SULFUR TEST KCl-40 AND GROWTH OF THE AUSTRALIAN CANOLA INDUSTRY

ACIAR Projects 8328 and 8804

ACIL Consulting
July 1998

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In order to monitor the effects of its projects, ACIAR commissions assessments of selected projects, conducted by people independent of ACIAR. This series reports the results of these independent studies.

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ISBN 1 86320 251 X

Editing and design by Arawang Communication Group, Canberra
Printed by Trendsetting, Canberra

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1. Summary

Two Australian Centre for International Agricultural Research (ACIAR) projects in the mid-1980s (Projects 8328 and 8804) funded research at the University of New England to help better understand and improve phosphorus and sulfur management in tropical agricultural systems. As tropical agriculture expands into more marginal land and production systems intensify, the demands for soil phosphorus and sulfur increase. Major outcomes of the research were a better understanding of the nutrient dynamics in South-East Asia and the development of a new and more reliable soil test for available sulfur. The new test (KCl-40) more accurately measured the sulfur available to plants, as it was able to measure the sulfur held within organic matter.

A spin-off from the development of the KCl-40 test was its application to Australian agriculture, specifically the pasture-based livestock industries and the canola industry. This economic evaluation focuses on the impact of the project outcomes for the canola industry.

Sulfur is critical for high canola yields and most New South Wales (NSW) and Western Australian soils are deficient in sulfur (less so Victoria). Even small rates of sulfur application can lift canola yields significantly, for example by 40 per cent. This was being demonstrated in field trials in the early 1990s and it quickly became standard practice for growers to apply sulfur. The use of KCl-40 in NSW research in the 1992–93 helped researchers to further demonstrate to growers the gains from sulfur and the appropriate rates to apply. While most growers had already begun to increase sulfur use, a small proportion of growers had not done so. It is this group which the University of New England research, through assisting work by the NSW Agriculture/Incitec, benefited.

The value of the production increase resulting from additional growers applying sulfur is estimated to have resulted in a benefit–cost return on the ACIAR research cost of around 3.4:1 on the estimated share of the ACIAR investment which could be attributed to canola. From an aggregate perspective, these benefits paid for about half of ACIAR's total research investment in the two projects. The KCl-40 test is now a routine component of soil tests conducted for growers in NSW, Victoria, South Australia and Western Australia, although its significance as far as influencing canola growers' decisions in respect of sulfur appears limited since the economic payoffs to using sulfur have led growers to routinely apply it.

For pastures, the economics of fertiliser application depend critically upon expected response in individual situations and hence there is a demand for accurate soil tests. The KCl-40 test now means that sheep and cattle graziers and dairy farmers can rely on soil tests for sulfur to help make much better decisions.

A summary of the estimated benefits to the ACIAR investment in the two projects is presented in Table 1.

Table 1. Returns to ACIAR investment through increased incomes of canola growers.

Present value of benefits of ACIAR share of research benefits	$2.4 m
Present value of ACIAR share of ACIAR project costs	$0.7 m
Net value of canola research to ACIAR investment	$1.7 m
Benefit-cost ratio	3.4
Internal rate of return	37%

2. Introduction

In the context of population pressure in Asia forcing the expansion of agriculture into areas of lower soil fertility, better understanding and measurement of the phosphorus and sulfur status of soils were identified by the Australian Centre for International Agricultural Research (ACIAR) as key issues for future research. Accordingly, ACIAR funded two projects focusing upon sulfur and phosphorus management in tropical cropping systems. As well as contributing to a better understanding of the issues with respect to tropical cropping in Asia, the resulting research work led to the development of an improved test for sulfur which had application in Australia. The focus of this economic analysis is a benefit–cost analysis of this sulfur test (KCl-40) as the test has related to the development of the canola industry in Australia (and as related to its use in other crops).

3. Background

3.1. The ACIAR Projects

In Asia, population pressure is forcing the expansion of agriculture into areas with infertile soils not previously used for crop production, while intensified cropping is draining the natural resources of soil nutrients from traditional cropping areas. Apart from nitrogen, the major nutrients limiting crop production in many areas are phosphorus and sulfur.

Phosphorus is being used widely in South-East Asia, but national decisions about the most efficient rates and sources for farmers are being made on the basis of very limited information about the reactions and transformations of fertiliser phosphate in the appropriate tropical soil–crop systems. The widespread use of 'high-analysis' phosphorus and nitrogen fertilisers (together with increased crop removal) has led to an increasing incidence of sulfur deficiency in the region. An Australian Development Assistance Bureau (ADAB; now the Australian Agency for International Development, AusAID)/Sulfur Institute seminar held in Indonesia in 1983 reviewed the scope of the sulfur problem in South-East Asia and identified research needs.

The initial ACIAR project (Project 8328), *Phosphorus and sulfur efficiency in tropical cropping* , was undertaken by researchers at the University of New England (UNE) and involved three parallel sub-projects.

The first studied the dynamics of phosphorus and sulfur in upland and flooded cropping areas, with a view to increasing the efficiency with which crops utilise these nutrients. Scientists characterised the phosphorus and sulfur status of soil samples collected from the major rice-producing areas of Indonesia and Thailand, and included some Australian soils. Small-scale greenhouse trials at Armidale (New South Wales [NSW], Australia) using upland and lowland rice examined the fate of the two elements applied to those soils, alone and in combination, using radioisotopes to separate nutrients from different sources. In the light of the results obtained, a survey of available fertiliser sources identified possible new material suited to the particular system. After further greenhouse trials, field tests of the most promising material considered both the initial response and residual value of the various fertiliser sources.

