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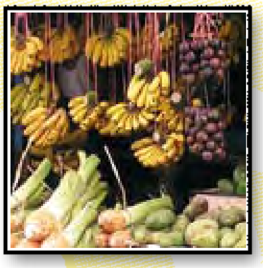
Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia

IMPACT ASSESSMENT SERIES **48**





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Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia

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July 2007

Australian Government
Australian Centre for International Agricultural Research

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Foreword

During 2006, the Australian Centre for International Agricultural Research (ACIAR) commissioned a study to review the importance of capacity building and options for quantifying the benefits from this means of research support. The study found that, although it is a complex area, it is possible to quantify the impacts of capacity building, and illustrated this through two case studies of ACIAR-funded research.

ACIAR has continued to focus some of its impact assessment studies on this capacity-building aspect of research outcomes. The study reported here is part of that focus.

In addition, ACIAR has started to use random samples of projects as the basis for selecting the impact studies it undertakes. It started this process during 2006, with its study of the benefits *to Australia* from ACIAR-funded research, randomly selecting five research activities (one of which is the topic of this report) for assessment in that exercise. The benefits from that same random sample are now being assessed *for all partner countries*.

The study reported here is particularly interesting. A preliminary assessment of the project review documents suggested that it had achieved none of its original aims. However, a more detailed examination revealed that the project had uncovered new sorghum plant material with characteristics of considerable potential benefit to Australia. Through other Australian funding, this was subsequently developed into a new variety.

Furthermore, it was found that, although no new varieties were developed in India from the original work, the project markedly enhanced the capacity of the Indian collaborators in some new biotechnology research techniques. This enhanced capacity aided successful application for funding from other sources.

Subsequent research has led to new varieties that are currently being field tested and are likely to be released to farmers within a few years. Based on information collected during interviews with a range of participants in the research system, this assessment concludes that it is appropriate to attribute a significant share of this impact to the capacity-building activities of the original ACIAR-funded project.

The total returns attributable to these two indirect effects are found to be substantive, with a net present value of benefits of around A$160 million and a benefit:cost ratio of 100:1.

Two supplementary messages thus emerge from this study. First, a random sample can identify unexpected project benefits: the project chosen for assessment here was thought to have had no impact. Second, the capacity-building part of at least some projects can provide substantial returns to the funds invested.

Peter Core
Director
ACIAR

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Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ADB	Asian Development Bank
AICSIP	All India Coordinated Sorghum Improvement Program
APNL	Netherlands to Andhra Pradesh [project]
APSIM–SORG	agricultural production systems simulator–sorghum [model]
CIE	Centre for International Economics
DFID	Department for International Development (UK)
GRDC	Grains Research and Development Corporation
IARI	Indian Agricultural Research Institute
ICAR	Indian Council for Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
NRCS	National Research Centre for Sorghum
PIG	particle inflow gun
QDPI	Queensland Department of Primary Industries
UQ	University of Queensland

Acknowledgments

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All errors and omissions remain the responsibility of the authors.

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Summary

ACIAR project CS1/1994/968, 'Overcoming production constraints to sorghum in rainfed environments in India and Australia', was identified as an important area of research as a result of the international sorghum research planning workshop held at the Queensland Department of Primary Industries (QDPI) Bribie Island Centre on 15–19 November 1993. It was undertaken in conjunction with the Indian Council for Agricultural Research (ICAR), the National Research Centre for Sorghum (NRCS), the Indian Agricultural Research Institute (IARI) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India and the University of Queensland in Australia, between July 1996 and March 1999. The project was aimed at overcoming the major production constraints in post rainy season sorghum in India and rainfed sorghum in Australia.

The project was principally aimed at sorghum grown in the rabi (i.e. dry) season as opposed to sorghum grown in the kharif (i.e. wet) season. Rabi sorghum is a higher quality and higher value crop than kharif sorghum and is grown primarily on marginal land. This project was one of the first projects targeting developments in biotechnology in the sorghum field. Before this project, little work had been conducted in this area. Other projects subsequently followed, such as a block grant from the Netherlands to Andhra Pradesh (APNL), as well as aid from the United Kingdom Department for International Development (DFID) and the Asian Development Bank (ADB). The ACIAR project acted as a catalyst for further work to be carried out in the biotechnology field for sorghum.

The research undertaken involved developing a sorghum transformation system to enable the creation of sorghum strains resistant to common pests such as the stem borer and shoot fly. Other aims of the project included developing methods to improve the efficiency of plant breeding and developing improved crop models. The approach taken was a collaborative one, with an additional aim of building up the capacity of researchers to undertake this and subsequent research. The project failed to deliver the expected outputs in India due to the technical difficulties involved with the science, and was thought by some to have been unsuccessful. Others recognised the major contribution the project had made to building knowledge and skills, as well as important research technology. In such situations, the impact is usually dependent on subsequent investments in research and their eventual technical success. This project offered a challenge for impact assessment to see if such investments had been made, what their outcome has been, and the extent to which the benefits can be traced back and in part attributed to the ACIAR project. Selecting this project for assessment is also part of an attempt to randomly select projects for the Impact Assessment Series to provide a more representative selection of projects.

This impact assessment aims to estimate the contribution that the project has made to wellbeing in India and Australia. It goes beyond the usual impact assessment as it also considers the contribution that the capacity-building elements of the project have made to these benefits, and to other research projects. The approach applied is the ACIAR framework for capacity-building evaluation as developed in Gordon and Chadwick (2007). This impact assessment will contribute to testing and further development of this framework.

