BREEDING AND QUALITY ANALYSIS OF RAPESEED

ACIAR Projects CS1/1984/069 and CS1/1988/039

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Executive Summary

This study is an ex-post, economic assessment of two projects supported by ACIAR and concerned with the breeding and quality analysis of rapeseed in Australia and China. These projects were carried out sequentially with the first one commencing on 1 July 1986. The second one was completed on 30 June 1991. The projects were essentially an exchange of knowledge and germplasm of rape (*Brassica napus*)* between plant breeders in Australia and China. The projects resulted in the release of varieties of rape that yielded improved seed in Australia, China and other developed and developing countries.

An economic evaluation of these projects was made in 1991 and the results published in Chudleigh (1991). Assumptions made in the 1991 analysis have now been updated. Despite the increased information available about the projects and their outcomes, it was still necessary to make various assumptions, particularly with regard to the valuation of benefits and their attribution to the ACIAR projects.

The benefits accruing to both Australia and China are now estimated to be a little less than those estimated in 1991. Among the reasons for this were difficulties experienced in hybrid seed production in Australia and the reduced benefits in China because improved rapeseed is not always segregated at crushing plants. Nevertheless, the 1999 analysis demonstrates that the projects have provided significant benefits, especially to China, as tabulated below.

The estimated investment criteria for the combined projects (discount rate is 5%)

	Net present value (A$ million as of 1996)	Benefit–cost ratio	Internal rate of return (%)
Estimated over 30 years from 1985–86	34	14	33
Estimated over 13 year period 1985–86 to 1998–99	9	4	28

It is concluded that the projects have provided a rate of economic return of at least 28% on the funds invested in both Australia and China. It is likely that as time passes the returns will be considerably higher than estimated

* For convenience and because we are primarily concerned with its seed, we will refer to rapeseed rather than rape for the rest of this report.

here because the areas planted to new, open-pollinated and hybrid varieties of rape will expand in China in the future. Further, there are likely to have been significant benefits to the rest of the world, though these are not estimated here.

1. Introduction

This study provides an economic assessment of projects CS1/1984/069 and CS1/1988/039, which were supported by ACIAR from 1986 to 1992. Both projects were associated with rape breeding in the People's Republic of China and Australia. The projects were focused on the application of Australian plant breeding expertise and materials, including equipment, germplasm, and testing methods, to Chinese plant breeding, and on the use of Chinese germplasm in an Australian hybrid rapeseed development program.

The objectives of the first project were to:

- develop a range of 'double low' germplasm (segregating material) which can be selected in different localities to produce open pollinated varieties (double low is a term which describes varieties which have oil low in erucic acid and meal which is low in glucosinolates);
- modify the genetic background of double low lines … to improve their suitability for hybrid seed production;
- develop double low … inbred lines … for China;
- develop appropriate analytical methods for screening and testing breeders lines for erucic acid and glucosinolate content:
- develop appropriate analytical techniques for testing seed delivered at receival depots.

The second project's objectives were to:

- evaluate and reselect 'double low' quality rapeseed lines for China;
- develop [further] 'double low' … genetic material … adapted to China;

- develop, monitor and support the quality analysis of rapeseed in the breeding programs of the Institute of Oil Crops Research (IOCR) and the Jiangsu Academy of Agricultural Sciences (JAAS);
- develop an appropriate method of monitoring glucosinolate levels for seed lots at receival depots.

The projects, carried out sequentially, involved plant breeders from an Australian private company, Pacific Seeds, located in Toowoomba, Queensland, and plant breeders and other personnel from the IOCR in Wuhan, Hubei Province, People's Republic of China.

This evaluation updates a 1991 economic evaluation of these two projects (Chudleigh 1991). In 1991, no varieties had been released in either China or Australia as a result of the projects. Assumptions made at that time have been revised to take account of events in the eight years between 1991 and 1999. The framework for the evaluation has also been restructured in the light of the greater amount of information now available.

Section 2 of this report provides the technical background to some important issues relating to aspects of rapeseed quality improvement that were the focus of the projects in China. This information is provided to aid understanding of the assumptions made later in the evaluation and interpretation of the results. Section 3 describes rapeseed production in China and Australia before the projects began and the circumstances leading to implementation of the first project. The outputs from the projects and their translation into benefits for China, Australia, and the rest of the world are described in sections 4, 5 and 6.

The quantitative investment analysis for the projects is provided in Section 7. First, project costs are described. Second, sets of assumptions used in the analysis are presented. These assumptions relate to the estimation of benefits for both Australian and Chinese production systems, the attribution of benefits and the implications for prices. Third, results of the investment analyses, including those of sensitivity analyses, are reported. Section 8 gives the conclusions of the study.

2. Technical Background

Rape (*Brassica napus*) is an oilseed crop belonging to the brassica family and grown in temperate-climate zones. China is the world's largest producer of rapeseed, growing both spring and winter crops. Canada, India, and European countries are also large producers. Rape is a relatively new crop in Australia, but production has increased rapidly since the 1970s and particularly since the early 1990s. Australia is now in the top ten rapeseed-producing countries in the world.

Since the late 1960s, plant breeders have been selecting rapeseed for so-called 'double-low' varieties. These are varieties that contain lower amounts of two chemical compounds: erucic acid in the oil and glucosinolate in the meal. The meal is what remains after the oil has been crushed from the seed. The oil and meal derived from these so-called 'double-low' varieties are considered superior to those derived from varieties that have higher levels of erucic acid and glucosinolates ('double-high' varieties). The reasons for this are given below.

Canadians were the first to breed plants yielding double-low varieties of rapeseed. Following this, they changed the name of the crop from rapeseed to 'canola' to differentiate it from double-high rapeseed. Australian farmers began growing double-lows in the early 1980s and have generally adopted the new name 'canola'. European countries changed to double-lows in the early 1990s.

Because this report covers both double-lows and double-highs, the older term 'rapeseed' is used.

Erucic Acid

The oil from rapeseed consists of saturated and unsaturated fatty acids. Double-low rapeseed oil is low in saturated fatty acids, which are generally accepted to be undesirable in the human diet because they lead to the production of cholesterol in the body.

Rapeseed oil contains mono- and polyunsaturated fatty acids. Both types are deemed to be more desirable than saturated fatty acids, although the relative proportions of the two are thought also to be important.