In the second sub-project, the scientists sought better criteria for establishing the phosphorus and sulfur status of plants and soils. Greenhouse experiments in Australia, both in solution culture and in a range of tropical and subtropical Australian soils, were used to study the uptake of these nutrients by important food crops such as maize, soybean and sweet potato, as well as rice. They also included measurements of tops and root growth, and investigated critical levels of the elements in these food crops, with emphasis on the effects of other nutrients, plant part and age. Complementary field studies in Indonesia and Thailand took into account additional factors such as climate, disease and insects. A nutrient uptake model for the crops under study was constructed, with particular emphasis on phosphorus and sulfur supply–demand relations.

Estimations of the accession rate of sulfur, and other nutrients, to agricultural areas in the region formed the third sub-project. Mixed anion–cation exchange resin columns were constructed in Australia and used to 'trap' ions from rainfall. The scientists also investigated the feasibility of including a lead peroxide pad to collect sulfur dioxide. They located these columns at strategically placed meteorological stations in Indonesia, Thailand and Malaysia, exchanging them by mail at two-month intervals to coincide with major changes in rainfall. Riverwater samples from the largest river draining the local catchment were sent to Armidale with each exposed column for mineral analysis.

The second project (Project 8804) extended Project 8328 and was also undertaken by the UNE researchers. This project *Sulfur and phosphorus management in tropical cropping system* consisted of an integrated series of laboratory management of crops. It is designed to improve the efficiency and reduce costs of fertilisers used in upland and lowland cropping systems in South-East Asian and Australian agriculture. A second focus is the provision of information, outlining where sulfur and phosphorus are required and in what quantities, to assist government decision-makers in Indonesia, Malaysia and Thailand.

The major objectives of Project 8804 were as follows.

- To investigate management options that will increase the efficiency of utilisation of sulfur added in fertilisers and crop residues.
- To monitor the contribution of sulfur and other nutrients from inputs via rainfall and irrigation waters.

►►►► To identify areas of sulfur deficiency, primarily in upland crops, and to develop a sulfur management recommendation package for particular soil/crop/climate regimes.

4. Pre-project Situation in Australia

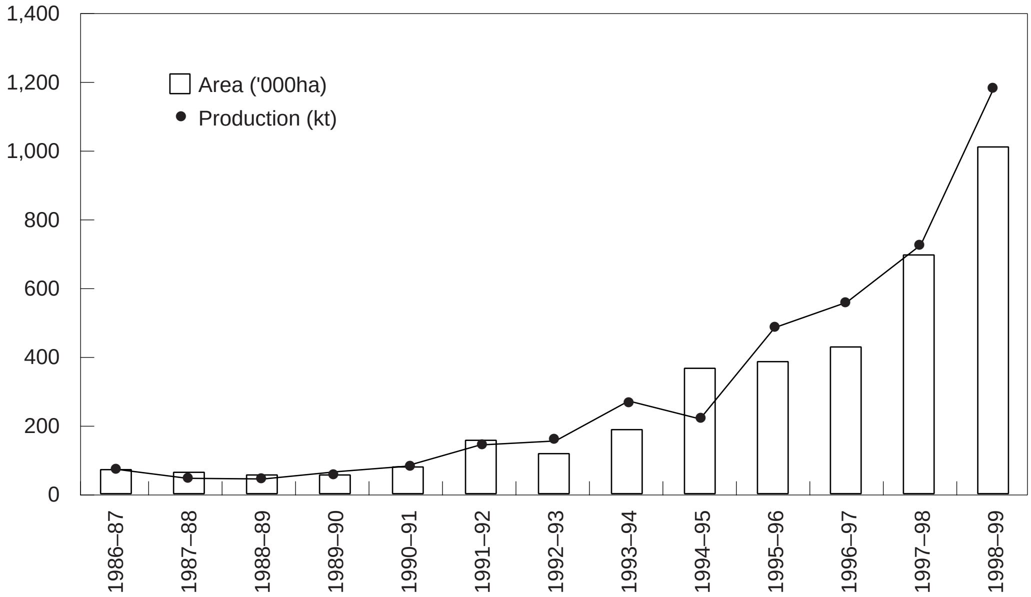
4.1. The Australian Canola Industry

Until the early 1990s the canola industry was relatively small. The growth in canola plantings and production has since been dramatic. Australia wide, the area sown increased from around 73 000 hectares in 1990–91 to a forecast one million hectares in 1998–99 (Figure 1). The area planted in 1990–91 was less than one per cent of the wheat area but is expected to represent nearly nine per cent in 1998–99, with the area planted to wheat itself also growing. In addition, yields have increased. Apart from the setback in 1992–93, the area has increased year on year and rapidly in the last two years. The area to canola fell in 1992–93 due to very dry conditions in that year.

A summary of the growing regions and canola's attributes are presented in Box 1.

Canola has become a much more important crop for several reasons. First, its relative profitability, as long as satisfactory yields can be obtained, has improved owing to price increasess, crop management improvement, improved varieties and a better knowledge of the crop's growing requirements. Second, its value as a break crop between the pasture phase of a rotation and wheat has been recognised.

Figure 1. Canola area and production: Australia.



Source: the Australian Bureau of Agricultural and Resource Economics.

Canola was first grown commercially in Australia in 1969, but has seen substantial expansion during the 1990s in (i) the area sown to canola and (ii) seed harvested. Other rapeseed had previously been grown commercially prior to 1969. Canola originated in Canada and is short for 'Canada oil low acid' (that is low in erucic acid). It resulted from a Canadian breeding program in the late 1960s which produced cultivars with little or no erucic acid and low levels of glucosinolates.[1]

The initial cropping interest in canola was short lived, partly because of crop failures. The lack of industry growth up to the late 1980s has been attributed to four main factors.

- The Canadian varieties not being appropriate for Australian growing conditions.
- Undesirable quality characteristics.

[1] Erucic acid is considered an undesirable fatty acid and many countries have regulations limiting the amount permitted in margarine and cooking oils. Glucosinolates in the seed break down during crushing to produce isothyocyanates in the meal which affect the taste and uptake of iodine in monogastric animals.

