ECONOMIC EVALUATION UNIT

WORKING PAPER SERIES

NO. 20 MAY 1995

PROJECT DEVELOPMENT ASSESSMENT: PINEAPPLE QUALITY IMPROVEMENT (PN9407)

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ISBN 1 86320 165 3

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ABBREVIATIONS

QDPI:	Queensland Department of Primary Industries
PPO:	Polyphenol oxidase
POD:	Peroxidase
ACIAR:	Australian Centre for International Agricultural Research
FAO:	Food and Agriculture Organization of the United Nations
CSIRO:	Commonwealth Scientific and Industrial Research Organisation

1. INTRODUCTION

1.1 The problem

This project deals with two main problems in the pineapple industry: blackheart injury and crown deterioration. Blackheart injury in pineapple occurs after continuous cool storage (three days at temperatures below 21°C) or low temperatures during fruit development (less than 25°C during the day or less than 20°C during the night combined with low light). Blackheart injury leads to the discolouration of the pulp of the pineapple. The only way to discover whether the injury has occurred is by cutting the pineapple open.

Nearly all of the blackheart injury experienced by the Australian pineapple industry occurs during fruit development. In Malaysia, as in many of the tropical regions, blackheart is primarily a postharvest problem.

Retention of crown (leaf) is an important determinant in product quality of pineapples. Although crown deterioration precedes fruit breakdown, the quality or freshness of the crown is used to judge the quality of the pineapple. While this problem is not a major one in Australia, it is of economic significance to the pineapple industry in Malaysia.

1.2 The project and its objectives

This project aims to develop strategies to inhibit two disorders currently limiting domestic and export marketing of Malaysian and Australian pineapples:

- ‘blackheart’ injury; and
- crown deterioration

The primary long term objective is to develop a transgenic pineapple resistant to blackheart injury, by molecular inhibition of the enzymes responsible for tissue discolouration. The project intends to apply recent developments in molecular biology, using already established molecular technology to address the pineapple blackheart problem.

To complement this, the project will also investigate additional non-molecular strategies to control crown deterioration in pineapples in Malaysia. Crown deterioration may be induced by chilling injury. This project will examine the physiology involved in crown deterioration and will develop strategies to reduce the incidence and the severity of damage to the crown.

Focus of research by cultivar

Research will concentrate on two main pineapple cultivars (cv Smooth Cayenne from Australia and cv Sarawak from Malaysia). The approximate share in total pineapple production of these two cultivars is as follows:

Focus of research: fresh versus processed or canned pineapple

The project focuses on fresh pineapples rather than processed or canned pineapple. In Malaysia the two problems tackled—blackheart injury and crown deterioration, affect pineapples for the fresh fruit market. In Australia the results of research are likely to affect not only pineapples for the fresh fruit market but also those for canneries.

The difference between Malaysia and Australia is brought about by differences in the nature of the black heart problem in the two countries. In Malaysia, black heart is a postharvest problem occurring when fresh pineapples are stored under cool temperatures to extend their shelf life.

In Australia, blackheart develops in growing fruit when exposed to inducing conditions during the final 3 to 6 weeks of maturation and ripening; fruit exposed at an earlier stage of maturity do not develop the disorder (Smith and Glennie, 1987). The disorder expresses itself severely during winter. The late winter months of July and August usually produce the highest incidence of black heart. In fresh market fruit, black heart symptoms are often more severe than in fruit seen in the cannery as the injury has more time to develop or intensify during the marketing process (Kelly, 1994).

This project has five main objectives:

- differentiate the relative importance of the enzymes—polyphenol oxidase and peroxi-dase—in the development of blackheart symptoms;
- develop a plant transformation system for pineapples;
- develop new genes and incorporate the genes in plants to create blackheart resistant pineapple plants;
- evaluate transgenic pineapple plants; and
- investigate the potential for non-molecular strategies to control crown deterioration in Malaysian cultivars.

1.2.1 *The role of enzymes in the development of blackheart*

Polyphenol oxidase and peroxidase are the two enzymes responsible for black heart injury in pineapples. However, their functional roles are not clear. The first aim is to differentiate the relative importance of the enzymes—polyphenol oxidase and peroxidase—in the development of blackheart symptoms.

1.2.2 *Development of a transformation system for pineapples*

This project will develop a genetic transformation system[1] for pineapples. This system will be the means of introducing new genetic material in pineapple plants. The development of a transformation system will be the most significant achievement of the project and will have the greatest impact on the industry world-wide.

The project will investigate techniques to produce embryogenic cells capable of regenerating into complete plants. Once regeneration is possible in plant culture, the project will investigate reliable procedures for the routine production of transformed plants.

From the development of a transformation system for pineapples there will be a spillover of new research techniques to other areas of pineapple research. This will include research on:

- physiological problems—for example, a currently approved project on flowering suppression involving Horticulture Research and Development Corporation and Golden Circle Ltd requires a plant transformation system and its success will depend directly on the success of this project;
- pathological problems;
- nematode resistance—for example, Dr Sterling (QDPI) is currently discussing the possibility of developing a nematode molecular project as soon as a pineapple transformation system has been produced; and
- entomological problems.

1.2.3 *Incorporation of genes in plants to create blackheart resistant plants*

The project will evaluate suitable marker genes and promoters. It will isolate and characterise the functions of the polyphenol oxidase (PPO) or peroxidase (POD) genes. Then the project will construct new genes based on anti-sense PPO or POD and introduce them into pineapple plants.

1.2.4 *Evaluation of the transgenic pineapple plants*

PPO and POD belong to multi-gene families that regulate a wide range of physiological functions. Thus a new gene inhibiting the activity of PPO and POD may create numerous physiological responses, in addition to blackheart suppression. A further 4 to 6 years of field testing will be necessary before commercial release.

1.2.5 Non-molecular strategies to control crown deterioration

The project will also investigate the potential of non-molecular strategies to control crown deterioration. The development of strategies to control crown deterioration will directly benefit current domestic marketing of fresh pineapple in Malaysia, through increased visual quality of the fruit. The saleability of the product will be increased and, consequently, postharvest losses reduced.

1.3 The scope of the paper

Section 2 discusses methods for evaluating postharvest research and some of the recent applications of those methods. Section 3 discusses the quantification of the impacts of research to improve the quality of pineapples. Section 4 summarises the results from the project development assessment and Section 5 makes some concluding remarks.

2. METHODS FOR EVALUATING POSTHARVEST RESEARCH AND SOME PAST APPLICATIONS

Lubulwa and Davis (1994) provide a brief overview of the development of methods for the evaluation of research. The early postharvest research evaluation papers concentrated on developing the methodology. Several subsequent studies have applied the methodology to specific research issues and projects. Table 1 provides a brief summary of 18 of these studies. One important feature is the considerable variability in the evaluation method used and the types of results reported. Only 11 out of the 18 provided a complete analysis that included an assessment of the lags from the start of the research and the adoption levels and patterns as well as the annual welfare impacts of the research. Table 1 lists these 11 at the top. The rates of return reported range from 21 to 143% which is similar to the types of returns reported for farm level research. The other studies have reported estimates of the annual welfare gains to the countries indicated from the research. Some of these are estimates of the potential gains rather than the gains from a specific and completed project. There are some very large estimates reported, especially for the livestock sectors. One of the 18 evaluations reported negative returns to the project. It is not possible to draw general conclusions from these studies since the methods and format for presentation are not necessarily comparable.

Table 1. Summary of some postharvest research evaluation studies.