Erucic acid is a mono-unsaturated fatty acid that can contribute up to 40% of the oil crushed from the older varieties of rapeseed. The results of experiments in the 1960s cast suspicion on erucic acid as a cause of heart lesions in a particular strain of rats. While the evidence for harmful effects not conclusive, a number of countries began to move to production of low erucic acid types of rapeseed. China and India are two of the world's largest producers and consumers of rapeseed oil. There are no known human health problems due to rapeseed oil consumption in those countries, but the amounts in the diet are small because it is used only as a cooking oil.

Glucosinolates

Rapeseed is crushed to extract its oil. The residue is rapeseed meal, which is a potentially valuable product for livestock feeding because of its high protein content and desirable amino acid composition. However, meal derived from rapeseed with high glucosinolate levels has been shown to depress the appetite of animals and lower their productivity. The material is harmless in the seed but when the seed is crushed the glucosinolates break down into isothiocyanates, which have a distinctive flavour disliked by animals and may thereby depress weight gain. Also, the isothiocyanates interfere with the uptake of iodine in monogastric animals such as chickens and pigs which may then develop goitres. High levels of isothiocyanates can kill chickens.

3. Pre-Project Situation

China

In 1986, before the project began, China was producing about 5 million tonnes per year of rapeseed. It was the world's largest producer.

The Chinese were concerned about the high levels of erucic acid in their rapeseed oil, because it affected the product's market image. Improving this image was particularly important to the Chinese, because they were attempting to position their industry to export rapeseed or oil to Japan, where the Canadians had already established a market for oil with low erucic acid levels.

Also important to China was the potential to increase the use of rapeseed meal as an animal feedstuff. The meal had thus far been used predominantly as a fertiliser. The fact that it contained high levels of glucosinolates severely restricted the amount of rapeseed meal that could be used as an animal feed. The Chinese Government was aiming to increase the country's output of animal products but saw feed supply problems as limiting this endeavour. Breeding double-low varieties of rapeseed was seen as an opportunity to achieve higher levels of self-sufficiency in regions where locally produced animal feed was scarce.

Australia

At the time the project commenced, Australian production was centred on Victoria and southern New South Wales but had been expanding into Queensland and northern New South Wales.

Most of the rapeseed varieties grown in Australia were open-pollinated. To obtain higher yields and improve disease resistance, Pacific Seeds had decided, in the late 1970s, to move away from open-pollinated and towards hybrid rapeseed varieties. Hyola 40, one of the hybrid varieties bred by Pacific Seeds, was available in these northern or shorter season areas. Unfortunately, it was susceptible to disease (blackleg) and its market penetration was short lived.

As regards yield, the varieties best suited to Australian conditions appeared to be those from Japan. The Chinese varieties, which are based on Japanese varieties, were known to grow well in Australia despite the shorter growing season here. Also seen as an advantage was the vigorous growth habit of the Chinese varieties, their greater numbers of side branches providing yield stability in shorter season regions. Also, the germplasm from China was expected to increase the characters available to the Australian breeders in the production of hybrids.

In 1980 (before ACIAR had been established), an Australian mission to China visited the Chinese Academy of Agricultural Sciences and the Jiangsu Academy of Agricultural Sciences at Nanjing. The Chinese were interested in the Australian double-low breeding procedures and screening methods. In 1981, a visit by Pacific Seeds personnel to China maintained contacts and discussed methods of breeding double-low varieties.

A visit to Australia by the Chinese plant breeders followed in 1983 and a decision in principle was made by Pacific Seeds in 1983 to work with the Chinese. The Chinese were most interested in quality analysis, especially how to measure glucosinolates and erucic acid contents when breeding for double-lows. They were keen to change from double-high to double-low varieties of rapeseed.

Pre-project planning focused on plant breeding . In 1985–86 the first ACIAR project was implemented. It was to involve collaboration on germplasm exchange and breeding technologies, development of equipment, and training. As elaborated later, the focus of the work changed as the projects developed.

4. Project Outputs and Outcomes for China

Development of Open-pollinated, Double-low Varieties

The most significant output for China as a result of the ACIAR projects has been the successful breeding in China, and the release there, of four open-pollinated varieties yielding double-low rapeseed: Zhong Shuang Nos 1–4.

The most successful of these new varieties is Zhong Shuang No. 4. About 3.4 million mu or 227,000 ha (1 ha = 15 mu) were planted to this variety in the 1996–97 season and somewhat more in 1997–98. The reasons for success of Zhong Shuang No. 4 are its adaptability, resistance to disease, and higher oil content (3–5% increase) compared with traditional varieties. It has the same or a slightly higher seed yield than the traditional, double-high variety that it displaced. There are more open-pollinated varieties to be released in the next five years.

The area of open-pollinated, double low varieties harvested by year is shown in Table 1.

Table 1. Areas sown to new open-pollinated, double-low rapeseed varieties in China

Year ending 30 June	Area (million mu)[a]
1994	0.5
1995	1.2
1996	2.0
1997	3.4
1998	3.5[b]

[a] *15 mu = 1 ha*
[b] *Estimate*

The new varieties became available in about 1990. The Hubei Crops Variety Examination and Approval Committee subsequently approved their release. Most varieties were released around 1993, with release dates varying by province.

The ACIAR projects transferred to IOCR the plant-breeding skills that allowed the Institute to build capacity and obtain additional resources from the Chinese Government, particularly for the development of disease-resistance varieties, though this did entail the use of predominantly Chinese germplasm and some genetic material from Poland.

That Australian germplasm was not used in the development of the open-pollinated varieties is immaterial. What the ACIAR projects provided was the science and technology , particularly in relation to measuring and analysing glucosinolates and erucic acid. The ACIAR projects also provided equipment and training for rapeseed improvement. These contributions helped the Chinese breed the double-low varieties. The staff of IOCR concur that the new varieties are a direct result of the Australia–China collaboration.

While Zhong Shuang No. 4 has a higher oil content, processors generally do not pay farmers on the basis of oil content. Hence, in many cases the additional oil content benefits the purchaser of the seed, rather than the farmer. In fact, farmers can be actually worse off growing the new varieties because of their higher seed cost and only marginally improved seed yields. The fact that their seed is not commonly segregated from other seed when it reaches the processor means that they are not paid for its higher oil content or higher value meal.

There is no price control over commercial products from rapeseed. There is a minimum price for grains, but not for rapeseed. The control of varieties is to some extent influenced by IOCR and the seed companies. This applies to both open-pollinated varieties and the hybrid varieties that are now being developed.

Local governments have told farmers of the benefits of Zhong Shuang No. 4 and farmers are now testing it in many areas. In general, there is no local government policy covering quality control or incentives for better quality. For the most part, farmers are growing the new varieties because they have to. In many cases, they do not know about the (currently uncaptured) benefits of the new variety. Understandably, there is some resistance from farmers and the extension effort needed to implement more widespread use of the new varieties is considerable.