- Variable yields.
- Widespread disease resulting in crop failures.

Box 1. Canola: growing practice and areas.

- Canola is predominantly a winter growing crop, planted between April–September and harvested between October–February. It is primarily grown in the medium to high rainfall areas of the wheatbelt and inland irrigated areas of southern Australia, in an arc from central NSW through central and south western Victoria, southern South Australia (SA) and the wheatbelt of Western Australia (WA).
- Canola is suited to a wide range of soil types with good drainage. The best wheat growing soils are ideal for growing canola and the same machinery is used for both crops. The inclusion of canola is a step towards the 'ideal' crop rotation. Canola can be as advantageous to wheat yield as a pulse crop because it improves soil structure and assists in the control of cereal root disease.

Source:Victorian Department of Natural Resources and the Environment (1998).

Canola is subject to a number of insect pests and diseases, but the major hazard to canola production in Australia is the disease blackleg. This disease had a disastrous effect on the industry in the mid-1970s. Factors which have been cited as significant negative factors, at least in the 1970s and early 1980s, are as follows (RIRDC 1994).

- Insect damage (medium importance).
- Need to windrow crops (medium).
- Seasonal variation in rainfall (medium).
- Competition in the supply side with wheat (high).
- Incidence of blackleg fungus (high).
- Perception by producers that canola is a difficult crop to grow—smaller seed, susceptibility to pod shattering and insect pests (medium).

The positive factors, up until the early 1990s and mainly occurring in the late 1980s, were considered to be improved cultivars with higher yields, quality and blackleg resistance (RIRDC 1994).

4.2. Sulfur and Canola

Sulfur deficiencies have been recorded in soils across Australia with most deficiencies recorded in areas with rainfall above 500 mm. However, responses to sulfur have not been recorded in areas with a history of single superphosphate use, since this fertiliser contains sulfur. The cumulative sulfur inputs made as an incidental input to phosphorus generally ensured sufficient sulfur. The exception was in the sandy-textured soils of South and Western Australia (Blair and Nicholson 1975). In addition, rainfall can contribute significantly to sulfur inputs, although this impact diminishes with distance away from the coast. The shift to compound fertilisers, which were low in sulfur, meant that the sulfur base was being reduced.

By the mid-1980s, canola was becoming a more popular crop, replacing rapeseed, but it was still grown only to a limited extent. Besides variety and management issues, growers and advisers were observing periodic crop failures—on the same farm and between farms. Trials with urea applications, on the basis of suspected nitrogen deficiency, met with mixed success. Further, as growers looked to increase yields through nitrogen application, sulfur became recognised as the limiting factor.

Canola has a high demand for sulfur (10 kg sulfur for each tonne canola grain harvested per hectare compared to 1.5 kg sulfur for wheat). This demand for sulfur derives from the high protein content of its seeds and the characteristic presence of sulfur-containing glucosinolates (Schnug 1994). Sulfur deficiency can occur on all soil types and is generally exacerbated by (i) high yields, (ii) soils with a light texture (iii) soils with low sulfur status, (iv) reduced root growth and rooting intensity in soils with sub-surface acidity, sodicity, salinity or hard pans (v) or even something as simple as inadequate phosphorus fertiliser. Unfortunately, canola sulfur deficiency has been induced by factors other than simply reducing single superphosphate inputs.

5. Project Outcome and Achievements

5.1. The KCl-40 Test

From the viewpoint of Australian agriculture, the key outcome of Projects 8328 and 8804 was a better understanding of the soil–plant sulfur system and the development of the KCl-40 test. Blair et al. (1991) developed the KCl-40 soil test and demonstrated its superiority over mono-calcium phosphate (MCP)—the standard test at the time—on a range of 18 pasture sites in NSW. The superiority of the KCl-40 was confirmed on other sites across Southern NSW (Anderson et al. 1994).

The KCl-40 soil sulfur test uses weak potassium chloride heated to 40•C for three hours to extract sulfur from the soil. It removes most of the sulfur already in the sulfate form and releases some organic sulfur. The fraction of sulfur released is about the amount that is available to plants. The key difference between the KCl-40 and MCP tests is the inability of the latter to sample the organic sulfur pool, and hence it underestimates the soil sulphate supplying capacity.

Until the development of KCl-40, the MCP test had to be used. It had limitations. It could not detect sulfur in organic matter and it was difficult to interpret the results as far as helping farmers make better decisions. Part of the complication arose from the variable rate of breakdown of organic matter following and in the cropping phase, and the subsequent variability in the rate of release of sulfur. Further, there were the differential effects of rainfall in adding sulfur. In summary, the KCl-40 test more accurately measured the sulfur likely to be available to plants.

The initial application of the KCl-40 test in Australia focused on tests for sulfur in pasture situations. Prior to its development, farm advisers, including fertiliser company representatives and researchers, had used the MCP test to assess sulfur levels. However, the perception at the time, and as part of the stimulus for the development of another test, was that interpretation of the MCP test results was variable. Scientifically the test was reliable but its interpretation as an aid for farmer decision-making was being questioned.

The UNE work, including the KCl-40 test, occurred at a time when there was substantial interest and growth in the canola industry (as discussed above) and a concurrent focus on sulfur as one of the factors limiting yields and therefore profitability.

5.2. The Sulfur Story

As far as the ACIAR projects impacting upon the canola industry, there are four key factors of significance (the context of these developments is detailed in Box 2).

▶▶▶▶ The importance of sulfur for canola was identified by NSW Agriculture in the late 1980s and followed up strip trials on growers' properties with extension material (NSW Agriculture 1992).

▶▶▶▶ The UNE work including the KCl-40 test process was formally published in 1991, but the knowledge was beginning to circulate the pasture and agronomy research industry prior to that publication.