Description	Commodity	Country	Research Type	Net Present Value ($M)	Internal Rate of Return (%)	C
Tropical fruits						
1 Non-chemical controls of fruit disease	Mango, Avocado, Longan, Lychee, Rambutan, Mangosteen	Thailand and Australia	Wastage reduction	78	38	ACI
2. Postharvest technology for bananas	Bananas	Malaysia, Philippines and Australia	Control of ethylene to delay ripening	51	48	ACI
3. Edible coatings for fruit shelf-life extension	Mango, Avocado, Lychee	Thailand and Australia	Wastage reduction and quality maintenance	42	34	ACI
4. Chemical controls of fruit disease	Mango, Longan, Lychee, Rambutan, Mangosteen	Malaysia, Philippines, Thailand, Australia	Wastage reduction	37	41	ACI
5. Cool storage, controlled atmospheres and chemical controls for tropical fruit	Mango, Longan, Lychee, Rambutan, Mangosteen, Durian	Thailand and Australia	Wastage reduction	19	27	ACI

6. Vacuum infiltration of fruit with calcium	Avocado	Indonesia and Australia	Wastage reduction	3	21	ACI
Grains						
7. Suppression of Grain Dust	Wheat	Australia	Wastage	14.5	143	
8. Integrated Pesticide Use in Grain Storage	Rice	Malaysia/Philippines/ Australia	Wastage-Storage	24.3	43	
9. Stored Grain Under Plastic	Rice	South East Asia/ Australia	Wastage-Storage	9.2	38	
10. Reduced Amylose in Rice	Rice	Indonesia	Quality	117.0	37	Onl
11. Reduced Amylose in Rice	Rice	Philippines	Quality	227.0	29	Onl
12. Increased Protein Content in Wheat	Wheat	Australia	Quality	447.0		Pote cost
13. Component Pricing and Grading	Soybeans	USA	Grading/Quality	-12.6		Ann cost
Livestock						
14. Pigmeat Fat Reduction	Pigs	USA	Quality	977.5		Pres
15. Reduction in Dark-Cutting in Beef	Beef	Australia	Quality	905.0		Pote cost
16. Boxed to Tray Ready Beef Processing	Beef	USA	Processing	845.6		Ann cost
17. Reduced Backfat Depth in Pigs	Pigs	Australia	Quality	66.0		Pote cost
18 Wool Carding Improvement (Sirocard)	Wool	Australia	Processing	21.9		Ben incl

3. QUANTIFICATION OF THE IMPACTS OF RESEARCH TO INHIBIT BLACK HEART INJURY IN PINEAPPLE

This section describes an approach to the quantification of the impacts of research to inhibit blackheart injury and crown deterioration in pineapple. The quantification of the impacts of research to inhibit blackheart injury and crown deterioration in pineapple relies on a distinction between the before-research situation—with the blackheart and crown deterioration in pineapple problem unsolved, and the after-research situation where the two problems are solved.

3.1 The before research and after research situations

The key aspects of the before and after situations are as follows:

3.2 Factors that influence the potential impacts of research

- *The size of the pineapple industry*

Table 2 shows the amounts of pineapples produced in the 64 regions[2] and countries explicitly recognised by the analysis in the 10-year period to 1990. Table 3 shows the quantities of pineapple consumed in the 64 regions and countries. The impact of this project on the countries collaborating in the project will depend on the production and consumption levels of pineapples in the country.

Table 2. The production of pineapples ('000 MT) in 64 regions or countries of the world :1981–1990.

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	COMMENT
1a	**AUSTRALIA-non-winter**	**126**	**111**	**115**	**125**	**130**	**142**	**147**	**154**	**142**	**96**	**Importer**
1b	**AUSTRALIA-winter-fresh**										**14**	**Importer**
1c	**AUSTRALIA-winter-cannery**										**32**	**Importer**

2	BANGLADESH	156	156	137	132	128	133	145	137	157	160	Non-trader
3	BHUTAN	0	0	0	0	0	0	0	0	0	0	Non-trader
4	INDIA	593	643	672	756	771	750	578	815	834	602	Non-trader
5	NEPAL	0	0	0	0	0	0	0	0	0	0	Non-trader
6	PAKISTAN	0	0	0	0	0	0	0	0	0	0	Non-trader
7	SRI LANKA	42	40	92	44	42	39	38	36	42	45	Exporter
8	MYANMAR	0	0	0	0	0	0	0	0	0	0	Non-trader
9	INDONESIA	182	306	323	475	309	386	348	358	215	283	Major
10	TIMOR/EAST T	0	0	0	0	0	0	0	0	0	0	Non-trader
11	KAMPUCHEA	5	6	7	8	8	9	10	10	11	12	Non-trader
12	LAOS	32	34	32	33	34	36	32	28	30	32	Non-trader
13	**MALAYSIA**	**187**	**188**	**183**	**176**	**182**	**174**	**178**	**195**	**216**	**210**	**Exporter,**
14	PHILIPPINES	972	1010	967	1036	1030	1273	1303	1181	1179	1156	Exporter
15	THAILAND	1993	1439	1341	1463	1769	1636	1510	1771	2005	1865	Exporter
16	VIETNAM	325	330	345	350	360	380	391	378	485	490	Non-trader
17	CHINA	91	134	125	132	183	300	412	485	511	550	Exporter
18	MONGOLIA	0	0	0	0	0	0	0	0	0	0	Non-trader
19	FIJI	4	4	4	5	3	3	5	7	7	4	Non-trader
20	PNG	9	8	8	10	10	11	11	11	12	12	Non-trader
21	SAMOA (WEST)	5	5	6	6	6	6	6	6	6	6	Non-trader
22	SOLOMON IS	0	0	0	0	0	0	0	0	0	0	Non-trader
23	TONGA	0	0	0	0	0	0	0	0	0	0	Non-trader
24	VANUATU	0	0	0	0	0	0	0	0	0	0	Non-trader
25	CHRISTMAS IS	0	0	0	0	0	0	0	0	0	0	Non-trader
26	COCOS IS	0	0	0	0	0	0	0	0	0	0	Non-trader
27	COOK IS	0	0	0	0	0	0	0	0	0	0	Non-trader
28	GUAM	0	0	0	0	0	0	0	0	0	0	Non-trader
29	KIRIBATI	0	0	0	0	0	0	0	0	0	0	Non-trader
30	NAURU	0	0	0	0	0	0	0	0	0	0	Non-trader
31	NEW CALEDONIA	0	0	0	0	0	0	0	0	0	0	Non-trader
32	NIUE	0	0	0	0	0	0	0	0	0	0	Non-trader
33	POLYNESIA (FRENCH)	1	1	2	3	2	2	2	4	5	5	Non-trader
34	SAMOA (AMERICAN)	0	0	0	0	0	0	0	0	0	0	Non-trader
35	TOKELAU	0	0	0	0	0	0	0	0	0	0	Non-trader
36	TUVALU	0	0	0	0	0	0	0	0	0	0	Non-trader
37	WALLIS	0	0	0	0	0	0	0	0	0	0	Non-trader
38	BURUNDI	0	0	0	0	0	0	0	0	0	0	Non-trader
39	RWANDA	0	0	0	0	0	0	0	0	0	0	Non-trader
40	KENYA	190	202	137	168	167	231	210	191	212	202	Exporter
41	TANZANIA	48	49	50	50	50	60	65	66	68	70	Non-trader
42	UGANDA	0	0	0	0	0	0	0	0	0	0	Non-trader
43	ZAIRE	133	135	140	143	146	130	130	136	142	143	Non-trader
44	ETHIOPA	0	0	0	0	0	0	0	0	0	0	Non-trader
45	SUDAN	5	5	5	5	5	5	5	5	5	4	Non-trader
46	MADAGASCAR	47	49	50	51	51	51	51	50	50	50	Non-trader
47	CAMEROON	33	31	30	32	32	33	34	34	34	35	Exporter
48	GHANA	6	7	6	5	6	6	8	10	10	12	Exporter
49	IVORY COAST	299	224	183	223	294	274	227	196	209	136	Exporter
50	NIGERIA	0	0	0	0	1	1	1	1	2	2	Non-trader
51	ANGOLA	35	35	35	35	35	35	35	35	35	35	Non-trader
52	MALAWI	0	0	0	0	0	0	0	0	0	0	Non-trader
53	MOZAMBIQUE	13	13	13	13	13	14	14	15	15	16	Non-trader
54	ZAMBIA	0	0	0	0	0	0	0	0	0	0	Non-trader
55	ZIMBABWE	0	0	0	0	0	0	0	0	0	0	Non-trader
56	OTHER AFRICA	299	328	291	244	347	368	372	282	383	322	Exporter
57	WA/ NA	0	0	0	0	0	0	0	0	0	0	Importer
58	LATIN AMERICA	1522	1534	1541	1717	1761	1933	2151	2254	2153	2096	Exporter
59	OTHER ASIA	229	182	146	116	124	154	162	199	237	241	Importer
60	USSR	0	0	0	0	0	0	0	0	0	0	Non-trader
61	N. AMERICA	596	577	608	655	544	513	586	628	598	526	Importer
62	JAPAN	58	52	44	36	41	37	39	36	36	35	Importer
63	EUROPE	2	1	1	1	1	1	1	1	1	1	Importer
64	OTHER DEVELOPED COUNTRIES	0	0	0	0	0	0	0	0	0	0	Importer
	WORLD TOTAL	8237	7839	7639	8243	8583	9125	9206	9713	10047	9499	