The payment of a premium to farmers for growing the new, double-low varieties is dependent on processors segregating their seed and, in turn, capturing a higher price for the additional oil content, the low erucic acid oil, or the lower glucosinolate oil. This is often difficult because of the small amounts of seed delivered to the processing plants, the yields of areas as small as 2–5 mu per farm. Some segregation is occurring in several provinces but the proportion of the total production of the new varieties that is subject to segregation is still quite low.

IOCR is working with some local governments to encourage adoption of the new varieties and some incentive schemes have been developed. One incentive is to pay farmers a higher price for the seed, based mainly on higher oil content. This is occurring in at least two crushing plants in Hubei Province, one a government-owned processing unit, the other a farmer cooperative. In one county in Hubei Province, the segregated, low erucic acid oil is being marketed and promoted, but on the basis of its better flavour and colour rather than health attributes.

There are no health regulations covering the level of erucic acid in rapeseed oil used for cooking in China. The retail price of the low erucic acid oil has been set higher than other oils and this in itself contributes to its positioning as a higher quality oil. Government has also begun providing information to the public on the advantages of low erucic acid oils. It is likely that the trend to low erucic oils will continue, albeit slowly.

Table 2 shows the extent of areas where the new, double-low rapeseed varieties were being segregrated in 1996–97.

Table 2. Areas in Yangtse Valley where double-low rapeseed varieties were segregated in 1996–97

Province	Area of new varieties (mu)[a]
Provinces in Central Valley	
Hubei	115,000
Jiang Xi	145,000
Hunan	65,000
Anhui	40,000
Shanghai	10,000
Jiangsu	10,000
Zhejiang	10,000
Subtotal	395,000
Provinces in Upper Reaches	
Guizhou	70,000
Yunan	200,000
Sichuan	55,000
Subtotal	325,000
TOTAL	720,000

[a] 15 mu = 1 ha

Of the estimated 720,000 mu (48,000 ha) where segregation is occurring, approximately 20% is associated with IOCR activities, as a result of which farmers are receiving some incentive, mainly through a 10% price premium for seed. This premium is thus applicable to about 144,000 mu (9,600 ha) of rapeseed.

For the remaining 80% of the new variety area where segregation is occurring (mainly at smaller processing plants where segregation is easier), the farmers have the choice of retaining ownership of the oil and the meal after paying a processing charge. An increasing proportion of farmers is choosing to retain ownership. In these cases, the farmers can achieve higher net revenue for their produce. Not only can they derive more oil from the higher oil content of the new variety, but also they can obtain a price for their rapeseed meal that is 10–20% higher than the price paid for high glucosinolate meal used only as fertiliser. Indeed, more and more farmers are using their low glucosinolate meal as feed for their own animals (mainly pigs, chickens, fish and cows). Where the farmer does not return meal as fertiliser to the soil, more chemical fertiliser may have to be purchased but this would be at no greater net cost to the farmer for delivery of the same nutrients.

Hence, there are two mechanisms whereby farmers are receiving benefits from the new varieties:

- where a price incentive has been supported; and
- where the farmer has been allowed to retain ownership of the meal and the oil.

For the remainder of the area of new, open-pollinated varieties, the farmers growing them are not necessarily obtaining any direct benefit. Benefits are accruing to the processors and marketers.

In addition, in one province (Yunan) where about 200,000 mu (13,300 ha) of the new variety Zhong Shuang No. 1 are grown, there has been a seed yield increase rather than a price or oil content increase.

Gross margin budgets for the traditional variety and Zhong Shuang No. 4 are given in Appendix 1.

Development of Hybrid Varieties

A second output associated with the ACIAR projects has been the recent development of a hybrid rapeseed variety that contains 50% Australian genetic material. The hybrid (Zhong You Zha 93-1) was released in 1998. Another four promising hybrids are in train. Zhong You Zha 93-1 yields up to 10% more seed than the traditional double-high varieties, although the seed cost is higher.

The area of the hybrid rapeseed harvested in 1998 was 500–600 mu (33–40 ha), and there were 30,000 mu (2,000 ha) sown to be harvested in May 1999. The commercial area will increase sharply again in the future as 2,700 mu (180 ha) have been sown in 1998 for plant seed production for harvest in May 1999. This area will provide about 150,000 kg of seed, sufficient to plant about 600,000 mu by direct sowing, that is about 40,000 ha in 1999.

A gross margin for producing the hybrid variety Zhong You Zha 93-1 is given in Appendix 1.

Other Outputs

Other outputs from the ACIAR projects include enhanced experience with alternative testing methods and the development of scientific capacity and infrastructure at IOCR.

Scientists at IOCR have continued to use the tape method developed in the project for the testing of glucosinolates. The other technology partially developed by the ACIAR projects (a form of 'glucose meter') required specialised equipment and was unreliable. A rapid, automated method for commercial testing in the factory remains a requirement. This is now being addressed at the Institute and the knowledge produced by the ACIAR projects CS1/1984/069 and CS1/1988/039 is being seen as extremely valuable in this work.

The capabilities and capacity built at IOCR over the past decade are seen by the Chinese as arising from the ACIAR projects. The ACIAR projects have resulted in increased funding for IOCR from the Chinese Government, resulting in growth and improved performance of the Institute

The Future

Rape is planted in China during September–October, and harvested in about May. The winter crop makes up 90% of the Chinese total and the Yangtse Valley area 80% of the total winter crop. Eighty percent of this is in the Central Valley area. Hence, of the 102 million mu (6.8 million ha) planted to rapeseed in China in 1997, approximately 75 million mu (5 million ha) is in the Yangtse Valley area. As the Yangtse Valley is predominantly a summer-cropping area, there are many hectares of land lying idle in winter which could be planted to rapeseed with no effect on crops planted in spring (e.g. rice from seedlings prepared in nurseries). Therefore, the degree of expansion of winter-grown rapeseed in the future could be considerable. One estimate is that the increase could potentially be as much as a further 240 million mu (16 million ha) grown in the Yangtse River area (including the Yellow River area) by the year 2030, an increase from the 102 million mu (6.8 million ha) currently grown in China.

IOCR staff predict that there is likely to be a large increase in plantings of the new open-pollinated varieties after 2000. They estimate that the new varieties associated with the ACIAR projects could contribute 30–40% of all winter-grown rapeseed in the Central Valley region. This would mean about 18–24 million mu (1.2–1.6 million ha), compared with about 3.5 million mu (230,000 ha) grown in 1997–98.