▶▶▶▶ Further, field trials (NSW Agriculture/Incitec) which specifically involved the UNE researchers and used the KCl-40 test were conducted from 1992–94, with the initial results used to bolster advisory material to canola growers in 1993 (NSW Agriculture 1993). This involvement added both technical capability as well as demonstrable independence. The UNE involvement helped researchers to better understand canola's requirements for sulfur, assess sulfur availability and determine the appropriate rates of sulfur application, especially in conjunction with high nitrogen applications.

▶▶▶▶ Grower adoption of the NSW Agriculture findings on the gains from sulfur was swift. It was facilitated by:

- two brochures—one prior to the 1992 NSW Agriculture/Incitec trials and one after the initial trials;
- Canola Check (a NSW Agriculture-supported system which encourages growers to check the health and status of their crops at key stages of the crop growth);
- a base of growers involved with a new crop who were keen to learn, experiment and adopt Departmental and research findings as they became available;
- growers seeking increased yields through the application of nitrogen;
- the low cost of applying sulfur;
- an ability to visually monitor canola crops for deficiency; and

- the capacity to apply sulfur throughout the growing period with a quick response to these applications.

In summary, the UNE research helped assure agronomy researchers and advisers of the importance of sulfur and the capacity of the KCl-40 test to more reliably measure sulfur available to plants. The initial research work in the pasture area was being picked up by crop advisors, particularly once it was recognised that canola yields were being constrained by sulfur deficiency.

Box 2. Sulfur research and canola: time profile

End June 1987	'ACIAR Project 8328, 'Phosphorus and sulfur efficiency in tropical cropping', concluded.
1989–1990	Periodic canola crop failures, initially thought to be caused by nitrogen deficiency.
1990	Major field study of canola in NSW reported significant grain yield increases from the addition of nitrogen but no significant responses to sulfur (Sykes and Colton 1990)
1991	Research paper by Blair et al. (1991), 'A sulfur soil test for pastures and crops', published in the Australian Journal of Soil Research.
1991	Helen Burns, NSW agronomist (Lockhart) reported that gypsum application gave a positive response in canola field trials.
1991	'Canola Check' identified sulfur deficiency in many regions of NSW (Wellington, West Wyalong, Temora, Young and Cowra) (GRDC 1993).
1992	John Sykes (NSW) encouraged researchers to investigate the then sporadic incidence of sulfur deficiency in NSW canola.
1992	NSW Agriculture and fertiliser companies published an advisory note (red brochure) on the impact on canola yields of sulfur deficiency.
1992	NSW Agriculture/Incitec research group instigated trial program.
Feb 1993	'Canola needs sulfur'—NSW Agriculture/Incitec brochure (green brochure). ■ reported results of 1992 NSW Agriculture and Incitec joint project of 14 field trials ■ In particular the following issues were addressed: canola demands for sulfur, deficiency systems, yield and oil content response to sulfur, difficulty in predicting deficiencies and the observation that analytical tissue tests are not yet a reliable guide, and fertiliser options. The conclusion reached was that growers could minimise the risk of losses by including sulfur in fertiliser programs with at least 25 kg/ha of sulfur.
1993	Estimated that 90 per cent of the NSW crop received more than 20 kg/ha sulfur. A good part of this was attributed to the NSW/Incitec recommendations to farmers (Good and Pinkerton 1995).
1994	The development of a soil test for sulfur, published in a research paper by Anderson et al. (1994) in the Norwegian Journal of Agricultural Science.
1995	Research papers published which reported the NSW/Incitec research trials.

5.3. The 1992–94 Research Trials

In 1992, John Sykes (NSW Agriculture) urged researchers to investigate the sporadic incidence of sulfur deficiency in NSW canola, following the reported responsiveness of canola to sulfur applications and encouragement from the fertiliser industry and farmersto. A research project was established, managed by NSW Agriculture and Incitec (Box 3).

Box 3. NSW Agriculture/Incitec sulfur trials

A joint project was instigated between NSW Agriculture, Incitec, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Plant Industry (Canberra) and the School of Agronomy (UNE, Armidale, NSW) (Good and Pinkerton 1995). The broad objects of the project were to:

- determine the optimum rate of sulfur fertiliser in relation to nitrogen fertilisers, soil type and paddock history;
- develop a soil test to indicate whether a paddock contained sufficient sulfur for a canola crop,
- develop a tissue test to diagnose sulfur deficiency in young canola crops; and
- determine yield recovery from applying sulfur fertiliser to a canola crop diagnosed as deficient.

The yield increases obtained for the 1992 and 1993 trials from applying sulfur were dramatic, especially where canola followed a pasture (Table 2). In addition, sulfur improved oil concentration with the most significant effects being recorded at sites where canola followed a legume dominant pasture.

The group reported that from its work,

> “it appears that recommendations to apply 20–30 kg/ha of sulfate prior to planting is sufficient to achieve maximum yields and replace the sulfur removed by the crop and is still the best practice for maximising yield with the least risk versus cost trade-off” (Good and Pinkerton 1995, p.6).

and summarised its work (in the advisory brochure) with the front page caption

> “sulfur deficiency can reduce yields by 80 per cent” .

Table 2. Effects of sulfur (S) and previous field history on clean seed yield of canola and oil concentration of canola seed.