There were four main outputs from this project:

- A sorghum transformation system was developed, improving the technology available for genetic engineering for insect resistance.

- A database of advanced yield trials was constructed.
- Training workshops were conducted to introduce scientists in the sorghum-breeding program to the methodology of adaptation and analysis.
- The agricultural production systems simulator sorghum (APSIM–SORG) model was applied to Indian datasets.

The primary outcome of the project was to improve the research capacity in the partner agencies in India to conduct research into sorghum, with the primary objective of breeding or engineering higher-yielding germplasms. This was done by building skills, techniques and knowledge:

- Skills: Scientists' skills were enhanced through a series of workshops and training into the use of the APSIM–SORG model, the analysis of multi-environmental trial data and the use of particle bombardment techniques; and through collaboration between Indian and Australian scientists.
- Techniques: New scientific techniques were developed for use in genetically modifying sorghum using *Bacillus thuringiensis* (*Bt*) genes to instil pest resistance. Techniques for analysis of multi-environment trial data were also improved.
- Knowledge: New techniques brought together existing trial information that provided new insights into the factors affecting performance of the sorghum.

The secondary and mostly unintended outcome of this project was the discovery that the sorghum variety CHS13R has high radiation-use efficiency. This was discovered during analysis of the multi-environment trial data in India. This finding was then used to test this variety in Australia and has led to positive results and potential widespread adoption of the variety in Australia.

Impact assessment

The eventual outcomes of the project were anticipated to be new pest-resistant strains of sorghum or better varieties or hybrids of sorghum that would improve yields for farmers.[1] This impact assessment explores the development of such varieties and their adoption by farmers, and assesses the contribution of the ACIAR project to the achievement of these final outcomes and consequent benefits to India. The project also delivered significant benefits for Australian farmers through the identification of a radiant responsive variety that was suitable for use in Australia. This impact has already been assessed in Pearce et al. (2006). These results are included in the final analysis.

Figure 1 summarises the way in which the ACIAR project so contributed.

The impact assessment shows that the project has yet to lead to many of the outcomes specified in Figure 1, such as increased use of genetically modified or higher-yielding sorghum by farmers. The outcomes for the scientists have all been achieved but those for the farmers have not. The reason for this is that it takes a number of years for new material to reach the farmers' fields through the release of new seeds.

As this project ended more than 7 years ago, it could have been expected that results would already be observed on farms. This has not been the case in this project due to the long time frame involved in biotechnology and the relatively small amount of prior work conducted in this field at the time the project started. The aim of the ACIAR project was to develop the capacity to insert genes into sorghum in India. This was achieved by developing a tool called the particle inflow gun (PIG) and training Indian scientists in its use. However, a number of other steps must be completed before genetically modified sorghum can reach farmers' fields.

1 While the genetic material researched was not being developed into a farmer-usable state within this project, the project built the capacity for Indian researchers to achieve this objective.

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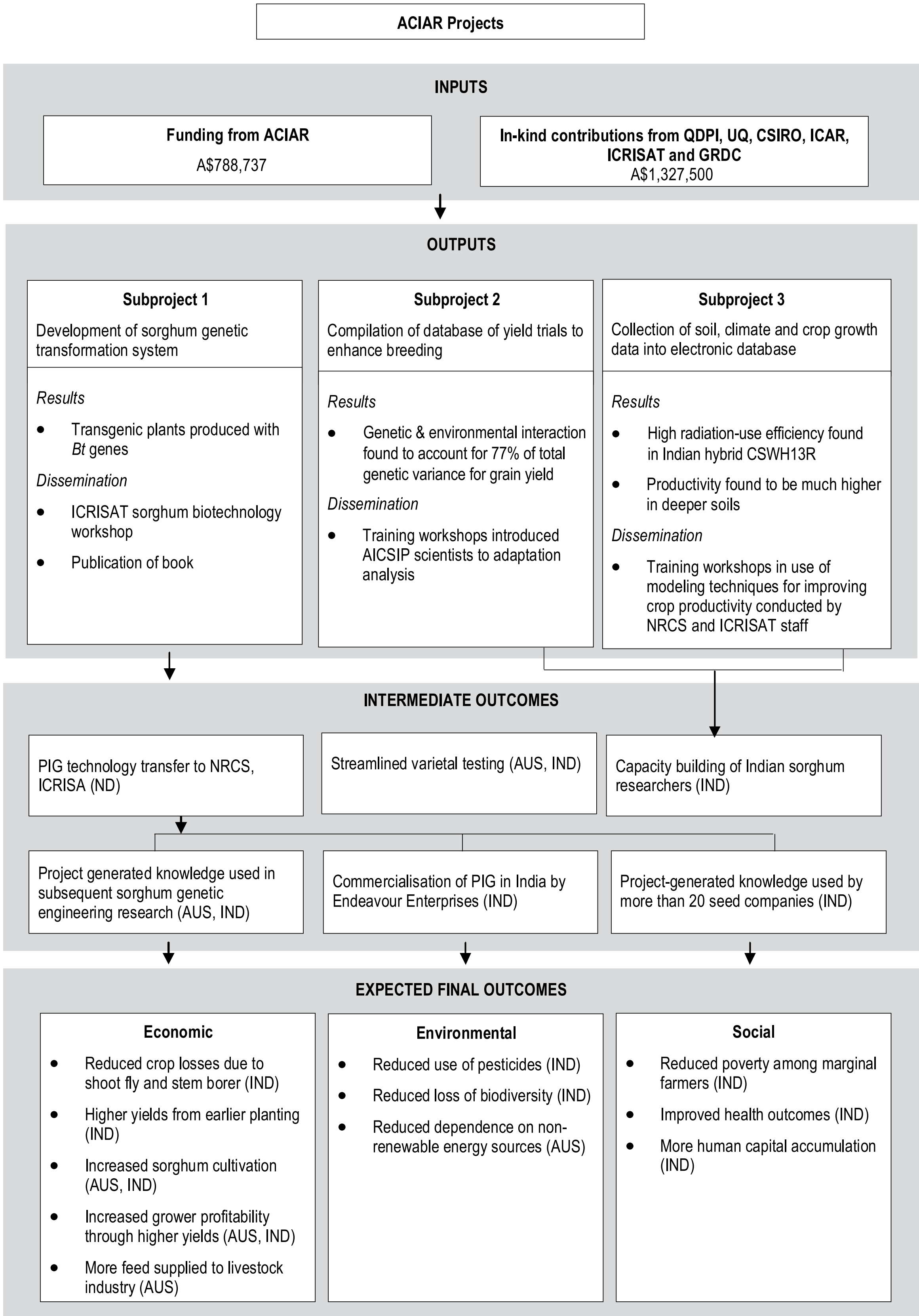

