RETURNS TO RESEARCH ON INSECT POLLINATION OF OIL PALM IN PAPUA NEW GUINEA

A LAYMAN'S GUIDE

George Antony
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Department of Agriculture and Livestock
P.O.Box 417, Konedobu, Papua New Guinea

in co-operation with
University of New England, Armidale, Australia
Australian Centre for International Agricultural Research, Canberra

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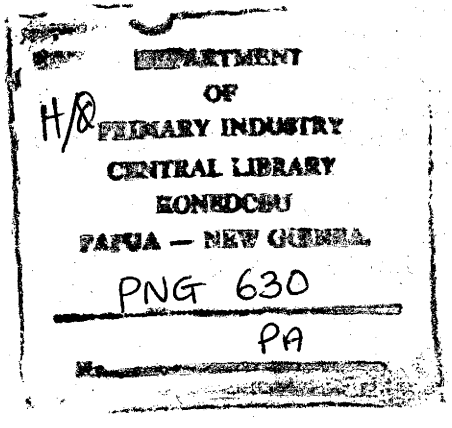

FOREWORD

This paper is one of a series of seven final papers of the **Priorities for Papua New Guinea Agricultural Research Project** published by the Department of Agriculture and Livestock (DAL), Government of Papua New Guinea.

The **Priorities for Papua New Guinea Agricultural Research Project** commenced in 1987 and was completed at the end of February 1990. It was supported by the Government of Papua New Guinea and the Australian Centre for International Agricultural Research (ACIAR) through a technical assistance programme.

An internal review of the project has been conducted by the Department of Agriculture and Livestock and a report published by the Department was released in February 1990. An external review of the project is scheduled to be conducted in May 1990.

On behalf of the Department of Agriculture and Livestock and the Government of Papua New Guinea, I would like to express my sincere thanks to the Government of Australia, ACIAR, the local advisory committee and all personnel involved with the project for helping the Government and People of Papua New Guinea to improve their understanding of the benefits and costs of various agricultural research programmes undertaken in the country. Special thanks are reserved for the following people for their efforts in ensuring the successful completion of the project:

Mr. Oscar Natera	-	Deputy Secretary, DAL and Chairman of the Project
Dr. Kwabena A. Anaman	-	Local Project Leader, DAL
Mr. Gae Y. Kauzi	-	Senior Project Economist, DAL
Dr. Kevin A. Parton	-	Australian Project Leader, Department of Agricultural Economics and Business Management, University of New England, Armidale, Australia
Prof. Jock R. Anderson	-	Former Australian Project Leader, World Bank, Washington D.C., U.S.A.
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Dr. James G. Ryan	-	Deputy Director, ACIAR, Canberra, Australia
Dr. Kenneth M. Menz	-	Research Programme Coordinator (Economics and Farming Systems), ACIAR, Canberra, Australia
Dr. Jeffrey S. Davis	-	Coordinator, Agricultural Research Priorities Programme, ACIAR, Canberra, Australia

I hope that the results and conclusions reported in this paper will contribute towards assuring continued support for agricultural research in Papua New Guinea from the national Government, the private sector and international organisations.

PAUL J. SAII, OBE
SECRETARY
DEPARTMENT OF AGRICULTURE AND LIVESTOCK

KONEDOBU
15TH MARCH, 1990

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1

INTRODUCTION[1]

Unlike in many other countries, there has been no numerical analysis of the economic results of past agricultural research in PNG. Partly for this reason, agricultural research has a general bad reputation in the country, and this may be undeserved. To produce some evidence about the actual effect of research, two past research projects have been analysed. The two projects have been selected because the scientists who worked on them said that they were successful. Because of the small number of projects, and the way they were selected, the studies are not representative of all past PNG agricultural research. Rather, they are intended to show the benefits of some of the economically successful research that has been carried out in PNG.

2

OIL PALM IN THE PNG ECONOMY

The first oil palms for commercial use were introduced to Papua New Guinea in the 1930s. At that time only the seed was exported for its oil content. The first plantings were very small, and no further development took place until 1966. Then the government of PNG planted 12 four-hectare trial plots of oil palm in several lowland regions of the country. At the same time, the first large-scale oil-palm development began at Hoskins (West New Britain Province) by Harrisons and Crosfield, in partnership with the PNG Government.

Agronomic conditions for oil palm in Papua New Guinea have proven to be very favourable. This has resulted in good yields, with the average PNG yield being well above the world average.

In its early production stage, most of the PNG production came from the plantation sector. Smallholder production then expanded, and today its share of the total national production is one half.

