	0
Total30 years		2570115	131329340		131895690		21210829	102300324	105194091	22884958	44095787	2042793	189999	2232792	3115971	2131802
Total 15 years to 96-97							6518615			13535487	20054101					2131802

The sensitivity of the results of the analysis to the discount rate is shown in Table 11.

Table 11. Sensitivity of investment criteria to discount rate.

Discount rate	0%	5%	10%	
Net present value (A$ million)		234	93	42
Benefit–cost ratio	76:1	38:1	21:1	

Average world production of mangoes, excluding Thailand and Australia, from 1992 to 1994 was 17.5 million tonnes, of which 54% was produced in India. Assuming that the maximum level of adoption is only similar to Thailand for the rest of the world (0.5%), and assuming a world price of A$0.78 per kg for mangoes (similar to Thailand), the potential gross saving to the rest of the world from a 10% reduction in wastage would be approximately A$7 million per annum. While this may give some indication of the increased benefits potentially available from one postharvest technology improvement for one fruit, there is no information at present available to assess that other producing countries have adopted any of the technology produced from the ACIAR projects.

7. Conclusion

The NPV of $93 million in 1996 dollars demonstrated that, given the estimates made in the analysis, the projects have provided significant benefits to both Australia and Thailand. If benefits are only considered up to and including the year 1996–97 (the first fifteen years), the NPV is still about one third of that from the 30 year time frame.

The ACIAR projects evaluated in this study have made a significant contribution to the tropical fruit industries in both Thailand and Australia. The benefits to each country would have each, by themselves, paid for the cost of the investment. The fact that both countries have directly gained is important, as this illustrates one of the strategies of ACIAR.

Interestingly, this set of projects has also provided benefits to Australia indirectly through assistance to Thailand. The sulfur dioxide fumigation technology developed and refined for longans in Thailand is now starting to be used in Australia for the export of longans and should contribute to the development of the Australian longan industry.

The magnitude of the benefits estimated for Thailand compared to Australia is directly related to the size of the tropical fruit industries in each country and the relative proportion of fruit in each country to which the specific technologies are applicable. Thailand has by far the greater quantity of production but Australia has a higher proportion of fruit to which the technologies are applicable.

Another impact of these ACIAR projects is the establishment of infrastructure in Thailand (reference cultural and plant disease herbaria) that will further enhance the Thai capability of both R&D and industry services in the future. The projects have also greatly enhanced the bank of knowledge concerning postharvest tropical fruit storage and handling in both Australia and Thailand.

Illustrative of the knowledge generation of the ACIAR projects has been the development of other projects associated with tropical fruit postharvest R&D. The ACIAR projects have identified constraints and opportunities that are being explored in other projects further supported by ACIAR, industry, QDPI, HRDC and RIRDC.

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