Figure 1. Projected pathways of project outputs and outcomes. Data source: CIE

Scientists must first identify the appropriate gene to insert into the plant to instil pest resistance. *Bt* genes were found to be appropriate for stem borer, but not for shoot fly. Once the correct gene has been identified, it must be inserted into the plant and its resistance tested. The plant is tested first in the laboratory before being taken outside for field trials. Small area trials are used first and then, if these prove successful, trials move to larger, multi-environment testing sites. Once the new pest-resistant strains have been shown to be effective, the seeds can then be multiplied for distribution through the seed distribution agencies. This is when they finally reach the farmers.

The whole product-development process of finding the right gene, testing it and ensuring that the levels of pest resistance in the sorghum plant are high enough to be effective takes many years. The benefits from this project have therefore not yet been realised as this process is still in progress. What this project has achieved is initiating this process and creating a base from which other work can continue. This means that, when the scientific process is completed and new seeds eventually reach the farmers, the benefits that they bring can partly be attributed to this ACIAR project.

In Australia, the final outcomes have already begun to arise, with an increase in the use and trialling of the CHS13R variety of sorghum.

Benefit measures

Benefits for each subproject (Figure 1) are measured separately as the projects were not interlinked.

- Benefits from subproject 1 are estimated using a supply and demand framework. Although this project has not led to any releases of pest-resistant strains into farmers' fields at the time of writing, such releases are expected and the likely yield increases of these new strains can be estimated. The benefits of pest resistance can be quantified. It is important to determine the share of the contribution that this ACIAR project made to achieving pest resistance, as other projects have also played a key role in achieving these outcomes. Newer scientific methods are also now in use and, if and when new strands of sorghum are released, there will also be the question of what share of their benefits can be attributed to this project. It can definitely be said that this project will have contributed to the discovery of shoot-fly and stem-borer-resistant strains of sorghum, and has greatly developed capacity among scientists in the field, many of whom are still using the original PIG brought into India. The benefits from this project were mainly brought about through capacity building as it was the training received by scientists in genetic transformation that has enabled them to make further discoveries and continue their work in the field.
- Benefits from subproject 2 accrued mainly to Australia. These arise as a result of the discovery of the CHS13R variety, which has subsequently been adopted in Australia. Without the ACIAR work it is likely that superior varieties would still have been introduced but the ACIAR findings brought forward their development, as well as reducing the cost of varieties that are now being adopted. Potential benefits from increased productivity of experiments after the compilation of the multi-environment trial yield database were not realised as the recommendations made through this project were not followed. The Australian benefits accruing from this project have been measured in a separate study by Pearce et al. (2006), from which the Australian benefits described below are taken.
- Benefits from subproject 3: The benefits from the modelling subproject appear to have been very small for both India and Australia as the model is not currently in use in India. However, there do appear to have been some unintended benefits, as the modellers who were involved and trained as part of this project are now using and applying an African version of the model in Africa. To estimate this impact requires following up on the uses made of the model in Africa and the extent to which these uses have improved productivity. Unfortunately, information could not be obtained to allow this potential avenue of benefits to be further investigated.

Benefits

The benefit estimates are presented in Table 1. The third column in Table 1 shows the expected benefits to India. This is the share of the expected total benefits from developing the pest-resistant sorghum that can be attributed to the ACIAR project relative to the cost of the project. Column 4 shows the benefits to Australia. The internal rate of return and benefit:cost ratios are calculated for the total expected benefits. The benefit:cost ratio reflects only the research and development costs on the costs side and so tends to be very high relative to benefit:cost ratios that include the costs of extension services and other investments required to support adoption of the new varieties.

Lessons

The main lesson learned from this assessment is the importance of continuity when funding capacity-building projects. Many of those involved in the design stage of this project envisioned that it would take place over a 6-year time frame, with the first 3 years treated as a first phase and the expectation that a second phase would ensue upon completion. This second phase did not take place, which significantly reduced the speed if not the likely impacts of this project. This was especially apparent in the modelling and crop-breeding objectives, as capacity built was not sufficient to allow for wide-ranging use of the methods developed and thus for substantial outcomes to be easily achieved.

