ADOPTION OF ACIAR PROJECT OUTPUTS

STUDIES OF PROJECTS COMPLETED IN 2004–2005




Australian Government
Australian Centre for International Agricultural Research

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The Australian Centre for International Agricultural Research (ACIAR) operates as part of Australia's international development cooperation program, with a mission to achieve more productive and sustainable agricultural systems for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia's contribution to the International Agricultural Research Centres.

ACIAR seeks to ensure that the outputs of its funded research are adopted by farmers, policymakers, quarantine officers and other intended beneficiaries. As part of its efforts to monitor the outputs and outcomes of its projects, ACIAR has commissioned project leaders and participants to revisit projects 3 to 4 years after completion, and report back to ACIAR on the medium-term outcomes of the work. This series reports the results of these studies.

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Foreword

The Australian Centre for International Agricultural Research (ACIAR) contributes to Australia's aid program by investing in agricultural research projects that are designed to reduce poverty and promote sustainable development. In 2008–09, ACIAR's funding base was around A$66 million.

One of the challenges facing ACIAR and its partner scientists is to ensure that projects leave a legacy that continues to benefit partner countries and communities, and Australia, well after the project itself is completed.

It is not good enough for projects to be delivering benefits only while donor funds are being provided. Successful projects impart knowledge and skills and leave in place technology that is sustainable under local conditions.

Formal, independent project impact assessments have always been an important part of ACIAR's accountability process and means of improving project selection and management. The adoption studies that form the body of this report are an important intermediate stage between completion of the projects and these rigorous independent impact assessment studies.

The studies are undertaken 3–4 years after each project is completed, to assess the level of uptake and the legacy of the project. They provide valuable insights into the uptake of project results and the impact on local communities, and form a basis for the impact assessments.

This is the sixth year these adoption studies have been undertaken. We now have an adoption-study portfolio containing 57 sets of projects from which we are able to learn important lessons that can be fed back into our project development, design and implementation process.

I want to thank particularly the Australian project participants who undertook the task of revisiting partner countries to gather and collate data and write the adoption statements that form the basis of this publication.

I also want to thank the many project participants in our partner countries who hosted visits, helped with data gathering, and provided useful insights on the ongoing impact and effectiveness of these projects. My sincere thanks go to each of you for your support.

Peter Core
Chief Executive Officer
ACIAR

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Overview

David Pearce

Introduction

This report summarises the adoption results for eight ACIAR projects completed in 2004–05. As is usually the case for ACIAR-funded research, the countries and research areas covered are diverse. The projects presented here cover seven individual partner countries (China – three projects, Indonesia – two projects, India – two projects, Malaysia, the Philippines, Brazil and Colombia), five broad farm-level commodities (chickpeas, legumes, pineapple, vegetables and livestock), as well as land management techniques (particularly related to fire) and fibre processing (specifically wool in China).

The eight adoption studies indicate a generally high level of uptake of the project results and, in some cases, a significant amount of capacity built in the partner countries as a result of the project. Of the projects presented here, six developed technologies designed for use by farmers, while one focused on the processing level. In addition, policy-orientated information was an output of three of the projects, while another one aimed to enhance the process of developing and adopting new ideas (with a particular focus on livestock smallholders).

Most projects reported a high or medium level of adoption, although in some cases there was no adoption of individual project outputs or of project outputs in particular partner countries.

What was discovered — project outputs

ACIAR-funded projects can be viewed as having three broad categories of output:

- new technologies or practical approaches to dealing with particular problems or issues, designed to be applied at the farm or processing level
- new scientific knowledge or basic understanding (pure or basic science) of the phenomena or social institutions that affect agriculture, designed as input into further research processes, ultimately to help in the future development of practical approaches at the farm or processing level
- the development of knowledge, models and frameworks to aid policymakers or broad-level decision-making, not necessarily at the farm level but in the overall environment in which farmers (and processors) must operate.

There is, of course, potential overlap between these categories, and many projects contribute to more than one of them. Table 1 summarises the types of outputs from the eight projects covered in this report.

New technologies or practical approaches feature highly as major outputs for almost all of these projects and, with the exception of the project on Chinese wool-textile mills, the outputs are targeted at the farm level. However, even in the wool mills project, a major goal was to improve raw-wool marketing systems and hence contribute to better returns to woolgrowers in China and Australia. Scientific knowledge emerged in over half of the projects. This was particularly related to better understanding of risk factors related to disease or environmental degradation, or to understanding of underlying genetics in some cases.

Table 1. Outputs of eight ACIAR projects completed in 2004–05

Project	New technology / practical approaches	Scientific knowledge	Knowledge, models for policy
Traits for yield improvement of chickpea for drought-prone environments of India and Australia	Release of new cultivars of chickpea with superior drought tolerance Identification of drought resistant lines		
Development of technologies to alleviate soil acidification in legume-based production systems in the tropics of Asia and Australia	Bioremediation using nitrate fertilisers Use of high-activity clays to improve soil fertility New commercial product LDD10	New research methodologies for assessing the risk of soil acidification	Soil acidification risk maps for North-East Thailand used for land use and environmental planning
Impacts of fire and its use for sustainable land and forest management in Indonesia and northern Australia		Extent of fire and burning practices in Indonesia	Indonesian national and regional fire policy implications

Table 1. (continued)

Project	New technology / practical approaches	Scientific knowledge	Knowledge, models for policy
Genetic engineering of pineapple with blackheart resistance	Developed genetic transformation technologies and experience in bringing transformed product to market Optimised postharvest handling	Identify and isolate gene for blackheart expression in pineapple	
Chinese wool-textile mills: economic analysis of fibre-input / textile product selection and new processing technologies	Development and validation of a detailed operations research decision-making model for Chinese wool-textile mills that incorporated new mill technologies and new end-user requirements Training of senior managers from 30 mills in use of the model Identification of measures to improve ▪ Chinese herder returns from wool ▪ flow of wool from Australia to Chinese mills	Development of a new approach (based on transaction-cost-analysis theory) to understanding and improving the commercial trade in wool between Australia and China	Analysis of institutional, technical and managerial reforms in China's economic transition, and the implications for wool-textile industry restructuring
Liriomyza huidobrensis leafminer: developing effective pest-management strategies for Australia and Indonesia	Recommendations on use of insecticides and, in some cases, natural parasitoids	Information on *Liriomyza* species Information on natural enemies Information on adverse effects of broad-spectrum insecticides	
Enhancing the contribution of livestock within smallholder mixed-farming systems in the Philippines	Range of techniques to adopt research and development (R&D) and new ideas to increase profitability		Variety of approaches to enhancing adoption of R&D and new ideas
High-yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China	Expanded range with new high-yielding anthracnose-resistant *Stylosanthes* varieties New ways to use stylo as a leaf meal	Increased understanding of anthracnose epidemiology and risk mapping—genetic structure and virulence of fungus-causing disease available in all participating countries	

Capacity development

As well as the specific output intended for the research, by bringing together diverse groups of researchers, and by connecting Australian and partner-country practitioners, ACIAR-funded projects can lead to the development of increased capacity (to do research, to apply research techniques or to understand policy issues) among partner-country researchers and decision-makers. ACIAR funding may also create research infrastructure that can generate returns from future use. Table 2 summarises the kinds of capacity developed in the projects covered in this report.

Capacity development included training in basic techniques and technologies (for example, laboratory techniques in the legume project or geographic information system technologies in the fire management project) that are applicable in areas outside the initial project research.

A component of most of the projects was formal training of partner-country researchers involved, including obtaining higher academic qualifications. In some cases, research infrastructure was provided, or new techniques were transferred to researchers in partner countries. In the case of the leafminer project, capacity building including the establishment of a new software platform.

A very interesting form of capacity building is seen in the Chinese wool-textile mills project. Here, much of the capacity development includes increased communication and linkages between different parts of the processing chain and between the wool chain and government. This form of 'soft' infrastructure will clearly be productive in years to come and so represents an investment in capacity.

Table 2. Research capacity built by eight ACIAR projects completed in 2004–05

Project	Partner-country/countries research capacity built	Research infrastructure	Capacity utilised
Traits for yield improvement of chickpea for drought-prone environments of India and Australia	Increased skills in: ▪ optimising genotype / environment (G × E) interaction in breeding programs ▪ agrophysiological techniques for drought-resistance traits ▪ PC-based data handling and multivariate analysis Eight scientists also visited Australia to see the G × E experiments	Increased collaboration between physiologists and breeders in India	Knowledge from the training courses and the advantages of collaboration continue to provide benefits to both physiologists and particularly breeders working in Indian research institutes

Table 2. (continued)

Project	Partner-country/countries research capacity built	Research infrastructure	Capacity utilised
Development of technologies to alleviate soil acidification in legume-based production systems in the tropics of Asia and Australia	Enhanced basic laboratory skills through on-the-job training and Crawford scholarship Increased understanding through Masters and PhD studies on related topics		Many researchers trained remain active in soil fertility studies in Hainan province, China, and in Cambodia and Thailand
Impacts of fire and its use for sustainable land and forest management in Indonesia and northern Australia	Training in geographic information systems, forestry resource inventory, agroforestry resource protection, fire management		Capacity developed continues to be used by local communities to address regional fire management issues
Genetic engineering of pineapple with blackheart resistance	Broad technical capacity in Malaysian agricultural biotechnology has been enhanced	Platform technologies for genetic modification established	The Malaysian Government continues to invest in agricultural biotechnology and continues to undertake genetic engineering studies
Chinese wool-textile mills: economic analysis of fibre-input / textile product selection and new processing technologies	Improved management capacity of mill managers Increased capacity within the Ministry of Agriculture in relation to wool marketing and trade	Information conduit between textile mills and garment makers Integration between Australian and Chinese industries	Mills managed more efficiently Better informed policy decisions and trade negotiations
Liriomyza huidobrensis leafminer: developing effective pest-management strategies for Australia and Indonesia	Capacity in identification of parasitoids, conducting ecological research etc. enhanced through on-the-job training and post- and undergraduate courses	LUCID™ software for managing identification and diagnostic keys adopted LUCID™ keys for parasitoids developed	Skills developed mostly being utilised in other integrated pest management projects (not specifically *Liriomyza*) including cocoa pod borer Information on leafminers incorporated into farmer field schools

Table 2. (continued)

Project	Partner-country/countries research capacity built	Research infrastructure	Capacity utilised
Enhancing the contribution of livestock within smallholder mixed-farming systems in the Philippines	Capacity building was a major focus of the entire project, with a very wide range of capacities within the innovation chain enhanced. These include capacity in continuous improvement, developing and leading innovation networks and related innovation. Also developed was specific capacity in pig and chicken enterprises including budgeting, marketing and related skills.		The capacity developed continues to be used in innovation by technical specialists and network leaders and in pig and chicken enterprises by farmers and marketing specialists.
High yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China	Detailed in-project training in molecular markers, pathogen diversity and experimental and analytical procedures delivered to four scientists (in China and India) Masters and PhD studies were also completed (on aspects of *Stylosanthes*)	Provision of some equipment and technology in the course of the project	Ongoing utilisation of this capacity in most cases, as those trained continue to work in related fields and develop other staff and students

Uptake of the R&D outputs—progress along adoption pathways

Table 3 summarises the adoption outcomes for the projects covered in this report. Whatever the various objectives of the individual projects, the ultimate aim of ACIAR-funded research is to provide producers, processors and/or decision-makers with knowledge, skills, technologies and/or techniques that will ultimately allow them to improve their wellbeing or the wellbeing of others. For this to occur, adoption of project outputs, even when these are knowledge based, is essential.

Most of the projects covered here had a number of different objectives and outputs. Summarising the often complex adoption outcomes for a range of projects is inevitably a difficult task and involves an element of judgment. For the summary presented in Table 3, a four-level classification scheme (as used in previous adoption reports) has been adopted.

In this classification scheme, the lowest level of adoption is *O*, or no uptake of the results by either initial or final users of the outputs of the project. As Table 1.3 indicates, three projects had no adoption for *some* of the project outputs. These outputs included bioremediation using nitrate fertilisers in the soil acidification project; any adoption in Hainan for this same project; use of genetically modified pineapples (Genetic engineering of pineapple with blackheart resistance); and epidemiology models (High yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China). There was, however, adoption of other outputs in each of these projects.

The next level of adoption is *N*, the circumstance in which there has been some uptake by initial users but no uptake by final or ultimate users of the research. Two projects had some outputs falling into this category.

The next level of adoption is *Nf*, denoting uptake by initial users, and some uptake by ultimate users. Four projects had outputs falling into this category.

The highest level of adoption, *NF* (use by initial and final users), was achieved to some degree by six of the projects reported here.

Table 3. Current levels of adoption of key project outputs for eight ACIAR projects completed in 2004–05

Project	New technology / practical approach	Scientific knowledge	Knowledge, models for policy
Traits for yield improvement of chickpea for drought-prone environments of India and Australia	*NF* — for the majority of outputs including technical aspects as well as cooperation between researchers		
Development of technologies to alleviate soil acidification in legume-based production systems in the tropics of Asia and Australia	*O* — bioremediation using nitrate fertilisers *NF* — use of high activity clays in Thailand *NF* — LDD10 *O* — in Hainan due to changes in agricultural production	*N* — methodologies for assessing risk in Thailand	*N* — soil acidification risk maps in Thailand
Impacts of fire and its use for sustainable land and forest management in Indonesia and northern Australia		*NF* — geographic information systems and fire-mapping techniques	Nf — particularly in the East Nusa Tenggara region
Genetic engineering of pineapple with blackheart resistance	*O* — genetically modified pineapple *NF* — postharvest handling		

Table 3. (continued)

Project	New technology / practical approach	Scientific knowledge	Knowledge, models for policy
Chinese wool textile mills: economic analysis of fibre-input / textile product selection and new processing technologies	*Nf* to *NF* – for the majority of project outputs		
Liriomyza huidobrensis leafminer: developing effective pest management strategies for Australia and Indonesia	N — for most of the relevant outputs	*Nf* — in most cases	
Enhancing the contribution of livestock within smallholder mixed farming systems in the Philippines	*Nf* to *NF*— in the majority of outputs		*Nf* to *NF* — for the majority of outputs
High yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China	*NF* — stylo varieties *Nf* — stylo germplasm *O* — epidemiology models	*NF*—pathogen population genetics and epidemiology	

Note:

Level of uptake is summarised as high, medium, low or none using the following abbreviations:

NF demonstrated and considerable use of results by the initial and final users

Nf demonstrated and considerable use of results by the initial users but only minimal uptake by the final users

N some use of results by the initial users but no uptake by the final users

O no uptake by either initial or final users.

Factors contributing to adoption of project outputs

A number of factors contribute to the uptake and ultimate impact of projects. Broadly, these centre on whether or not:

- final or ultimate users *know* about the project outputs
- next or final users have *incentives* to adopt the outputs
- adoption is either *compulsory* or indirectly *prohibited*
- potential users face *capital constraints*, limiting ability to raise funds to adopt the outputs
- the outputs are *complex* to absorb relative to the capacity of the users

- use of the outputs faces *cultural* constraints
- adoption of the outputs increases *risk and uncertainty*
- there is *continuity of staff* in organisations associated with adoption.

Table 4 summarises some of the major factors contributing to adoption for the projects reported here.

Knowledge of project outputs was not a constraint to adoption, particularly as in most cases there was a dissemination component of the project. The targeting of the chickpea project to young or mid-level scientists helped dissemination in this case, while the broad recognition by Indonesian governments and land users that fire-management issues were significant, led to widespread institutional support for adoption of the outputs of the fire project in Indonesia.

As always, economic incentives provide a major impetus for adoption once results are disseminated. In some of the projects reported here, there appeared to be a number of economic disincentives operating. In particular, the costliness of some soil-remediation options was a disincentive. In other cases, the availability of alternatives (conventionally bred cultivars rather than genetic modification (GM) in the case of pineapples, or broad-spectrum insecticides rather than integrated pest management for leafminer control) provided a constraint to the adoption of project outputs.

Capital constraints were not evident in projects reported here.

In most cases, the project outputs seem not to have been so complex that they were unusable by the next or final users. However, in two cases there were significant problems with complexity. In the soil acidification and legume project, soil acidity issues proved to be very complex and hence difficult to convey in a simple manner. Similarly, with regard to the GM component of the pineapple project, both the research itself, and the regulatory requirements for undertaking research on GM germplasm, proved to be very complex.