Previous crop	Sulfur rate (kg/ha)							
	0	10	20	40	0	10	20	40
	Yield (kg/ha)				Oil concentration (%)			
S responsive sites								
Cereal	2 629	2 754	2 820	2 909	43.73	44.10	44.10	44.07
Pasture	3 248	4 119	4 380	4 533	39.07	39.90	41.72	42.01
Non S responsive sites								
Cereal	2 491	2 495	2 558	2 577	43.73	43.70	43.70	43.70
Pasture	3 866	4 184	4 268	4 283	43.77	44.20	43.87	44.00
	Percentage change in yield				Percentage change in oil concentration			
S responsive sites								
Cereal		5%	7%	11%		1%	1%	1%
Pasture		27%	35%	40%		2%	7%	8%
Non S responsive sites								
Cereal		0%	3%	3%		0%	0%	0%
Pasture		8%	10%	11%		1%	0%	1%

Source:Good et al. (1995), p.223

5.4. Grower Responses to Information

On the basis of the hypothesis (and previous NSW Agriculture advice) that sulfur deficiency was part of the problem leading to periodic crop failures, farmers quickly began to adopt a strategy of applying some or additional sulfur at sowing. As a result, 90 per cent of the canola crop was receiving additional sulfur before the NSW Agriculture/Incitec group research was completed (or even much advanced) and results obtained. Thus the NSW Agriculture/Incitec research essentially confirmed to most farmers the need for sulfur (A.J. Good, pers. comm.). However, it is considered that the group's work significantly influenced the remaining 10 per cent of growers to increase sulfur application rates in the fertiliser program.

The rapid take up of the 'apply sulfur theme' was facilitated by a strong industry association; a new industry culture which saw farmers keen to learn and share information with others; the Canola Check program (a network of extension officers focusing on assisting growers with crop monitoring) and the relatively low cost of applying sulfur compared to the potential pay-offs (Table 3).

Table 3. Commercial payoffs from applying sulfur.

	No sulfur	Sulfur applied Trial result		Net value ($/ha)	
		Outcome	% change	Costs/returns	
Sulfur cost (applied)	–	20 kg/ha		20 kg @ $0.80/kg	$16
Canola yield	1.3 t/ha	3.8 t/ha	192%	2.5 t @ $375	$938
Oil %	34.10%	42.30%	24%	3.8 t @ $33/t premium	$125
					$1 047

Source: NSW Agriculture/Incitec (1993).

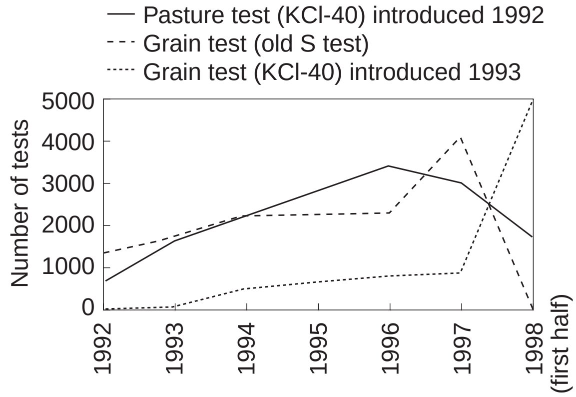
The simple rule of thumb became

> 'you could not afford not to apply sulfur'.

Following the trials, which included using the KCl-40 test, canola growers are reported to routinely undertake soil tests to test for pH, nitrogen, phosphorus and sulfur (with the KCl-40 test now used for sulfur testing). The tests—undertaken as a package from the soil sample—cost around $35 per sample for the set of tests. A typical practice in NSW is a winter/spring surface soil test on prospective canola paddocks (to test the pH and sulfur) and an autumn test deeper into the soil profile, to test for phosphorus, nitrogen and sulfur. As well, farmers typically monitor the crop through the growing season, often using test strips to highlight potential deficiencies. Even through base levels of sulfur are applied prior to sowing, crop monitoring for sulfur deficiency is required because of potential deficiencies when high rates of nitrogen are applied. Corrective strategies, including broadcasting fertiliser, can then be undertaken.

Since it was developed, use of the KCl-40 test by the fertiliser companies has replaced the old MCP test. Data from Incitec for NSW shows that (for grain) the KCl-40 test was not used much (that is, requested by growers/advisors) until 1998 when the old test ceased to be offered (Figure 2). On the other hand the test has been of increasing interest for graziers, although this has declined in recent years, possibly reflecting a decline in livestock returns and a more difficult season, at least in 1998.

Figure 2. Use of sulfur (S) tests.



Source: Incitec.

As far as the results of the tests (using KCl-40) are concerned, it seems that these have had relatively little impact on canola grower decisions with regard to applying sulfur. Given the cost and pay-off from applying sulfur, farmers prefer to apply the standard application of sulfur regardless of testing, on the basis that they cannot afford not to (A.J. Good, pers. comm.; L. Jenkins [NSW Agriculture and former Canola Check manager] pers. comm.). Moreover, to effectively apply the recommended minimum requires a higher rate of spreading, suggesting that a degree of excess fertiliser is applied. (Typically sulfur is applied as gypsum prior to sowing.) That said, there is some indication that some farmers who have now been cropping on a canola–wheat rotation are finding high levels of sulfur and reducing slightly their application rates. Some farmers have also expressed a concern that excess sulfur may be causing unintended effects 'downstream', but this is apparently of small significance as sulfur does not move through the soil to any great extent.

In Victoria, sulfur deficiency (and therefore testing) is of much less significance, as the grey soils of Victoria hold significant levels of sulfur deeper in the profile. The Grains Research and Development Corporation (GRDC) supported research at Rutherglen, Victoria, during the early 1990s—conducted on the same basis as the NSW Agriculture/Incitec group research—which found no response to added sulfur.

5.5. Assessing the Relevance of the ACIAR Research

The ACIAR research led to the development of the KCl-40 sulfur test and, initially, its application to pastures. In the subsequent research (the NSW Agriculture/Incitec work which focused on canola) it provided a much improved means of testing for sulfur levels as relevant to availability to plants. That is, KCl-40 was better able to distinguish between responsive and non-responsive sites than the MCP test.

Two sets of research outcomes are relevant to the impact on the canola industry (and growers' profitability).