There has been a rapid increase in the production of the crop since its introduction. In 1971/72, a total of 34,000 t of palm oil was produced. Production then rose sharply to nearly 130,000 t (excluding palm kernel) in 1986, despite very low prices in the world market that year. From 1977 to 1986, each year's production exceeded that of the year before, despite fluctuations in prices. The steady increase in production was due to increased plantings, through the new oil-palm projects starting to come into production. At present, production is concentrated in West New Britain and Oro provinces.

For 1977 to 1986, yearly export volumes averaged 68,900 t for palm oil and 8,600 t for palm kernel. The export volume has grown from 24,500 t of oil and 3,000 t of kernel (1977) to 128,900 t of oil and 14,400 t of kernel (1986). This represents a five-fold increase.

Export earnings over the same period averaged K27.2 million, with a peak of K75.7 million in 1984 (due to improved prices and increased production). The crop contributed, on average over the period, about 7.5 per cent of agricultural export earnings, and 3.6 per cent of total PNG export income. Its contribution to the gross domestic product is around one per cent.

A total of about 5,300 rural households are involved in the industry as smallholder producers, while the number of wage earners employed in the industry is about five thousand.

The country is a small supplier of the world market in vegetable oils. PNG provided 2.4 per cent of the world's palm oil exports in 1985 (against 1.0 per cent in 1980). However, its share of the wider market of vegetable oils was still only about 0.8 per cent in 1985 (FAO, various years).

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This paper is a simplified version of Antony, Kauzi and Prior (1988). The analysis of the original paper has not been updated.

The authors are obliged to Jeff S. Davis, Project Coordinator, and Jock R. Anderson, Project Leader, for their contributions to this work. Assistance received from Tremar Menendez and Betty Wilkinson is also gratefully acknowledged.

3

OIL-PALM RESEARCH IN PNG

3.1 A Short History

From 1967, both agronomic and entomological studies have been carried out by the PNG government and the New Britain Palm Oil Development Ltd. (NBPOD). The latter set up agronomic and plant-breeding facilities at the Dami oil-palm research station in West New Britain Province. Government research input was focused on results from agronomic and entomological work on the trial plots and the first commercial plantings.

Further expansion of the commercial oil-palm development occurred in the 1970s, and this lead to the establishment of an industry-funded research institute in 1980. The Papua New Guinea Oil Palm Research Association (PNGOPRA) has its headquarters at Dami, alongside the NBPOD plant-breeding station. Agronomic and pest research is now run by PNGOPRA, while plant breeding and seed production remains under complete commercial control. Funding for PNGOPRA's research is obtained by a levy on producers' fruit production as well as by direct government contribution. Research results have been summarized in annual reports since 1981.

3.2 The Research Project on Insect Pollination

Of all oil-palm research undertaken in PNG, it was probably the work on the introduction of pollinating insects that has had the biggest impact on the industry. This research project is easy to separate from the rest of oil-palm research in its costs and effects, and it is well documented.

Before the introduction of the pollinating weevil, production in PNG oil-palm plantings depended upon the hand pollination of each individual palm over some 40,000 ha. Teams of men collected fresh pollen regularly and mixed it with talcum powder. Estate workers and smallholders then blew this mixture into the female flowers of each palm, using special applicators. As the palms grew taller, this operation became much less efficient, and yields began to diminish. Difficulties in application during the wet season also resulted in poor pollination. Similar problems were also experienced in Malaysia where the oil palm was also an introduced crop, and where hand pollination was practised.

In 1977, the Malaysian subsidiary of Unilever sponsored a research project by the Commonwealth Institute of Biological Control in Cameroon where the oil palm is native. The research discovered that the natural pollination of the oil palm by insects (Syed 1978). The weevil **Elaeidobius kamerunicus** was identified as the most efficient pollinator. After exhaustive testing on a range of host plants (jointly funded by Malaysian and PNG oil-palm companies), the insect was accepted for introduction to Malaysia and PNG in 1980. Work on the PNG side has been - and is being - carried out by PNGOPRA.

1000 pupae of **E. kamerunicus** arrived in PNG on 10 November 1980. Many generations of the weevil were bred in strict quarantine conditions away from any of the main oil-palm developments. It was further tested against important native plants and declared safe to field test, in April 1981, on an isolated four-hectare block near the quarantine laboratory in Morobe Province.

Following excellent initial reports from Malaysia, PNG field testing was cut by several months. The population was bred to many thousands in the laboratory. The first plantation release was in June 1981, in a central position in each area of the oil-palm developments of both West New Britain and Oro Provinces. After two months, five hectares around the release sites were covered with the weevils. Distribution to the whole development followed, using whole male flowers cut from the original five-hectare sites. One flower was placed in every 20 hectares of oil palm. Within five months the whole 40,000 ha was covered with weevils. Hand pollination stopped, mainly because pollen was no longer available from the weevil-covered flowers.