The biotechnology part of this project did achieve some observable positive results. These results can be attributed partly to this ACIAR project, but equally important is that they contributed to the continued funding of research by other organisations.

During the initial design stages of this impact assessment it was felt by many within ACIAR that this was a poor choice of project for an impact assessment as the benefits were regarded to have been relatively small. However, during the course of conducting the analysis it was discovered that the legacy from the capacity building will lead to substantial benefits. This underlines the importance of measuring the capacity-building elements of a project, as failing to do so may lead to a serious underestimation of project benefits.

Table 1. Results of the benefit–cost analysis under varying discount rates

Discount rate	**Present value (PV) of costs** A$m	**PV of benefits India** A$m	**PV of benefits Australia** A$m	**Benefit:cost ratio**
1%	2.07	1,874.0	86.9	944.3
5%	1.99	161.8	39.7	100.7
10%	1.91	29.1	15.9	23.6
Internal rate of return				28.07

Sources: CIE calculations; Australian benefits from Pearce et al. (2006)

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1 Description of the research

Background

Sorghum is an important crop for food and fodder in India and parts of Australia as it is one of few crops that can withstand hot and arid conditions. However, yields of sorghum in both countries are very poor, with little or no improvements in productivity over the past two decades. Traditionally, little effort has gone into researching sorghum as a large proportion of the crop is produced by subsistence farmers. Insect damage and shortages of nitrogen and water are the main constraints on sorghum production. In an attempt to overcome some of these problems, project CS1/1994/1998, 'Overcoming production constraints to sorghum in rainfed environments in India and Australia', was initiated.

An integrated approach was planned in this project, in which plant breeding, crop modelling and genetic transformation were all combined to target insect pests and overcome water and nitrogen deficiencies. The project began in July 1996 and ended in 2000.

The ACIAR project

Objectives of the research

The objective of the research was to develop technologies for optimal development of sorghum genotype and crop-management combinations that best match major biotic and abiotic production constraints in dry-season (rabi) sorghum in India and dryland sorghum in Australia. The three main objectives of the projects were to:

- enhance genetic-transformation techniques to aid development of sorghum varieties with high and stable levels of resistance to sorghum shoot fly
- develop methods to improve the efficiency of selection for plant breeding through better analysis, and design multi-environment testing
- develop improved crop models and climatic and soil databases, to be able to simulate water and nitrogen effects on crop production and predict the consequences of management manipulations of the crop.

The reviewers of ACIAR project CS1/94/968 in 1999 noted that the project had made excellent progress towards meeting all three of the main objectives but that, due to complications and a late start date, extensions would be needed if all aims were to be completed. The project was given extra time for completion but no extra funding was provided to continue the research.

Prior and subsequent work on sorghum

Before the ACIAR project, very little work had been undertaken in the biotechnology field. The ACIAR project was one of the first to attempt to achieve results in this area. The success of the project in developing and using the particle inflow gun (PIG) has led to further research in this area and has enabled Indian scientists to get further funding and continue this line of work. The PIG is an instrument first developed in Finer et al. (1992). It uses particle bombardment to introgress foreign genes into crop cultivars. Subsequent sorghum projects carried out included that supported by a large grant (APNL) from the Netherlands to the Andhra Pradesh government to carry out further work on genetically modifying sorghum. The APNL grant was received in 1998 and work carried on until 2007. The project has only recently terminated. Other projects at the time included work supported by aid from the UK Department for International Development (DFID) and the Asian Development Bank (ADB).

Pathways to the objectives

This ACIAR project was initiated by the Queensland Department of Primary Industries (QDPI) and involved the University of Queensland (UQ), the National Research Centre for Sorghum (NRCS), the Indian Agricultural Research Institute (IARI), the Indian Council for Agricultural Research (ICAR) and as well as the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

The project objectives were to be achieved using a series of separate but interacting subprojects:

- Genetic engineering for insect resistance. A sorghum transformation system was developed to enable genetic modification of sorghum into pest-resistant strains. This was done in Queensland and India by ICRISAT, UQ, IARI and NRCS scientists. A workshop was also held at ICRISAT in Hyderabad, where Dr Carl Rathus conducted training sessions on use of the PIG for Indian scientists and researchers from NRCS, ICRISAT and a number of private companies and Indian universities.
- Improved breeding methods. This involved constructing a database of rabi sorghum trials conducted by the All India Coordinated Sorghum Improvement Program (AICSIP), and improving methods for analysis of this dataset. The database was constructed at NRCS, overseen by Dr Rana and developed with Dr Kaul of NRCS in conjunction with Australian scientists in Queensland. The scientists then collaborated to deliver a workshop, run in India, on analysis methodology.
- Improved management strategies. In this subproject, data from past sorghum experiments were collated in an electronic database, CROPBAG. Major field experiments were initially conducted in Australia with participation from Indian NRCS scientists, then in India at ICRISAT. The latter were conducted using funds from a special project grant associated with this project, given to Fran Bidinger to conduct preliminary work towards the modelling subproject. The results of the Australian and Indian experiments were then used for modelling of rabi sorghum in India using the agricultural production systems simulator (APSIM) sorghum (SORG) model. The Australian scientists travelled to India to assist in Indian field experiments and follow up on data analysis. Indian scientists were also trained in the use of the APSIM–SORG model.