- *Fresh versus processed or canned pineapple*

The Malaysian pineapple industry is primarily concerned with processing, with the volume of fresh pineapple produced being relatively small. The Malaysian government has targeted increased fresh pineapple production as a possible strategy to increase returns to poorer regions within Malaysia. The results of research under this project are likely to affect the production, domestic consumption and exports of fresh pineapples in Malaysia.

It is estimated (ACIAR, 1994) that domestic consumption of fresh pineapples in Malaysia is about 0.52kg/person/year. With a population of 17 million people, this implies a consumption level of fresh pineapple in Malaysia of about 8868 tonnes per year. This is about 4.22% of total pineapple production in Malaysia.

Malaysia also exports fresh pineapples, mainly to Singapore with smaller quantities exported to Brunei and Hong Kong. The total export of fresh pineapple in Malaysia in 1990 was approximately 23 340 metric tonnes (Abdullah, 1993b).

Thus the total fresh pineapple sector in Malaysia is about 41 208 metric tonnes out of a total production of about 210000 (see Table 2). This is about 19.62% of total production in Malaysia.

The research on blackheart injury is likely to affect both the domestic market and the export market for Malaysian pineapples. The research on crown deterioration is likely to be of economic significance in the Malaysian domestic market for fresh pineapple, because, as ACIAR (1994) notes:

> 'In Malaysia the trend is to market fresh pineapples with the crowns attached. Although crown deterioration precedes fruit breakdown, quality or perceived freshness of the crown is commonly used to judge fruit quality. Deterioration of the crown therefore significantly affects the saleability of the fruit, leading to lower prices and reduced grower returns.'

In estimating the impact of research, the processed pineapple component of the Malaysian pineapple production is excluded. This is because this part of the pineapple industry is not affected by blackheart injury nor by pineapple crown deterioration.

In Australia the research on blackheart injury is likely to affect both the fresh and processed pineapple industry in winter and only the fresh pineapple industry in summer. Winter pineapple fruit is the poorest quality being less palatable and more subject to internal blackheart injury. Mild black heart can occur at other times of the year, but is rare and is associated with fruit maturing during extended periods of cloudy cool weather (Kelly, 1994).

The estimated production of pineapple in the winter and summer months is shown below for the whole of Australia. These estimates are based on Kelly (1994) and data from the Brisbane Wholesale market, Rocklea[3]. The estimates are consistent with the FAO (1994) figures for Australia.

Month	Crop season	Cartons sold at Rocklea (a)	Fresh (Mt, 1990) (b)	Cannery (Mt, 1990) (b)	Total (Mt, 1990)
Jan.	summer	31 545	7243	8876	16 119
Feb	summer	23 537	5404	6623	12 027
Mar	summer	17 019	3908	4789	8696
Apr	summer	9773	2244	2750	4994
May	winter	14 015	3218	7508	10 726

Jun	winter	10 406	2389	5575	7964
Jul	winter	9657	2217	5174	7391
Aug	winter	13 279	3049	7114	10 163
Sep	winter	12 374	2841	6629	9470
Oct	summer	30 614	7029	8614	15 643
Nov	summer	38 385	8813	10 800	19 614
Dec	summer	37 567	8625	10 570	19 196
	Total	248 171	56 980	85 021	142 001
	Total FAO				**142 000**

a: Department of Primary Industries, Queensland.
b: Based on Kelly (1994).

- *The extent of trade in the commodity*

The differences between Table 2 and Table 3 indicate the difference between consumption and production of pineapples in 1990 in 64 regions and countries of the world. Countries whose consumption is equal to the production of pineapples are non-traders in pineapples. Countries consuming amounts of pineapples different from the quantities they produce make up the difference through trade. Thus a research project that affects the world price of pineapples will affect both the producers and consumers in those countries that trade (export or import) in pineapples. The last column in Table 2 and Table 3 indicates the trade status of the different countries or regions recognised in the research evaluation model used in the analysis. Only 18 of the 64 countries or regions trade in pineapples.

Table 3. The consumption of pineapples (‘000 MT) in 64 regions or countries of the world 1981–1990.

		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	**COMMENT**
1	AUSTRALIA-	117	103	106	131	135	147	148	161	161	165	Importer
2	BANGLADESH	156	156	137	132	128	133	145	137	157	160	Non-trader
3	BHUTAN	0	0	0	0	0	0	0	0	0	0	Non-trader
4	INDIA	592	643	672	756	771	749	578	815	834	602	Non-trader
5	NEPAL	0	0	0	0	0	0	0	0	0	0	Non-trader
6	PAKISTAN	0	0	0	0	0	0	0	0	0	1	Non-trader
7	SRI LANKA	42	40	92	44	42	39	38	35	41	44	Exporter
8	MYANMAR	0	0	0	0	0	0	0	0	0	0	Non-trader
9	INDONESIA	191	302	320	446	319	351	281	271	182	194	Exporter
10	TIMOR/EAST T	0	0	0	0	0	0	0	0	0	0	Non-trader
11	KAMPUCHEA	5	6	7	8	8	9	10	10	11	12	Non-trader
12	LAOS	32	34	32	33	34	36	32	28	30	32	Non-trader
13	MALAYSIA	48	29	26	23	16	14	24	22	24	27	Exporter
14	PHILIPPINES	491	526	548	559	511	769	769	661	640	651	Exporter
15	THAILAND	1703	1175	1093	1122	1410	1204	1017	1144	1317	1189	Exporter
16	VIETNAM	320	326	342	347	357	379	390	378	485	490	Non-trader
17	CHINA	81	130	108	119	177	267	337	413	449	487	Exporter
18	MONGOLIA	0	0	0	0	0	0	0	0	0	0	Non-trader
19	FIJI	3	4	4	4	3	3	5	7	7	4	Non-trader
20	PNG	9	8	9	10	10	11	11	11	12	12	Non-trader
21	SAMOA (WEST)	5	5	6	6	6	6	6	6	6	6	Non-trader
22	SOLOMON IS	0	0	0	0	0	0	0	0	0	0	Non-trader
23	TONGA	0	0	0	0	0	0	0	0	0	0	Non-trader
24	VANUATU	0	0	0	0	0	0	0	0	0	0	Non-trader
25	CHRISTMAS IS	0	0	0	0	0	0	0	0	0	0	Non-trader
26	COCOS IS	0	0	0	0	0	0	0	0	0	0	Non-trader
27	COOK IS	0	0	0	0	0	0	0	0	0	0	Non-trader
28	GUAM	0	0	0	0	0	0	0	0	0	0	Non-trader
29	KIRIBATI	0	0	0	0	0	0	0	0	0	0	Non-trader
30	NAURU	0	0	0	0	0	0	0	0	0	0	Non-trader
31	NEW CALEDONIA	0	0	0	0	0	0	0	0	0	0	Non-trader
32	NIUE	0	0	0	0	0	0	0	0	0	0	Non-trader
33	POLYNESIA (FRENCH)	1	1	2	3	2	2	2	4	5	5	Non-trader
34	SAMOA (AMERICAN)	0	0	0	0	0	0	0	0	0	0	Non-trader
35	TOKELAU	0	0	0	0	0	0	0	0	0	0	Non-trader