4

ANALYSIS OF COSTS AND BENEFITS

Firm figures could be obtained only up to 1986, so this study is concentrated on the period

1982 to 1986. The effects of the introduction of pollinating insects are likely to continue for a very long time, or indefinitely, if the insects do not disappear for some reason. Therefore, such a restriction of the study period will result in a great underestimation of expected total benefits.

4.1 Objectives

One aim of the present study is to calculate the financial benefits resulting from research. However, agricultural research is expected to satisfy a number of objectives, and financial benefits are only one of them. Agricultural research was evaluated in this paper in the light of objectives for the agricultural sector.

DAL (1987) gave the development objectives of the agricultural sector as:

(1) Economic growth, contribution to government revenue and to the stabilization of the balance of payments.

(2) Employment creation and development with equity.

(3) The strengthening of the role of the agricultural sector in the economy.

(4) Increasing rural living standards.

The list of national objectives was presented by DFP (1988) as: (1) economic growth; (2) employment creation; (3) economic self-reliance; and (4) equity.

4.2 Method

The details of the analytical method are not essential to the main thrust of this paper. They are described at length by Antony, Kauzi and Prior (1988). In broad terms, the calculation follows usual methods of project appraisal (Gittinger 1982). In this paper, incremental gross benefits of the project are calculated as follows:

(1) Collect actual production figures (production with project),

(2) calculate with-project producers' surpluses[2],

(3) estimate the level of production that would have been possible without the project over the same time period (production without project),

(4) calculate without-project producers' surpluses, and

(3) subtract without-project gross margins from with-project gross margins.

Incremental net benefits are defined in this study as incremental gross benefits less research costs. Incremental benefits are discounted to account for the effect of time and summarized, resulting in the net present value (NPV). The discount rate was 10 per cent, the same figure that is used for project appraisal by the Department of Agriculture and Livestock (DAL). The internal rate of return (IRR) shows the "interest rate" returned on the invested research funds through increased production.

NPV and IRR are calculated at the national level. The price used for this purpose is the f.o.b. export price. Incremental net benefits are arrived at by deducting foreign-exchange expenditures from total export revenue. This reflects the fact that at the national level only those expenditures are losses to the country that actually leave the country. Payment for goods and services within the country benefit the PNG economy. On the basis of detailed cost components available for one mill, two thirds of domestic transport and mill-processing costs were used to represent foreign-exchange costs.

Incremental benefits to smallholders and plantations are distributional effects that are worked out on a different basis from the national effects. Smallholders' benefits are calculated at farmgate prices that are already net of variable cash expenditures (mainly transport costs). Planters' surpluses could not be calculated separately from the processing phase. Smallholder fruit is bought by the mills, and thus a firm price exists for its valuation. However, plantations and mills are parts of the same companies and, even if some accounting price for valuing plantation fruit could have been found, its worth would have been doubtful. Planters' surpluses, therefore, include the margins of the processing phase. Variable costs of planters/processors, included here, are: (a) pollination costs (in the without-project case); (b) costs of harvesting and transporting the fruit; (c) purchase price of smallholder fruit; (d) processing and produce-transport costs; and (e) export taxes.

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[2] In this study, producers' surpluses are equivalent to gross margins.

On the basis of the development objectives listed in section 4.1, other distributional effects are also followed. Apart from the distribution between smallholders and plantations, benefits redistributed to the government are also worked out. Of the taxation effects, only export tax is calculated, since company taxation and the effect of insect pollination on it could not be covered in the study. The expected balance of stabilization funds is calculated. No other analyses of distributional effects are carried out in the study. As only some selected distributional effects are looked at, the benefits of individual groups do not add up to the national benefits.

4.3 Calculation of Research Costs

Costs of the research consisted of: (a) the employment of one entomologist on the project; (b) "overhead" (capital, consumable and administration) costs of the research institute, allocated on a per-research-scientist basis; and (c) payments made to the Malaysian company to contribute to the costs of the original research on insect pollination.

4.4 Benefits from Research

4.4.1 Without-research scenario

If the weevil had not been introduced, assisted pollination would have been continued in PNG palm-oil production. This would have meant lower yields and higher production costs.

Most of the costs of doing assisted pollination (those of pollen collection and distribution) were paid by the provincial DPI and plantations. There were no separate accounts, but provincial DPI costs in WNBP were estimated as K15,000 in 1981 (A.J. Barnes, personal communication). The estimated figure of K10,000 was used for Oro. Plantations spent some K65/ha on pollination in 1980 (Prior 1983). Smallholders were supposed to work 2.5 days every week pollinating their palms but, according to local sources, 1.5 days was closer to the actual time spent.