The Chinese Government is now paying more attention to double-low rapeseed varieties and has plans to integrate their production, processing and distribution into one system. The oil and seed are already in demand. Demand for protein feed for animals is also increasing, especially in the Central Yangtse Valley area where soybean production is low and rapeseed meal is seen as an important animal feed for the future.

Imports and Exports

China has imported in the order of 2 million tonnes of vegetable oils, including palm and soybean oils, in recent years, rising to 3 million tonnes in 1997–98, with another 0.5 million tonnes imported through 'non-official' sources. Depending on the substitution between oil types, domestic rapeseed oil could replace a large amount of this. Rapeseed is also imported into China, some of it from Australia.

China still hopes to export rapeseed oil to Japan now that it is producing low erucic oils. The Japanese are interested in the Yangtse Valley area as an alternative to Canada as a source of oil.

Overall, the ACIAR projects have been associated with a number of significant outputs, many of which have already been translated into successful outcomes and very significant benefits to China, with even greater benefits likely in the future. The proportion of benefits actually captured by small farmers is still not high but is increasing as segregation of varieties increases and as other policy and marketing strategies are implemented.

5. Project Outputs and Outcomes for Australia

For Australia, the key output from the ACIAR projects is the new, higher-yielding hybrids developed by Pacific Seeds based on the germplasm contributed from IOCR in China.

Two new hybrids were developed: an early-maturing type (Hyola 42) and a mid-maturing type (Hyola 51), both released in 1992. A later-maturing hybrid was also planned but did not eventuate, because of problems in seed production for the other two hybrids. Both hybrids developed were higher yielding (approximately 10%) than the existing open-pollinated varieties, but the level of resistance of the new hybrids to blackleg disease was low and yields fell when disease pressure was high.

The new hybrids were stronger and bushier, particularly suiting them to the shorter season areas of Australian rapeseed production, i.e. northern and drier southern areas. Also, disease was less of a problem in the drier areas. Hyola 42 was more successful than Hyola 51 and produced a higher and more stable yield. Hyola 42 achieved a market share in the mid-1990s of as much as 70% of the shorter season market. One of the two parents (the B line) for each of Hyola 42 and 51 was developed with germplasm obtained through the ACIAR projects.

Unfortunately, the hybridisation system used in the projects was not able to reliably produce commercial quantities of seed of sufficient genetic purity. Commercial production of seed for Hyola 42 and 51 was limited by self-pollination, particularly when the plants were heat or cold stressed. While seed could be produced reasonably successfully during summer in Tasmania and Canada, production was still rather erratic and seed was sometimes produced only just in time for sale. This made production of seed costly and quantities available unpredictable. In turn, this lowered the adoption rate and hence the market share that the hybrids could achieve.

Another factor limiting the penetration of Hyola 42 and Hyola 51 was the development of new, open-pollinated varieties tolerant to triazine herbicide. Those varieties permit selective chemical control of weeds, particularly wild radish, in Western Australia. They have proven very popular and have taken about 60% of the market from Hyola 42.

Pacific Seeds introduced a new hybridisation system (INRA-Ogura) in 1991. This halted the flow of new products from the company, and it has not yet resumed. Nevertheless, new hybrids based on the Chinese germplasm and produced under the new hybridisation system are likely to be released at some future time.

The outcomes of the ACIAR projects for Australia were that two hybrids were developed which captured some market share of the expanding rapeseed production in Australia in the 1990s. The hybrids were associated with a cost reduction in producing rapeseed because of their higher yield. This occurred despite the higher price of seed for the hybrid type. However, for the various reasons already discussed, the market share of the hybrids could not be sustained and has declined to low levels at present. Their production for the Australian market will probably cease in the near future.

In addition, the growth habit of the two hybrids is now incorporated in a number of open-pollinated rapeseed varieties that have been produced in Australia.

6. Project Outputs and Outcomes for the Rest of the World

This assessment focuses on benefits accruing to China and Australia from research undertaken in projects CS1/1984/069 and CS1/1988/039. However, apart from benefits being captured by Australia and China, it is apparent that benefits are also accruing to the rest of the world from the hybrids developed under the ACIAR projects. This section briefly discusses these benefits but, because there is as yet insufficient information, does not provide estimates of monetary returns.

Some Hyola 42 seed was exported from Australia to South Africa initially but the production of seed for that market is now undertaken in Canada. Approximately 40 tonnes of Hyola 42 was exported from Canada to South Africa in the 1999 season.

In addition, there are three hybrids produced and sold in Canada by a sister company to Pacific Seeds. These hybrids have been derived from one of the lines developed in the ACIAR projects. About 2000 tonnes of seed from the hybrids is sold in Canada and the USA. Despite the problems with the hybridisation system mentioned earlier, these three hybrids have captured about 15% of market share in Canada. Canada dominates world exports of rapeseed (about 50% of world trade). With 18% of total world production, Canada is one of the three largest producers. It is likely that the 15% market share of the three hybrids would constitute over 900 million tonnes of rapeseed being produced from genetic material developed under the ACIAR projects. Because Pacific Seeds is foreign owned, there is no royalty stream back to Australia from any of these sales.

7. Investment Analysis

A benefit–cost analysis was undertaken for the investment in the two ACIAR projects. Benefits were identified separately for China and Australia. The analysis covers a 30-year period commencing in the year when the first project commenced (1985–86). All benefits and costs were expressed in 1996–97-dollar terms. The discount rate used was 5% and all costs and benefits were discounted to 1996–97. Conservative estimates were used at all times.

Details of the investment costs, assumptions on which benefits were based, and the results of the analyses, including sensitivity analyses, follow.

Project Costs

Table 3 gives total project costs.

In addition to the ACIAR costs reported in Table 3, a further $34019 (1996–97 $ terms) per annum expenditure by Pacific Seeds to cover salaries and communication costs has been included each year from the start of the project (1985–86) to the year in which the hybrids were released (1992–93).

There were two sets of additional costs in China associated with producing the outcomes from the projects. Firstly, there were additional research costs incurred by the IOCR in working with the ACIAR-supported breeding program. R&D continued after the ACIAR projects were completed, when the IOCR researchers worked closely with a range of local governments to promote the benefits of the new, open-pollinated varieties.. Further, the first hybrid based on the Australian germplasm has been released only in the past two years, so that there was a significant amount of research undertaken after the end of the ACIAR projects to develop this hybrid. The scientists at IOCR therefore made a high level of additional input.