36	TUVALU	0	0	0	0	0	0	0	0	0	0	Non-trader
37	WALLIS	0	0	0	0	0	0	0	0	0	0	Non-trader
38	BURUNDI	0	0	0	0	0	0	0	0	0	0	Non-trader
39	RWANDA	0	0	0	0	0	0	0	0	0	0	Non-trader
40	KENYA	108	92	69	67	77	141	123	89	109	83	Exporter
41	TANZANIA	48	49	50	50	50	60	65	66	68	70	Non-trader
42	UGANDA	0	0	0	0	0	0	0	0	0	0	Non-trader
43	ZAIRE	133	135	140	143	146	130	130	136	142	143	Non-trader
44	ETHIOPA	0	0	0	0	0	0	0	0	0	0	Non-trader
45	SUDAN	7	8	5	5	5	5	5	5	5	4	Non-trader
46	MADAGASCAR	47	49	50	51	51	51	51	50	50	50	Non-trader
47	CAMEROON	30	29	28	29	28	30	31	33	33	34	Exporter
48	GHANA	6	7	6	4	4	3	4	4	2	3	Exporter
49	IVORY COAST	53	52	50	52	60	57	55	59	42	36	Exporter
50	NIGERIA	0	0	0	0	1	1	1	1	2	2	Non-trader
51	ANGOLA	35	35	35	35	35	35	35	35	35	35	Non-trader
52	MALAWI	0	0	0	0	0	0	0	0	0	0	Non-trader
53	MOZAMBIQUE	13	13	13	13	13	14	14	15	15	16	Non-trader
54	ZAMBIA	0	0	0	0	0	0	0	0	0	0	Non-trader
55	ZIMBABWE	0	0	0	0	0	0	0	0	0	0	Non-trader
56	OTHER AFRICA	128	134	129	127	155	142	146	141	163	168	Exporter
57	WA/ NA	7	6	8	19	7	8	2	5	9	5	Importer
58	LATIN AMERICA	1408	1447	1472	1607	1634	1791	1995	2087	1968	1886	Exporter
59	OTHER ASIA	234	221	185	164	184	199	217	239	285	289	Importer
60	USSR	5	4	3	3	3	1	1	0	0	0	Non-trader
61	N AMERICA	1132	1076	1086	1130	1045	1115	1217	1171	1139	1159	Importer
62	JAPAN	209	204	171	184	201	212	217	210	213	252	Importer
63	EUROPE	497	495	451	460	542	585	675	809	829	916	Importer
64	OTHER DEVELOPED COUNTRIES	9	12	12	14	15	14	15	15	17	16	Importer
	WORLD TOTAL	7905	7556	7466	7897	8182	8712	8789	9272	9488	9246	

Malaysia currently exports fresh pineapples, mainly to Singapore with smaller quantities exported to Brunei and Hong Kong. Over 90% of Australian pineapple exports are to New Zealand. Reduced wastage rates and a longer shelf life for pineapples are likely to make it possible for Australian and Malaysian exporters of pineapples to access export markets which are inaccessible before research because of blackheart injury and crown deterioration in pineapples.

For example, it would become possible to transport pineapples over longer distances under refrigeration without the risk of blackheart injury. The after-research excess demand and therefore the aggregate domestic demand for fresh pineapples shifts to the right. The total retail demand for fresh pineapples is the horizontal sum of the domestic and overseas demands for fresh pineapples. The retail supply of fresh pineapples shifts to the right after research, and the quantity sold on the domestic market and on the world market is likely to increase.

- *The physical impacts of eliminating blackheart injury*

Kelly (1994) argues that the winter season incidence of blackheart is higher in the fresh pineapple market than in canneries. Underhill (1993) estimated the incidence of blackheart on the fresh fruit market at 14%.

In the case of canneries, Table 4 shows that blackheart injury is currently affecting about 7.6% of pineapples. In summer, the incidence of blackheart is lower and estimated to be about 1.8%.

Table 4. Before research blackheart injury of pineapples in Queensland: 1988–1990.

Cause of wastage	**1988**	**1989**	**1990**

Blackheart injury			
Castaway[a]	146	199	376
Seizure[b]	0	2 849	1 563
Total blackheart injury (Cartons)*	146[c]	3048[d]	1939[e]
Total spoilage—including blackheart (cartons)	689	3650	2546
Total winter—June to August production (Cartons)	48 286	51 628	33 342
Blackheart injury as percent of winter production	0.3%	5.9%	5.8%

* A carton weighs approximately 22 kilograms

a Data was obtained by Dr Underhill, QDPI, based on castaway certificates asked for by agents in the Brisbane market prior to disposing of pineapples which are not suitable for sale.
b Data was obtained by Dr Underhill, QDPI, based on seizures of pineapples by market produce quality control authorities in the Brisbane market because they are deemed unsuitable for sale.
c Of the 146 cartons, 25 cartons were taken as 50% due to blackheart, and 121 cartons as 75% due to blackheart.
d Of the 3048 cartons, 2861 cartons were taken as 50% due to blackheart, and 187 cartons as 75% due to blackheart.
e All of the 1939 cartons were taken as 50% due to blackheart.

Source: Based on data obtained by Dr Steven Underhill on pineapples rejected for sale on the Brisbane market.

The incidence of blackheart injury in Malaysia's fresh pineapple market is estimated to be about 7.6% annually.

The inhibition of blackheart injury and control of crown deterioration reduces postharvest wastage of pineapples in both Malaysia and Australia. After research, blackheart injury is zero percent on transgenic blackheart resistant pineapples. This translates into a shift to the right in the retail supply function for fresh pineapples, so that at any given fresh pineapple price after research, more fresh pineapples are supplied on retail markets than is currently the case—that is, before research.

- *Quality and product reputation implications*

The inhibition of blackheart injury will improve the quality of pineapples and improve the reputation of pineapples with consumers in Malaysia and Australia. This phenomenon is represented by a shift to the right in the demand curve for pineapples. Thus, for any given price, consumers are likely to buy more pineapples after blackheart inhibition and with reduced crown deterioration than is currently the case.

In Malaysia the control of crown deterioration will improve the quality of pineapples and increase the product reputation of pineapples with consumers. This is likely to lead to a further shift to the right in the demand function for pineapples.However, crown deterioration is not a problem in Australia.

- *The cost implications at the farm level of introducing blackheart resistant pineapple plants*

The introduction of transgenic blackheart resistant pineapple plants may have the following cost implications.
Under current practice, the pineapple grower cuts off the top part of a pineapple plant and uses that cutting as planting material. In the base-case analysis, we assume that the cuttings of transgenic blackheart-resistant pineapples are freely available in Australia and Malaysia.

However, the blackheart-resistant pineapple plants may cost more than the existing plants. This cost increase could arise as a result of the transgenic blackheart resistant pineapple plants being subject to protection under plant variety rights. The price set to cover these rights will depend on the owner of the plant variety rights. It is currently estimated that this could add to the cost of planting materials by about 15% (Dr Walker, Division of Horticulture, CSIRO, Merbein, Victoria, personal communication, September 1994). Currently, growers plant the top of an existing plant. Each one of these planting materials currently costs about 3 cents (Max Stehenson, personal communication, September 1994)[4]. Thus the transgenic blackheart resistant plants may cost about 3.45 cents each.

One of the sensitivity analyses deals with the cost of planting materials for the new pineapple plants being higher than those for traditional varieties. The increase in the cost of planting materials may be higher than half a cent. Another sensitivity analysis assumes that the price of planting materials for transgenic pineapples is three times the price of planting materials for non-transgenic pineapples.