The yield-reducing effect of the absence of the weevil has been estimated by comparing detailed yield records at various locations before and after the introduction of the weevil. All other possible yield-influencing factors are thus ignored. Still, this is not likely to result in error, as the only change in production techniques over these years was the weevil introduction. It has been concluded that, without the pollinating insects, yields in West New Britain would have been some 40 per cent less in 1982 than the actual, and around 1/3 less in the following years. In Oro province, the initial improvement in fruit set was much smaller (although this would increase as the palms become older and taller). A yield-reduction figure of four per cent was used for Oro.

Another result of better fruit set is the increase in extraction rates in the oil mills, as the fruit-to-frame ratio in the bunches increases. It is assumed that, without insect pollination, the extraction rates of oil and kernel would have stayed at the same level as before the introduction of the weevil. In fact, this is an assumption that causes the benefits of insect pollination to be underestimated. As palms grow taller, assisted pollination becomes quite difficult. Consequently, under continued hand pollination, fruit set and the extraction rates would have declined. This stage would have already been reached in some of the earlier plantings in West New Britain. However, the yield-reducing effect of trees growing tall was not accounted for when estimating without-project yields or extraction rates. Essentially, before-project figures were used throughout this analysis in an attempt to avoid the overestimation of benefits.

A basic assumption of the without-project scenario is that there was no such international spillover of the research on the insect-pollination of oil palm in PNG that contributed to an increase in the supply of oil-palm products in other countries. In particular, the assumption is that PNG research on weevil pollination did not lead to a higher Malaysian production. Only if this assumption holds can one use the same international market price without project as was observed with the project. Otherwise, increasing international supply would have reduced with-project prices, while without-project prices would have been higher.

According to the Director of PNGOPRA, "there has been no substantial increase in yield due to the introduction of the weevil into Peninsular Malaysia; only the benefit in Sabah is similar to that experienced in PNG" (H.L. Foster, personal communication). The palm-oil production of

Sabah and Sarawak was 10 per cent of the Malaysian total in 1985. Thus, even if PNG research had had and impact in Malaysia, it did not influence world prices by the way of significantly increasing Malaysia's crop.

4.4.2 With-research situation

At the national level, the main benefit is the added production. Other benefits are actual costs savings for DPIs and planters/processors and the frreing of own labour for smallholders. These latter benefits are considered as distributional effects.

When it comes to calculating distributional effects, the cost savings of stopping assisted pollination can be measured in money terms for the plantation sector as well as for DPI. It is much more difficult to calculate the value of freed smallholder labour. Smallholders have little opportunity of finding paid employment to utilize the day a week when they suddenly do not have to work. This extra time is most likely to be used partly for gardening - thus improving the supply of subsistence food and, thereby, nutritional status - but mainly as leisure time. As mentioned before, if fruit price falls below some K10/t FFB, smallholders cease to harvest their crop. Since harvesting a tonne of fruit takes 1-1.5 man-days (AgBank 1986), the value of subsistence labour seems to be in the range of K7 to K10/man-day. Again, in order to arrive at a conservative figure, K7/man-day was used in pricing the smallholders' labour freed by stopping assisted pollination.

Separate data series could be found for smallholder and plantation production in West New Britain and Oro provinces (DAL sources). Therefore, benefits of both smallholders and plantations can be separated for the two provinces.

Financial effects on price-stabilization funds have been calculated by valuing smallholder production at both gross settlers' (that is, before stabilization) and farm-gate (stabilized) prices. However, since these prices are averages across the estates, the resulting total figures do not necessarily equal the actual stabilization payments.

Some government benefits from the new technology could be measured quite precisely. An export tax of 2.5 per cent is levied on all exports, and the difference between the actual and without-project situations is easily calculated.

Data described for the above parameters were drawn from both industry and DAL sources. A full data set was not yet available for 1986, and the missing data (such as extraction rates for WNB) have been calculated on the basis of previous years' figures.

5

DISCUSSION

Despite the very conservative analysis (most of all, stopping it in 1986), returns to the research project proved outstanding (Appendix). Due to better pollination, an extra 425,000 tonnes of fresh fruit bunch (FFB) have been produced during the period 1982 through 1986.

At the national level, in discounted values and at 1986 prices, a K315,000 research investment resulted in a gross financial benefit of around K89.5 million. In other words, if research on insect pollination of oil palm in Papua New Guinea had not been undertaken, and the resulting new technology not introduced, K315 thousand could have been saved in direct costs, at the expense of not earning about K89.5 million. Net benefits to PNG after deducting research costs amount to K89.2 million.