The aim when developing this project was that these three objectives would come together and interlink at the end of the project. However, in reality, this did not happen and the three projects remained very distinct. In the initial development phase of the project, it was anticipated that subproject 1 would develop genetically modified sorghum resistant to shoot fly, and that these resistant strands would then be fed into the yield trials that would have been streamlined and made more efficient by subproject 2. One of the aims of developing the APSIM–SORG model for use in India was to model the yield gains that could be achieved if the planting season were brought forward as a result of shoot-fly resistance. As shoot-fly resistance was never achieved and the project ran for only 3 years, the three subprojects were run separately with very little interaction. The impacts and benefits of these three projects will thus be assessed separately.

Outcomes

Subproject 1: Genetic transformation

This activity achieved the most concrete outcomes of the project. The PIG brought to India is still in use in laboratories today and has brought forward the development of genetically resistant strains of sorghum. This has not yet led to a pest-resistant strain that has been widely adopted in the farmers' fields.[2] This is mainly due to the long time frame involved in the biotechnology field. This subproject led to a renewed interest in the field and acted as a catalyst for further funding (e.g. APNL) in the area.

Subproject 2: AICSIP construction and analysis

A database of multi-environment trial data was constructed and analysed as part of this project. The analysis of this database led to the finding that the number of trial sites could be significantly reduced

2 Appendix B explains the difference between stem-borer and shoot-fly resistance.

while retaining the same level of productivity of experiments. Recommendations were thus made for the number of trial sites to be reduced, which could have led to substantial cost savings. However, it seems that these recommendations were not implemented. The benefits of this subproject appear to have accrued mainly to Australia, as one unintended outcome of this subproject was the identification of Indian genotype CHS13R as having higher radiation-use efficiency. This discovery led to greater interest in Australia and increased farm plantings of this genotype in Australia.

Subproject 3: Adapting the APSIM–SORG model to rabi conditions in India

This aim was achieved in that the model was successfully adapted to the conditions, but it has nevertheless not proven useful for Indian purposes. An outcome of the project was that all those involved in modelling within ICRISAT were transferred to work together as a special modelling unit in South Africa, and the model has been successfully used and applied in Africa. This impact assessment does not track the value that may have resulted from application in Africa. To estimate this impact would require following up on the uses made of the model in Africa and the extent to which these uses have improved productivity. Unfortunately, information could not be obtained to allow this potential avenue of benefits to be further investigated.

Costs of the research

The estimated expenditure on the project by ACIAR and other organisations over the 3-year period is shown in Table 2.

Capacity-building inputs

The project included a large capacity-building element in India that will be essential in achieving the final outcome of increased yields of sorghum there. The main capacity-building elements of this project were as follows:

- Training: Several workshops were delivered throughout the course of this project by Australian scientists in India. Dr Cooper and Dr Chapman delivered a workshop in India on analysis methods. A workshop was also conducted by Dr Carl Rathus on the use of a newly developed PIG for genetic transformation of sorghum.
- Learning by doing: Australian scientists worked side by side with their Indian counterparts in both field experiments and genetic transformation experiments. Dr Kaul (NRCS) travelled to Australia to participate in data analysis with Dr Cooper who then travelled to India to conduct field experiments.
- Enhancing technical skills: The technical skills of scientists were enhanced through the development and use of environmental databases and crop models. Dr Rana collaborated on the development of the AICSIP database with Dr Cooper.
- Improvement of networks: The research brought together a number of Australian and Indian scientists.

The capacity built was essential in achieving the outcomes of this project in India.

In Australia, the benefits from this project did not stem from capacity-building efforts but came more from the discovery and use of a higher-yielding sorghum variety.

Table 2. Estimated project costs (nominal Australian dollars)

Agency	**Year 1** (1996–97)	**Year 2** (1997–98)	**Year 3** (1998–99)	Total
ACIAR	244,545	268,542	275,650	788,737
QDPI	97,500	97,500	97,500	292,500
UQ	72,500	72,500	72,500	217,500
CSIRO	40,000	40,000	40,000	120,000
ICAR/NRCS	62,500	62,500	62,500	187,500
ICRISAT	100,000	100,000	100,000	300,000
GRDC	70,000	70,000	70,000	210,000
Total	687,045	711,042	718,150	2,116,237

Source: ACIAR project database

2 Research outputs and adoption

Research outputs

The outputs from each subproject are distinct and are described separately. They included:

Subproject 1: Genetic transformation

Enhanced genetic-transformation techniques

The particle inflow gun (PIG) developed in Australia enabled the genetic transformation of sorghum by particle bombardment. The plans for this gun were then transferred to Indian engineers to enable them to construct their own versions.

Capability to incorporate into sorghum different gene types that target specific insect-pest species

The initial aim was to transfer genes from the *Bacillus thuringiensis* (*Bt*) bacterium into sorghum in order to create a strain 'resistant' to the shoot fly (see Appendix B for more information). The project was successful in building the capacity to insert this gene using the PIG. However, problems were encountered when trying to develop shoot-fly resistance and the project focused instead on resistance to stem borer. The PIG is still in use in Indian laboratories by the scientists trained in its use, and they have trained others. This has greatly advanced the development of stem-borer-resistant strains of sorghum which are currently being trialled in field experiments.

Sorghum tissue and culture transformation book

A book entitled 'Sorghum tissue culture and transformation', containing the research articles presented during the workshop held at ICRISAT as part of this project, was distributed freely in India and is still used as a reference guide by many researchers in the field.