Table 3. Total expenditure on projects by ACIAR, Pacific Seeds and the Oilseeds Research Institute (A$1996/97)

Year ending 30 June	ACIAR Project CS1/1984/069[a]	ACIAR Project CS1/1988/039[a]	Pacific Seeds[b]	IOCR research and extension costs [c]	Total costs
1986	89355	0	34019	72699	196073
1987	125148	0	34019	72699	231866
1988	110896	0	34019	72699	217614
1989	34848	32133	34019	72699	173699
1990	0	83730	34019	72699	190448
1991	0	66337	34019	72699	173055
1992	0	19044	34019	72699	125762
1993	0	0	34019	72699	106718
1994	0	0	0	138128	138128
1995	0	0	0	123588	123588
1996	0	0	0	109049	109049
1997	0	0	0	94509	94509
1998	0	0	0	79969	79969
TOTAL	360247	201244	272152	1126835	1960478

Sources: [a]*ACIAR project documents*
[b]*Estimates by Pacific Seeds*
[c]*Estimates by IOCR*

It was assumed that all eight personnel of IOCR associated with rapeseed breeding were involved in supporting the ACIAR projects and their outcomes. A scientist year was valued at 60,000 Yuan [$1AU ≈ 6.4 Yuan]. This is assumed to cover salary, housing and other Institute-supported living expenses, and science support and overheads such as laboratories and consumables. From 1994–95 onwards, the total input was assumed to fall as scientists moved to other work such as the additional hybrids and other open-pollinated varieties that have not been included in the outputs from the ACIAR projects.

Secondly, the extension personnel in the various provinces provided additional input. Although these extension personnel would still have been working with rapeseed had there been no ACIAR project, there were some additional costs associated with rapeseed extension that should be costed against the ACIAR project outcomes. It was assumed that:

- an extension person costs about 7,200 Yuan per annum;
- the marginal cost of the extension of the open-pollinated varieties and the hybrids amounted to an additional 10% of costs per extension officer; and

- 600 extension-officers were involved across all provinces where the varieties were being introduced.

The estimated additional research and extension costs by year are summarised in Table 3.

Estimation of Benefits to China

Benefits to China included in the analysis were those from the open-pollinated varieties and some minor benefits accruing to date from the release of the one hybrid variety.

Open-pollinated Varieties

Assumptions used in the estimation of benefits from open-pollinated varieties in China are shown in Table 4. Four types of benefits were estimated separately:

- benefits from the price increase achieved by farmers where IOCR was operating;
- benefits from increased seed yield in one province;
- benefits for farmers where they were retaining ownership of the oil and the meal; and
- benefits from the higher oil content of the new varieties that were not captured by farmers.

The benefits to farmers where there were price increases stimulated by the IOCR activities in areas where varieties were being segregated, were estimated through the additional revenue gained by farmers less the additional costs they incurred in growing the new varieties (the additional cost of seed for planting).

Benefits from the increased seed yield in Yunan Province were estimated through a cost reduction estimate that included both variable and fixed costs.

Table 4. Assumptions for estimating benefits from open pollinated varieties

Assumption	Value
Price increase benefits	
Area of open-pollinated varieties that is segregated in processing (mu)	720,000[a]
Proportion of above area to which price increase applies (%)	20
Cost of traditional seed for planting (yuan per kg)	5
Cost of new variety seed for planting (yuan per kg)	12
Direct seeding rate for both traditional and new varieties (kg per mu)	0.5
Fertiliser, pesticide and labour cost increases for new variety (% per mu)	0
Additional cost of producing new variety (yuan per mu)	3.5
Average price for traditional seed product (yuan per kg)	2
Level of price increase for new product (%)	10[b]
Yield for both traditional and new varieties (kg per mu)	133
Seed yield increase	
Area to which seed yield increase applies (mu)	200,000
Yield of traditional variety (kg per mu)	140
Yield of Zhong Shuang No 1 (kg per mu)	154
Cost of production of traditional variety (yuan per ha)	2338.24
Cost of production of new variety (yuan per ha)	2390.74
Cost reduction (yuan per kg)	0.078
Retention of ownership of oil and meal products	
Area of open-pollinated varieties that is segregated during processing (mu, 1996–97)	720,000
Proportion of area to which retention by farmer of ownership of oil and meal applies (%)	16
Oil concentration, traditional variety (%)	34.0
Oil concentration, new variety (based on a 4% increase) (%)	35.36
Value of oil (yuan per kg)	7
Yield of seed (kg per mu)	133
Contract rate for processing (yuan per 100 kg seed)	20
Value of low glucosinolate meal (yuan per kg)	1.1[c]
Value of seed (yuan per kg)	2
Cost of taking ownership and marketing (yuan per 100 kg)	30
Higher oil content not captured by farmers but by others	
Total area of new, open-pollinated varieties (million mu in 1996/97)	3.4
Total area of new, open-pollinated varieties that are not segregated (million mu 1996–97)	2.68
Total area of new open pollinated varieties that is segregated but where farmers do not benefit from higher oil content (million mu in 1996–97)	0.64
Oil concentration, traditional variety (%)	34
Oil concentration, new variety (%)	35.36
Value of oil (yuan per kg)	7
Yield of seed (kg per mu)	133
Value of seed (yuan per kg)	2

[a] *15 mu = 1 ha*
[b] *The additional price received for the low erucic acid oil marketed in one region is already included in the 10% increase in the price of seed received in the various areas under control of IOCR. This increase in price will cover: the 4% increase in the oil content, any margin in the value of oil due to its low erucic acid content, and the 10–20% increase in the value of the meal.*
[c] *This is the government price; the actual free market price is higher due to the fact that other protein meal (e.g. soybean meal) is in short supply in the Central Valley area.*

Where farmers were retaining ownership of the oil and the meal (where varieties were segregated), the additional gross revenue from the sale of these products was estimated through comparisons with the revenue that would have been received had the rapeseed itself been sold. The additional costs of processing paid by the farmer were subtracted from this additional gross revenue received.

Finally, where segregation was not occurring, or where segregation was occurring but farmers were not taking oil and meal ownership, benefits were estimated by simply valuing the additional oil content of the new varieties.

Hybrids

Benefits from the increased seed yield of the hybrid variety produced and released in China were estimated through a cost reduction estimate that included both variable and fixed costs. Assumptions used in the estimation of benefits are in Table 5.