The rate of return (IRR) on the investment was in excess of 800 per cent. This is much higher than that reported in most previously documented cases (Ruttan 1982).

With the exception of profits sent out of PNG by the companies and the foreign-exchange costs of the increased production, the benefits of the research were captured by Papua New Guinea. Due to the country's small supplier role, increased PNG production could not have driven down international vegetable-oil prices. In this case, producers get the same price for their additional production as they would have received in the without-project case.

Within the country, the biggest beneficiaries have been shareholders (including the PNG Government) in the companies owning plantations and oil mills. Their gross margin (including the processing margin on the smallholders' and plantations' crops as well) has

increased by about K78.3 million due to the introduction of the insects.

On the basis that one tonne of FFB required around one man-day of pollination labour under hand pollination, more than two million man days (around 20,000 man years) of labour have been freed over the same period. The plantation sector made direct cash savings through lower labour requirements. It is difficult to tell, however, exactly how the smallholders used their newly-available time.

Smallholders had a net increase in their revenue of around K12.5 million, including K500,000 estimated as the value of freed smallholder labour. (Actual wage savings by the plantation sector were around K4 million, on a production almost the same size as that of the smallholders.)

The end to assisted pollination did not disadvantage the previously-employed labourers either. All adult labour not needed in hand pollination was employed either in harvesting the increased crop or as general plantation labour. Only school-aged children have actually lost income-earning opportunity, but this probably improved school attendance.

The stabilization fund showed a small net gain of K116,000, meaning that producers received almost as much from the fund in bad years as they paid into it in good years.

The public shared in the benefits from the new technology in four ways:

(i) Benefits to the provincial administrations were around K109,000 for WNB and around K73,000 for Oro.

(ii) The national government profited from the cost savings and production increases in the plantation sector as a shareholder. Since neither the payment of dividends by the companies nor the effect of new technology on dividends have been followed up in the present analysis, these benefits have not been calculated.

(iii) The export tax has yielded the PNG government some K2.5 million in excess of what the revenue would have been without the weevil, over the five-year period 1982 to 1986.

(iv) Tax collection from companies may well have increased, but this has not been followed up either.

Regional effects of the new technology have been uneven. The labour-saving effects of stopping hand pollination have been similar in West New Britain and Oro provinces, depending only on the age and, therefore, the height of the palms. The yield increase has been much smaller in Oro, however, for unknown reasons. Consequently, smallholders gained less in terms of money income than plantations in Oro (through wage savings), or smallholders in West New Britain.

The above benefits are calculated on the basis of no research spillover from PNG to Malaysia. The Malaysian crop has not increased significantly after the introduction of the weevil. Thus, even if Malaysia would not have accepted the weevil without PNG research, PNG research did not affect world prices.

6

CONCLUSION

The research on insect pollination of oil palm in PNG proved a well-chosen project, with outstanding economic results. Total benefits were significant, and their distribution included smallholders, as well as the public sector. In fact, benefits to smallholders and the public sector have been underestimated in this summary analysis, due to measurement problems and lack of data.

The measurement of total benefits has been restricted to a short time period. Since the pollinating insects are expected to continue their beneficial work indefinitely, total benefits may well be many times those calculated in the present study.

The lack of evidence about the effect of insect pollination on previously hired labourers and smallholders through labour savings is the main shortcoming of the present study. Without such data, the evaluation of distributional consequences is incomplete.

Few conclusions can be drawn about PNG agricultural research in general - agricultural research elsewhere - on the basis of the present analysis. The research project studied was an adaptive piece of research. Much agricultural research in PNG is likely to fall in this category, but most will cost much more than the research project examined here. This means higher expenditures and lower returns on research funds, especially if there is a long lag between research expenditures and adoption of the resulting new technology (that is, benefits are heavily discounted compared to costs). The advantage of the new technology over the old is usually far narrower than in the present case.

However, this study demonstrates that the potential for high returns to research in PNG most definitely exists. Realistic identification of the problem and possible research options is needed for research success. Scientists must be aware of the whole process of research and adoption, and have to identify research projects on the basis of expected benefits. In this way the chance of generating research results that do not improve the welfare of the country can be reduced.

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APPENDIX

CALCULATION OF RESEARCH BENEFITS

Details of the calculation are given in the following tables. Table A1 is a summary of the basic data that have been used. Table A2 shows how gross benefits were calculated for the without-project case, both at the national level and for smallholders, plantations, the stabilization fund and the government. Table A3 contains a similar calculation of gross benefits for the with-project case. The calculation of the overall return to research resources from national-level data is detailed in Table A4, while incremental gross benefits for smallholders, plantations, the stabilization funds and the government are shown in Table A5.