Subproject 2: Developing and analysing the AICSIP database

Recommendations for streamlining yield trials

Analysis of the AICSIP database showed that the number of trial sites could be streamlined with no loss of efficiency. However, nothing resulted from this, as the recommendations were not acted on. The main reason for this appears to be that the trial sites are given large grants to conduct experiments and that there is strong resistance to limiting the number of those benefiting from this funding. Shortly after the end of this project, Dr Rana retired and Dr Kaul transferred to another field of work, and therefore neither the database nor the analysis methods taught remain in use.

Analytical methods for database analysis

Dr Kaul was also trained in methods for analysing the AICSIP database.

Subproject 3: Developing the APSIM–SORG model for India

Testing and developing the APSIM–SORG model for use in modelling the rabi sorghum crop in India

Dr Ravi Kumar spend 5 months in India studying with Dr Graeme Hammer and developing the APSIM–SORG model for use on the rabi sorghum crop there. Ravi Kumar was the primary beneficiary of this part of the project, but the modelling capabilities are not currently in wide use in India due to a lack of capacity to continue the modelling work. This is largely because further funding was not received after the initial 3-year project to enable further development and application of the model throughout India.

An increase in the capacity of Indian scientists to conduct modelling of the rabi sorghum crop in India

The main beneficiary of this was Dr Ravi Kumar, and he has since trained others in the use of this model. Due to constraints in India and the lack of further funding, the model has not been as useful as had been anticipated at the project outset but is still being used to construct forecasts of the rabi sorghum crop for statistical purposes.

Capacity built

An increase in the capacity of scientists in India to genetically transform sorghum

This has led to an increase in the number of experiments on sorghum and the ability to construct strains genetically modified for pest resistance. Although a pest-resistant strain has not yet been released, advances have been made towards releasing a stem-borer-resistant strain of sorghum. The genetic transformation technique that was taught at the workshop is still in use today by scientists, and many others have been trained in its use.

An increase in the capacity of Indian scientists to analyse multi-environment trial data

The primary beneficiary of this was Dr Kaul, who received training in statistical analysis methods for analysing the AICSIP database.

Improved capacity of local scientists to write scientific research papers

A by-product of the training given to Dr Ravi Kumar was to improve his ability to write scientific research papers. He has since had papers published.

Unexpected outcomes

Developing local entrepreneurship

The plans for building the PIG developed in Australia as part of the project were transferred to ICRISAT in India. An engineer who had previously worked at ICRISAT was then able to modify and improve the gun and begin selling it commercially as part of a business (Endeavour Enterprises). The business currently sells PIGs to universities and other research institutions for use with sorghum and other crops.

Development of pest-resistant strains of sorghum

The initial aim of this project was to develop a strain of sorghum resistant to shoot fly. Scientific constraints prevented this and efforts were instead focused on developing stem-borer-resistant strains. Work on these strains has continued after the project and scientists in the field estimate that they are 2–3 years away from achieving a stem-borer-resistant strain of sorghum.

Development of a modelling unit based in Africa

Identification of sorghum variety CHS13R as having higher radiation-use efficiency was the most important of the unintended outcomes. This has led to establishment of a special modelling unit in South Africa and the adoption of the variety in Africa.

Adoption

Pathways to adoption

The project did not itself produce a new variety of sorghum, so the adoption pathway in India is mainly through the development of capacity, technology and knowledge that led, in turn, to the development of new varieties. Indian researchers are the next users of these outputs. Capacity was built in a number of ways, such as improving the ability to use biotechnology, training on data-analysis methods for multi-environment trials and modelling the Indian rabi sorghum crop.

A new variety of sorghum has been developed but has not yet been adopted by farmers. Research into new varieties and hybrids is still being conducted. It is hoped that higher-yielding varieties will be released in India soon. Benefits can only be estimates at this stage. The information on yield improvements from new sorghum varieties is based on best guesses on what is likely to occur in the future. These best guesses are based on initial trial results and extensive discussion with those who participated in the training sessions and experts in the field of sorghum research. All assumptions made have been verified by checking their validity with experts or by using more than one method of accounting.

The key adoption pathway for the Indian benefits of the project is summarised in Figure 2.

In Australia, this project has already led to changes in farmers' fields, as identification of the CHS13R variety as having higher radiation-use efficiency has led to an increase in the number of farmers planting this variety.

As it currently stands, the project has not reached beyond the first two stages of the adoption pathway in India.

Applicability of the research

Applicability of the final outcomes

The final users of new varieties of sorghum and of advice on management practices would most likely be in the states of Karnataka, Maharashtra and Andhra Pradesh as these are the main rabi sorghum-growing areas of India. In Australia, the primary beneficiaries will be farmers in Queensland and New South Wales, the main sorghum-producing states.