- First, the extent to which the ACIAR funding of the two projects brought forward the research outcomes. That is, how long would it have taken before other researchers would have developed the equivalent of the KCl-40 test.

- Second, the extent to which the knowledge generated during the course of the research and the subsequent KCl-40 test led to either;
  - cost savings to farmers in terms of lower testing costs; and/or
  - productivity improvements in terms of applying the knowledge generated.

The importance and relevance of sulfur in Australian agriculture has been researched extensively, including at UNE, for many years. Moreover, sulfur tests (principally MCP) have been developed and used widely in the industry, albeit with a growing concern that they were not sufficiently reliable. It is highly probable that a stimulus to develop a better test would have occurred. It may even have been that a canola-based stimulus may have been the source, given the significance of sulfur for canola and the subsequent realisation of the importance of better test results.

It is more probable that the pressure for better tests would have come from the grazing industry, given the lower margins per hectare and the relatively greater cost of sulfur per hectare. However, the relatively high wool and beef returns in the late 1980s would likely have meant that the economic pressure for a better test would have taken some time. It is most probable that the pressure for a better test would not have arisen until the mid 1990s. To that end, the ACIAR funding of the two projects could be said to have brought forward the demand for a test for pasture by a decade. The canola driven demand would have seen more significant immediate pressure for a better test. However, as discussed, grower response to the test results is limited—they prefer to minimise risk by always applying sulfur at sowing and monitoring the crop.

6. Benefits to Australia

The benefits to Australia of the ACIAR and subsequent research/advisory work have been measured as the increased profits (‘producer surplus’) accruing to growers in the Australian canola industry. In fact, these increases would have accrued only to some growers—those who did not initially increase sulfur applications but adopted a more intensive sulfur fertiliser program on the basis of the original UNE work assisting with the NSW Agriculture/Incitec work. The monetary value of these benefits has been estimated as follows.

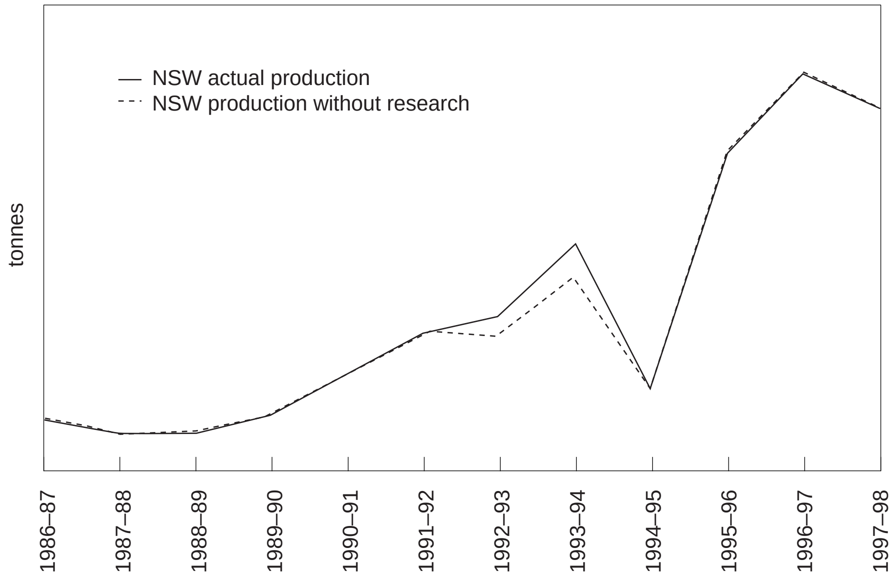
- The proportion of growers responding to the new information and the extent to which the research brought forward their decision to apply more sulfur. (In the absence of knowledge of the specific production importance of the growers involved, the proportion of production has been assumed to be equal to the proportion of growers.)

- The increase in seed yield (and oil production) attributable to using the research information.

- The on-farm pre-harvest value of canola (less the costs of applying sulfur), including both the additional tonnage and higher oil yield.

In the base case, the research is estimated to have impacted upon 5 per cent of growers with the research bringing forward their decision to apply sulfur by two years. A yield increase of 35 per cent has been adopted in this analysis and an oil increase of 7 per cent on the basis of the NSW/Incitec trial results (Table 2). The resulting impact on canola production is shown in Figure 3. These assessments are considered to be conservative.

Figure 3. New South Wales (NSW) canola production: actual, and (estimated) without the research.



The benefits of all the research (that is, both ACIAR and the NSW Agriculture/Incitec group work) as additional profits to canola growers is estimated to have a value of $2.9m 1998 values and prices (Table 4).

7. Benefits Overseas

No assessment has been made of the benefits overseas of the main focus of the ACIAR research in South-East Asia or the development of the KCl-40 test itself.

8. Project Costs

Research investment costs for the two ACIAR projects are set out in Table 5. Besides the funding from ACIAR, UNE committed some funds as did others, namely the Australian Wool Research and Promotion Organisation (AWRAPO).

Table 4. Estimated value of research benefits.

Year	NSW actual production (t)	Proportion of industry benefitting from the research	Yield increase resulting from research (t)	NSW production without research (t)	Pre harvested value of higher Canola yield (net of sulfur costs) in 1998 prices ($/t)	Yield benefit ($)	Oil gain on production (valued at $33/t of seed produced) ($)	Increased profits to Canola growers from the research findings ($)
1984–85								
1985–86								
1986–87	43 100		–	43 100		–	–	–
1987–88	34 000		–	34 000		–	–	–
1988–89	34 000		–	34 000		–	–	–
1989–90	50 000		–	50 000		–	–	–
1990–91	81 500		–	81 500	274	–	–	–
1991–92	117 700		–	117 700	247	–	–	–
1992–93	133 000	5%	2 287	130 713	285	652 309	86 466	738 775
1993–94	192 600	5%	3 313	189 287	310	1 028 325	125 214	1 153 538
1994–95	73 200	0%	–	73 200	314	–	–	–
1995–96	272 300	0%	–	272 300	306	–	–	–
1996–97	340 000	0%	–	340 000	271	–	–	–
1997–98	310 000			310 000	273	–	–	–
1998–99	472 000			472 000		–	–	–
							Interest rate	10%
							1998 value of benefits ($m)	$2.9

Table 5. Research costs of ACIAR projects 8328 and 8804.