Cultural constraints did not emerge as an issue in these projects, and risk did not seem to be an issue in adoption. Continuity of staff was, however, an issue in the stylo project.

Table 4. Factors influencing the adoption and impact of the results of eight ACIAR projects completed in 2004–05—analysis of the reviews

Factors contributing to uptake	Factors inhibiting uptake
Do potential users know about the outputs?	
▪ The chickpea project was targeted at young or mid-level scientists. This means that benefits are ongoing as young scientists move into positions of leadership. ▪ The fire project in Indonesia was widely recognised to be a significant project and was institutionalised within regional governments.	▪ In the stylo project, there is no partnership between commercial poultry raisers, farmers growing stylo and feed processors using leaf meal.
Are there sufficient incentives to adopt the benefits?	
▪ While there are economic incentives in adopting the outputs from the Chinese wool-textile mill project, the model needs to be commercialised.	▪ Some centres have limited facilities for physiological research. ▪ In soil remediation, some solutions may be too costly. ▪ In some cases, there are changing economic and environmental frameworks leading to less interest in project outputs (soil acidification project). ▪ Alternative pineapple cultivars are available. ▪ In the leafminer project, the implementation of integrated pest management (IPM) must compete with the existing pressures (economic and informational) to use broad-spectrum insecticides.
Is adoption compulsory or effectively prohibited?	
	▪ There are significant intellectual property and regulatory requirements acting as barriers to development of genetically modified pineapples.
Are there capital constraints on users' ability to raise funds?	
Are outputs complex in comparison with the capability of the users?	
▪ Regular contact with extension officers seemed to be an important determinant of adoption in the leafminer project.	▪ Soil acidity issues are complex and difficult to comprehensively convey, so extension was very difficult in the case of the legume production project. ▪ The time frames and complexity in producing transgenic pineapples were longer and greater than expected. ▪ Intellectual property and regulatory matters are complex and time consuming.
Are there cultural barriers to adoption?	

Table 4. (continued)

Factors contributing to uptake	Factors inhibiting uptake
Does adoption increase risk or uncertainty?	
	■ There may be a perception (but not reality) that IPM is a more difficult or uncertain approach to leafminer control than existing methods.
Was there sufficient continuity of staff to ensure adoption?	
■ In the chickpea project, while there was some movement of people, on the whole those involved have continued to be in positions of influence.	■ In the stylo anthracnose project, a number of key personnel trained in the project retired or were transferred.

Lessons

The results that emerge from the adoption studies reported here provide a number of lessons for ACIAR-funded projects.

Institutional structures of partner country research

Assumptions and institutions underlying the conduct of scientific research often differ significantly between countries. In the chickpea yield-improvement project, the Australian team leader found that hierarchical structures for universities and research in India affected the conduct of the research, particularly as it related to the establishment of protocols for physiological studies. Some effort to understand these underlying institutional differences may lead to increased research producitivity.

Keeping up with changing agricultural systems

Agricultural research in developing countries often takes place in the context of significant changes in underlying agricultural systems. Economic growth, demographic change and changing policies often lead to changes in product and land-use demand.

This effect was very much evident in the project studying soil acidification in legume-based production, particularly as it applied to Hainan province in China. During the course of the project, the agricultural system in Hainan changed significantly, moving away from grazing and forage production towards cropping, with some implications for adoption of the original research.

Whether such changes could be predicted probably depends on the country and commodity concerned, but there are a number of common economic drivers that could be considered at the outset of major projects, to test whether expected changes in underlying agricultural systems will affect the adoption and outcomes of the research.

Cross-disciplinary research

While the majority of ACIAR-funded research considers specific farm- and commodity-level research, in the fire project in Indonesia there is scope for very positive outcomes from broad-based biophysical and ecological research. While the fire project in Indonesia was not typical, it was apparently very successful because it applied appropriate techniques to a well recognised problem (or series of problems)—in this case problems that could not be dealt with using a single commodity framework alone.

There may be value in ACIAR considering whether other such cross-boundary research would be beneficial in other partner countries.

Interaction between breeding and GM

Traditional breeding and genetic modification sometimes provide alternative paths to the same ultimate outcome which, in the case of the pineapple project, was blackheart resistance. In that project, conventionally bred hybrids are available on the market and are being accepted without a 'GM' label. This means the GM product may never be adopted. This, along with the much higher intellectual property and regulatory burdens for GM products, illustrates a tension that is likely to emerge in research for a range of commodities.

Without making any judgments about the efficacy or safety of GM products (which have proved to be valuable and safe in many contexts) there may be scope to investigate some broader economic and institutional drivers when considering GM projects.

Commercialisation of outputs

The Chinese wool-textile mill project provides an interesting illustration of a case where commercialisation of the project outputs is essential to generate further adoption. In this case, the relatively large enterprises involved in textile production require the models and tools developed during the project to be available commercially, so that the costs of the models are fully transparent and appropriate ongoing support and product development are available, otherwise they have little incentive to adopt this kind of technology.

Understanding economic incentives and information provision

Economic and informational incentives for adoption are always important. In the case of the pest-management project for leafminer, current provision of products and information to farmers appears to mitigate against adoption. In particular, most of the information farmers receive about controlling leafminer comes from firms concerned with selling pesticides. Farmers seem to have significant disincentive to adopt the ultimately more beneficial integrated pest management simply because of this lack of wider information.

The best ways to deal with this sort of problem will vary by country and commodity, but this case again reveals the importance, when designing a research program, of understanding the incentives facing the target audience. Ideally, the research design should also include methods of increasing information provision to farmers.

Enhancing the contribution of livestock within smallholder mixed farming systems in the Philippines (ASEM/1997/041)

Richard Clark

Summary project information

Project number	ASEM/1997/041
Project name	Enhancing the contribution of livestock within smallholder mixed farming systems in the Philippines The project is also known as the Leyte Improvement and Innovation Program (LLIP).
Collaborating institutions	Australia: University of Queensland (commissioned organisation); Queensland Department of Primary Industries (now Queensland Primary Industries and Fisheries within the Department of Employment, Economic Development and Innovation); Curtin University of Technology; University of Sydney Philippines: Visayas State College of Agriculture (now Visayas State University)
Project leaders	Australia: Dr Richard Clark Philippines: Dr Alberto Taveros
Duration of project	1 July 2000 – 31 December 2004
Funding	$1,323,946 (ACIAR contribution: $893,746)

Countries involved	Philippines and Australia
Commodities involved	Pigs and chickens
Related projects	AS2/94/121, AS2/94/23, AS1/97/135 and AS2/98/25

1. Motivation for the project and what it aimed to achieve

In the Eastern Visayas region of the Philippines, also known as Region VIII, more than half the population is dependent on agriculture. The island of Leyte contains 72% of the region's livestock farms and 74% of the region's poultry farms. The mixed smallholder farming system in the Philippines is 'very mixed'. Smallholders need to access a variety of food options to meet their family food requirements, and to use a range of agricultural practices and technologies to meet their financial needs, while maintaining or improving family efficiency.

Two broad agricultural problems underpinned the project: 1. suboptimal livestock productivity—a problem that is common to livestock in smallholder mixed farming systems throughout the world, and 2. the poor adoption of many research solutions by farmers when a research and development pipeline or transfer-of-technology approach is used in which solutions and technologies are produced without a clear

A biogas-driven generator providing electricity for household, farm and neighbourhood use.

understanding of farmers' needs, contexts and constraints, and without the contribution of the farmers' intellect, skills and experiences. An opportunity existed for the project to enhance the rate and scale of improvements and innovations in agricultural enterprises, partnerships, networks and value chains, rather than pursuing a pipeline approach of technology push from researchers to the end-users.

The project was considered to be a logical extension of the research activities that had been conducted in a previous ACIAR-funded livestock project that had also involved collaboration between Visayas State College of Agriculture and the University of Queensland.

The project aimed to:

1. increase the capacity of participating producers to improve the management, profitability and long-term sustainability of their livestock systems through continuous improvement in their creativity, decisions, processes, practices and performance
2. improve the contribution of livestock, in a measurable and sustainable way, to the social and economic wellbeing of smallholder families in western Leyte.

2. What the project produced

Table 1 summarises the major outputs and output-clusters from the project. The output-clusters are bundles of outputs that, when used in combinations, can produce greater systemic impacts than would be achieved by using single outputs alone. The concept of output-clusters also provides for greater transferability to other locations and contexts because, while similar output-clusters will be required in the new situation, the specific outputs that will meet the needs of the new situation can be selected from within the cluster. While work had been undertaken on pig and chicken production before the project, little focus had been given to the systemic development, selection and integration of technologies and practices for positive outcomes and impacts in the context of smallholder profit, efficiency and environmental health.

Table 1. The major output-clusters and outputs of ACIAR project ASEM/1997/041

Technology and policy output clusters and outputs
1. Sustainable improvement and innovation technologies, and policy cluster
1.1 Sustainable improvement and innovation model
1.2 Forum on sustainable improvement and innovation for R&D organisations
1.3 Project performance management framework
1.4 Partnership and network development processes and associated tools

Table 1. (continued)

2. Pig profit technologies cluster
2.1 Pig system map
2.2 Pig profit improvement process
2.3 Profit focusing framework thinking tool
2.4 Pig profit indicator tool
2.5 Least-cost feed formulations suited to smallholder contexts
3. Pig and other enterprise environment and energy technologies, and policy cluster
3.1 Pig enterprise environment and energy system map
3.2 Environment and economic indicators tool
3.3 Biodigester and biogas installation designs
3.4 Model of human infrastructure for smallholder pig environment system improvement
3.5 Fertiliser formulations using biodigester by-products
4. Chicken profit technologies cluster
4.1 Chicken system map
4.2 Chicken profit indicator tool
4.3 Bio-economic model of chicken production
5. Information systems
5.1 Pig and chicken production profit information system
Capacity development output clusters and outputs
1. Continuous improvement and innovation methodology and tools cluster
1.1 Capacity in key knowledge and skill areas of continuous improvement and innovation
1.2 Continuous improvement and innovation booklet
1.3 Manual for improvement and innovation network members and leaders
1.4 Accreditation of Philippine specialists, extensionists and project leaders

Table 1. (continued)

2. Forming and leading improvement and innovation partnerships and networks cluster
2.1 Regional improvement and innovation network of partnerships
2.2 Network tool
2.3 Improvement and innovation forums
3. Capacity in pig enterprise profit and marketing improvement and innovation cluster
3.1 Manual for technical specialists
3.2 Pig enterprise recording sheets
3.3 Pig gross margin analysis tool
3.4 Pig partial budget analysis tool
3.5 Pig price calendar
3.6 Increased understanding of smallholder pig profit and marketing as a system
4. Capacity in pig and other enterprise environment and energy improvement and innovation cluster
4.1 Instruction manual
4.2 Environment and economic improvement performance assessment tool
4.3 Capacity building and guide to maintaining waste management systems
4.4 Pig and other enterprise environment and energy system design and installation services
5. Capacity in chicken enterprise profit and marketing improvement and innovation cluster
5.1 Instruction manual
5.2 Illustrated farmer manual
5.3 Illustrated manual for extensionists, technical specialists and farmer networks
5.4 Chicken mortality tool
5.5 Chicken activity timeline
6. Capacity in establishing and managing input–output cooperative stores cluster
6.1 Input–output stores
6.2 Record sheets for use in input–output stores

Table 1. (continued)

6.3 Guide for training in basic accounting
7. Capacity in marketing and value chains for impact on profit cluster
7.1 Supply-chain mapping tool
7.2 Marketing cost analysis tool
7.3 Understanding marketing timelines tool
7.4 Guide for conducting a reconnaissance survey
7.5 Guide for conducting a SWOT analysis of livestock supply chains
7.6 Improved capacity to identify and assess markets and value-chain opportunities

3. Adoption—how the project outputs are being used

Table 2 indicates, for each output, the current level of use and whether the output is in a form that can be used by the final user. It is expected that the level and scale of adoption of many LLIP outputs will increase in the future for the following reasons:

- Leyte Improvement and Innovation Network (LIIN) activities —Members of LIIN continue to develop partnerships in relation to a range of improvement and innovation opportunities across agricultural enterprises, and they continue to share their experiences, improvements and innovations with others in their communities.
- Partnerships with non-government organisations (NGOs)—Strong partnerships have been established with NGOs such as Community Awareness and Services for Ecological Concerns (CASEC) Incorporated and the Mag-uugmad Foundation Incorporated(MFI). These organisations in turn have strong partnerships with a large number of farmer networks and people's organisations.
- Partnerships with government agencies—Partnerships have been developed with municipal, provincial and national government agencies, and with universities. These partnerships have the potential to increase the scale of adoption throughout the Eastern and Central Visayas regions.
- Establishment and growth of pig (and other) enterprise environment and energy system design and installation services —There is strong demand for these services in several provinces.
- Institutionalisation of the Sustainable Improvement and Innovation (SI&I) model and Continuous Improvement and Innovation (CI&I) process through Visayas State University (VSU)—VSU has partnerships with a number of key groups and centres such as the National Coconut Research Centre, PhilRootcrops, the National Abaca Research Centre, the Philippine Veterinary Medicine Association, the Visayas Consortium for Agriculture and Resources Program, and the Eastern Visayas Integrated Agricultural Research Centre.

In relation to the capacity outputs, Table 3 shows the areas of knowledge, skills and practices developed to different levels by different users groups. Two main areas of social infrastructure were developed in LLIP: 1. regional improvement and innovation networks and partnerships such as LIIN, and 2. pig enterprise environment and energy system design and installation service teams.

Table 2. The current level of use for each output from ACIAR project ASEM/1997/041 and whether it is in a form that can be used by the final user

Technology and policy output-clusters and outputs	Form of output[a]	Level of adoption[b]
1. Sustainable improvement and innovation technologies and policy cluster		
1.1 Sustainable improvement and innovation model	I	*NI*
1.2 Forum on sustainable improvement and innovation for R&D organisations	I	*NI*
1.3 Project performance management framework	I	*NI*
1.4 Partnership and network development processes and associated tools	F	*NF*
2. Pig profit technologies cluster		
2.1 Pig system map	F	*NF*
2.2 Pig profit improvement process	F	*NF*
2.3 Profit focusing framework thinking tool	F	*NF*
2.4 Pig profit indicator tool	F	*NF*
2.5 Least cost feed formulations suited to smallholder contexts	F	*NF*
3. Pig and other enterprise environment and energy technologies and policy cluster		
3.1 Pig enterprise environment and energy system map	F	*NF*
3.2 Environment and economic indicators tool	F	*NF*
3.3 Biodigester and biogas installation designs	F	*NF*
3.4 Model of human infrastructure for smallholder pig environment system improvement	I	*NI*
3.5 Fertiliser formulations using biodigester by-products	F	*NF*

[a] I = the output is in a form that can be used by intermediate users. F = the output is in a form that can be used by final users.

[b] NF = demonstrated and considerable use by next and final user. Nf = demonstrated and considerable use by next user and minimal use by final user. NI = intermediate output with considerable use by next user and has led to further outputs for the final user. Ni = intermediate output with considerable use by next user but yet to lead to further outputs that have final users. N = some use by the next user. O = no uptake by next or final user.