- *Implications for postharvest inputs as a result of blackheart inhibition*

Information on the cost of producing transgenic pineapples suggests that transgenic blackheart resistant pineapples will not require additional inputs in the postharvest stages[5]. The strategy for producing transgenic pineapples is to ensure that, apart from the minor change in the genetic composition of the plant to inhibit blackheart, no other changes are introduced. A major aim of the project is to produce a transgenic pineapple, so similar to the existing pineapple plants, as not to require different inputs in its postharvest handling from current practice (personal communication, Dr Simon Robinson, CSIRO, Adelaide, September 1994).

- *The implications for farm level and postharvest inputs of crown deterioration inhibition*

The strategies to control crown deterioration do not require changes in farm level costs of producing pineapples.

Inhibition of crown deterioration is likely to affect postharvest costs differently according to what is identified as the cause of the deterioration by the project research. If crown deterioration is due to chilling injury, then simple avoidance-based strategies could reduce crown deterioration without any added postharvest costs. For example, ACIAR (1994) notes that:

> 'Observations carried out on Gangol pineapple showed that the crown is chilling sensitive. At ambient temperature, the crown remains fresh for up to 4 weeks. Under refrigeration for 2 weeks at 8°C, the crown leaves become dry 3 days after being removed to ambient temperature.'

Thus avoiding refrigeration of pineapples could achieve crown deterioration inhibition at no added postharvest cost.

However, if crown deterioration is due to other physiological changes (say desiccation), then the postharvest costs are likely to change. For example, it would be necessary to use plastic wrappings, manipulation of temperature and atmospheric composition, or waxing and senescent inhibitors in the control of crown deterioration.

• *Applicability of research*

The work on black heart will focus on the smooth cayenne cultivar for Australia, but it will also include work on cv Sarawak by Malaysian scientists. Smooth cayenne is the principal cultivar used for fresh fruit marketing (Kelly, 1994). Smooth cayenne is an ideal cultivar for canning as well as for producing pineapples to be sold as fresh fruit. Consequently growers can service both markets with minimal risk. While smooth cayenne is a very good quality variety especially in summer production cycle, it does have its drawbacks for fresh fruit, the most important of which is its susceptibility to blackheart injury during the colder months. However, there are other cultivars and these include: rough leaf cultivars (Macgregor, Alexander, Queen and Ripley Queen); and the imported cultivar hybrid 53/116 (Kelly, 1994). This study assumes that smooth cayenne contributes 80% of total pineapple production in Australia.

In the case of Malaysia, the study assumes that the research on blackheart injury is applicable to 30% of pineapple production. For crown deterioration it is assumed that the research is likely to have 100% applicability. The work on crown deterioration will cover four main cultivars, Mauritius, Sarawak, Gandul and N36. • *Technological spillovers*

The analysis does not consider the technological spillovers of research between countries. Prices of pineapples in other trading countries, not collaborating in this project, would change in response to the world price spillovers of this project.

Nonetheless, there may be significant spillovers to other pineapple growing areas of the world. Smith (1983) and QDPI (1987) point out that blackheart injury occurs in various parts of the world including Queensland in Australia, Hawaii, Florida, Ivory Coast, Cameroon, South Africa, Malaysia and Taiwan. Abdullah (1993a, 1993b) indicates that blackheart injury occurs in the Philippines, India and Japan as well. In Australia, South Africa and Taiwan, blackheart injury is a field disorder for pineapples. In the other parts of the world, blackheart injury is a postharvest disorder for pineapples when the fruit is stored under refrigeration.

• *The cost of initial, adaptive and extension research*

Under the base case, research costs equal to $A1 542 654 are incurred in the first 3 years of the project. In the next four years, after the production of a transgenic blackheart resistant pineapple, a further $A 60 000 per annum are incurred by the Australian and Malaysian pineapple industries in the process of testing the transgenic pineapples before their commercial release and communicating results to farmers.

Use is made of standard research evaluation equations in the estimation of welfare benefits accruing to consumers and producers in the different countries. These equations have been discussed extensively elsewhere (for example, Alston et al, forthcoming and Davis et al, 1987). They are thus not discussed here.

The paper estimates changes in producer and consumer surplus in the 64 regions and countries recognised in the analysis. The paper estimates changes in producer and consumer surplus in the 64 regions and countries recognised in the analysis.

• *Demand and supply elasticities*

The analysis assumes that the farmgate price for pineapples in 1990 was \$A 246 per tonne (Rao, 1993, Table 5.3). The farmgate prices in Australia are \$A25 per tonne lower in winter compared to summer. The \$A25 is a risk premium to take into account the higher probability of blackheart injury in the winter months. The own-price elasticity of supply is assumed to be 0.4, and the own-price elasticity of demand is –0.4.

The next section briefly describes the research evaluation model.

3.3 A research evaluation model

The analysis is this paper is based on an extension of a model developed in Davis et al (1987), Davis (1993) and Davis and Lubulwa (1994). Appendix A gives a summary of the model. The model was used to take into account the joint impacts of the following aspects of the proposed research:

- the reduction in wastage due to blackheart injury in pineapple in Australia and Malaysia, leading to a pivotal shift in the retail supply function;
- the improvement in quality, and the associated enhancement in product reputation of pineapples, leading to a parallel shift to the right in the total (domestic and export) demand for fresh pineapples;
- the improvement in perceived quality and the associated enhancement in product reputation of pineapples, leading to a parallel shift to the right in the total (domestic and export) demand for fresh pineapples;

The estimation is done in three stages, where the after-research equilibrium values of the previous stage become the before-research equilibrium values of the next stage. First, for the case where research reduces wastage, the change in welfare from the research can be estimated using the before-research and after-research equilibrium values determined as in Appendix A and the following:

The change in the consumers' surplus (CS_h) in country h:

$$\Delta CS_h = (P_{rh} - P^*_{rh})\, Q_{rh} + 0.5[(P_{rh} - P^*_{rh})\, (Q^*_{rdh} - Q_{rdh})]$$

The change in producer surplus (PS_h)) in country h:

$$\Delta PS_h = (P^*_{fh} - P_{fh})\, Q_{fh} + 0.5[(P^*_{fh} - P_{fh})\, (Q^*_{fh} - Q_{fh})]$$

where the different variables are as defined in Appendix A. The values denoted by the asterisk are the equilibrium values for prices and quantities after research.

4. PROJECT DEVELOPMENT ASSESSMENT RESULTS

4.1 The base case

Assumptions used in the base-case scenario have been described in section 3. The salient features of the base-case scenario are as follows.

The key assumptions made in the project development assessment.

Variable	*Malaysia*	*Australia Winter Fresh*	*Australia Winter Cannery*	*Australia Summer*
Production (MT)	210 000	13 714	32 000	96 287
Proportion of output for the fresh pineapple market	0.1962	1	0	0.449
Production level used in the analysis	Only fresh	All production	All production	Only fresh
Price/metric ton				
Fresh pineapple	$A246	$A221	$A221	$A246
Pineapples to canneries	Not included	$A221	$A221	Not included
Wastage due to blackheart before research -fresh	7.6%	14%	7.6%	1.8%
Wastage due to blackheart after research	0%	0%	0%	0%
Blackheart-free premium per ton after research	$A10	$A25	$A25	$A10
Proportion affected by crown deterioration before research	100%	Not applicable	Not applicable	Not applicable
Proportion affected crown deterioration after research	0	Not applicable	Not applicable	Not applicable
Price premium due to better control of crown deterioration after research, per metric ton	$A10	Not applicable	Not applicable	Not applicable
Cost of planting materials before research	$A0.03	$A0.03	$A0.03	$A0.03
Increase in cost of planting materials per item	$A0.0045	$A0.0045	$A0.0045	$A0.0045
Applicability of blackheart research	30%	80%	80%	80%
Adoption pattern				
1995 to 2003	0	0	0	0
2004	5%	5%	5%	5%
2004 to 2017	10% increasing at 5% pa to 65%	10% increasing at 5% pa to 100%	10% increasing at 5% pa to 100%	10% increasing at 5% pa to 65%
2017 to 2025	65% ceiling	100% ceiling	100% ceiling	65% ceiling
Planning horizon	30 years	30 years	30 years	30 years
Time for initial research	3 years	3 years	3 years	3 years
Time for the evaluation of transgenic plants	4–6 years	4–6 years	4–6 years	4–6 years
Elasticity of supply	0.4	0.4	0.4	0.4
Elasticity of demand	–0.4	–0.4	–0.4	–0.4
Discount rate	8% pa	8% pa	8% pa	8% pa