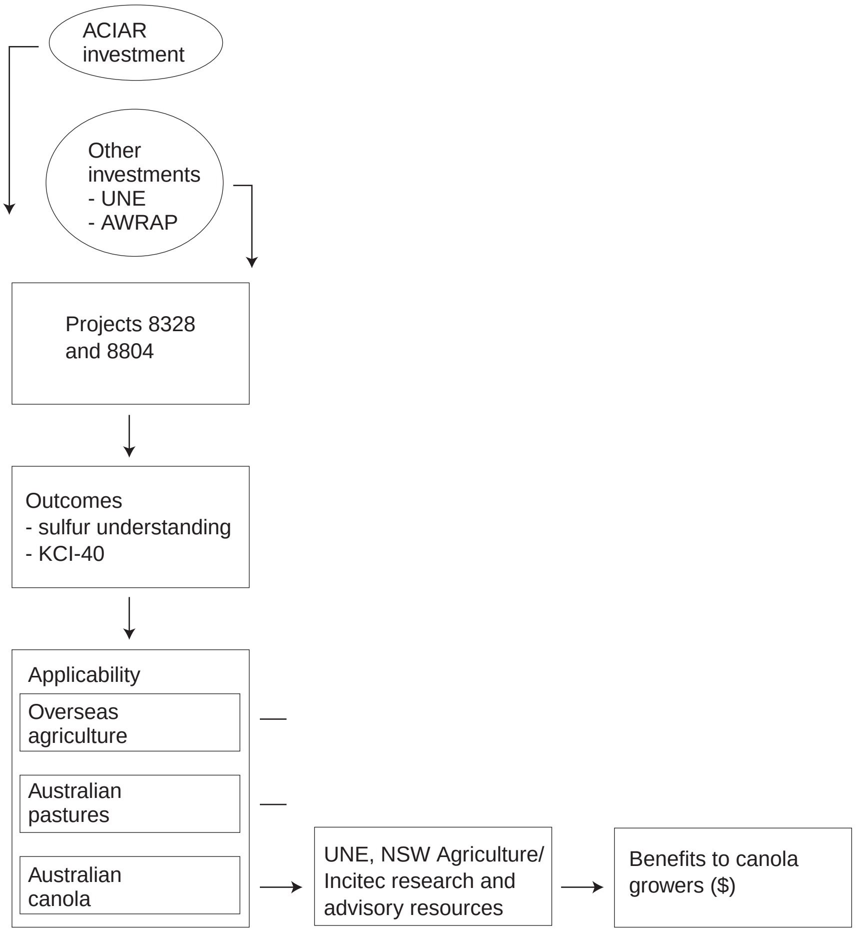
	Research costs (A$)—8328			Research costs (A$)—8804			Total		
	ACIAR	Commissioned organisation	Others	ACIAR	Developing country collaborators	Australian commissioned organisations	ACIAR	Other	Total
1984–85	29 431	33 600	3000				29 431	36 600	66 031
1985–86	264 191	33 600	3000				264 191	36 600	300 791
1986–87	252 341	33 600	3000				252 341	36 600	288 941
1987–88				71 887			71887	-	71887
1988–89				292 969	30 000	93 000	292 969	123 000	415 969
1989–90				265 190	30 000	63 500	265 190	93 500	358 690
1990–91				115 312	30 000	62 700	115 312	92 700	208 012

9. Investment Analysis

9.1. Approach

The outcomes of the research had application in generating benefits in three broad areas—tropical agriculture, Australian pasture productivity and Australian canola yields. As well there may have been benefits to overseas canola growers (although these have not been identified to date). Only one area of these benefits has been assessed here—namely the benefits to Australian canola growers. This in itself has implications for assessing the investment return on ACIAR's funds. Further, other agencies also contributed to funding the original research and additional resources were subsequently invested in applying the research outcomes to canola (Figure 4).

Figure 4. Investment costs.



Note: UNE = University of New England, AWRAPO = Australian Wool Research and Promotion Organisation.

A number of judgements have been made regarding the relative importance of ACIAR's investment. Key assumptions underlying the analysis are as follows.

- The proportion of the total investment in Projects 8328 and 8804 relating to canola has been put at 15 per cent. Ordinarily it would be reasonable to apportion the respective costs on the basis of respective benefits. However, in the absence of measured benefits to overseas agriculture and Australian pastures, a more subjective assessment has had to be made. Given that the prime purpose of the project related to improving overseas agriculture, it is probable also that the benefits are greatest in this area. Assuming a 70 per cent share to overseas agriculture, the balance was split equally between Australian pastures and canola—hence the 15 per cent allocation to canola.

►►►► From a pure economic efficiency viewpoint, it could be argued that the ACIAR costs attributable to the eventual canola benefit should be put at virtually zero since this research outcome was an unintended spillover to the main focus of the research, was not originally expected as a prospective benefit, and did not influence the decision to sponsor the two projects. However, in the absence of any information as to the benefits in other areas, 15 per cent of the ACIAR project research costs have been allocated to the canola benefits.

►►►► The proportion of benefits attributed to individual research investments (or agencies) is the same as the investment contributions of the respective agencies. That is, the allocation of benefits between individual research agencies has been made on the basis of the research costs incurred by the respective agencies.