Table 2. (continued)

4. Chicken profit technologies cluster		
4.1 Chicken system map	F	*Nf*
4.2 Chicken profit indicator tool	F	*Nf*
4.3 Bio-economic model of chicken production	I	*N*
5. Information systems		
5.1 Pig and chicken production profit information system	F/I	*Nf*
Capacity development output-clusters and outputs		
1. Continuous improvement and innovation methodology and tools cluster		
1.1 Capacity in key knowledge and skill areas of continuous improvement and innovation	F	*NF*
1.2 Continuous improvement and innovation booklet	F	*NF*
1.3 Manual for improvement and innovation network members and leaders	F	*NF*
1.4 Accreditation of Philippine specialists, extensionists and project leaders	I	*NF*
2. Forming and leading improvement and innovation partnerships and networks cluster		
2.1 Regional improvement and innovation network of partnerships	F	*NF*
2.2 Network tool	F	*NF*
2.3 Improvement and innovation forums	F	*NF*
3. Capacity in pig enterprise profit and marketing improvement and innovation cluster		
3.1 Manual for technical specialists	I	*NI*
3.2 Pig enterprise recording sheets	F	*NF*
3.3 Pig gross margin analysis tool	F	*NF*
3.4 Pig partial budget analysis tool	I	*Nf*
3.5 Pig price calendar	F	*NF*
3.6 Increased understanding of smallholder pig profit and marketing as a system	F	*NF*

Table 2. (continued)

4. Capacity in pig and other enterprise environment and energy improvement and innovation cluster		
4.1 Instruction manual	I	*NF*
4.2 Environment and economic improvement performance assessment tool	F	*NF*
4.3 Capacity building and guide to maintaining waste management systems	F	*NF*
4.4 Pig and other enterprise environment and energy system design and installation services	F	*NF*
5. Capacity in chicken enterprise profit and marketing improvement and innovation cluster		
5.1 Instruction manual	I	*Ni*
5.2 Illustrated farmer manual	F	*Nf*
5.3 Illustrated manual for extensionists, technical specialists and farmer networks	I	*Ni*
5.4 Chicken mortality tool	F	*Nf*
5.5 Chicken activity timeline	F	*Nf*
6. Capacity in establishing and managing input–output cooperative stores cluster		
6.1 Input–output stores	F	*NF*
6.2 Record sheets for use in input–output stores	F	*NF*
6.3 Guide for training in basic accounting	F	*Nf*
7. Capacity in marketing and value chains for impact on profit cluster		
7.1 Supply-chain mapping tool	F	*Nf*
7.2 Marketing cost analysis tool	F	*Nf*
7.3 Understanding marketing timelines tool	F	*Nf*
7.4 Guide for conducting a reconnaissance survey	I	*Ni*
7.5 Guide for conducting a SWOT analysis of livestock supply chains	I	*Ni*
7.6 Improved capacity to identify and assess markets and value-chain opportunities	F	*NF*

Table 3. Areas of knowledge, skills and practices developed to different levels by different user groups associated with ACIAR project ASEM/1997/041

Area of knowledge, skills and practices
Continuous improvement and innovation process and tools User groups: 1. smallholder farmers and other enterprise managers; 2. extensionists, technical specialists and network leaders; 3. government and non-government managers of projects, programs and units; 4. enablers of extensionists, technical specialists and network leaders and organisational managers
Forming and leading improvement and innovation partnerships and networks User groups: 1. extensionists and farmers who create, lead and support networks and partnerships; 2. government and non-government managers of partnership-based projects, programs and units
Pig enterprise profit and marketing improvement and innovation User groups: 1. smallholder pig farmers, and farmers moving into pig enterprises; 2. extensionists and technical specialists; 3. enablers of extensionists and technical specialists in pig enterprise profit and marketing
Chicken enterprise profit and marketing improvement and innovation User groups: 1. smallholder chicken farmers, and farmers moving into chicken enterprises; 2. extensionists and technical specialists; 3. chicken enterprise profit and marketing specialists
Pig and other enterprise environment and energy improvement and innovation User groups: 1. farmers and other enterprise managers with existing enterprise environment and energy management systems, or farmers and enterprise managers wanting to improve their systems; 2. extensionists and technical specialists; 3. pig (and other) enterprise environment and energy improvement and innovation specialists
Establishing and managing input–output cooperative stores User groups: 1. people responsible for different roles in cooperative input–output stores e.g. storekeepers, treasurers and business managers; 2. extensionists and technical specialists; 3. input–output cooperative store specialists
Marketing and value chains for impact on profit User groups: 1. smallholder farmers and supply-chain partners; 2. extensionists and technical specialists; 3. marketing and supply-chain specialists
Sustainable improvement and innovation model User groups: 1. project teams and partners in sustainable improvement and innovation projects and programs; 2. government and non-government leaders of sustainable improvement and innovation projects, programs and units; 3. government and non-government managers and policy developers; 4. enablers of partners, leaders and managers in sustainable improvement and innovation projects, programs and units

A smallholder biodigester in Eastern Leyte using pig effluent to produce biogas for household and neighbourhood use.

The following principles of the project have supported the rate and scale of output use:

1. creating and supporting active partnerships and networks
2. focusing on value for end-user partners
3. focusing on outcomes from the outset
4. applying continuous improvement and innovation to project management and performance
5. focusing on strong leadership for institutionalisation of successful mechanisms.

Whenever application of any of these five principles is neglected, the rate and scale of adoption (and impact) is hampered.

Gabi chips produced from yautia (*Xanthosoma sagittifolium*) are becoming a popular native delicacy as a result of innovation by processing enterprises establised in Anilao, Liloan, Southern Leyte that are using the Continuous Improvement and Innovation process.

4. Impact—the difference the project has made or is expected to make

Table 4 lists the impacts achieved during the project, and Table 5 those achieved since the project. For the impacts achieved during the project, specific economic, social and environmental results are available. The after-project impacts achieved were identified from surveys and workshops conducted during the adoption study.

LLIP was based on several key principles. These principles, and especially the principle of focusing on outcomes from the outset, were critical to the successful achievement of impacts during the project. These same principles, plus an additional principle developed from R&D during the project—*Focusing on the sustainability of outcomes, improvements and innovations from the outset*—were critical to the successful achievement of after-project impacts. In relation to this principle, it is essential to empower both individuals and partnerships, so that they can continue to achieve more rapid and increased scales of improvements and innovations.

The magnitude of impact achieved since LLIP is largely the result of the application of the first and fifth principles listed above. It is through the institutionalisation by VSU of the SI&I model and the CI&I process and tools that strong partnerships with NGOs, farmer networks and people's organisations, and government agencies have been developed to further grow the impacts in the Eastern and Central Visayas regions.

Table 4. Impacts achieved during project ASEM/1997/041

1. Impacts on enterprise profit
The majority of smallholder pig farmers involved in the Leyte Improvement and Innovation Network (LIIN) achieved sustainably higher incomes and an increase in profit from their pig enterprises. The increases in profitability have made a valuable contribution to the economic position of the smallholder families. The average gains in gross margins for those LIIN chicken farmers who implemented improvements and innovations were substantially greater than for those who did not implement improvements. Notwithstanding the relatively unprofitable nature of smallholder chicken enterprises, farmers continue to raise chickens, as this is an integral part of their farming system and is a source of food. Smallholder farmers involved in the LIIN were able to apply their increased capacity in achieving improvements in profit to their other enterprises (including rice, copra, vegetable, duck and fish farming, meat retailing and small store enterprises) and to establishing additional enterprises. The flow-on benefits from increases in income and profit included improved income and food security, being able to finance house repairs and financing children's schooling.
2. Impacts on pig enterprise environment and household efficiency
Major benefits in localities where pigs are commonly raised near residential housing were achieved through improvements in the following areas: cleanliness of surroundings; control of mosquitoes and flies; reductions in on-farm smell; and relationships with neighbours. These improvements have increased the preparedness of the smallholder pig farmers to work within expected local government requirements in relation to raising pigs. Installation of waste-management systems led to the following benefits: 1. production of biogas provides gas for cooking, which reduces household costs associated with buying LPG or firewood, and increases household labour efficiency in situations where previously firewood needed to be gathered for cooking; 2. using the effluent from biodigesters, or collected and treated pig waste, to fertilise crops such as vegetables and rice, thereby reducing fertiliser costs; 3. smallholder farmers who had not previously been able to grow vegetables were able to grow these in pots and small gardens by using the biodigester effluent. This improved food security, and provided another source of income for smallholder families.
3. Impacts on input–output marketing
Through the establishment of cooperative input–output stores, LIIN members were able to address capital and credit constraints that had affected their ability to purchase necessary inputs such as feed and biological supplies, and achieved reduced input costs through collective buying. They were also able to enter into collective selling, create market outlets for their products and increase the price received for their products. Collaboration between one input–output store and a meat retailer led to the meat retailer increasing his operation from once or twice a week to daily. Significant increases in net operating profit were achieved by the Hindang Swine Raisers Cooperative store and this surplus was retained to increase the stores operating capital, so that future profits could be distributed to members as rebates/dividends, thus contributing to farmer income and income security. Other input–output farmer-managed stores established in the region engaged in other business opportunities such as construction of biodigesters for other farmers and selling weighing services to butchers and farmers in their areas.

Table 4. (continued)

4. Impacts on human capital and regional social capital
The majority of LIIN members have improved confidence, self-reliance and ability to manage and improve their pig and chicken enterprises, and to manage and improve other enterprises in which they are involved. They are also more likely to diversify into new enterprises. This has led to improved profit, income security, household efficiency and food security.
The majority of LIIN members have improved confidence, self-reliance and ability to build and benefit from partnerships. These partnerships support the smallholders achieving improvements in profit, income security, household efficiency and food security.
LIIN provides an infrastructure for local improvement that goes beyond the scope of livestock and agriculture improvement. This infrastructure supports smallholder farmers to continue improving the management, profitability and long-term sustainability of their animal production systems, and to extend their influence into other related business and alternative enterprises. This has led to improved profit, income security, household efficiency and food security.
LIIN has led to partnership development between smallholder farmers, service providers and customers in value chains, which has led to improvement in the services available to smallholder farmers and improved presence of the smallholder farmers in value chains.

Smallholder farmers, members of the Leyte Improvement and Innovation Network, meeting in Hindang, Eastern Leyte, to contribute to the adoption study for ACIAR project ASEM/1997/041.

Table 5. The following impacts and benefits of ACIAR project ASEM/1997/041 have been achieved since the project's completion. They are either impacts additional to those achieved during the project, or increases in the level and scale of impacts achieved during the project.

1. Impacts on enterprise profit in agricultural and non-agricultural enterprises
Improved income and profit from agricultural enterprises, which is providing greater income security and sources of income for smallholder families. The benefits are being used to address family needs such as improving nutrition, house improvements, providing quality education for children, and accessing medical services. Partners involved in non-agricultural enterprises have also recorded improved income and profit from their enterprises, which is providing greater income security for these people. Improved productivity of agricultural enterprises is improving the quantity and quality of food available, thereby providing increased food security for families. Some families no longer need to buy staples such as rice and vegetables because they are able to produce enough for their families, plus surplus produce which they can 'share as blessings and gifts to neighbours' or sell to gain additional income. The increased income and profit from more profitable enterprises is supporting less profitable but necessary enterprises and other farm expenses, and in some cases is enabling the employment of workers.
2. Impacts on pig enterprise environment and household efficiency
Major benefits in localities where pigs are commonly raised near residential housing have been achieved through improvements in the following areas: cleanliness of surroundings; control of mosquitoes and flies; reductions in on-farm smell; and relationships with neighbours. These improvements have increased the preparedness of the smallholder pig farmers to work within expected local government requirements in relation to raising pigs. Larger scale pig and chicken enterprises have benefited from the application of biodigester technology which has led to more effective and efficient waste management in these enterprises. Installation of waste management systems led to the following benefits: 1. production of biogas provides gas for cooking, which reduces household costs associated with buying LPG or firewood and increases household labour efficiency in situations where previously firewood needed to be gathered for cooking; 2. using the effluent from biodigesters, or collected and treated pig waste, to fertilise crops such as vegetables and rice, thereby reducing fertiliser costs; 3. smallholder farmers who had not previously been able to grow vegetables were able to grow them in pots and small gardens by using the biodigester effluent. This improves food security and provides another source of income for the smallholder families. In a small number of situations, smallholder operators of biodigester/biogas systems have been able to pool excess biogas to provide energy for a local bakery. This has provided additional income for the smallholders, a cheap source of energy for the bakery operator and, as a consequence of the increased availability of energy to the bakery, a larger source of bread and baked products is available in the community. The expansion of the bakery enterprise has also led to increased employment.

Table 5. (continued)

3. Impacts on input–output marketing
Cooperative input–output stores have continued to overcome capital and credit constraints that affect the ability of smallholder farmers to purchase necessary inputs such as feeds and biological supplies, and have achieved reduced input costs through collective buying. They were also able to enter into collective selling, create market outlets for their products and increase the price received for their products. The stores have usually been able to obtain feeds from suppliers on credit and at a discount for bulk buying. This enables the stores to sell to members on credit and at lower prices. The stores often enter into collective selling opportunities, value-chain alliances and the creation of market outlets for the products produced by smallholder farmers. This has led to increased prices for products and greater certainty of sales. Cooperative input–output stores are also engaging in other business opportunities which provide services to other farmers (e.g. biodigester construction and weighing services) and other enterprises such as butchers.
4. Impacts on human capital and regional social capital
Improvements in ability in the following areas of human-capital have been identified by partners: 1. analysing profit and determining whether an enterprise is gaining or losing; 2. evaluating the operations of an enterprise and determining where improvements can be made, and exploring different options to achieve these improvements; 3. seeing the advantages and disadvantages of any opportunity; 4. seeing better ways and means to improve, particularly with regard to marketing; 5. establishing relevant benchmarks and measures for different enterprises; 6. generating knowledge for improvements and innovations; 7. finding solutions to problems that are encountered; 8. planning improvements; 9. transferring lessons from improving one enterprise to the improvement of other enterprises; 10. sharing knowledge, technologies, improvements and innovations, and educating neighbours and children about these improvements; 11. raising/growing and selling agricultural products; 12. awareness of environmental issues; 13. capacities in daily living; 14. managing organisations; 15. dealing with different people; 16. strengthening and expanding organisations. LIIN continues to provide an infrastructure for local improvement, and other people's organisations have been strengthened in relation to social infrastructure to support improvement and innovation.

Chinese wool-textile mills: economic analysis of fibre-input/textile product selection and new processing technologies (ASEM/1998/060)

Colin Brown, Scott A. Waldron, John W. Longworth and Zhao Yutian

Summary project information

Project number	ASEM/1998/060
Project name	Chinese wool-textile mills: economic analysis of fibre-input/textile product selection and new processing technologies
Collaborating institutions	Australia: University of Queensland (UQ) China: Research Centre for Rural Economy (RCRE)
Project leaders	Australia: Dr Colin Brown and Professor John Longworth China: Professor Ke Binsheng
Duration of project	1 July 1998 – 30 June 2001; extension 1 July 2001 – 30 June 2005
Funding	$699,622
Countries involved	Australia and China
Commodities involved	Wool
Related projects	AS1/1997/70 and AS1/1997/69

1. Motivation for the project and what it aimed to achieve

Economic reforms and market developments pose major challenges for the viability of the vast majority of Chinese wool-textile mills. To ensure their long-term future, Chinese mills must adapt to changing market and policy environments, and improve the viability and efficiency of their operations. The long-term viability of Chinese mills is central to the interests of the wool and wool-textile industries of both China and Australia. Chinese wool-textile mills are significant employers and provide a market for wool from poor pastoral areas of Western China. Australia is the world's largest supplier of wool, and China is Australia's largest wool export market.

The primary goal of project ASEM/1998/060 was to improve the long-term economic viability of Chinese wool-textile mills. Ways to improve mill viability were identified through the development of a model that allows managers to test and make more profitable decisions. The analysis adopted a whole-mill approach that takes into account the entire operation of the mills, including the source of their fibre inputs, the markets for their textile products, and their costs and revenue structures.

The mill model also incorporated findings from the processing-prediction and effluent-treatment research of projects AS1/1997/070 and AS1/1997/069. These CSIRO/ACIAR wool-textile science projects aimed to improve the technical efficiency with which Chinese wool-textile mills undertake particular operations. Project ASEM/1998/060 takes the next two crucial steps of showing: 1. how the output from these CSIRO/ ACIAR projects can best be used to improve overall mill profitability; and 2. the measures needed in the

The modernisation and increasing sophistication of China's wool garment manufacturers have placed increasing pressure on China's wool-textile mills to meet user preferences and demands in their wool-textile outputs. Examining these demands and preferences, and providing a means for wool-textile mills to account for them in their managerial decisions, was a key part of the project.

textile-product and wool-supply chains to facilitate the application of these technologies and processes. A demonstration of how these technologies and processes can assist mill profitability, and an analysis of how the domestic and imported raw material supply chains can be improved, are important steps towards ensuring the adoption of these new technologies by Chinese wool mills.