Under these conditions, together with the assumptions described in Tables 2 to 4, the project-development assessment indicates that blackheart inhibition research is socially worth undertaking. Table 5 shows that this type of research could lead to a net present value of benefits of about $A 3.6 million. The benefits and costs associated with the project are discounted at 8% per annum over a 30 year planning horizon. Table 5 shows that the project has an estimated internal rate of return of about 14%. This internal rate of return is lower than the rates of returns from previous postharvest projects on tropical fruits summarised in Table 1. Figure 1 gives a graphical representation of the flow of benefits over the 30 year period.

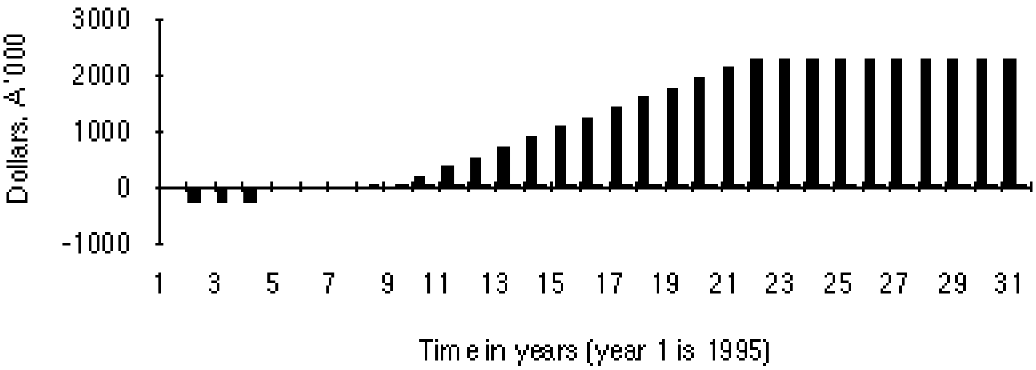

Figure 1. The flow of net benefits from blackheart inhibition research (ACIAR PN9407).

Table 5. Flow of benefits accruing to Australia, Malaysia and the rest of the world due to research to improve the quality of pineapples (PN9407): $A'000, 1994.

Comment	Year No.	Year	Australia winter fresh cannery	Australia winter fresh	Australia summer	Malaysia fresh	Rest of world	Total costs	Research	Net benefits
Start project	1	1995	0	0	0	$0	$0	$0	$760	($760)
	2	1996	0	0	0	$0	$0	$0	$773	($773)
End of project	3	1997	0	0	0	$0	$0	$0	$800	($800)
Start assessing transgenic plants	4	1998	0	0	0	$0	$0	$0		$0
	5	1999	0	0	0	$0	$0	$0		$0
	6	2000	0	0	0	$0	$0	$0		$0
	7	2001	0	0	0	$0	$0	$0		$0
	8	2002	0	0	0	$0	$0	$0		$0
Complete assessment of transgenic plants	9	2003	$39	$93	$17	$6	($36)	$119		$119
Commercial release of transgenic pineapples	10	2004	$78	$185	$34	$12	($72)	$237		$237
	11	2005	$118	$278	$51	$18	($108)	$356		$356
	12	2006	$157	$371	$67	$24	($145)	$475		$475
	13	2007	$196	$464	$84	$30	($181)	$593		$593
	14	2008	$235	$556	$101	$36	($217)	$712		$712
	15	2009	$275	$649	$118	$42	($253)	$831		$831
	16	2010	$314	$742	$135	$48	($289)	$949		$949
	17	2011	$353	$835	$152	$54	($325)	$1068		$1068
	18	2012	$392	$927	$168	$60	($361)	$1187		$1187
	19	2013	$432	$1020	$185	$66	($398)	$1306		$1306
	20	2014	$471	$1113	$202	$72	($434)	$1424		$1424
Ceiling adoption	21	2015	$510	$1206	$219	$78	($470)	$1543		$1543

22	2016	$549	$1298	$219	$78	($470)	$1675		$1675
23	2017	$589	$1391	$219	$78	($470)	$1807		$1807
24	2018	$628	$1484	$219	$78	($470)	$1939		$1939
25	2019	$667	$1577	$219	$78	($470)	$2071		$2071
26	2020	$706	$1669	$219	$78	($470)	$2203		$2203
27	2021	$746	$1762	$219	$78	($470)	$2335		$2335
28	2022	$785	$1855	$219	$78	($470)	$2467		$2467
29	2023	$785	$1855	$219	$78	($470)	$2467		$2467
30	2024	$785	$1855	$219	$78	($470)	$2467		$2467
Discounted benefits and costs		$1835	$4337	$699	$249	($1500)	$5620	$2001	$3619
Internal rate of return									14%

4.2 The distribution of benefits

Table 6 shows the distribution of research benefits across the 64 regions and countries recognised in the model and between producers and consumers within individual countries. The main beneficiaries from the research project are the two collaborating countries, Australia and Malaysia. It is estimated that over a 30 year period Australia's economic surplus is likely to increase by about $A7 millions and Malaysia's economic surplus by about $A0.2 millions. Table 5 indicates that, on balance, the rest of the world's countries lose. Table 6 shows that this result is from a combination of significant gains to consumers and losses to producers in countries that trade in pineapples but do not collaborate in the research project to inhibit blackheart and crown deterioration Countries that either do not produce or trade in pineapples—or which produce canned (processed) pineapples—are not affected by the movements in the world price of fresh pineapples. Consumers in countries that trade in pineapples benefit from the research, because the reduction in blackheart injury in pineapples increases the retail supply of pineapples, and consequently leads to lower prices.

Table 6. The distribution of benefits under the base case scenario of ACIAR PN, 9407: pineapple quality improvement.

	COUNTRY OR REGION	PRODUCER	CONSUMER	TOTAL	COMMENT
1	AUSTRALIA-winter-fresh	$202	$1633	$1835	Importer before, exporter after
	AUSTRALIA -winter-cannery	$471	$3866	$4337	Importer before, exporter after
2	AUSTRALIA-summer	$564	$134	$699	Importer before, exporter after
3	BANGLADESH	$0	$0	$0	Non-trader
4	BHUTAN	$0	$0	$0	Non-trader
5	INDIA	$0	$0	$0	Non-trader
6	NEPAL	$0	$0	$0	Non-trader
7	PAKISTAN	$0	$0	$0	Non trader
8	SRI LANKA	($427)	$76	($350)	Small exporter
9	MYANMAR	$0	$0	$0	Non trader
10	INDONESIA	$0	$0	$0	Exporter, processed pineapple
11	TIMOR/EAST T	$0	$0	$0	Non trader
12	KAMPUCHEA	$0	$0	$0	Non trader
13	LAOS	$0	$0	$0	Non trader
14	MALAYSIA	$201	$48	$249	Major exporter, Collaborator
15	PHILIPPINES	$0	$0	$0	Exporter, processed pineapple
16	THAILAND	$0	$0	$0	Exporter, processed pineapple
17	VIETNAM	$0	$0	$0	Non trader
18	CHINA	($1329)	$238	($1091)	Exporter
19	MONGOLIA	$0	$0	$0	Non trader
20	FIJI	$0	$0	$0	Non trader
21	PAPUA NEW GUINEA	$0	$0	$0	Non trader
22	SAMOA (WEST)	$0	$0	$0	Non trader
23	SOLOMON ISLAND	$0	$0	$0	Non trader
24	TONGA	$0	$0	$0	Non trader