►►►► Given the actual (and estimated) research investments, ACIAR is estimated to have contributed some 83 per cent of the total research investment relating to the prospective canola benefit (Table 6). This same proportion has been used to distribute the benefits as a means of assessing the pay-offs to the ACIAR investment.

Table 6. ACIAR's share of the research investment costs and total research benefits.

	Investment in Projects 8328 and 8804 (actual in 1998 prices)			Proportion of total project costs borne	ACIAR costs for canola (15%)	Research/advisory costs after the project relevant to canola	Total research/advisory costs to deliver canola related research benefits		Benefits to canola growers	Net benefits to the research investment
	ACIAR ($)	Other ($)	Total ($)	(%)	$	$				
1984–85	50 453	62 743	113 196	45	7568		7568		–	(7568)
1985–86	431 332	59 755	491 087	88	64 700		64 700			(64 700)
1986–87	377 097	54 695	431 792	87	56 565		56 565			(56 565)
1987–88	99 959	–	99 959	100	14 994		14 994			(14 994)
1988–89	379 657	159 395	539 053	70	56 949		56 949			(56 949)
1989–90	318 228	112 200	430 428	74	47 734		47 734			(47 734)
1990–91	131 410	105 641	237 051	55	19 711		19 711			(19 711)
1991–92	–	–	–			83 877	83 877			(83 877)
1992–93	–	–	–					–	738 775	738 775
1993–94	–	–	–					–	1 153 538	1 153 538
1994–95	–	–	–					–	–	–
1995–96	–	–	–					–	–	–
1996–97	–	–	–					–	–	–
1997–98	–	–	–					–	–	–

	Investment in Projects 8328 and 8804 (actual in 1998 prices)			Proportion of total project costs borne	ACIAR costs for canola (15%)	Research/advisory costs after the project relevant to canola	Total research/advisory costs to deliver canola related research benefits		Benefits to canola growers	Net benefits to the research investment
	ACIAR ($)	Other ($)	Total ($)	(%)	$	$				
Interest rate										
Present value (1998)	4 696 496		6 078 910		704 474	148 593	853 068	–	2 878 700	2 025 632
ACIAR share of total canola related research and advisory costs					83%	17%	100%			

9.2. Quantification of Investment Returns

In summary terms, the internal rate of return (IRR) for the combined investments in the original ACIAR projects and subsequent advisory work, given the base case benefit assumptions, is calculated at 37 per cent. Given the proportionate assumptions used in the analysis, the IRR applicable to the ACIAR investment is the same.

In net present value (NPV) terms, the base case benefit–cost ratio is estimated to be 3.4 (Table 7).

Table 7. Returns to ACIAR investment through increased incomes of canola growers.

Present value of benefits of ACIAR share of research benefits	$2.4 m
Present value of ACIAR share of ACIAR project costs	$0.7 m
Net value of canola research to ACIAR investment	$1.7 m
Benefit-cost ratio	3.4
Internal rate of return	37%

Of more particular significance is that the above conservative estimate of the canola benefits occurring from the ACIAR research investment (1998 present value of $2.4m) comes to about half of the total ACIAR investment in the two projects (1998 present value of $4.7m). Yet this aspect of the research benefit is likely to have been the smaller component of the ACIAR projects, given the overseas focus and probable main area of benefit and, to a lesser extent, the Australian pasture emphasis.

The returns on the investment by ACIAR are most sensitive to the proportion of growers (production) which responded to the information and the extent to which the information brought forward their decisions to apply more sulfur. Even so, on a very conservative estimate for these two areas, the return on the ACIAR canola investment was high — an IRR of 17 and 18 per cent, respectively. However, taking low estimates for these two aspects in combination the return was virtually nil. To the extent that more growers responded, the benefits (and IRR) were significantly higher than the base case. For the other variables, the estimated IRR was quite robust against the base case.

Sensitivity analysis was conducted for the four or main variables for which there was uncertainty (Table 8).

Table 8. Sensitivity analysis.

	Parameter value			Internal Rate of Return (%)		
	Base case	High alternative	Low alternative	Base case	High alternative	Low alternative
Research impact	5%	10%	2%	37	52	17
Number of years	2	3	1	37	40	18
Yield increase	35%	40%	25%	37	39	30
Preharvest canola value	80%	90%	70%	37	39	34
Oil gain	7	10	5	37	38	36
Oil value ($/t per % point change)	$1.4	$1.6	$1.0	37	37	36
ACIAR project costs attributable to canola	15%	20%	5%	37	31	61

10. Conclusions

This economic evaluation of ACIAR projects has focused upon the benefits to Australian canola growers resulting from research outcomes of the two projects. It has found that the research helped improve the understanding of soil sulfur availability and measurement, thus benefiting research and growers' understanding of appropriate levels of sulfur to apply for maximum crop yields. However, the research outcomes, and specifically the new sulfur test (KCl-40), occurred at a time when the canola industry had already begun to apply higher rates of sulfur.

Nonetheless, the work had a significant impact in encouraging the small proportion of growers not applying the recommended levels of sulfurto change their ways.

The economic pay-off as far as benefiting the canola industry was significant. The value of the benefits—higher profits—is estimated at $2.4m in 1998 terms. This represents a return to the estimated canola share of the ACIAR projects of around 3.4:1 or an IRR of 37 per cent. Significantly the return to the Australian canola industry was about half of the total ACIAR investment in the two projects.

In large measure, the benefits to the canola industry were an unintended spin-off from the ACIAR projects, yet the value of this spin-off was significant. Moreover, from ACIAR's viewpoint this benefit was realised with no additional investment from ACIAR. For Australia, the ACIAR projects resulted in additional capability in agricultural research which subsequently resulted in direct and significant benefits for Australia. The canola outcome is illustrative of the often unexpected, yet important and profitable, pay-offs from research.

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