Project ASEM/1998/060 had a long gestation, with many organisations such as the CSIRO Wool Technology Group, the Department of Agriculture, Forestry and Fisheries (DAFF, Australia), the International Wool Secretariat (IWS), Agriculture Victoria and the Cooperative Research Centre for Premium Wool Production interested in some or all of the project. As the lead organisation on Project ASEM/1998/060, the China Agricultural Economics Group at the University of Queensland liaised extensively with these other interested parties. In addition, a 'China wool group' (involving researchers on projects AS1/1997/070, AS1/1997/069 and ASEM/1998/060, the ACIAR program coordinators on these projects, as well as interested IWS and DAFF and other Australian Government and wool-industry officials) was established in September 1999. This forum provided a useful conduit for the exchange of information between the suite of ACIAR wool-textile projects in China and associated organisations.

2. What the research project produced

The primary output from the project is a sophisticated operations research decision-making model, known as CAEGWOOL, for Chinese wool-textile mills. The model was developed based on meetings with 30 mills in China, pre-tested in close association with three mills before being presented to 30 mills at a major project workshop in 2004. The development of the mill model was accompanied by a series of analyses and methods that are also a major contribution to this area, including approaches to determine mill-specific product-cost coefficients and a detailed analysis of wool prices. An electronic version of the model, along with a detailed technical manual and a comprehensive guide and discussion to the accompanying analysis, was published by ACIAR as a technical report (Brown et al. 2005b) with an accompanying CD (Zhao et al. 2005) in both English and Chinese and has been widely distributed in China.

It can be reported that the model and methods used were reported widely in various industry and academic conferences in China and Australia.

A further major output was an in-depth analysis of both the domestic and imported wool-marketing chains, the results of which are reported by Brown et al. (2005a) and Longworth et al. (2004, 2005).

A paper by Longworth et al. (2006) based on information and analysis from the project was presented at a key Wool Industry Seminar in Beijing in 2006 associated with the Free Trade Agreement negotiations:

In addition, John Longworth presented a paper (Longworth 2006) at a trade conference in Xi'an, while Zhao Yutian, the principal investigator of the project in China, has also presented or published several influential papers (Zhao 2004, 2006a,b,c) based on the information and analysis developed through the study.

On the capacity-building side, the project has been instrumental in developing the management capabilities of Chinese mill managers, in:

- improving knowledge about the Chinese wool and wool-textile industry within the Chinese Ministry of Agriculture and the Australian industry

- raising the level of information about the Chinese wool and wool-textile industries and problems in Sino-Australian wool trade flows with trade negotiators and officials
- building networks and information flows between sectors of the Chinese industry and between the Chinese and Australian industries.

3. Adoption—how the project outputs are being used

Although the mill model was in a form that could be used directly by the mills, following the successful technical workshop of the model in Wuxi in 2004 and recommendations of the project impact assessment in 2005, measures were taken to commercialise it. This was to involve the reprogramming of the model to develop a more user-friendly interface and to provide ongoing training, technical support and maintenance for the model. This activity was developed by the RCRE in conjunction with the China Wool Textile Association, and with the backing and support of the UQ team (which would provide advice and technical support on future model refinements). A detailed proposal was developed and put to Australian Wool Innovation (AWI) and in-principle support for the proposal was provided to the Chinese team. ACIAR offered to support the commercialisation through co-funding arrangements if primary funding could be secured. However, a change in direction at AWI at the time (an emphasis on end-markets) meant that the proposal did not proceed. Despite this setback, various mills have used variants of the model and analysis contained within it, while the workshop, technical manual and publicity about the model have helped mills adapt their management procedures.

Adoption of the domestic wool-supply-chain analysis has been pronounced. It has, for example, been used extensively in China – Australia Free Trade Agreement negotiations by all parties (the Chinese

In the late 1990s and early 2000s, the Chinese wool-textile industry sought to upgrade its equipment and restructure its ownership and governance. Another critical element in the transition and modernisation process was the development of managerial skills. This was the focus of ACIAR project ASEM/1998/060.

Ministry of Agriculture, DAFF/Department of Foreign Affairs and Trade and AWI) (see Longworth 2006, 2007). The work within the project on domestic supply chains led directly to a project aimed at practical investigation and implementation of various wool-marketing trials and reforms. This was funded by DAFF under the China–Australia Agricultural Technical Co-operation program in 2007 and 2008. It allowed the recommendations from Project ASEM/1998/060 to be implemented in collaboration with the major fine-wool producers and government agencies and marketing in China.

The analysis of the supply chain for imported wool has also been used extensively by all parties in China — Australia Free Trade Agreement negotiations. Furthermore, the project was instrumental in facilitating the research in a PhD study by Ben Lyons who is now a senior manager within AWI and who has been involved in numerous visits, missions, delegations and meetings aimed at resolving specific wool-trade issues between China and Australia and in promoting cooperation between the two countries and industries (Lyons 2009).

4. Impact—the difference the project has or is expected to make

The project has had an impact in four main areas:

- an improvement in decision-making in, and profitability of, Chinese wool-textile mills. The impact on Chinese wool-textile mills relates to refinements and changes in the information systems and decision processes mills use. The impacts on Chinese wool-textile mills would have been significantly larger if efforts to 'commercialise' the CAEGWOOL model had succeeded.
- an improvement in domestic wool marketing in China. The project has facilitated improvements in domestic wool marketing through the provision of more accurate price and product information on which to base decisions, and in the reduction in costs associated with more efficient supply channels.
- an improvement in supply chains for imported wool. The project has had an impact on imported wool supply chains through much better informed wool industry participants and officials, improved goodwill, fewer interruptions to trade flows, smoother trade negotiations, and fewer distortions associated with 'irrational' responses.
- improved capacity building and integration across the entire spectrum of Chinese and Australian wool and wool-textile industries, with a direct and significant impact on capacity, networks and integration across the Chinese and Australian wool textile and wool industries.

Some trading intermediaries in both the domestic and imported wool supply chains that have benefited from imperfections in the wool supply chains may be adversely affected to the extent that the project has improved supply-chain efficiency. However, as these intermediaries are typically general (non-wool specific) intermediaries, any adverse individual impact will be offset by a move into other, more lucrative commodity trading, while the benefits of the improved efficiency and income in the supply chains serviced by more specialised wool intermediaries will be significant.

The diverse and multidimensional nature of the project, as well as the subsequent spin-offs, make it difficult to attach a precise monetary value of the impacts. For instance, the monetary value of the potential long-term, trade-related benefits of the ACIAR project to both countries could be enormous. Nonetheless, a conservative estimate of the benefit is in the order of $13.38 million.

While the monetary benefits of ACIAR Project ASEM/1998/060 are hard to measure precisely, the intangible benefits flowing to both China and Australia from this project have been most significant. The China Wool Textile Association (the peak organisation for the wool mills in China) supported the industry-wide promotion of the CAEGWOOL model. In addition, the Chinese Ministry of Agriculture (MoA) also valued the contributions made by the project in terms of their improving the domestic supply chain for wool. This was confirmed when the MoA agreed to allow the recommendations of this project to be trialled in three major Chinese woolgrowing counties in 2007–08 as part of the subsequent Australian Trade Commission/AWI project. From the Australian side, more efficiently organised and managed, and hence more profitable, mills in China, and an improved understanding of the Australia-to-China wool supply chain, taken together have the potential to make a major contribution to increasing the demand (and hence price) for the Australian wool clip, of which about two-thirds is sold to China.

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Traits for yield improvement of chickpea for drought-prone environments of India and Australia (CIM/1996/007)

Neil Turner

Summary project information

Project number	CIM/1996/007
Project name	Traits for yield improvement of chickpea for drought-prone environments of India and Australia
Collaborating institutions	Australia: Centre for Legumes in Mediterranean Agriculture (commissioned organisation); South Australian Research and Development Institute; CSIRO Plant Industry; Agriculture Victoria; NSW Department of Primary Industries; Queensland Department of Primary Industries and Fisheries India: CCS Haryana University; Indian Institute of Pulses Research; JNKVV Agricultural University; Indian Council of Agricultural Research; Indian Agricultural Research Institute; International Crops Research Insititute for the Semi Arid Tropics
Project leaders	Australia: Dr Neil Turner, Centre for Legumes in Mediterranean Agriculture India: Mangla Rai, Indian Council of Agricultural Research; A.N. Asthana, Indian Institute of Pulses Research; Masood Ali, Indian Institute of Pulses Research
Duration of project	1 July 1998 – 30 June 2001; extension 1 July 2001 – 30 June 2005
Funding	$1,163,674

Countries involved	Australia and India
Commodities involved	Chickpea
Related projects	CS1/1992/016, CS1/1994/036 and CS1/1995/100

1. Motivation for the project

In the mid 1990s there were about 50 breeders in India breeding for improved yields of chickpea in their local environment. As chickpea yields poorly relative to wheat under irrigated conditions, chickpeas were being replaced by a wheat–rice rotation in areas where irrigation had been introduced and chickpeas were being increasingly grown under marginal, non-irrigated conditions. As a consequence of this shift in production, yields were stable or even declining, despite the breeding effort. Breeders in India have traditionally worked with entomologists and pathologists to incorporate insect and disease resistance into chickpea, but had not worked with physiologists to improve the yield of chickpea in the marginal rainfed environments in which chickpea was being grown. In Australia, chickpeas are grown without irrigation and, whether grown on current rainfall in areas of southern Australia with a Mediterranean-type climate or on stored soil moisture in north-eastern Australia with a subtropical climate, as in India they suffer from terminal drought. In the mid-1990s, the Cooperative Research Centre (CRC) for Legumes in Mediterranean Agriculture (CLIMA) had a program involving plant breeders and physiologists aimed at improving yields of cool-season food legumes, particularly chickpea, in water-limited environments. Most of the

Crossing chickpeas at CCS Haryana Agricultural University, Hisar.

chickpea cultivars being grown in Australia at that time were selections from lines introduced from India. Chickpea is grown under similar climatic conditions in India and Australia and the fact that the successful selections in Australia were largely of Indian origin provided an opportunity to introduce chickpea breeders in India to the methodologies used in Australia. This enabled them to evaluate and select lines adapted to water-limited environments and to evaluate the physiological and phenological characteristics that made Indian lines suited to Australian conditions.

One of the principal aims of the project was to link physiologists working in Indian institutes with the chickpea breeders working in the same institute. This was achieved by having a breeder and a physiologist working together at all centres that were funded through the project. The combination of physiologist and breeder was utilised in two ways: 1. to evaluate the phenological, yield components and the genotype by environment (G × E) interaction of a set of common genotypes at seven sites in India and five sites in Australia, and 2. to identify a number of morphological, physiological and biochemical characteristics that confer a yield advantage under terminal drought, and to develop screening methodologies for these characteristics in breeding populations. To achieve the interaction among the scientists, a training program in the measurement of the physiological and biochemical characteristics, 'Agro-physiological techniques for drought-resistance traits', was undertaken at the beginning of the project in December 1998. This was followed by a training program on data recording, analysis and interpretation, 'Modern PC-based data handling and multivariate analysis', in February 2000. A third training course, 'Strategies for optimising G × E studies in breeding programs', was conducted at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the Indian Institute of Pulses Research (IIPR) in March–April 2003. A final objective was to develop breeding populations to test the usefulness of screening methodologies identified and determine whether molecular technologies can further improve the efficiency of breeding for drought resistance in chickpea.

2. What has the research project produced

The technical outputs of the project were as follows:

- A number of new cultivars of chickpea with superior drought tolerance were released in India as a result of the project (e.g. BG 1053, BG 1103, BG 1105, BG 1108, ICP 97-67). In addition, a number of drought-resistant lines (ICCV 10, BG 256, BG 364, ICC 4958, ICCV 92944) were identified as suitable parents and used in crossing programs both in India and in Australia.
- Techniques for screening breeding populations and advanced lines for osmotic adjustment, relative water content, transpirational cooling, membrane stability, sucrose synthase and root growth were developed and used by physiologists in association with breeders.
- Modern PC-based methods of data recording, statistical analyses and analysis of G × E interaction are now available to researchers in India, leading to more complete analysis of information collected in the All-India Co-operative Research Project on Chickpea (AICRPC).
- Recombinant inbred lines of chickpea differing in osmotic adjustment and seed size were developed and evaluated.
- Numerous papers were published in international, regional and conference proceedings outlining the methodologies developed in the project and the outcomes of the research.

The following were the policy outputs of the project:

- The G × E studies in Australia resulted in a paper published in the *Australian Journal of Agricultural Research* that indicated that breeding for improved drought resistance would be better conducted in Western Australia, than in New South Wales. This is because the increasing chance of rain in northern New South Wales near maturity made selection for terminal drought avoidance and tolerance difficult.
- The successful interaction of breeders and physiologists in the project provided an example to policymakers of the importance of including physiologists in teams aiming to improve crop yields in water-limited environments.

The project also had several capacity-building outputs, as follows:

- The training in 'Agro-physiological techniques for drought-resistance traits' at the beginning of the project made breeders aware of the potential of incorporating physiologists to add value to breeding projects, particularly for drought-prone environments. It also trained physiologists in a wider range of techniques than was currently in place at any one centre in India. One of the breeders involved was employed by ICRISAT and has worked closely with the physiologists and pathologists in breeding chickpea for a range of environments in the developing world and Australia. The training in 'Modern PC-based data handling and multivariate analysis' is being routinely utilised at most centres in India now that personal computers are available to all scientists.

Labourers preparing bags for harvesting chickpeas at the Indian Institute of Pulses Research, Kanpur.

Professor Turner discussing the adoption of the project with Dr Jitenrda Kumar (breeder), Professor P.S. Deshmukh (physiologist) and Dr T.P. Singh (physiologist) at the Indian Agricultural Research Institute, New Delhi.

- The training in 'Strategies for optimising G × E studies in breeding programs' was primarily developed for the breeders and statisticians involved with the AICRPC and other pulses (mung bean, urd bean, lentil, lathyrus and peas). Two years after the project finished, a statistician was appointed to analyse the annual results from AICRPC. The appointee established a coordinated experiment with 25 genotypes at 8–10 sites across the chickpea-growing regions of India to evaluate the G × E interaction. Two more statisticians will be appointed shortly, to analyse the results from the All-India Coordinated Research Project on Mung Bean, Urd Bean, Lentil, Lathyrus (MULLa) and other pulse crops and to establish an experimental program to understand the G × E interaction in breeders plots.
- Eight scientists travelled across Australia to see the G × E experiments being conducted in five states from Western Australia to Queensland. All commented on how this had helped them understand Australian agricultural systems and the G × E interaction in the genotypes introduced from India as part of the project.
- Of the nine scientists who spent 1–6 months training in Australia, six have used their experience and training in India and, of the five interviewed, all indicated that the experience had been invaluable in their scientific development. The principal breeder at the key centre, the Indian Institute of Pulses Research (IIPR), had only just started as a chickpea breeder when he went to Australia for training,

experience that provided him with new methods of selection now utilised routinely in India. The physiologist at IIPR gained experience in the use of physiological techniques for evaluating genotypes and recombinant inbred lines for drought-resistance traits. The physiologist and the breeder work together in using these techniques at IIPR. The head of biotechnology at IIPR spent time in Australia gaining experience with the development of molecular markers and transformation techniques in pulses. They are now being used and adapted at IIPR. All credit their experience in Australia as a learning experience in project management, creative thinking, attitudes to research and ethics.

3. Adoption—how the project outputs are being used

At the start of the project and except at one centre, physiologists were not working with breeders, even where both were on the staff. The project brought together a physiologist with a breeder at five centres and most still are working together. Even at one centre where both the principal breeder and physiologist have retired, their successors have continued and even extended the collaboration. Further, the success of the project and the linkages forged have encouraged breeders and physiologists of other crops to work together. Moreover, the Director General of ICAR has been reported as stating publicly that all future key breeding nodes will have a physiologist as part of the team, funded by ICAR. This is already the case in all the key chickpea-breeding programs (*NF*[1]).

The project is credited with the development of five new drought-resistant cultivars of chickpea to date: BG 1053, BG 1103, BG 1105, BG 1108 and ICP 97-67. These were reported to have been widely adopted in the states where chickpea is grown (*NF*).

Osmotic adjustment, transpirational cooling, relative water content, membrane stability, chlorophyll content and root growth are all screening techniques being used regularly in breeding programs at a number of centres, not only to screen chickpea and other crops for drought-resistance traits, but also for high-temperature tolerance (*NF*).