25	VANUATU/NE	$0	$0	$0	Non trader
26	CHRISTMAS IS	$0	$0	$0	Non trader
27	COCOS IS	$0	$0	$0	Non trader
28	COOK IS	$0	$0	$0	Non trader
29	GUAM	$0	$0	$0	Non trader
30	KIRIBATI	$0	$0	$0	Non trader
31	NAURU	$0	$0	$0	Non trader
32	NEW CALEDONI	$0	$0	$0	Non trader
33	NIUE	$0	$0	$0	Non trader
34	POLYNESIA (FRENCH)	$0	$0	$0	Non trader
35	SAMOA (AMERICAN)	$0	$0	$0	Non trader
36	TOKELAU	$0	$0	$0	Non trader
37	TUVALU	$0	$0	$0	Non trader
38	WALLIS & FUT	$0	$0	$0	Non trader
39	BURUNDI	$0	$0	$0	Non trader
40	RWANDA	$0	$0	$0	Non trader
41	KENYA	($489)	$87	($401)	Exporter
42	TANZANIA	$0	$0	$0	Non trader
43	UGANDA	$0	$0	$0	Non trader
44	ZAIRE	$0	$0	$0	Non trader
45	ETHIOPA	$0	$0	$0	Non trader
46	SUDAN	$0	$0	$0	Non trader
47	MADAGASCAR	$0	$0	$0	Non trader
48	CAMEROON	($327)	$59	($269)	Minor exporter
49	GHANA	($114)	$20	($93)	Exporter
50	IVORY COAST	($1293)	$231	($1061)	Exporter
51	NIGERIA	$0	$0	$0	Non trader
52	ANGOLA	$0	$0	$0	Non trader
53	MALAWI	$0	$0	$0	Non trader
54	MOZAMBIQUE	$0	$0	$0	Non trader
55	ZAMBIA	$0	$0	$0	Non trader
56	ZIMBABWE	$0	$0	$0	Non trader
57	OTHER AFRICA	($16)	$3	($13)	Exporter
58	WEST ASIA/ NORTH AFRICA	$0	$0	$0	Importer
59	LATIN AMERICA	($101)	$18	($83)	Exporter
60	OTHER ASIA	($207)	$766	$559	Importer
61	USSR	$0	$0	$0	Non trader
62	NORTH AMERICA	($452)	$1671	$1219	Importer
63	JAPAN	($30)	$111	$81	Importer
64	EUROPE	($1)	$4	$3	Importer
65	OTHER DEVELOPED COUNTRIES	$0	$0	$0	Importer
	WORLD TOTAL	($3346)	$8966	$5620	

4.3 Sensitivity analyses

The above results are based on a number of assumptions which, if varied, are likely to change the results of the project-development assessment. The most critical of these are the assumptions on the incidence of blackheart injury after research, the farm level costs associated with blackheart injury resistant pineapples, and the after-research postharvest costs. These assumptions are varied in the following sensitivity analyses.

The incidence of blackheart injury after research

The assumption that blackheart-injury-resistant pineapples will lead to complete non-occurrence of blackheart injury after research may not hold. For example, the project intends to focus on only one cultivar of the cultivars grown in Australia. In Table 7, one of the sensitivity analyses assumes that the after-research reduction in blackheart injury is about half that assumed in the base case. Under this scenario, the net present value is about $A 2.3 millions and the internal rate of return is estimated to be 13 per cent which are both lower than in the base case.

Table 7. A summary of results from the sensitivity analyses

	Base case	Blackheart injury reduced by half	Cost of planting materials increase by 15%	Planting material costs treble	Postharvest costs increase
Changing Cells:					
Change in postharvest costs in Malaysia	0	0	0	0	20
Cost saving after research (winter crop—Australia)	0	0	0.045	0.06	0
Cost saving after research (crop for cannery—Australia)	0	0	0.045	0.06	0
Cost saving after research (summer crop—Australia)	0	0	0.045	0.06	0
Cost saving after research (Malaysia)	0	0	0.045	0.06	0
Change in wastage rate for winter crop sold fresh—Australia	–0.0581549	–0.029	–0.0581549	–0.0581549	–0.0581549
Change in wastage rate for winter crop sold to cannery—Australia	–0.0182053	–0.009	–0.0182053	–0.0182053	–0.0182053
Change in wastage rate for summer crop—Australia	–0.0182053	–0.009	–0.0182053	–0.0182053	–0.0182053
Reduction in black heart injury in Malaysia	–0.058155	–0.029	–0.0581549	–0.058155	–0.0581549
Result Cells:					
Present value of research benefits accruing to producers of fresh winter pineapples in Australia	$1835	$1626	$1835	$1835	$1835
Present value of research benefits accruing to producers of winter pineapples in Australia	$4337	$4148	$4337	$4337	$4337
Present value of research benefits accruing to producers of summer pineapples in Australia	$699	$540	$699	$699	$699
Present value of research benefits accruing to producers of pineapples in Malaysia	$249	$63	$249	$249	$249
Net present value	$3619	$2270	$3617	$3616	$3619
Internal rate of return	14.46%	12.59%	14.45%	14.45%	14.46%

The after research cost of planting materials

In Table 7, one of the sensitivity analyses explores the implications of increasing farm level costs as a result of an increase in the cost of planting materials associated with protection under plant breeders rights. Current information indicates that the increase in farm-level costs resulting from patenting the transgenic pineapples is likely to be small. Table 7 shows results for two sensitivity analyses of the implications of the after research costs of planting materials. One sensitivity analysis assumes that the cost of planting materials increases by 15%. Another sensitivity analysis assumes that the cost of planting materials for transgenic pineapples is three times the before-research costs. Under these two scenarios, the net present-value changes slightly. However the internal rate of return for the project does not change.

The after research postharvest costs

In Malaysia, the inhibition of crown deterioration may necessitate an increase in postharvest costs. This may be the case if, for example, crown deterioration inhibition requires controlled atmospheres or the use of special wrapping materials. In Table 7, it is assumed that postharvest costs increase after research. However, because Malaysia's level of production as a share of world production is small, this increase does not significantly alter the world market and it does not change the estimated net present values and internal rate of return.

5. CONCLUDING REMARKS

This paper has discussed an economic assessment of the project on the improvement of pineapple quality (ACIAR PN9407). The analysis has taken into account the differences in the incidence of blackheart injury in Australia between the summer and winter months. It has taken into account the demand and supply functions of pineapples in 64 regions and countries of the world, and the implications of price spillovers of research on the world price of pineapples.

- A transformation system will allow successful introduction of new genetic material into pineapples thereby effectively removing the key impediment to further molecular improvement of pineapples; it will for example be easier to develop more disease resistant cultivars of pineapples. These potential benefits are not considered in the analysis because at this stage before a transformation system is developed they are based on speculation.
- There may be technological spillovers to the rest of Asia and other pineapple growing areas. However, technological spillovers to these other countries while always benefiting the consumers and while they may have a positive net benefit, may not benefit all producers of pineapples.

The paper concludes that this project is associated with net benefits of about $A3.6 million and an internal rate of return of about 14%. However, if the reduction in blackheart injury is lower than those assumed in the analysis, the net present value and the internal rate of return associated with the project may be lower than estimated in this paper.

1 The absence of a transformation and regeneration system for pineapple has hindered molecular biology research on pineapple. Enquiries in the USA and elsewhere indicate that no work on a pineapple transformation system has been undertaken (Robert Paull, Plant Molecular Physiology, University of Hawaii at Manoa, personal communication, July 1993).