Table 5. Assumptions for estimating benefits from Chinese hybrids

Assumption	Value
Area of hybrid 1998 harvest (mu)	600[a]
Area of hybrid 1999 harvest (estimate) (mu)	30000
Yield of traditional variety (kg per mu)	133
Commercial yield increase (%)	8
Cost of production of traditional variety (yuan per ha)	2338.24
Cost of production of new hybrid (yuan per ha)	2413.24
Cost reduction for new hybrid (yuan per kg)	0.052
Cost reduction (yuan per mu)	6.917

[a] *15 mu = 1 ha*

Estimation of Benefits to Australia

Tables 6, 7 and 8 show the assumptions used in the estimation of benefits for the hybrids released in Australia. Pacific Seeds provided most of these assumptions. Assumptions are presented for each of the two production zones, in accord with the market share captured by the two hybrids that were developed.

The cost reductions estimated in Table 6 were applied to the quantities of the new hybrids produced as estimated in Tables 7 and 8.

Table 6. Assumptions for estimating benefits from Australian hybrids

Assumption	Value
Short season zone	
Yield increase (%)	10
Cost of new hybrid seed ($ per kg)	10
Cost of open-pollinated seed ($ per kg)	2.80
Sowing rate for open-pollinated variety (kg per ha)	4
Sowing rate for hybrid varieties (kg per ha)	3
Cost of production ($ per ha) See Appendix 2	232.20
Cost of production ($ per tonne) See Appendix 2	232.20
Cost reduction ($ per tonne)	9.47
Mid season zone	
Yield increase (%)	10
Cost of new hybrid seed (per kg)	10
Cost of open-pollinated seed ($ per kg)	2.80
Sowing rate for open-pollinated variety (kg per ha)	4
Sowing rate for hybrid varieties (kg per ha)	3
Cost of production ($ per ha) See Appendix 2	221.20
Cost of production ($ per tonne) See Appendix 2	110.60
Cost reduction ($ per tonne)	1.51

Table 7. Australian rapeseed production by zone

Year	Australia	Short season zone		Medium season zone	
	Production[a] (tonnes)	Production[b] (%)	Production (tonnes)	Production[a] (%)	Production (tonnes)
1991–92	170,000	10	17,000	90	153,000
1992–93	177,900	13	23,127	87	154,773
1993–94	305,000	16	48,800	84	256,200
1994–95	263,900	20	52,780	80	211,120
1995–96	557,100	25	139,275	75	417,825
1996–97	641,800	30	192,540	70	449,260
1997–98	860,000	35	301,000	65	559,000

Sources: [a]*Australian Commodity Statistics*
[b]*Estimate by Pacific Seeds and Agtrans*

Table 8. Estimates of market shares of the new hybrids

Year	Short season zone		Medium Season zone	
	Production (tonnes)	Market share (%)	Production (tonnes)	Market share (%)
1991–92	17,000	0	153,000	0
1992–93	23,127	70	154,773	5
1993–94	48,800	70	256,200	10
1994–95	52,780	70	211,120	2
1995–96	139,275	60	417,825	2
1996–97	192,540	40	449,260	0.5
1997–98	301,000	30	559,000	0.5

Source: Estimates of market shares by Pacific Seeds

Attribution of Benefits

The ACIAR projects contributed to the development of the double-low, open-pollinated varieties and to the hybrids that have been released to date in China. Because Canadian, Polish and Chinese germplasm was involved as well as Chinese, Canadian and Australian expertise, it is difficult to apportion the benefits to each of the three parties. The simple approach adopted is to ascribe one-third of the benefits to each of the efforts made by the three parties (Canadian, Australian and Chinese).

For the Australian benefits, a 50% attribution to the ACIAR projects has been assumed. This was in accord with the simple assumption that one of the two hybrid parents was based on the Chinese germplasm.

Implications for Prices

The increasing Australian production and export of rapeseed during the 1990s has been associated with reasonably constant world prices. Further, the increased quantities of rapeseed produced in Australia as a result of the cost reductions produced by the ACIAR projects have been very small and are therefore unlikely to have caused any price reductions in the Australian or world markets. For example, the maximum level of production from the two hybrids would have been in the year ended June 1998 and nearly all of this would have been from the short season variety Hyola 42, about 90,000 tonnes. The additional production of rapeseed due to the yield improvement from Hyola 42 would have been only about 9,000 tonnes in that year, as against a total Australian production in the short season zone of about 300,000 tonnes. An additional area of rapeseed may also have been grown in that year as a result of the cost reduction. However, this is not likely to have been very significant given the magnitude of the cost reduction in relation to price (say 3%) and assuming a moderate elasticity of supply of 1.0. Given these assumptions, the additional rapeseed production in the year ended June 1998 may have been less than 20,000 tonnes.

In that year Australia exported over 500,000 tonnes of rapeseed amid a total annual world trade of about 4.5 million tonnes. Therefore, the additional quantity of rapeseed produced in Australia because of the yield increase and the cost reduction has been small and any world price impact would have been minimal, irrespective of the price elasticity of demand faced in world markets.

Of potential importance to the world price in the future is the increased amount of rapeseed produced in China attributable to the ACIAR projects. Higher production of oil in China due to the ACIAR projects may well restrict future imports or even encourage exports, so contributing to lower world prices.

The magnitude of the impact of the ACIAR projects on international rapeseed prices, and on individual country production and trade, will depend on the respective elasticities of supply and demand in producing and trading countries.

Results

Detailed results of the economic analysis are shown in Appendix 3. Table 9 provides a summary.

Table 9. Estimates of investment criteria for ACIAR rapeseed projects (discount rate is 5%) (1996 $)

	Net present value (A$ million as of 1996)	Benefit–cost ratio	Internal rate of return (%)
Estimated over 30 years from 1985–86	34	14	33
Estimated over 13 year period 1985–86 to 1998–99	9	4	28

The sources of benefits are shown in Table 10.

Table 10. Source of benefits by country

Source of benefits	Present value as of 1996	
	A$ million (1996 $)	% of total benefits
Chinese benefits	35	95
Australian benefits	2	5
Total benefits	37	100

The sensitivity of the investment parameters to the discount rate is shown in Table 11.

Table 11, Sensitivity of investment criteria to discount rate

Discount rate	0%	5%	10%
Net present value (A$ million) over 30 years	51	34	25
Benefit–cost ratio over 30 years	27	14	8

Excluded from the above analyses are the benefits to the rest of the world.