The advent of a personal computer on each scientist's desk has led to the widespread adoption and use of PC-based data handling and analysis. Further, data collected by the AICRPC are now analysed using multivariate and principal component analysis, and experiments to determine the G × E interaction in chickpea have been initiated across India. In future, a similar program will be implemented in the All-India Coordinated Research Project on Mung Bean, Urd Bean, Lentil and Lathyrus (MULLa) (*NF*).

Recombinant inbred lines (RILs) were developed for differences in osmotic adjustment, a putative drought-resistance trait. However, osmotic adjustment in chickpea was found not to be highly heritable, and breeding for high osmotic adjustment and the development of molecular markers for the trait have therefore not been pursued (O).

The networks between the Australian and Indian breeders and physiologists developed during the project are still active, as evidenced by the joint scientific papers on the project results and the results of subsequent research projects that have been, and are continuing to be published in international journals (*NF*).

1 See Table 3 on page 13 for explanation of codes for levels of adoption.

Dr P.S. Basu (physiologist) and Dr S. Chaturvedi (breeder) discussing chickpea selections at the Indian Institute of Pulses Research, Kanpur.

The three formal training programs were all considered by the participants to be important in the successful implementation of the project and in their personal development. The techniques and training received have been adopted by breeders working in conjunction with physiologists at several centres and on other crops. Personnel trained at the beginning of the project are now routinely training others in India (*N*).

The training in 'Agro-physiological techniques for drought-resistance traits' is now being passed on nationally through regular training programs for postgraduate students and staff at a number of centres. The eight scientists who visited Australia to see the experiments across the continent commented on how helpful this had been in understanding the G × E interaction in the genotypes introduced from India as part of the project and how it had encouraged them to introduce similar studies in India. Of the nine scientists who spent 1–6 months training in Australia, six have all used their experience and training in India, and indicated that the experience had been invaluable in their scientific development (*NF*).

Several participants in the project indicated that major benefits to them were learning how to put together a project proposal and how to implement and manage multilocation projects involving several disciplines. One of the unexpected benefits of the project was the adoption of lessons learned from the management of the project. The development of strict protocols for the G × E studies, contrasting with a lack of strict protocols in the physiological studies, led to good results in the G × E studies and unreliable results in the physiological studies. These outcomes were observed by those who are now leading chickpea improvement projects in India and have stimulated the adoption of strict guidelines and protocols for all studies in their projects (*NF*).

4. Impact—the difference the project has or is expected to make

The initial impact of this project is on the research community. The breeders of chickpea (and other crops) will be able to more reliably breed for improved drought resistance, so that, with climate change, crops available to farmers will be more adaptable to the hotter and drier climate expected, leading to improved food and income stability for farmers and rural communities.

With the spread of irrigation in northern India, rainfed chickpea production is falling in the northern states but increasing further south in the states of Maharastra, Madhya Pradesh, Andhra Pradesh and Karnataka. The G × E studies have identified the phenological requirements for chickpeas in these southern states, which will make for more rapid breeding for these environments. While the main centre for pulses research is located in the north at Kanpur, the G × E analysis of data from throughout India should guide the breeding objectives for the major chickpea growing areas. It is not clear at the time of the review if this was being undertaken.

The project provided an opportunity to bring a range of chickpea genotypes from India for evaluation and incorporation in the Australian chickpea-breeding program. Some crosses were made, but the outbreak of Ascochyta blight shortly after the project commenced and the lack of tolerance to Ascochyta blight in the genotypes has limited their use in Australian breeding programs. Nevertheless, the linkages made through the project have resulted in a cooperative breeding project between Western Australia and ICRISAT for improving the Ascochyta tolerance of desi chickpea, and a joint project between physiologists and breeders in Australia and India to improve the salinity and boron-toxicity tolerance of chickpeas.

Professor P.S. Deshmukh explaining an experiment on improving the drought resistance of chickpea at the Indian Agricultural Research Institute, New Delhi.

Liriomyza huidobrensis leafminer: developing effective pest-management strategies for Indonesia and Australia (CP/2000/090)

Peter Ridland

Summary project information

Project number	CP/2000/090
Project name	*Liriomyza huidobrensis* leafminer: developing effective pest-management strategies for Indonesia and Australia
Collaborating institutions	Australia: Department of Primary Industries, Victoria (DPIV); CSIRO Entomology (CSIRO); Centre for Environmental Stress and Adaptation Research (CESAR), La Trobe University and University of Melbourne Indonesia: Institut Pertanian Bogor (IPB); Universitas Udayana, Denpasar (UNUD); Universitas Hasanuddin, Makassar (UNHAS); Universitas Sam Ratulangi, Malino (UNSRAT); International Potato Center – Centro Internacional de la Papa, Bogor (CIP); Balai Pengkajian Teknologi Pertanian Sumatera Barat (BPTP), Sukarami; Laboratory of Entomology, Museum Zoologicum Bogoriense, Centre for Research and Development in Biology (LIPI), Cibinong
Project leaders	Australia: Peter Ridland (DPIV) Indonesia: Aunu Rauf (IPB)
Duration of project	1 January 2001 to 30 June 2003; extension 1 July 2003 to 31 December 2004
Funding	$598,356

Countries involved	Australia, Indonesia (excluding East Timor) and other South-East Asia
Commodities involved	Potato, cucurbits, tomato, brassicas, other vegetables
Related projects	CP/2005/167

1. Motivation for the project and what it aimed to achieve

Vegetable growers in Indonesia faced an invasion of several exotic pest species of polyphagous *Liriomyza* leafminer flies. Since detected in 1994, *Liriomyza huidobrensis* (Blanchard) (Diptera: Agromyzidae), the potato leafminer fly, has become a major problem in potatoes and many other vegetable and flower crops grown in many highland agricultural areas in Indonesia. In Java and Sumatra, many potato growers reported yield losses of 30–70%, despite spraying 16–20 times per crop. At the same time, *Liriomyza sativae* (Blanchard), the vegetable leafminer, also became a major problem in lowland areas in Indonesia, infesting mainly beans, tomatoes and cucumber. Both leafminer species have continued to spread eastward through Indonesia and more widely through South-East Asia. Given the rapid spread of these pests, it is likely that vegetable and cut-flower producers in Australia and Papua New Guinea will have to contend with at least one of these pest species in the near future.

Professor Ir Wayan Supartha (Universitas Udayana), Professor Aunu Rauf (Institut Pertanian Bogor), Ketut Suparta (farmer), Professor Ir Wayan Susila (Universitas Udayana), Ir Wayan Sunada (farmer) discussing leafminer issues in potato at Pancasari, Bali.

The collaborating institutions came together to focus on the leafminer problem in Indonesia, following a planning meeting held in Bogor in 2000 to analyse the needs for further research to improve management of *Liriomyza* species.

The project aimed to reduce the reliance on insecticides to control leafminers and to strengthen the foundations for effective pest management of *Liriomyza* species. This was to be achieved by:

- obtaining comprehensive information on the distribution of *L. huidobrensis* and *L. sativae* and their parasitoids in vegetable crops in easterly regions of Indonesia (North and South Sulawesi, Bali, Lombok)
- assessing the potential for natural enemies to minimise the impact of *L. huidobrensis* on potatoes
- investigating effects of insecticides on the leafminers and their natural enemies
- increasing preparedness of Australian horticultural industries for the arrival of *L. huidobrensis* or related *Liriomyza* species into Australia.

2. What the research project produced

The project team focused on collecting high-quality information about the factors that were likely to be limiting the spread and impact of the invasive polyphagous *Liriomyza* species in Indonesia. The research undertaken covered taxonomy, biology, ecology, population dynamics and toxicology, and has built the necessary foundations for the development of robust pest-management programs in the future.

The project highlighted the dangers associated with uncontrolled and indiscriminate use of broad-spectrum insecticides for controlling leafminers. Repeated applications of profenofos were shown to be ineffective in controlling *L. huidobrensis* numbers on potatoes in the field. Rather, they reduced parasitism and predation that correlated with increased damage and decreased yield in the pesticide-treated fields. In contrast, there were no detrimental effects associated with repeated applications of abamectin, a more selective pesticide.

Surveys of native parasites and predators of *Liriomyza* species revealed a rich complement of natural enemies in Indonesia (19 species of parasitic wasps and 1 species of a predatory fly). These findings demonstrated that importation of exotic parasitoid species would not be required for Indonesia or Australia (in the case of an incursion of polyphagous *Liriomyza* species). Conservation and exploitation of the rich fauna of endemic leafminer parasitoids were shown to be important components for developing a sustainable integrated pest management (IPM) strategy for controlling leafminer pests in Indonesia. At the practical level, the project has produced information that will assist farmers in Indonesia appreciate, conserve and exploit their local biodiversity, thereby reducing their dependency on, and use of, chemical pesticides.

The benefits of correct identification of leafminer species in devising control strategies were also demonstrated. The project developed illustrated Lucid® keys for identifying the leafminer pests and their parasitoids. The keys are now available on the internet.

Liriomyza sativae damage on longbean at Lepang, Bali.

Essential information was provided for responding to leafminer incursions into Australia, and information for effective control strategies that can be implemented against leafminer in Indonesia. The project has developed strong links between scientists in Indonesia and Australia.

Capacity building of our collaborative partners was enhanced by 1. contributing to several formal meetings in Indonesia and Australia to discuss and plan work activities, 2. participating in training courses, 3. provision of opportunities to develop their research management skills, 4. developing their scientific writing skills, and 5. the opportunity given to two scientists to present some of their research at two international entomological congresses.

The collaborating scientists continue to play a significant role in entomological research in Indonesia. In addition, the project has successfully contributed to the training of many students (19 postgraduate; 23 undergraduate) in Indonesia who are now working in a number of other Indonesian universities and government institutions. Warsito Tantowijoyo (CIP) was awarded a John Allwright Fellowship to study the effects of altitude on the competition between *L. huidobrensis* and *L. sativae* and, for this research, has been awarded a PhD from the University of Melbourne. Intensive field work was carried out in Central Java, laboratory experiments at IPB and data analysis at the University of Melbourne.

3. Adoption—how the project outputs are being used

Outputs fell into three groups: 1. information on *Liriomyza* species, 2. information on natural enemies and 3. the role of insecticides in pest management. Generally, the adoption process was similar in each area. Results were disseminated by publication in international (eight papers) and Indonesian scientific journals, presented at international and Indonesian national conferences and in seminars with Dinas Pertanian, BPTP and BPTPH in South Sulawesi, North Sulawesi, Bali and West Sumatra. There was also awareness-raising about all three areas in the communities associated with population-dynamics trials (Solok area, West Sumatra; Pangalengan, West Java; Malino, South Sulawesi).

Much of the information on leafminers and their natural enemies gathered in this project has been incorporated into a farmer field school (FFS) module prepared by Warsito Tantowijoyo as part of a CIP/FAO project to develop a comprehensive FFS curriculum for the integrated crop management of potato. The curriculum was tested in a season-long training of trainers. The manuals have subsequently formed the basis for potato farmer field schools currently being delivered in West Java and Central Java as part of ACIAR Project CP/2005/167 – Optimising the productivity of the potato/*Brassica* cropping system in Central and West Java and the potato/*Brassica*/*Allium* system in South Sulawesi and Nusa Tenggara Bara.

The project focused on assessing the factors likely to be limiting the spread and impact of *Liriomyza* species in Indonesia, and large-scale extension activities were not a major component of the project. The need for a wide-scale extension program was a major recommendation of the project review in December 2003.

4. Impact—the difference the project has or is expected to make

The decline in importance of *Liriomyza* species in Indonesia can be attributed to the build-up of endemic parasitoids of leafminers responding to the invasive *Liriomyza* populations. At the same time, farmers have also become more aware of the capacity of vegetable crops, apart from potato, to tolerate foliar damage by *Liriomyza* infestations, and so they have reduced the amounts of broad-spectrum insecticides being used to control *Liriomyza* on crops other than potatoes. In turn, the reduction in the overall abundance of *Liriomyza* in the diversified cropping landscape has meant that fewer *L. huidobrensis* flies are invading potato crops.

Ir Arifuddin Siala, leader of Vetran farmer group, discussing the parasitoid rearing and release procedures followed by group members at Malino, South Sulawesi with Professor La Daha (Universitas Hasanuddin) and Ir Zulkifli Razak (Dinas Pertanian, South Sulawesi).

Given the very large numbers of vegetable farmers in Indonesia and the time frame of the project, it cannot be claimed that this project had a direct contribution to the declining importance of *Liriomyza* in Indonesia. The project has, nevertheless, provided compelling documentation of the importance of natural enemies for the control of *Liriomyza* and for the adverse effects of relying on broad-spectrum insecticides. This comprehensive array of knowledge is being passed to next users (scientific community) rather than to final users (farmers). It does provide the foundation for improved pest-management programs now that the *Liriomyza* species are in the more stable post-invasive phase.

The major influence of the project on farmers' behaviour occurred in South Sulawesi where farmer groups at Malino rear and release parasitoid wasps each year. These farmers are spraying much less than they previously did to control leafminers and they attribute the reduced pest pressure to the presence and augmentation of the natural enemies in their crops.

The greatest impediment to the successful implementation of sustainable IPM practices in vegetable farming in Indonesia remains the intense pressure applied to potato farmers to use insecticides by the Indonesian agricultural chemicals industry. Farmers are pressured to use cheap, broad-spectrum insecticides such as profenofos, which the project has shown to be counter-productive for control of agromyzid leafminers. It is also a problem that farmers are being sold black-market abamectin and cyromazine of uncertain quality. Generally, the main source of advice for most farmers appears to be from the pesticide reseller. Potatoes in Indonesia have a range of important pests and diseases and farmers rely on very frequent sprays, often as a 'cocktail' as insurance against crop loss. Farmers often struggle to understand that spraying with broad-spectrum insecticides against one type of pest will have adverse effects on the natural enemies of another pest (such as leafminer).

Significant benefits for Australia have already emerged from the project, including:

- improved risk assessment of leafminer pests entering Australia (which species, and how and where)
- better-tailored contingency planning depending on which leafminer pest should first enter Australia (i.e. *L. huidobrensis* versus *L. sativae* or even *L. trifolii* from other neighbouring countries)
- improved capacity for earlier detection and identification
- improved response capability in terms of which pesticides are most effective
- early registration of chemicals most compatible with IPM
- a better understanding of the capacity of local natural enemies to deal with new infestations of leafminer
- preparation of robust IPM strategies for dealing with leafminer infestations
- a stronger research capability to address problems arising from the introduction of a suite of serious plant pests.

In 2008, an incursion of *Liriomyza sativae* was detected on Warraber Island in the Torres Strait. Three members of the project team (Ridland, Malipatil and La Salle) have been appointed to the scientific advisory panel to provide technical recommendations to the Consultative Committee on Emergency Plant Pests (CCEPP).

High-yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China (CS1/1995/129)

Sukumar Chakraborty

Summary project information

Project number	CS1/1995/129
Project name	High yielding anthracnose-resistant *Stylosanthes* for agricultural systems in India and China
Collaborating institutions	Australia: Commonwealth Scientific and Industrial Research Organisation (CSIRO); Cooperative Research Centre (CRC) for Tropical Plant Pathology India: Indian Grassland and Fodder Research Institute; International Crop Research Institute for Semiarid Tropics China: Chinese Academy of Tropical Agricultural Sciences Brazil: Empresa Brasileira de Pesquisa Agropecuária Colombia: Centro Internacional de Agricultura Tropical
Project leaders	Australia: Dr Sukumar Chakraborty India: Dr P.S. Pathak China: Liu Guodao Brazil: Dr Celso Fernandes Colombia: Dr Segenet Kelemu

Duration of project	Original project: 1998–2000; extension: 2001–2003
Funding	$1,197,222.00
Countries involved	Australia, Brazil, China, Colombia and India
Commodities involved	Beef/buffalo, pigs, sheep/goat and non-specific
Related projects	ACIAR Special purpose grant (1994–1996) to CIAT

1. Motivation for the project and what it aimed to achieve

Declining soil fertility, build up of diseases and pests in the absence of appropriate crop rotation, and low yield and quality of feed is affecting a number of production systems. The pasture legume *Stylosanthes* (stylo), due to its adaptation to infertile soils in marginal agroclimatic regions, is increasingly being used to supply forages and restore soil fertility. In India, where seed production was estimated at 2,500 tonnes in 1996–97, stylo plays a vital role in mitigating fodder shortages, in improving soil fertility under agropastoral systems and, perhaps most significantly, in the restoration of degraded lands. In southern China, stylo occupies over 100,000 ha. The beef industry in northern Australia is reliant on stylo for forage in the dry season. Development of improved pastures can further accelerate if new stylo cultivars adapted to large tracts of clay soils can be found.