2 The list of regions and countries in the analysis emphasizes ACIAR's mandate regions and countries. The countries where ACIAR has not had, or is not likely to have, a project are aggregated into nine regions at the bottom of the list.

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APPENDIX A: PROJECT EVALUATION METHODOLOGY

The analysis is this paper is based on an extension of the following model developed in Davis et al (1987), Davis (1993) and Davis and Lubulwa (1994). The core of the model involves the following relationships:

Farm level supply:

$$Q_{fh} = a_h + b_h P_{fh} \quad (1)$$

where:

Q_{fh} is the quantity of a commodity produced at the farm level in country h

P_{fh} is the farmgate price of the commodity in country h

a_h and b_h are the intercept and slope of the supply curve in country h

Farm to retail production linkage:

$$Q_{rsh} = \delta_h Q_{fh} \quad (2)$$

where:

Q_{rsh} is the quantity supplied at the retail level

δ_h, is farm to retail-level conversion factor and is the rate at which the farm-level quantity is converted to the retail quantity in country h. The wastage rate of the commodity from the farm level to retail is then $(1–\delta_h)$ where $0<\delta_h<1$. For example, if 30% of the farm product is lost between the farm gate and consumer purchases the wastage rate is 0.3 and therefore $\delta_h = 0.7$.

Farm to retail price linkage:

$$P_{fh} = \delta P_{rh} – M_h \quad (3)$$

where:

P_{rh} is the retail level price

M_h, is the postharvest cost per unit of farm level output produced.

Retail sector supply:

$$Q_{rsh} = \delta_h[a_h + b_h(\delta_h P_{rh} – M_h)] \quad (4)$$

Retail demand:

$$Q_{rdh} = c_h – d_h P_{rh} \quad (5)$$

where:

c_h and d_h are the intercept and slope of the demand curve in country h.

In a linear model such as this, if estimates of the supply and demand elasticities are available, the following relationships hold:

$$b_h = \varepsilon_{sh} Q_{fh}/P_{fh} \qquad (6)$$

$$a_h = (1 - \varepsilon_{sh}) Q_{fh} \qquad (7)$$

$$d_h = -\varepsilon_{dh} Q_{rh}/P_{rh} \qquad (8)$$

$$c_h = (1 - \varepsilon_{dh}) Q_{rh} \qquad (9)$$

where

ε_{sh} is the farm level supply elasticity in country h and

ε_{dh} is the retail level demand elasticity

If the country is a net exporter the retail-to-world price linkage is:

$$P_{rh} = P_w - z_h \qquad (10)$$

where:

P_w is the 'world market' price

z_h is the transport cost from country 'h' to the world market before research.

The excess supply from this exporting country 'h' is given as:

$$Q_{esh} = Q_{rsh} - Q_{rdh} \qquad (11)$$

If the country is an net importer the retail-to-world price linkage is:

$$P_{rj} = P_w + z_j \qquad (12)$$

where:

P_w is the 'world market' price

z_j is the transport cost to country 'j' from the world market before research.

The excess supply from this importing country 'j' is given as:

$$Q_{esj} = Q_{rdj} - Q_{rsj} \qquad (13)$$

The world market equilibrium 'before research' is given by solving the following:

$$\sum_{h=1}^{n} Q_{esh} = \sum_{j=n+1}^{N} Q_{edj} \tag{14}$$

where there are h=1…n exporting countries and j=N–n importing countries.

Davis and Lubulwa (1994) indicate that the equilibrium world price associated with the system of equations (1)–(14) is given by the following equation:

$$P_w = -\frac{\sum(\delta_i a_i - c_i)}{\sum(\delta_i^2 b_i + d_i)} + \frac{\sum(\delta_h^2 b_h + d_h)Z_h - \sum(\delta_j^2 b_j + d_j)Z_j}{\sum(\delta_i^2 b_i + d_i)} + \frac{\sum \delta_i b_i M_i}{\sum(\delta_i^2 b_i + d_i)} \tag{15}$$

The domestic equilibrium values of P_{rh}, Q_{sh}, Q_{dh} and P_{fh} can be found by substitution this world price into the appropriate equation.

The impact of research

Agricultural research could lead to changes in:

- the unit cost of producing a commodity at the farm level, and thus shift the farm level supply curve for a commodity—for example research which increases the yield per hectare or reduces on-farm inputs;
- the wastage rate of an agricultural commodity between the farmgate and the retail market thereby shifting the retail supply curve for a commodity—for example research that reduces early ripening or rots in fruits;
- postharvest costs;
- the cost of transporting products from one region or country to another; and
- the quality of a product —while changes in product quality can lead to shifts in supply curves, the simplest form of quality change is one that leads to a shift in the demand curve for the product.

Definitions:

Δk_{hh} is the change in the farm level unit cost of producing a commodity in country 'h' due to the research undertaken in country 'h' and Δk_{ih} is the spillover effect of this research to country 'i'.

δh is farm-to-retail level conversion factor and is the rate at which the farm-level quantity is converted to the retail quantity in country h. The wastage rate of the commodity from the farm level to retail is then $(1–\delta_h)$ where $0<\delta_h<1$. For example, if 30% of the farm product is lost between the farm gate and consumer purchases the wastage rate is 0.3 and therefore $\delta_h = 0.7$.

$\Delta\delta_{hh}$ is the change in the farm to retail conversion rate in country 'h' because of the research undertaken in country 'h' and $\Delta\delta_{ih}$ is the spillover effect of this research to country 'i'.

M_h is the postharvest cost per unit of farm level output produced.

ΔM_{hh} is the change in postharvest input costs in country 'h' because of research undertaken in country 'h' and $\Delta\delta_{ih}$ is the spillover effect of this research to country 'i'.

Δz_{hh} is the change in world market transport cost from (to) country 'h' associated with the new technology developed in country 'h' and $\Delta\delta_{ih}$ is the spillover effect of this research to country 'i'.

Δg_{hh} is the vertical shift in the demand function for a commodity in country 'h' because of research undertaken in country 'h' that improves product quality or enhances product reputation of a given commodity. $\Delta\gamma_{ih}$ is the spillover effect of this research to country 'i'.

After Research

The technologies resulting from agricultural research can be represented in the following manner.

Change in farm level unit cost of production

Δk_{hh} is the change, because of research, in the unit cost of producing a commodity. This is equivalent to a parallel shift in the farm-level supply function.

Reduction in the postharvest wastage rate:

$$\delta^*_h = (\delta_h + \Delta\delta_{hh}) \quad (16)$$

Reduced wastage is translated into a higher farm to retail conversion factor.

Change in the postharvest input costs

$$M^*_h = (M_h + \Delta M_{hh}) \quad (17)$$

Change in the world market transport costs

$$z^*_h = (z_h + \Delta z_{hh}) \quad (18)$$

A shift in the aggregate demand curve due to changes in product quality and product reputation

Δg_{hh} is the vertical shift in the aggregate (domestic and export) demand curve for fresh pineapple

The ‘after research’ world equilibrium price is found by substituting these changes in the appropriate equations and solving for the equivalent of equation (2) which gives:

$$P_W^* = -\frac{\sum(\delta_h^* a_i - c_i)}{\sum(\delta_i^{*2} b_i + d_i)} + \frac{\sum(\delta_h^{*2} b_h + d_h) z_h^* - \sum(\delta_j^{*2} b_j + d_j) z_h^*}{\sum(\delta_i^{*2} b_i + d_i)} + \frac{\sum \delta_{h^i}^* b_i M_i^*}{\sum(\delta_i^{*2} b_i + d_i)} + \frac{\sum \delta_i^* b_i k_i}{\sum(\delta_i^{*2} b_i + d_i)} - \frac{\sum \delta_i^* d_i g_i}{\sum(\delta_i^{*2} b_i + d_i)} \quad (19)$$

Again these can be substituted into the appropriate equations to find the ‘after research’ domestic equilibrium values of P^*_{rh}, Q^*_{sh}, Q^*_{dh} and P^*_{fh}.