Table A1
Basic Parameters

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
BASIC PARAMETERS									
Discount rate (%)	10								
Base year	1986								
CPI (1986 = 100%)		71.2	75.1	80.3	87.2	91.1	95.0	100.0	
Farmgate prices (K/t FFB)									
WNB		16.1	10.6	23.6	34.7	62.3	48.1	20.6	
Oro		21.1	10.6	11.8	41.1	51.3	30.6	24.9	
Levy(-), Bounty(+) (K/t)									
WNB		-4.9	.6	11.6	.7	-26.7	-4.9	20.3	
Oro		.1	.6	-.2	7.1	-37.7	-22.4	24.6	
Gross settlers' prices (K/t FFB)									
WNB		21.0	10.0	12.0	34.0	89.0	53.0	.3	
Oro		21.0	10.0	12.0	34.0	89.0	53.0	.3	
Oil price (f.o.b., K/t)		532	323	282	305	549	487	240	
Kernel price (f.o.b., K/t)		192	117	140	152	324	227	68	
Yields (w/o project) (FFB, t/ha)									
WNB Pl		18	18	18	18	18	18	18	
Oro Pl		18	18	18	18	18	18	18	
Production (with project) (FFB, t)									
WNB S/H		108810	96919	166904	148772	207025	212896	192888	
Pl		81256	86481	148052	128128	129412	146861	163083	
Oro S/H		339	5352	23961	45267	66612	78000	102000	
Pl		7246	22203	59681	78584	79247	107116	99389	
Pollination labour use (man-days/ha)									
WNB		17	17	17	17	17	17	17	
Oro		17	17	17	17	17	17	17	
Pollination field costs (K/ha)									
WNB Pl		65.1	64.7	69.2	75.1	78.5	81.8	86.2	
Oro Pl		65.1	64.7	69.2	75.1	78.5	81.8	86.2	
Harvesting and transport costs (K/t FFB)									
WNB S/H				9.31	10.11	10.56	11.38	11.98	
Pl				10.51	11.41	11.92	11.48	12.08	
Oro S/H				9.31	10.11	10.56	11.38	11.98	
Pl				10.51	11.41	11.92	11.48	12.08	

Table A1
Basic Parameters
(continued)

Item		1979	1980	1981	1982	1983	1984	1985	1986	Total
Extraction Rates (w/o project) (% of FFB)										
WNB	Oil				18.0	18.0	18.0	18.0	18.0	
	Kernel				3.7	3.7	3.7	3.7	3.7	
Oro	Oil				21.0	21.0	21.0	21.0	21.0	
	Kernel				3.7	3.7	3.7	3.7	3.7	
Extraction Rates (with project) (% of FFB)										
WNB	Oil				21.0	23.0	23.9	22.8	22.8	
	Kernel				3.5	4.7	4.6	4.4	4.4	
Oro	Oil				21.8	21.8	21.7	21.7	22.4	
	Kernel				4.4	3.6	3.5	3.4	3.7	
Produce quantities (with project) (t)										
WNB	Oil		36068	34260	70172	64104	84200	83966	81161	
	Kernel		4392	3296	11221	11375	13680	13860	15663	
Oro	Oil		1499	5903	18616	27025	38436	43860	45111	
	Kernel		215	1093	3750	4986	6104	6950	7451	
Processing and produce-transport costs										
WNB	Processing (K/t FFB)				15.0	16.0	17.0	17.0	18.0	
	Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
	Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
	Total (K/t FFB)				15.5	16.5	17.4	17.4	18.5	
Oro	Processing (K/t FFB)				15.0	16.0	17.0	17.0	18.0	
	Oil t'port (K/t)				2.2	2.3	1.6	1.7	1.7	
	Kernel t'port (K/t)				3.5	3.4	3.4	3.8	4.0	
	Total (K/t FFB)				15.6	16.6	17.5	17.5	18.5	