Anthracnose disease is the most serious threat worldwide to the economic utilisation of stylo, destroying some 500,000 ha in Australia in the 1970s. Chronic damage from anthracnose affecting pasture stability goes largely unnoticed. There is only a limited range of stylo germplasm available for the various utilisation schemes in India and China. Access to improved germplasm will benefit both countries.

Stylosanthes seabrana, introduced by this project, has been a great success story for India, where 'Phule kranti' is the first-ever stylo variety to be released there. Adapted to heavy soils, it has outperformed other species in many marginal areas.

Given that promising germplasm selected for superior agronomic performance and anthracnose resistance will help to expand areas under this versatile legume, the aims of the project were to:

- select germplasm with improved anthracnose resistance and herbage and seed yield for adaptation in contrasting agroecological regions
- improve anthracnose resistance through developing a genetic map as a basis for the development of cultivars with high yield, persistence and multiple sources of resistance and other adaptive characters
- synthesise knowledge of anthracnose epidemiology to better respond to changes in stylo, its pathogen *Colletotrichum gloeosporioides* and the environment, and to characterise pathogen populations in participating countries to better target pathogen race exclusion and management.

2. What the research project produced

Cultivars released from a comprehensive evaluation and selection of germplasm—In India, a *S. seabrana* cultivar 'Phule kranti' with high anthracnose resistance and yield was released from screening of stylo accessions at eight regional sites. In China, two cultivars, 'Reyan7' and 'Reyan10', have resulted from evaluation of *S. guianensis*, *S. seabrana* and *S. scabra* in four provinces. In Brazil, one *S. capitata*–*S. macrocephala* multiline cultivar 'Estilosantes Campo Grande' was released from screening in five states.

Improved resistance—After three cycles of recurrent selection, seven elite lines, equally productive and resistant as cultivars 'Seca' and 'Siran' were produced. Partial genetic maps constructed on three F^2 populations of *S. scabra*, *S. fruticosa* and *S. hamata* show up to seven putative quantitative trait loci for anthracnose resistance, and some have been converted into easy-to-use markers. One population and technical know-how were transferred to India.

Anthracnose epidemiology and risk mapping—For the first time, information on the genetic structure and virulence of *C. gloeosporioides* populations is now available for all participating countries. At centres of host–pathogen diversity in Brazil and Colombia, selectively neutral molecular markers reveal extensive genetic differentiation in the pathogen from native stylo, but virulence analysis show simple races on native stylo and complex races attacking three or more stylo accessions only at cultivated sites. Genetic diversity is high in India and China and low in Australia. Eight race clusters in India pose a potential threat to Australian stylo. The native *S. fruticosa* is widely distributed in peninsular India but it does not harbour unique pathogen strains to threaten commercial cultivars. In Australia, new, highly aggressive strains have appeared on 'Seca' during the three years of this project, and a new race has attacked *S. seabrana* varieties 'Primar' and 'Unica' within two years of their release.

Market analysis and commercial development—stylo seed production has been a major income earner for resource-poor farmers in parts of India, but severe drought reduced production from 450–500 tonnes in 2001–2002 to 250–300 tonnes in 2002–2003, and even less in subsequent years. Net returns for stylo are still profitable, but the rising cost of labour is eroding margins. A market analysis has estimated the use of stylo for wasteland revegetation, for cut and carry fodder, for intercropping and legume lays and for weed management in plantation horticulture. Stylo as a dried leaf-meal offers the biggest commercial potential and it is already a success in southern China where it is used to feed poultry, fish, pigs and cattle.

Over 2 tonnes of leaf-meal was produced and used in a poultry-feeding trial in the extended phase of the project. Leaf-meal from *S. scabra, S. guianensis* and *S. seabrana* offered similar benefits for weight gain, feed intake or feed conversion ratio.

3. Adoption—how the project outputs are being used

Over 1.5 tonnes of seed from the first ever commercial *S. seabrana* cultivar 'Phule kranti' now cover an estimated 160 ha. The multiline 'Estilosantes Campo Grande' now covers over 2,000,000 ha of *Brachiaria* and *Panicum maximum* pastures in Brazil. The two new Chinese stylo varieties form a part of the areas sown to stylo.

Personnel trained in the project have, in turn, contributed to the development of staff and students at their respective institutions, with six MSc and five PhD students in India alone. Stylo germplasm is now a useful source of further research and development in India and China.

Future adoption in Brazil will continue at its current pace, with strong commercial interest. Adoption of project cultivars in India and China will depend on further development and use of stylo leaf-meal technology.

Loss of key personnel, corporate memory and a run-down of facilities and infrastructure has hampered adoption in India. Soaring land prices in southern China have hampered stylo adoption as pastures are converted to horticulture plantations.

4. Impact—the difference the project has or is expected to make

Advanced knowledge and understanding of stylo performance, new high yielding anthracnose resistant varieties and a leaf-meal technology that can significantly alleviate rural poverty are the outputs of this project. Impacts have come from the adoption of new stylo varieties and the capacity and infrastructure developed in the project. Adoption of new stylo varieties by a commercial beef cattle enterprise in Brazil has ensured that impacts will be long-lasting. This has transformed the stylo seed industry in Brazil, providing economic and social benefits to producers. In India, a new stylo variety has further increased the geographical range for stylo usage for wasteland and watershed development, generating economic benefits for graziers, and environmental benefits through the revegetation of degraded wastelands.

The most significant potential impact is expected from adoption of stylo leaf-meal technology but the limited effort on commercialisation was not adequate to transform the way stylo is used in India and China. Further efforts on adoption of leaf-meal technology by bringing together smallholder farmers and cooperatives, poultry operators and feed manufacturers can generate sustained economic benefit for the entire value chain. Among the beneficiaries will be the resource-poor farmers in India and China.

Impacts of fire and its use for sustainable land and forest management in Indonesia and northern Australia (FST/2000/001)

Jeremy Russell-Smith

Summary project information

Project number	FST/2000/001
Project name	Impacts of fire and its use for sustainable land management in Indonesia and northern Australia
Collaborating institutions	Australia: Charles Darwin University; Tropical Savannas Management Cooperative Research Centre; Bushfires NT Indonesia: Center for International Forestry Research; various national and regional agencies and institutions
Project leaders	Australia: Jeremy Russell-Smith, Tropical Savannas Management Cooperative Research Centre; Bushfires Council of the Northern Territory Indonesia: Siliwoloe Djoeroemana, Wira Wacana Christian University
Duration of project	1 July 2002 – 30 June 2005
Funding	$794,664
Countries involved	Australia and Indonesia
Commodities involved	Livestock; Fish-other; Forestry products; Rice
Related projects	FST/1997/042

1. Motivation for the project and what it aimed to achieve

The motivation

The management of fire in Indonesia has fundamental, complex and contentious cultural, political and economic implications. This is as true for the savanna landscapes of eastern Indonesia as it is for the perhumid forests and swamps of western Indonesia and Papua. The project was born out of a meeting in 1995 between northern Australian and eastern Indonesian tertiary educational institutions at which, perhaps surprisingly to many casual observers, broad-based fire-management research was identified as the highest regional priority affecting terrestrial economic development. These issues were explored in an ACIAR-sponsored workshop, 'Fire and sustainable agricultural and forestry development in Indonesia and northern Australia' (Russell-Smith et al. 2000).

The objectives of the project

On this basis, an action-research-based project was approved for funding through ACIAR to explore ways and means by which fire-management activities (otherwise proscribed under Indonesian national legislation) could be applied to the economic benefit of impoverished rural communities.

Burning practice—burning strategic firebreaks along a ridgeline for protection of agro-forestry plantings, Ngaru Kahiri village, East Sumba.

Given a research collaboration involving partners from 1. northern Australian and eastern Indonesian (principally from the province of East Nusa Tenggara—NTT) institutions with interests relating primarily to fire management in savanna landscapes, and 2. the Center for International Forestry Research (CIFOR) based at Bogor, Indonesia, with experience primarily in fire management of tropical forests and peatlands in western Indonesia, the project had two geographic foci, linked by a number of common objectives, as follows:

- determine ***current and past patterns of fire*** at sites in western Indonesia (southern Sumatra and East Kalimantan), eastern Indonesia (Sumba and Flores) and northern Australia
- review national, state/regional ***policy frameworks*** regarding fire-management issues and past and current impacts of these policies
- determine ***impacts of a range of fire-management strategies***, particularly for forestry
- determine ***appropriate fire-management strategies*** and identify policies (that facilitate improved livelihood) for different land-use objectives through participatory planning methods
- ***enhance land and forest management capacity*** of stakeholders and associated institutions through technology transfer, training and education.

History of the project

The project commenced in July 2002 and was completed in June 2005. ACIAR funding for the project was $774,664, and total funding, including partner contributions, $1,067,516. Major institutional partners were:

- Australia—Charles Darwin University; Tropical Savannas Management Cooperative Research Centre; Bushfires NT
- Indonesia—CIFOR and a range of Indonesian national and regional (NTT) agencies and institutions, including the Regional Development Planning Board NTT (BAPPEDA NTT); Ministry of Agriculture; BPTP Naibonat NTT (Research Centre for Agricultural Technology of NTT); Ministry of Forestry; Ministry of Environment; Nusa Tenggara Community Development Consortium; and the university sector (Sekolah Tinggi Ilmu Ekonomi Kristen Wira Wacana, Waingapu, NTT; Universitas Kristen Satya Wacana, Salatega, Java; Universitas Nusa Cendana (UNDANA), Kupang, NTT).

In practical implementation, the project focused principally on savanna burning issues, while drawing substantively on CIFOR's national and international forest fire experience for informing policy considerations. In NTT, key challenges were to research and demonstrate practical technical, policy and governance solutions for recognised, apparently intractable savanna fire-management problems and associated livelihood issues. This undertaking would require the development of collaborative supportive partnerships involving government (provincial, regency, local), local communities, active non-government organisations (NGOs) and research institutions, in a policy environment hitherto unconducive to developing community-based solutions. After considerable initial discussion, it was agreed that the on-ground activities of the project would focus on four fire-prone village sites, two each in Sumba Timur (East Sumba) and Ngada (Flores) regencies. Initial plans to work also at sites in Timur Barat (West Timor) had to be shelved when the East Timor crisis erupted.

2. Outputs—what the research project produced

Technical and policy outputs

Technical assessments of fire extent and burning practices in western Indonesia and NTT study locations

Using a variety of geospatial, social research and participatory mapping approaches, assessments were undertaken in both locations of the current extent and patterns of burning with respect to land use, social and other physiographic influences. On the basis of a detailed study of eight sites across Borneo and Sumatra, Dennis et al. (2005) found multiple direct and underlying causes associated with the internationally significant forest and peatland fires of the 1990s, including the observations that no single cause dominated at any one site and that there were wide differences in fire causes between sites. Such findings are at odds with general misperceptions that forest and peatland fires in perhumid parts of Indonesia are attributable to single causes such as forest clearing for oil palm plantations or, conversely, fires lit for livelihood purposes.

In the NTT study, Fisher et al. (2006) found that, in 2003 and 2004, fires burnt an annual average of 29% of eastern Sumba (comprising mostly grassland savanna) and 11% of central Flores (with large forested areas). Most fire activity occurred under harsh, late dry-season conditions, and while the great majority of individual fires affected less than 5 ha, some late dry-season fires were hundreds of hectares in extent. Based on detailed assessments conducted at village sites, Russell-Smith et al. (2007b) found that, while burning is used as an essential agricultural management tool in defined seasonal contexts, the reality is that today much burning is unmanaged and uncontrolled, with attendant significant economic impacts.

Assessments of national and regional fire policy implications

The above studies helped inform assessments of current Indonesian national and regional fire policy settings. In particular, forest and peatland fires and associated transboundary haze issues emanating particularly from western Indonesia have resulted also in the promulgation of an Indonesian Government regulation that, in effect, prohibits all forest and land fires, including the use of prescribed burning in plantation management and the traditional use of fire in productive agroforestry and grassland management systems throughout Indonesia.

As part of the broader project, Tacconi (2003) provided an insightful assessment of policy options focusing on western Indonesia, suggesting that the policy of proscription needed to be revised to focus on managing 'really problematic fires', but allowing for sustainable fire-management activities, including in livelihood applications and plantation operations, where climatic (essentially non-ENSO) conditions are conducive. Detailed assessment of the underlying causes of unwanted fires in NTT found similarly that, taking advantage of the Indonesian Government policy of *autonomi*, which empowers provincial and regency governments to find local solutions to local problems, it is essential to 1. get the fire policy framework right and recognise the importance of strategic fire management as a useful tool for addressing a range of haze, biodiversity, forestry and agricultural issues, and 2. develop cooperative fire-management partnerships between government authorities and local communities (Tacconi and Ruchiat 2006; Russell-Smith et al. 2007a,b).

Capacity developed by the project

Capacity building, extension and training components focused especially on NTT sites and, overall, constituted the main project activities as follows:

GIS training: Over the course of the project, on-the-job training in fire mapping, geospatial database development and analysis, and related validation activities was provided to two government staff members from BAPPEDA offices in East Sumba and Ngada (Flores). With training support from Charles Darwin University (CDU), these staff contributed major technical inputs for the project as a whole, including reporting and publication outputs.

Forest resource inventory training: This was undertaken at two village sites in East Sumba and Ngada, and involved teams of over 30 personnel, including staff from regional forestry departments (Dinas Kehutanan), BAPPEDA, local non-government organisations (NGOs), villagers, and forest inventory and geographic information system (GIS) specialists from Australia and Java. These inventories reinforced and quantified anecdotal observations concerning the scarcity of available natural valued timber products and forest resources. Funding assistance for these activities was provided by the Crawford Fund.

Agroforestry resource protection and fire-management training: A major activity of the project focused on the establishment and maintenance of agroforestry plots at village study sites in East Sumba and Ngada, and associated demonstration of practical fire-management techniques to protect these plantings. These trials involved, in addition to project personnel, large numbers of community members, government officials and

Forest inventory team (local villagers and Forestry Department staff, inventory specialists from Australia and Java), Lukuwinggir village, East Sumba. Note small patches of forest in savanna.

staff from NGOs. The trials were used additionally throughout the course of the project for demonstration and extension. It is pleasing to report that, despite the exuberance of participants under sometimes less than ideal (e.g. very windy) conditions, fire-management training exercises were completed without misadventure.

Tertiary education initiatives: As well as staff exchanges between contributing Indonesian and Australian institutions (some assisted by funding form the Crawford Fund), a major activity involved the transfer and adaptation of CDU's Masters in Tropical Ecology and Management course to Universitas Kristen Satya Wacana (UKSW), Salatega. The Tropical Savannas CRC provided a scholarship to UKSW for a Masters study on savanna fire and soil impacts; this study was ultimately awarded a university medal.

In summary, in terms of the commitment of time and resources, the above capacity-building activities constituted the major activities of the project, reflecting the requirements to build constructive and effective partnerships between 1. Australian and Indonesian research, educational and natural resource management institutions, and 2. Indonesian provincial, regional and local government institutions with local communities and NGOs.

3. Adoption—how the project outputs are being used

Capacity utilisation—how the capacity built is being utilised

As set out in Section 2, the various outputs of the project aimed to build capacity and confidence at regional and local scales in NTT to overcome chronic institutional and practical community fire-management problems as these affect local rural livelihoods and economy. While focusing on just two regional areas in NTT (the regencies of East Sumba and Ngada, central Flores), the project has been, and continues to be, very influential in instigating changed practices for local farming communities. As set out below, it is clear that, following the end of the formal project, the outcomes of that action-research-based project continue to develop and expand.