The investment criteria for the current (1999) analysis are generally lower than those estimated in 1991. For example, the net present value (NPV) of the projects as estimated in 1991 was A$41 million as opposed to $34 million estimated in 1999. However, the comparisons are not particularly meaningful because:

- 1991 results were reported in 1990–91 dollar terms, whereas 1999 results are reported in 1996–97 dollar terms;
- the NPVs referred to 1985 in the case of the 1991 analysis and 1996 in the case of the 1999 analysis;
- the discount rates used were 10% in 1991 and 5% in 1999;
- the 1991 analysis projected forward benefits 20 years while the 1999 analysis projected forward 30 years;
- the 1991 analysis assumed the principal benefit was from a speeding-up of the impact in China from the ACIAR projects, whereas the 1999 analysis assumed a percentage of the benefits was directly attributable to the ACIAR projects.

Apart from these framework changes, a number of other, more specific, factors contributed to the changes in results. For Australia, the yield increase estimates for the hybrids were less than expected (10% instead of 20% assumed in 1991). Also, the cost of production of rapeseed in 1991 was assumed to be higher than in 1999 so that the impact assumed of the yield increase was also higher per tonne at that time. Market share estimates were lower in the 1999 analysis, although the quantity of rapeseed produced in Australia during the later 1990s was greater than expected in 1991.

For China, different benefits were expected in 1991 than those assumed in 1999. In particular, the benefits associated with lowering the glucosinolate levels in the meal were lower in the 1999 analysis, because of difficulties in segregating the higher value meal. Also, not only were the seed yield increases expected in 1991 from the new varieties greater (5–10%) than those assumed in 1999 (0% in most cases), the adoption rates for new varieties produced from the ACIAR projects have been lower than originally expected. This was because of the difficulty in segregating seed from the new varieties at the processing plants, a factor which prevented the majority of farmers capturing benefits from the increased oil yield exhibited by the new varieties (as opposed to any seed yield increases—the amount of seed being the factor on which they are predominantly paid).

8. Conclusion

The NPV of A$34 million shows that the ACIAR investment has provided significant benefits, particularly to China, with minimal benefits to Australia. If benefits are only considered up to and including only 1998–99, the total NPV is still positive at A$9 million, with a benefit–cost ratio of 4. The benefits to the rest of the world, which have not been included in this estimate, might be considerable.

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APPENDIX 1 Costs of production for traditional variety, Zhong Shuang No. 4 and Zhong You Zha 93-1

Traditional variety (direct seeding) Yuan per ha

Cost of seed 0.5 kg per mu 7.5 kg per ha @ 5 yuan per kg		37.5
Cost of fertiliser		750.0
Cost of pesticides		225.0
Cost of labour		975.0
Fixed costs[a]		350.74
Total cost		2338.24
Revenue	2000 kg per ha @2.0 yuan per kg	4000.0
Net margin		1661.76

[a] Fixed costs were estimated as 15% of total costs of production, based on the proportion of fixed costs in the Australian cost of production. The fixed costs for the China production system might be less than that for Australia because of the manner in which capital investment in land is treated and the relatively lower investment in capital equipment associated with labour-intensive production systems.

Zhong Shuang No. 4 (direct seeding and no price premium or retained ownership)

Cost of seed 0.5 kg per mu 7.5 kg per ha @12 yuan per kg		90.0
Cost of fertiliser		750.0
Cost of pesticides		225.0
Cost of labour		975.0
Fixed costs		350.74
Total cost		2390.74
Revenue	2000 kg per ha @2.0 yuan per kg	4000.0
Net margin		1609.26

Zhong You Zha 93-1 hybrid (direct seeding)

Cost of seed 0.25 kg per mu 3.75 kg per ha @30 yuan per kg		112.5
Cost of fertiliser		750.0
Cost of pesticides		225.0
Cost of labour		975.0
Fixed costs		350.74
Total cost		2413.24
Revenue	2160 kg per ha @2.0 yuan per kg	4320.0
Net margin		1906.76

APPENDIX 2 Cost of production for rapeseed in Australia

Short season areas – former variety

	$ per ha
Cost of seed bed preparation	10
Cost of seed 4 kg @$2.80 per kilo	11.20
Fertiliser	84
Herbicides	42
Sowing	4
Insecticides	6
Harvesting	37
Insurance	4
Fixed costs[a]	34
Total costs	232.20
Yield 1 tonne per hectare	
Cost of production	232.20 $ per tonne

Source: Based on gross margins budgets supplied by Victorian Institute of Dryland Agriculture
[a] Based on ABARE (1995), and includes cost categories of other materials, rates, interest and rent.

Short season areas – new hybrid

	$ per ha
Cost of seed bed preparation	10
Cost of seed 3 kg @$10 per kilo	30.00
Fertiliser	84
Herbicides	42
Sowing	4
Insecticides	6
Harvesting	37
Insurance	4
Fixed costs (a)	34
Total costs	245
Yield 1.10 tonnes per hectare	
Cost of production	222.73 $ per tonne

Source: Based on gross margins budgets supplied by Victorian Institute of Dryland Agriculture
[a] Based on ABARE (1995), and includes cost categories of other materials, rates, interest and rent.

Medium season areas – former variety

	$ per ha
Cost of seed bed preparation	11
Cost of seed 4 kg @$2.80 per kilo	11.20
Fertiliser	72
Herbicides	39
Sowing	3
Insecticides	5
Harvesting	36
Insurance	10
Fixed costs (a)	34
Total costs	221.20
Yield 2 tonnes per hectare	
Cost of production	110.60 $ per tonne

Source: Based on gross margins budgets supplied by Victorian Institute of Dryland Agriculture
Based on ABARE (1995), and includes cost categories of other materials, rates, interest and rent.

Medium season areas – new hybrid

	$ per ha
Cost of seed bed preparation	11
Cost of seed 3 kg @$10 per kilo	30.00
Fertiliser	72
Herbicides	39
Sowing	3
Insecticides	5
Harvesting	36
Insurance	10
Fixed costs (a)	34
Total costs	240
Yield 2.20 tonnes per hectare	
Cost of production	109.09 $ per tonne

Source: Based on gross margins budgets supplied by Victorian Institute of Dryland Agriculture
[a] Based on ABARE (1995), and includes cost categories of other materials, rates, interest and rent.