Source: DAL and industry sources

Table A2
Hand Pollination: Gross Benefits without Project

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
HAND POLLINATION: Gross Benefits Without Project									
1 National benefits									
Production									
FFB (t)				305394	332088	399047	454732	467467	1958727
Oil (t)				57384	63348	76036	87192	89953	373913
Kernel (t)				11300	12287	14765	16825	17296	72473
Produce value (K'000)									
(@ f.o.b. price)				17764	21189	46527	46282	22765	154527
less: Foreign-exchange costs (K '000)									
(2/3 domestic t'port, processing)				5009	5847	7371	8654	9398	36280
Economic surplus (K '000)				12755	15342	39156	37627	13367	118247
2 Smallholders' benefits									
Production (FFB, t)									
WNB S/H				119217	114440	159250	163766	148375	705049
Oro S/H				23039	43526	64050	75000	98077	303692
Produce value (K '000)									
(@ farmgate price)									
WNB S/H				2814	3971	9921	7877	3057	27640
Oro S/H				271	1788	3283	2293	2441	10077
Pollinating labour (K '000)									
(K7/man-day @1981)									
WNB S/H				50	48	65	66	61	290
Oro S/H				10	18	26	30	40	125
S/H producer surplus (K '000)									
WNB S/H				2764	3923	9857	7811	2996	27350
Oro S/H				262	1770	3257	2262	2401	9952
3 Plantations'/Processors' benefits									
Production (FFB, t)									
WNB S/H				119217	114440	159250	163766	148375	705049
WNB Pl				105751	98560	99548	112970	125448	542278
Total				224969	213000	258798	276736	273824	1247326
Oro S/H				23039	43526	64050	75000	98077	303692
Oro Pl				57386	75562	76199	102996	95566	407709
Total				80425	119088	140249	177996	193643	711401

Table A2
Hand Pollination: Gross Benefits without Project
(continued)

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
Produce quantities (t)									
WNB Oil				40494	38340	46584	49813	49288	224519
Kernel				8324	7881	9576	10239	10131	46151
Oro Oil				16889	25008	29452	37379	40665	149394
Kernel				2976	4406	5189	6586	7165	26322
Produce values (K '000)									
WNB				12585	12892	28677	26583	12518	93254
Oro				5179	8297	17851	19699	10247	61273
less: Value of S/H fruit (K '000) (@ gross settlers' price)									
WNB				1431	3891	14173	8680	45	28219
Oro				276	1480	5700	3975	29	11461
Pollination costs (K '000)									
WNB Pl				406	411	434	514	600	2366
Oro Pl				221	315	332	468	457	1794
Harvest & field t/port costs (K '000)									
WNB Pl				1111	1125	1187	1297	1516	6235
Oro Pl				603	862	908	1182	1155	4711
Processing and produce-t/port costs (K '000)									
WNB				3493	3524	4506	4825	5055	21403
Oro				1254	1979	2449	3113	3585	12378
Export tax (2.5%) (K '000)									
WNB Pl				315	322	717	665	313	2331
Oro Pl				129	207	446	492	256	1532
Planters'/processors' surplus (K '000)									
WNB				5829	3619	7660	10603	4990	32700
Oro				2696	3454	8015	10468	4764	29397
4 Stabilisation funds									
Levy(-), Bounty(+) (K '000)									
WNB S/H				1383	80	-4252	-802	3012	-579
Oro S/H				-5	309	-2417	-1682	2412	-1384
5 Government cost/revenue effects									
Pollination costs, prov. DPI (K '000)									
WNB				16	16	16	16	16	79
Oro				11	11	10	10	11	53
Nat. gov't tax revenue on exports				444	530	1163	1157	569	3863

Source: DAL and industry sources

Table A3
Weevil Pollination: Gross Benefits with Project

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
WEEVIL POLLINATION: Gross Benefits With Project									
1 National benefits									
Production									
FFB (t)				398598	400751	482296	544873	557360	2383878
Oil (t)				88788	91129	122636	127826	126272	556651
Kernel (t)				14971	16361	19784	20810	23114	95040
Produce value (K'000)									
(@ f.o.b. price)				27134	30281	73737	66975	31877	230005
less: Foreign-exchange costs (K '000)									
(2/3 domestic t'port, processing)				6558	7082	8946	10397	11233	44217
Economic surplus (K '000)				20576	23199	64791	56578	20644	185788
2 Smallholders' benefits									
Production (FFB, t)									
WNB S/H				166904	148772	207025	212896	192888	928485
Oro S/H				23961	45267	66612	78000	102000	315840
Produce value (K '000)									
(@ farmgate price)									
WNB S/H				3939	5162	12898	10240	3973	36213
Oro S/H				282	1860	3415	2384	2539	10480
S/H producer surplus (K '000)									
WNB S/H				3939	5162	12898	10240	3973	36213
Oro S/H				282	1860	3415	2384	2539	10480
3 Plantations'/Processors' benefits									
Production (FFB, t)									
WNB S/H				166904	148772	207025	212896	192888	928485
WNB Pl				148052	128128	129412	146861	163083	715536
Total				314956	276900	336437	359757	355971	1644021
Oro S/H				23961	45267	66612	78000	102000	315840
Oro Pl				59681	78584	79247	107116	99389	424017
Total				83642	123851	145859	185116	201389	739857