Adoption to date

Technical and policy outputs: GIS database development and associated fire mapping continues to be expanded in East Sumba and, more recently, Timur Barat, particularly through the auspices of regional and provincial BAPPEDA offices and NGOs. These developments reflect tacit recognition on the part of relevant authorities and community organisations of 1. the utility of geospatial databases for regional natural resource management planning and evaluation, and 2. the value of incorporating the development of strategic approaches to fire management in regional planning, especially for integrated catchment-management approaches. Given that regional government offices, especially BAPPEDA, are the final user, it is reasonable to classify adoption as *NF*[1].

1 See Table 3 on page 13 for explanation of codes for levels of adoption.

Likewise, given the purposes of the project in informing regional and NTT provincial government policy about the need for supportive policy for sustainable application of savanna burning in rural land management systems, it is clear that positive steps have been achieved. For example, the various regional governments mentioned earlier are clearly supportive. Likewise, recent conversations with the NTT Vice-Gubernor, Pk Eston Foenay, indicate solid support at the provincial level. However, given further progress is still required to reach all regency governments in NTT, adoption to date may be classified as *Nf*.

Capacity-building outputs: The demonstration fire-management and agroforestry trials have continued to grow beyond the villages where they were initially implemented, both through the support of regional BAPPEDA offices, but particularly with the assistance of local NGOs. On Flores, eight more villages in the Aesesa catchment now practise fire-management techniques for preserving forest and garden (*kebun*) resources. In 2007, one of the original participating villages, Dorameli, hosted fire-management training for four surrounding villages. On Sumba, in 2008 alone, a local church NGO has provided fire-management and associated agroforestry training for over 1,000 participants from three large regional areas; a major concern is that the organisation cannot keep up with the demand. These developments have continued to occur principally through the support (including financial) of local communities. It is evident that, within the locales affected directly by the undertaking of the project, adoption to date can be classified as *NF*.

Adoption in the future

Given the preceding comments, it is highly likely that the benefits of the project will continue to develop and expand. This is not unexpected, given that the self-evident and substantial benefits of coordinated fire management require very little capital expenditure by local communities and government.

Typical savanna and garden scene in East Sumba with cultivated gardens in cleared valleys surrounded by flammable savanna grassland.

Completing a forest inventory in small gully patch of forest surrounded by burnt savanna.

Factors affecting adoption

The success of the project to date has relied initially on recognition of the project's significance (see Section 1) and the goodwill and support demonstrated by all parties over a long period (at least 5 years) of the project's gestation. By the time the project came to formally start it was well institutionalised / socialised within regional governments, research institutions, NGOs and communities—all of which participated and contributed willingly. A second and associated factor was that staff selected by Indonesian partners (from government, research institutes and NGOs) were of the highest calibre. In short, it would have been difficult for this project to fail.

4. Impact—the difference the project has made or is expected to make

Community impacts—the beneficiaries of the project

The major beneficiaries of the project itself remain the rural farming communities of fire-prone savanna landscapes in eastern Indonesia, particularly NTT, where 80% of the 4.5 million population depends on subsistence-level agriculture. The underlying premise of this project is simple: that effective, coordinated means for managing unwanted and economically destructive fires in fire-prone savanna environments of NTT has tangible livelihood benefits for local rural communities. As demonstrated by this project, achieving such strategic fire management has direct economic impacts both for protection of annual crops (e.g. maize), and longer term development of perennial agroforestry systems. In a province recognised for its seasonally harsh climatic conditions, the project also has indirect impacts on addressing chronic food insecurity issues.

Quantifying the longer term impact(s) of the project on rural livelihoods and economies in NTT presents obvious challenges. However, on the bases of observations made in the original study, and comments made to the author of this report during a recent visit, it is possible to make some informed qualitative observations. Thus, in the published account of our study into the impacts of burning practices on rural livelihoods in NTT, we made the following observations (Russell-Smith et al. 2007b):

> Over the three year study period numerous examples were observed by project staff where uncontrolled landscape fires destroyed buildings, crops, and inflicted needless damage to forest resources—e.g. killing mature trees on forest margins, and thereby further promoting incursions of flammable grasses and weeds (e.g. *Chromalaena odorata*). In 2002, most of the *kebun* at Dhereisa (Flores) were burnt from an uncontrolled hunting fire and, was it not for the enterprise of women through their weaving, significant hardship, including starvation, would have ensued.

Elsewhere in the same paper it was noted that: 'In late 2002…thousands of cattle died in East Sumba given the extended dry season, exacerbated by extensive fires.'

In a recent follow-up visit to study sites in Flores and East Sumba, villagers at both sites observed that, in the 3 years since the project had formally ceased, neither had their *kebun* nor agroforestry plots been burnt. They were proud both of this achievement, as well as the observation that strategic, coordinated approaches to fire management had now spread to surrounding villages and more extensively within respective catchments and beyond. The important issue here is that this simple fire-management technique has been demonstrated to substantially reduce risk to critical seasonal food security and attendant livelihood issues in participating communities.

I return here to comments made in the opening section of this report:

> The project was born out of an early meeting in 1995 between northern Australian and eastern Indonesian tertiary educational institutions where, perhaps surprisingly to many casual observers, broad-based fire management research was identified as the highest regional priority affecting terrestrial economic development.

Following a detailed assessment of fire impacts conducted at four NTT study sites as part of this project, Russell-Smith et al. (2007b) concluded:

> …social and political factors, combined with the natural propensity of regional savanna landscapes to increasingly carry fire as the dry season progresses, conspire to significantly impact on environmental assets, livelihood resources, and thereby economic conditions. Given these factors, it is axiomatic that, without effective fire management and a supportive policy environment, sustainable livelihoods development will continue to be elusive in savanna landscapes of eastern Indonesia.

Gunung (Mt) Ebulobo from Dorameli village study site, central Flores. Note the small patches of forest remnants in parched savanna landscape.

Factors affecting the magnitude of the impact

The benefits to rural communities are immediately tangible and require no expensive application of technological aids. As addressed in detail, however, in various of the published outputs of this project (e.g. Tacconi 2003; Dennis et al. 2005; Russell-Smith et al. 2007a,b), it is often the political and social frameworks that conspire against application of sound and sustainable land-management practices (e.g. tenure disputes between alienated communities and the Department of Forestry). Achieving a collaborative dialogue is essential but potentially fraught.

Benefits for Australia

While addressing broadly similar fire management issues in fire-prone savanna landscapes in eastern Indonesia and northern Australia, the main benefits to Australia have revolved around developing closer institutional linkages between NTT and the Northern Territory of Australia. These linkages continue to be tenuous but, over the past decade and half, have developed soundly thanks in small measure to relationships developed through the current project.

5. Lessons

As described above, this project has been very successful, albeit at the localised scales of impoverished rural communities in the poorest province in Indonesia. The objectives were economically humble, but far-reaching in the context just described. As noted in the final external review of the project, undertaken by Professor Bungaran Saragih (former Minister of Agriculture, Republic of Indonesia) and Dr Alan House (CSIRO, Australia):

> ...this project was clearly not a typical ACIAR project in that it incorporated biophysical and ecological research with socioeconomic development. ACIAR should be congratulated on supporting a project that lay outside its normal arena of interest.

While recognising that ACIAR will continue to support commodity-focused R&D, we would hope that ACIAR might benefit from this example, and support cross-disciplinary action research programs focusing on broader economic outcomes.

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Development of technologies to alleviate soil acidification in legume-based production systems in the tropics of Asia and Australia (LWR1/1998/124)

Suzanne Berthelsen

Summary project information

Project number	LWR1/1998/124
Project name	Development of technologies to alleviate soil acidification in legume-based production systems in the tropics of Asia and Australia
Collaborating institutions	Australia: CSIRO Land and Water (CLW); Queensland Department of Natural Resources and Mines (NRM) Thailand: Khon Kaen University (KKU) China: Chinese Academy of Tropical Agricultural Science (CATAS)
Project leaders	Australia: Andrew Noble, Michael Webb and Suzanne Berthelsen (CLW); Phil Moody (NRM) Thailand: Sawaeng Ruaysoongnern (KKU) China: Liu Guodao (CATAS)
Duration of project	1 July 2000 – 30 June 2004 (original); 1 July 2004 – 30 June 2005 (extension)
Funding	Funding $1,609,478 (ACIAR: $812,029; in-kind: $797,449)
Countries involved	Australia, Thailand and China

Commodities involved	Crops and pastures
Related projects	CS1/95/129, LWR1/96/196 and SMCN/2002/085

1. Motivation for the project and what it aimed to achieve

In the mid 1990s, research work in northern Australia provided evidence of significant acidification of soils under *Stylosanthes* dominant pastures. Similar observations had been made in fields that had been growing *Stylosanthes* continuously for several years in North-East Thailand and in India. This led to ACIAR funding a small project (LWR1/96/196) during 1997–98 to determine the impact of the introduction of the legume *Stylosanthes* into animal-feed and pasture-production systems. This study included visits to the Indian Grassland and Forage Research Institute, Dharwad, Karnataka, in southern India and, in China, to institutes including the Forage and Grass Section of Guangdong Province Agricultural Office, Guangzhou, and the Chinese Academy of Tropical Agricultural Sciences, Danzhou, Hainan. From this study it became clear that, while these legumes have had a significant positive impact on the productivity and profitability of the cattle, pig and poultry industries in these areas, the increasing use of legumes and accompanying management practices had resulted in accelerated land degradation, including soil acidification and nutrient depletion. This soil fertility decline is due to soil organic carbon decline and nutrient removal in the harvested product, and raises a question about the long-term sustainability of these systems.

Project LWR1/1998/124 built on this initial work by focusing on the remediation and minimisation of soil acidification under legume-based cropping systems in northern Australia, North-East Thailand and southern China. The areas of research that were considered important to the sustainable use of *Stylosanthes* in pasture-based production systems were the delineation of soils with respect to vulnerability to accelerated soil acidification and the development of management strategies to minimise or reverse the impact of soil acidification and land degradation.

The project began in July 2000 as a 4-year project under the leadership of Dr Andrew Noble (Australia), Professor Sawaeng Ruaysoongnern (Thailand) and Professor Liu Guodao (China). When Dr Andrew Noble left CSIRO in 2002 to take up a position with the International Water Management Institute (IWMI), based in Bangkok, Thailand, the project work in Thailand continued through informal collaboration with IWMI within the context of the Soil Remediation Research Project (SRRP) that IWMI implemented in North-East Thailand. There was an extension of 1 year to the project to allow completion of field trials in Thailand and China and, in particular, to concentrate on extension activities. The project (original plus extension) was finalised at the end of June 2005.

The overall objective of the project was to find ways to reverse the negative impacts of accelerated acidification and nutrient depletion through the development of innovative methods of preventing or limiting these processes. This was achieved through four interlinked subprojects:

- Selected, existing production systems were evaluated, to quantify the degree of soil degradation associated with acidification and nutrient depletion. This information was used to assist in the development of a risk-assessment model.

- Innovative production systems and management practices were developed and assessed for their ability to neutralise surface and subsoil acidification and to reduce nutrient depletion. The approaches used included bioremediation by roots, application of soil conditioners and plant residues, and pasture management.
- A risk-assessment model was developed to delineate soil types and identify crop systems that are predisposed to accelerated acidification and nutrient depletion. This provided knowledge for land planning and technology transfer.
- A technology transfer subproject ensured that producers and extension personnel of *Stylosanthes*-based production systems were made aware of management strategies and practices that reduce soil acidification and nutrient depletion and thus improve long-term sustainability.

2. What the research project produced

Technical outputs

- New research methodologies for assessing the risk of soil acidification were developed to allow the identification of soils and land uses prone to degradation. These included pedo-transfer functions based on soil cation-exchange capacity, pH buffer capacity, clay content and soil organic carbon to allow soil types to be ranked for their susceptibility to rapid acidification. In addition, net acid addition rates were measured for several key production systems, using a paired site (degraded versus undegraded) approach.
- Benchmark monitoring sites based on soil type and cropping systems were established in Hainan and Thailand. These sites formed the basis of an inventory of the soil resources within the target regions.

A farmer field day in Thailand to demonstrate the use of clay amendment to organic rice fields.

- The role of bioremediation using nitrate-based rather than ammonium-based nitrogen fertilisers was shown to be effective in ameliorating soil acidification to a depth of a least 120 cm in sandy soils in North-East Thailand and northern Australia.
- The addition of clay and organic material additions was an approach introduced to improve the productive capacity of the sandy soils by enhancing their nutrient- and/or water-holding capacity. A further adaptation of this clay technology was to include clay minerals as part of the traditional composting process for organic waste materials and thus reduce loss of nitrogen through volatilisation of ammonium compounds. Clay technology is seen as a way of 'kick-starting' the remediation process for a degraded system, and allowing intensive agriculture on sandy soils.
- The effect of fire in combination with over-sowing of grass and inputs of nitrogen was found to successfully reduce stylo dominance to below that of other management systems.

Policy outputs

- The pedo-transfer functions developed for assessing acidity risk were linked with spatial soil survey data to produce soil acidification risk maps for north-eastern Thailand for rice and cassava cropping systems. These maps have been used to provide input into regional land use and environmental planning at provincial level through collaboration with Land Development Department and provincial staff.

Mr Tang Jun, Professor Liu Guodao and Dr Huan Hengu (L-R) at the site of glasshouse trials in China.

Capacity developed by the project

Improved knowledge generated included:

- awareness of the potential for soil degradation associated with soil acidity resulting from *Stylosanthes*-based pasture systems
- awareness of the benefits of including legumes as part of the cropping system, e.g. when used as an intercrop under coconuts and mangoes to increase organic matter, supply nitrogen and reduce erosion.

Training and skills-development activities included the following:

- Thai and Chinese scientists involved in the project were trained in Australia in basic laboratory skills and new soil-chemical techniques for assessing the risk of soil acidity.
- A number of students in both Thailand and China used components of the project work to complete their MSc and PhD studies, thus increasing awareness of soil acidity as an important degradation issue in Asia.
- Mr Huan Hengfu, a student from Hainan, was awarded a Crawford Scholarship to undertake training in laboratory techniques for chemical analysis of soils and plants. He used this experience to analyse the soil and plant samples collected from one of the project amendment trials.
- As part of his involvement in the project, Mr Huan Hengfu successfully submitted his MSc thesis, 'The research on the effect of different soil amendments on acid soil chemical properties', and went on to complete his PhD. He is now back at CATAS to continue new research work initiated as a spin-off from project results.

Extension of research results:

- During the life of the project, Professor Sawaeng Ruaysoongnern was very active in transferring the research results to the end users in North-East Thailand through numerous farmer meetings and workshops, a TV documentary program, a radio program and a number of newspaper reports. He also transferred these experiences in soil rejuvenation to northern regions of Cambodia.

3. Adoption—how the project outputs are being used

The project output that is most likely to see further adoption is the use of high-activity clays to improve soil fertility and productivity through nutrient retention and increased water-holding capacity. In collaboration with this project, this work was further promoted by IWMI. As part of its Soil Remediation Research Project (SRRP) undertaken in North-East Thailand, this technology was initially demonstrated mainly on organic rice farms, but has now become more widespread and the main adopters are intensive vegetable growers. Three years on there is still much farmer interest, and extension and research is continuing in many new research projects. Adoption is progressing, but only gradually. This is because of the time and effort and ongoing commitment necessary to demonstrate the technology and for farmers to see the benefit. At this stage, further adoption is most likely to occur in North-East Thailand but, depending on further research effort, it may spread to areas of Vietnam and Cambodia.

There are a number of other factors limiting adoption. The process is most suitable for, and mainly restricted to, the remediation of light-textured sandy soils with low organic matter, low clay content, low nutrient retention (cation-exchange capacity) and poor water-holding capacity. Because of the high application rates necessary (research results indicated up to the equivalent of 50 t/ha), the cost of purchasing the materials required means it will be suitable only for selected agricultural systems, such as intensive, high-return vegetable production. The higher incomes of such farmers allow them to make the initial investment in the clay material, and the small areas involved mean that they can build on this reserve over time. Other limitations are the availability of suitable clay materials (specifically bentonite) and the cost of transport if deposits are some distance away.

Another significant output was the adaptation of this clay technology to include clay minerals as part of the traditional composting process of organic waste materials and thus reduce loss of nitrogen by ammonium volatilisation. In Thailand this has led to the commercial production of a product called 'LDD10'. This is produced by co-composting waste acid bentonite resulting from the processing of vegetable oils (rice, soybean and oil palm) with rice husks and the manure from community poultry farms. The use of 'LDD10' is promoted by the Thai Land Development department and the product is distributed to farmers at a nominal cost.