APPENDIX 3. Detailed results from the economic assessment of ACIAR-supported projects CS1/1984/069 and CS1/1988/039

Year number	Year ending 30 June	China benefits in 1999 Yuan ('000 Yuan)	China benefits in Australian dollars (A$ 1999	Inflation adjustment factor –consumer price index	China benefits Adjusted A$1996/97	Discount factor at 5%	Discounted China benefits A$	Discounted China benefits attributed to ACIAR
1	1986	0	0	75.6	0	1.71	0	0
2	1987	0	0	82.6	0	1.63	0	0
3	1988	0	0	88.5	0	1.55	0	0
4	1989	0	0	95.2	0	1.48	0	0
5	1990	0	0	102.5	0	1.41	0	0
6	1991	0	0	106.0	0	1.34	0	0
7	1992	0	0	107.3	0	1.28	0	0
8	1993	0	0	109.3	0	1.22	0	0
9	1994	7142541	1102482	111.2	1081783	1.16	1439853	479903
10	1995	17142099	2645957	116.2	2596278	1.10	3141497	1047061
11	1996	28570165	4409929	119.8	4327130	1.05	4759843	1586456
12	1997	48569280	7496879	120.2	7356121	1.00	7356121	2451795
13	1998	49997789	7717375	121.0	7572478	0.95	6884071	2294461
14	1999	50205306	7749407	122.5	7603908	0.91	6284221	2094531
15	2000	50412823	7781438	122.5	7635337	0.86	5736542	1911989
16	2001	50412823	7781438	122.5	7635337	0.82	5215038	1738172
17	2002	50412823	7781438	122.5	7635337	0.78	4740944	1580157
18	2003	50412823	7781438	122.5	7635337	0.75	4309949	1436506
19	2004	50412823	7781438	122.5	7635337	0.71	3918135	1305915
20	2005	50412823	7781438	122.5	7635337	0.68	3561941	1187195
21	2006	50412823	7781438	122.5	7635337	0.64	3238128	1079268
22	2007	50412823	7781438	122.5	7635337	0.61	2943753	981153
23	2008	50412823	7781438	122.5	7635337	0.58	2676139	891957
24	2009	50412823	7781438	122.5	7635337	0.56	2432854	810870
25	2010	50412823	7781438	122.5	7635337	0.53	2211685	737155
26	2011	50412823	7781438	122.5	7635337	0.51	2010623	670141
27	2012	50412823	7781438	122.5	7635337	0.48	1827839	609219
28	2013	50412823	7781438	122.5	7635337	0.46	1661672	553835
29	2014	50412823	7781438	122.5	7635337	0.44	1510611	503487
30	2015	50412823	7781438	122.5	7635337	0.42	1373283	457715
Total over 30 years							105179868	35056450
Total over 20 years							65274739	21756070
Total over 14 years – to 1999							30123155	10040048

Appendix 3, cont.

Year number	Year ending 30 June	Benefits to Australia $AU (1998–99)	Benefits to Australia adjusted for inflation $AU (1996–97)	Benefits to Australia discounted at 5% (1996–97 as the base year)	Benefits to Australia due to the ACIAR projects	Benefits to China and Australia due to the ACIAR projects	Total discounted research costs	Net benefits to China and Australia due to the ACIAR projects
1	1986	0	0	0	0	0	335351	–335351
2	1987	0	0	0	0	0	377685	–377685
3	1988	0	0	0	0	0	337591	–337591
4	1989	0	0	0	0	0	256633	–256633
5	1990	0	0	0	0	0	267979	–267979
6	1991	0	0	0	0	0	231910	–231910
7	1992	0	0	0	0	0	160507	–160507
8	1993	165031	161933	237086	118543	98415	129716	–31301
9	1994	362251	355450	473104	236552	623130	159901	463229
10	1995	356351	349661	423089	211545	1146787	136256	1010531
11	1996	804199	789100	868010	434005	1928622	114501	1814121
12	1997	732941	719180	719180	359590	2811385	94509	2716877
13	1998	859605	843466	766787	383393	2805371	76161	2729210
14	1999	166824	163692	135283	67641	2372996	0	2372996
15	2000	0	0	0	0	2198344	0	2198344
16	2001	0	0	0	0	2093661	0	2093661
17	2002	0	0	0	0	1993963	0	1993963
18	2003	0	0	0	0	1899012	0	1899012
19	2004	0	0	0	0	1808583	0	1808583
20	2005	0	0	0	0	1722460	0	1722460
21	2006	0	0	0	0	1640438	0	1640438
22	2007	0	0	0	0	1562322	0	1562322
23	2008	0	0	0	0	1487926	0	1487926
24	2009	0	0	0	0	1417072	0	1417072
25	2010	0	0	0	0	1349592	0	1349592
26	2011	0	0	0	0	1285326	0	1285326
27	2012	0	0	0	0	1224120	0	1224120
28	2013	0	0	0	0	1165829	0	1165829
29	2014	0	0	0	0	1110313	0	1110313
30	2015	0	0	0	0	1057441	0	1057441
Total over 30 years				3622197	1811098	36803109	2678699	34124410
Total over 20 years				3622197	1811098	23502729	2678699	20824030
Total over 14 years – to 1999				3622197	1811098	11786707	2678699	9108007

IMPACT ASSESSMENT SERIES

No.	Author and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome — an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Centre for International Economics (1998)	Biological control of the banana skipper in Papua New Guinea	8802-C

ECONOMIC ASSESSMENT SERIES (DISCONTINUED)

No.	Author and year of publication	Title	ACIAR project numbers
1	Doeleman, J.A. (1990a)	Biological Control of Salvinia	8340
2	Tobin, J. (1990)	Fruit Fly Control	8343
3	Fleming, E. (1991)	Improving the Feed Value of Straw Fed to Cattle and Buffalo	8203 and 8601
4	Doeleman, J.A.,(1990b)	Benefits and Costs of Entomopathogenic Nematodes: Two Biological Control Applications in China	8451 and 8929
5	Chudleigh, P.D. (1991a)	Tick-borne Disease Control in Cattle	8321
6	Chudleigh, P.D. (1991b)	Breeding and Quality Analysis of Canola (Rapeseed)	8469 and 8839
7	Johnston, J. and Cummings, R. (1991)	Control of Newcastle Disease in Village Chickens with Oral V4 Vaccine	8334 and 8717
8	Ryland, G.J. (1991)	Long Term Storage of Grain Under Plastic Covers	8307
9	Chudleigh, P.D. (1991c)	Integrated Use of Insecticides in Grain Storage in the Humid Tropics	8309, 8609 and 8311
10	Chamala, S., Karan, V., Raman, K.V and Gadewar, A.U. (1991)	An Evaluation of the Use and Impact of the ACIAR Book *Nutritional Disorders of Grain Sorghum*	8207
11	Tisdell, C. (1991)	Culture of Giant Clams for Food and for Restocking Tropical Reefs	8332 and 8733
12	McKenney, D.W., Davis, J.S., Turnbull, J.W. and Searle, S.D. (1991)	The Impact of Australian Tree Species Research in China	8457 and 8848
	Menz, K.M. (1991)	Overview of Economic Assessments 1–12	