Table A3
Weevil Pollination: Gross Benefits with Project
(continued)

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
Produce quantities (t)									
WNB Oil				70172	64104	84200	83966	81161	383603
Kernel				11221	11375	13680	13860	15663	65799
Oro Oil				18616	27025	38436	43860	45111	173048
Kernel				3750	4986	6104	6950	7451	29241
Produce values (K '000)									
WNB				21359	21281	50658	44038	20544	157880
Oro				5775	9000	23079	22937	11333	72125
less: Value of S/H fruit (K '000) (@ gross settlers' price)									
WNB				2003	5058	18425	11283	58	36828
Oro				288	1539	5928	4134	31	11920
Harvest & field t/port costs (K '000)									
WNB Pl				1556	1462	1543	1686	1971	8217
Oro Pl				627	897	945	1230	1201	4899
Processing and produce-t/port costs (K '000)									
WNB				4890	4581	5858	6273	6571	28173
Oro				1304	2058	2547	3237	3728	12873
Export tax (2.5%) (K '000)									
WNB Pl				534	532	1266	1101	514	3947
Oro Pl				144	225	577	573	283	1803
Planters'/processors' surplus (K '000)									
WNB				12377	9647	23566	23694	11430	80715
Oro				3412	4282	13082	13763	6090	40630
4 Stabilisation funds									
Levy(-), Bounty(+) (K '000)									
WNB S/H				1936	104	-5528	-1043	3916	-615
Oro S/H				-6	321	-2514	-1750	2508	-1440
5 Government cost/revenue effects									
Pollination costs, prov. DPI (K '000)									
WNB				0	0	0	0	0	0
Oro				0	0	0	0	0	0
Nat. gov't tax revenue on exports (K '000)				678	757	1843	1674	797	5750

Source: DAL and industry sources

Table A4
Returns on Research Resources: No Spillover

Item	1979	1980	1981	1982	1983	1984	1985	1986	Total
RETURNS ON RESEARCH RESOURCES									
National econ. surplus current (K '000)				7821	7857	25635	18951	7277	67541
National econ. surplus real 1986 (K '000)				9739	9011	28140	19948	7277	74115
National econ. surplus disc. 1986 (K '000)				14259	11993	34049	21943	7277	89521
Research costs current (K '000)	9.0	5.0	57.4	16.5	45.8	11.1	24.7	11.7	181
Research costs, real 1986 (K '000)	13	7	76	21	53	12	26	12	219
Discounted 1986 value of research costs	25	12	123	30	70	15	29	12	315
Net present value	89206								89206
Benefit/cost ratio	284								
Internal rate of return (%)	818								

Table A5
Selected Distributional Effects

Item		1979	1980	1981	1982	1983	1984	1985	1986	Total
SELECTED DISTRIBUTIONAL EFFECTS										
(Incremental gross benefits) (K '000)										
Current values										
Smallholders' surplus	- WNB				1175	1240	3041	2430	978	8863
	- Oro				20	90	157	122	138	528
Plant's'/proc's' surplus	- WNB				6548	6029	15906	13091	6441	48015
	- Oro				716	828	5068	3295	1326	11233
Stabilisation funds					553	36	-1372	-308	1000	-91
Provincial government	- WNB				16	16	16	16	16	79
	- Oro				11	11	10	10	11	53
National government					234	227	680	517	228	1887
Foreign-exchange costs					1549	1235	1574	1743	1836	7937
Real 1986 values										
Smallholders' surplus	- WNB				1463	1422	3338	2557	978	9758
	- Oro				25	103	173	129	138	568
Plant's'/proc's' surplus	- WNB				8154	6914	17460	13780	6441	52750
	- Oro				891	950	5563	3469	1326	12199
Stabilisation funds					689	42	-1506	-324	1000	-100
Provincial government	- WNB				20	19	17	16	16	88
	- Oro				13	12	11	11	11	59
National government					292	261	747	545	228	2071
Foreign-exchange costs					1929	1416	1728	1834	1836	8744
Disc. 1986 values										
Smallholders' surplus	- WNB				2142	1892	4039	2813	978	11865
	- Oro				37	137	209	141	138	663
Plant's'/proc's' surplus	- WNB				11939	9202	21127	15158	6441	63867
	- Oro				1305	1264	6731	3816	1326	14442
Stabilisation funds					1008	56	-1823	-357	1000	-116
Provincial government	- WNB				29	25	21	18	16	109
	- Oro				19	17	14	12	11	73
National government					427	347	904	599	228	2504
Foreign-exchange costs					2825	1885	2091	2018	1836	10654