In Hainan, the strategy of using fire and sowing of brachiaria grass proved to be a very successful means of reducing stylo dominance in a pasture system. However, this particular project output currently has little relevance, as there are no longer large areas of stylo pastures for grazing or for cut-and-carry forage production in Hainan. Since the conception and initiation of the original project, the agricultural system in Hainan has changed significantly. Using vast areas of land for grazing or forage production is no longer

Rice grown on clay-amended soil in Thailand.

supported, and the emphasis is now on cropping. The main drivers for this change are economics and land shortages. Large areas of high-income crops such as bananas, pineapples and cassava are now being grown on areas that were once used for forage production. Despite this, as a result of the project work, the role of legumes, in particular *Stylosanthes* spp., has come to be seen in a broader perspective. This has led, in turn, to the development of new strategies that retain the benefit of growing a legume while minimising the negative effects such as soil acidification when growing *Stylosanthes* spp. as a monoculture (e.g. cut-and-carry forage production). An example is the use of legumes for intercropping under coconuts and mangoes to increase organic matter, supply N and reduce erosion. In addition, 3 years on, a focus of the current research effort in Hainan is to use legumes such *Stylosanthes* spp. for composting and green manuring to increase soil organic matter and nutrient levels, especially nitrogen, in cropping systems.

Another positive project output was the demonstration that nitrate fertilisers were effective in bioremediating soil acidity to a considerable depth in the profile. However, nitrate fertiliser is expensive and this method of bioremediation is not realistic in South-East Asia and unlikely to be adopted in Australia.

The methods developed to assess risk of acidification (pedo-transfer functions and calculation of net acid addition rates) have been used to produce acidity risk maps for North-East Thailand for rice and cassava systems, but to date their use in land-use planning has been limited. Although at this stage similar risk maps have not been produced in Hainan, the soil survey approach used in the establishment and soil analysis for the 'benchmark monitoring sites' has led to CATAS, in conjunction with the local agricultural bureau, to undertake a soil fertility mapping program and an inventory of the soil nutrient status of all soils in all provinces of Hainan. This survey will allow the identification of priority 'hot spots' for concentrating future research and extension efforts.

4. Impact—the difference the project has or is expected to make

Overall, the project was successful in developing many innovative management practices that improved the productive capacity of a soil by reducing nutrient depletion. However, by the end of the project, and even 3 years after that, the understanding of soil-acidifying processes and their role in soil degradation appeared to be limited. The concept of soil acidification proved difficult to convey to farmers (end users), as it is a gradual and insidious process not often directly linked to soil degradation. Also, as the project progressed, project activities were adapted to accommodate the changing agricultural systems in each country. In Thailand, the technologies developed during the project addressed mainly the larger issue of soil degradation and poor soil fertility rather than soil acidity itself, or soil acidity as a result of legume based-pasture systems as this was seen as the bigger problem. In Hainan, where there had been a much longer history of legume-based grazing and cut-and-carry forage systems, the agricultural system has changed significantly. Using vast areas of land for grazing or forage production is no longer supported, and the emphasis is now on cropping. The main drivers for this change are economics and land shortages. Large areas of high-income crops such as bananas, pineapples and cassava are now being grown on areas that were once used for forage production. In Hainan (and also Thailand) there is a large research effort looking at the potential of cassava for biofuel production and selecting high-yielding varieties for that purpose.

Professor Liu Guodao at an experiment site growing different varieties of stylo.

On a positive note, if the use of high-activity clays can be encouraged in North-East Thailand (and extended to other areas), it has the potential to significantly benefit a select group of farmers. North-East Thailand has two-fifths of the agricultural area of Thailand and 80% of the population are involved in farming, 20% of them growing vegetables. However, this area of Thailand generally has low productivity because the sandy soils have low fertility, low cation-exchange capacity and low water-holding capacity. An economic impact survey (Saleth et al. 2009) carried out by IWMI collected data from 250 farmers representing vegetable growers, organic rice farmers and farmers in intensive farming systems involving crops and animals. Approximately half of the 250 farmers used clay additions. The survey results demonstrated that, while the benefit of the clay addition was agronomic, the method resulted in significant economic changes, such as increasing farm inputs (e.g. fertiliser applications) and improving market response. The benefit of clay additions was highest for the vegetable growers. While the use of clay incurred more costs (purchase of the clay and fertiliser) and labour, the net returns for the vegetable growers were found to be over twice that of those not using clay. The secondary effects cited in the report include improved farm-management options such as crop rotation, livestock development and farm diversification, all of which will enhance income levels and improve the efficient use and conservation of both the land and water resources in the region. However, the adoption of the clay technology, by its nature, will be slow. To identify and concentrate on the farming systems that are most likely to benefit will be important, and success will depend on continued research support and a concerted extension effort.

Reference

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Genetic engineering of pineapple with blackheart resistance (PHT/1999/040)

Mike Smith and Umi Kalsom Abu Bakar

Summary project information

Project number	PHT/1999/040
Project name	Genetic engineering of pineapple with blackheart resistance
Collaborating institutions	Australia: Queensland Department of Primary Industries & Fisheries (QDPI&F) (now the Department of Employment, Economic Development and Innovation) Malaysia: Malaysian Agricultural Research & Development Institute (MARDI)
Project leaders	Australia: Dr Mike Smith, QDPI&F Malaysia: Dr Umi Kalsom Abu Bakar, Biotechnology Centre, MARDI
Duration of project	1 July 2000 – 31 December 2003; extension 1 January – 31 December 2004
Funding	$675,819
Countries involved	Australia and Malaysia
Commodity involved	Pineapple
Related projects	PHT/1994/007

Motivation for the project and what it aimed to achieve

Management of produce quality and minimisation of damage and losses are essential in sustaining profitable production and marketing of any horticultural product. Blackheart is a major postharvest quality defect of pineapple that develops inside fruit during cool weather cultivation or cool storage, and affects the availability and quality of fruit for fresh market and processing.

ACIAR project PHT/1994/007 (Pineapple quality improvement) was developed to select blackheart-resistant lines of pineapple in Australia and Malaysia with acceptable agronomic and postharvest characteristics. The project was seen as a test case for the application of genetic engineering in horticultural crops in both countries, and the project review team of Professor Rob Henry of Southern Cross University, and Professor Helen Nair of the University of Malaya, strongly endorsed an extension of the research under a new ACIAR project PHT/1999/040 (Genetic engineering of pineapple with blackheart resistance). In parallel with this project, the pineapple industries and government agencies in Australia and Malaysia at the time were supporting research on related molecular biology/transformation projects, and they indicated an interest in providing further support to ensure the completion of the research begun under ACIAR funding.

The technology underpinning the research (including a novel transformation protocol), together with development of some of the transformed lines, were developed in project PHT/1994/007. Project PHT/1999/040 focused on transfer and development of the transformation technologies with Malaysian colleagues, and evaluation of transformed pineapple lines to assess plants and fruit for their agronomic and commercial suitability. ACIAR and the project teams also made external linkages needed to broker intellectual property (IP) management plans with IP owners to allow release and marketing of transgenic pineapples by Australia and Malaysia, and with provisions to ensure access to planting material by smallholders in developing countries.

In association with the molecular studies, postharvest scientists were investigating the enzymes responsible for blackheart development in pineapple, and developing strategies to extend shelf life while improving appearance and eating quality. This was particularly important to Malaysia where pineapples are held in refrigerated storage while they are sea freighted to distant markets.

What the research project produced

The projects succeeded in identifying and isolating the gene responsible for blackheart expression in pineapple. They also succeeded in developing new genetic-transformation technologies for pineapple improvement, and partner institutions have learned from practical experience the steps needed to bring to market the new, transformed plants developed by the technology. In many ways, pineapple was the vanguard for this new technology and provided the knowledge, models and framework to aid decision-makers develop a coherent strategy for future work with genetically modified (GM) crops. From providing a safe and ethical policy for working with GM plants, to negotiating the path for freedom to operate with the final products, many valuable lessons were learned along the way.

From a postharvest perspective, the projects succeeded in identifying the level of blackheart susceptibility/resistance of the major pineapple cultivars grown in Malaysia. Furthermore, conditions that contribute to both blackheart and crown deterioration were identified, and procedures optimised for postharvest handling of new Malaysian-bred cultivars, Josapine and N36, which extended shelf life from 4 to 7 weeks and from 5 to 9 weeks, respectively. This work was significant in expanding export opportunities for fresh pineapples in the Middle Eastern and European markets. In addition, postharvest research with minimally processed pineapple, including gamma irradiation and preconditioning of fruit, has improved product safety while maintaining fruit quality. These new pineapple technologies offer potential to overcome quarantine restrictions of some countries in the region, and export opportunities need to be fully explored.

Transgenic pineapple plants have been produced by both MARDI and QDPI&F, and are currently undergoing the final stages of evaluation to validate the effectiveness of the gene-silencing technology in control of blackheart in pineapple. The commitment shown by these public institutions is best demonstrated by the fact that resources have been provided to continue the work long after the ACIAR project has finished. Planting to harvest cycles of 12–18 months is needed to evaluate plants and fruit, while several cycles of testing are necessary. A final assessment of fruit for blackheart resistance will be made at the end of 2009. In an earlier cycle of evaluation, however, some transgenic lines showed blackheart expression while non-transformed control plants developed symptoms of the disorder.

Finally, the development of close working relationships between partner institutions has led to a shared understanding of the technical and cultural issues needed to further progress the technology. This was facilitated through joint research and publication, aided by technology transfer and exchange of genetic materials, while taking advantage of opportunities for presenting work at scientific and industry meetings. In fact, the work of one of the project leaders, Mr Abdullah Hassan, was recognised internationally with a gold medal presented at the 2008 Innova Awards in Brussels for his team's research in improving the quality and extending the shelf life of exported, fresh-market pineapples.

Blackheart disorder in pineapple: improved genetics and postharvest treatments are being used to control its expression and development. The fruit on the left is a transgenic line and that on the right a non-transgenic control.

Adoption—how the project outputs are being used

Since the completion of the project in 2005, the Malaysian Government has continued its investment in agricultural biotechnology, with new laboratories and glasshouse facilities being built at the MARDI campus at Serdang. This has significantly improved MARDI's capacity to undertake genetic engineering studies on a range of agricultural crops. The project helped to provide the intellectual framework necessary for planning infrastructure development, staffing and capital raising for research, as well as to satisfy regulatory issues. Also in 2005, the National Biotechnology Policy was launched, and the Malaysian Biotechnology Corporation, which will further explore investment and commercialisation opportunities for Malaysian plant biotechnology in partnership with MARDI, was subsequently established. Some of the platform technologies underpinning future advancement in Malaysia's biotechnology sector include tissue culture, transformation, molecular genetics and functional genomics. The ACIAR projects have helped play an important role in building technical capacity and proficiency in these areas.

The final validation of the putative blackheart resistant transgenic lines is still needed, and obstacles to the commercial release of a GM pineapple are foreseen. Moreover, new hybrid cultivars with resistance to blackheart have been released from conventional pineapple breeding programs. They are already being

Dr Peng Fatt Lam (left) mentoring new staff member Dr Chien Yeong Wee.

accepted in the marketplace and are not burdened with a 'GM label'. It is unlikely that a commercial partner could be found to cover the additional costs of regulation and intellectual property ownership needed to bring one of the transgenic lines developed by the project to market. Nevertheless, the technology associated with pineapple transformation that was developed as a result of the project is highly regarded internationally and a technology-transfer agreement has been entered into between the lead organisation (QDPI&F) and another major institution.

In Malaysia, the postharvest research effort has led to improved preconditioning and packaging systems for handling and storage of fresh pineapple destined for export by sea. Fresh pineapples can now reach destinations in the Middle East and Europe with a better appearance and eating quality, and an extended shelf life. Growers, exporters and retailers are benefiting from improved sales and consumers benefit from a healthier fresh fruit product. Further improvements can be gained by improving skin colour at the retail level and by reducing incidence of marbling and leathery pocket, both internal blemishes seen with the cultivar N36.

The introduction of new hybrid cultivars into the Malaysian pineapple industry has led to demand for planting material exceeding supply. This has led to the creation of a number of bodies, both public and private, to accelerate the production and release of propagating material. Schemes based on biotechnology approaches (tissue culture and bioreactors for rapid multiplication of the hybrid cultivars), as well as conventional propagation approaches, have been, or are being adopted.

Impact—the difference the project has made or is expected to make

Under the Ninth Malaysia Plan (2006 to 2010), the Malaysian Government has allocated A$4.8 billion for biotechnology development, as outlined in the Malaysian Biotechnology Corporation's prospectus. The objective is to intensify biotechnology's potential as a growing source of wealth creation, and enhance applications of biotechnology in various economic sectors. The target is to build global biotechnology and biotechnology-related companies in Malaysia. The projects have helped position MARDI as the leading plant-biotechnology research provider in Malaysia and, in a more general sense, has helped foster closer collaborative ties between research groups within MARDI and other organisations in Malaysia. The experience gained by senior members of the MARDI project team has also been recognised and it is satisfying to learn that succession plans are in place so that the skills and knowledge gained during the course of the project are not lost.

The postharvest team has also contributed prominently to elevating the profile of the Malaysian pineapple industry and has received national and international recognition for its work in improving the quality and shelf life of fresh pineapples, for developing value-added pineapple products and for minimising wastes associated with processing. The lessons gained from pineapple research have been applied directly to a number of other crops including jackfruit, banana and cempedak.

The projects have confirmed the resistance to blackheart of two Malaysian hybrid cultivars, Josapine and N36, and experience gained from trial shipments to export destinations have led to further developments to improve postharvest quality. Information provided by the Malaysian Pineapple Industry Board has confirmed Josapine's value as a fresh market pineapple for domestic and overseas markets, while N36 has consolidated its position as both a canning and fresh market pineapple. Josapine currently occupies 28% of area under cultivation, while N36 holds 10%, and the area under cultivation for both of these cultivars continues to grow.

Fresh pineapple exports from Malaysia are valued at approximately A$50 million and, while Singapore continues to be the main destination, sales to the Middle East are growing, especially for the new hybrids with blackheart resistance. The Middle East currently has 28% of the fresh pineapple export market and efforts continue to open up markets in Europe. Postharvest research has identified some of the factors involved in quality control of refrigerated shipments of pineapples and should lead to further export options for the industry.

Johor continues to be the most important State for pineapple production in Malaysia, with approximately 8,600 ha under cultivation, producing around 205,000 tonnes of the country's 316,200 tonnes annually. Further expansion is planned for Sabah and Sarawak. The industry continues to be a significant employer, from growing the fruit through to export of processed products.

Lessons learned

- Although the development of the technology required for pineapple genetic engineering was complex and time-consuming, the research team led the world in this enterprise, as has been acknowledged internationally from invitations to present the work in various fora and a technology-transfer agreement that has been entered with the United States Department of Agriculture (USDA) in Hawaii. Nevertheless, the team underestimated the time frames required for producing transgenic pineapples and for their further evaluation to validate the technology, and this work continues.
- Likewise, IP and regulatory matters were complex and time consuming and, from the perspective of scientists, at times frustrating.
- The balance achieved by the Malaysian team in dealing with blackheart was better than that in Australia, where undue emphasis was probably placed on the transgenic technology. The Malaysian team was also concentrating on evaluation of conventionally bred pineapples from both blackheart and consumer perspectives. It investigated postharvest-handling strategies to improve quality of fresh pineapple exports and made substantial and widely recognised progress in this area. Nevertheless, the project was also important in developing Malaysia's policy framework for GM fruits and helped position the country strategically as plant-biotechnology leaders in the region.

Because of the progress within conventional breeding programs in developing cultivars with a greater level of blackheart resistance, the goal of a blackheart-resistant transgenic pineapple is not as important as it was when the project started. However, breeders and industry leaders know that disease- and pest-resistant pineapples, as well as control of ripening and natural flowering, are still worth pursuing. Now that the initial ground has been broken, these goals are achievable with transgenic technologies. The test will be whether consumer attitudes, and industry and government support, are conducive to further R&D. The Malaysians appear to believe so, as do the Americans (via USDA in Hawaii). The signals in Australia are mixed.

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