Figure 2. Adoption pathway. Source: CIE

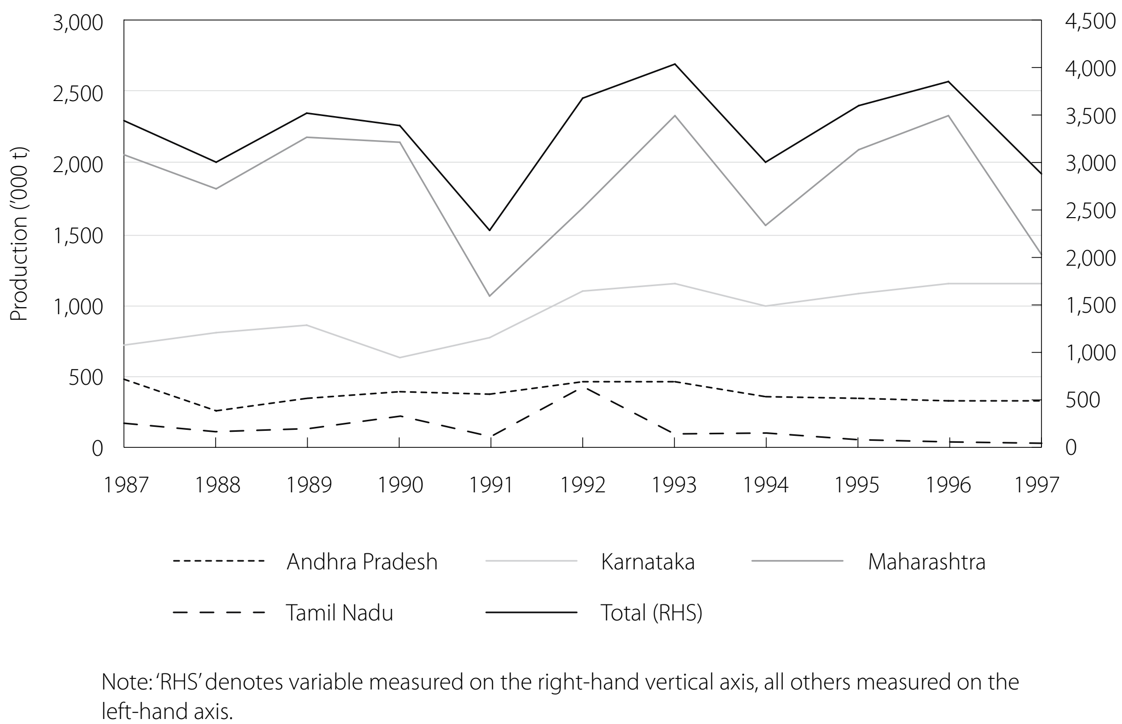

Figure 3. Production of sorghum. Data source: Department of Agriculture, India, and Centre for Monitoring Indian Economy

Figure 3 shows the production of rabi sorghum in India in the four main production regions. Total production varied between 3 and 4 million tonnes between 1987 and 1997, as measured on the right-hand vertical axis. The largest producing region was Maharashtra. Production of rabi sorghum trended downwards from 1996 to 1997.

Figure 4 shows that yields of rabi sorghum in India were much larger in the Tamil Nadu region than they were in other parts of the country from 1987 to 1992, but that yields in this area declined sharply from 1993 onwards and have now reached levels similar to those in the other states. The other states have had relatively stable yields in the range 400–800 kg/ha.

There have also been benefits from this project in Australia. The results have been applicable to researchers and farmers, mainly those in Queensland, as this is the largest producing area and where most sorghum research is undertaken.

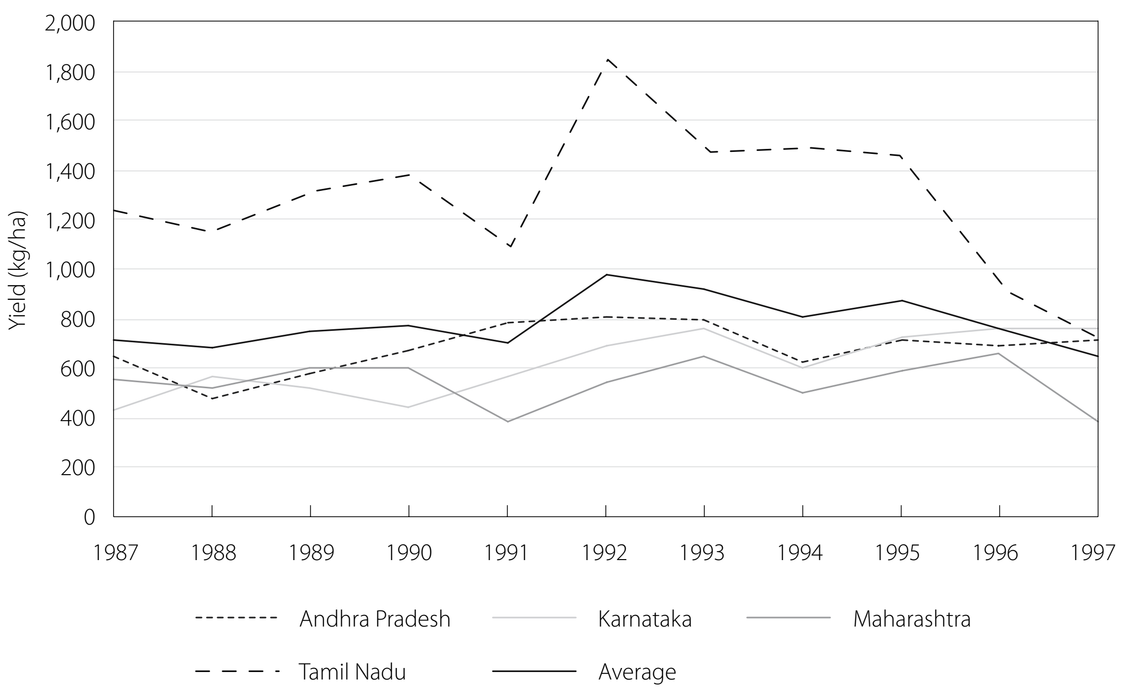

Figure 4. Sorghum yields in India. Data source: Department of Agriculture, India, and Centre for Monitoring Indian Economy

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia*. ACIAR Impact Assessment Series Report No. 48, July 2007

3 Capacity utilised

Changes in scientific outputs

Many of the scientific outputs of this project have not yet occurred as the research begun in this project is still underway. Some of the outputs achieved to date are:

India

- progress towards developing a stem-borer-resistant strain of sorghum
- increased capacity of scientists to genetically transform sorghum
- use of the PIG to genetically transform sorghum

Australia

- discovery of the high radiation-use efficiency of CHS13R
- increased on-farm use of CHS13R.

Indirect effects

There may also have been some indirect effects from this research. For instance, the PIG developed in this project may have been used to genetically transform other crops in some institutions in India that were trained in its use. However, this cannot be verified and the effects of this are unknown.

Another indirect effect from this project was the interest gained in modelling by scientists at ICRISAT. At the end of the project, ICRISAT moved a large proportion of its modelling staff to a specialised station in Zimbabwe where the APSIM–SORG model is being developed and applied to African conditions. Neither of these spillover effects is included in the estimates.

What would have happened in the absence of this research project

In the absence of this project, several key scientific breakthroughs might eventually have been made, although it is likely that these would have taken much longer. This would impede the development and adoption of genetically modified sorghum as well as delaying progress on scientific yield trials, experiments and breeding options. The transformation mechanism for sorghum would have taken much longer to identify, thus delaying the development of genetically modified sorghum. The counterfactual differs between the two locations, as conditions for growing sorghum differ between Australia and India and this project thus had different implications for each. The counterfactual for each country is outlined below.

- Australia:
  - slower identification of variety CHS13R as having higher radiation-use efficiency
  - longer time delay in trialling and adopting this variety
  - delay in increase in yields resulting from the use of CHS13R.
- India:
  - inability to genetically modify sorghum using the particle inflow gun
  - failure to achieve a pest-resistant strain of sorghum that can be adopted on farms
  - lack of interest in the biotechnology field for sorghum
  - failure to access further funds to carry out research on genetically modified sorghum.

Economic outcomes

The final outcome of this project for India will ultimately be releases of more productive varieties of sorghum, thus enabling farmers to gain higher yields. Subproject 1 could lead to more productive varieties through an increase in pest resistance to either stem borer or shoot fly, resulting in less crop damage and/or an earlier planting season. The expected outcome is enhanced productivity of varieties grown beyond what they would otherwise have been (higher yields per unit input) in the absence of this project.

Subprojects 2 and 3 are not anticipated to have any measurable benefits to India. The benefits of subproject 2 are measured as benefits to Australia, as it was through this project that the CHS13R strand was identified as having higher radiation-use efficiency. Subproject 3 economic outcomes are thought to be negligible for both India and Australia, but it is possible that there may have been a positive impact of this component of the project in Africa.

The project was completed in 2000, and it seems that not enough time has passed for these economic impacts to have reached farmers' fields. This is due to the long time frame for biotechnology projects described previously. However, it is hoped that these outcomes may still be achieved at a later date. Measuring the potential benefits of these outcomes requires assumptions to be made about a number of key factors such as the:

- likely increase in productivity resulting from a new variety
- likely adoption rate by farmers
- time frame for adoption.

Another issue that needs to be considered when quantifying these economic outcomes is the share of the benefits that can be attributed to this project. The ACIAR project was only one of a number of projects being undertaken on sorghum at that time. Other projects, such as those conducted by APNL and DFID, had larger budgets and ran over a much longer period. It may be that those projects are responsible for the developments made in the sorghum field, rather than the ACIAR project.

There may also be flow-on benefits to other Indian organisations and other research areas due to enhanced technology, knowledge and skills in crop research in India. This project might also have an impact on staff retention and the accumulation of skills in the participating organisations.

It is also possible that, thanks to this research, agricultural productivity could increase in other areas associated with sorghum; for example, increased sorghum yield could lead to better diets for animals, which could improve yields of meat or other animal products such as dairy.

In Australia, economic outcomes of this project are estimated to have been brought about through the increased use of CHS13R, a variety of sorghum with higher radiation-use efficiency. The benefit is in terms of bringing forward its use and hence improvements in yield.

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia*. ACIAR Impact Assessment Series Report No. 48, July 2007

4 Impact assessment

Benefits from the capacity built

The benefits from the capacity built from this project would be expected to flow as depicted in Figure 5. The capacity-building impact-assessment framework also identified the returns to the individuals involved in the research, in terms of their personal remuneration for skills gained. The following analysis does not include such benefits, as it was not clear that remuneration for the scientists involved is linked to the type of training received under the project (apart from formal qualifications) as this is based mostly on years of service. Moreover, any gain in salary for the researchers comes at a cost to the institution of a higher wages bill. Thus, in this assessment, the two offset each other, and the focus of the analysis is on the value of greater productivity and innovation in research that resulted from the capacity built.

The benefits from the capacity built as a result of this project included the following:

- Increased stock of knowledge: Knowledge was dispersed through the training of staff. This was done in a number of ways, either by running training courses for groups of scientists or through one-on-one training with Indian scientists staying in Australia, as well as through Australian scientists travelling to India to conduct training there. The stock of knowledge was also increased through the publication of a book that is now in wide use among scientists in the sorghum field. A number of publications have also resulted from this project and more are expected.
- Increased ability to provide training: The training received by many of the scientists involved in this project enabled them to go on and train others in the methods they had learned. For example, scientists trained in the use of the particle inflow gun were able to return to their laboratories and teach others.
- International connections: Some of the training run as part of this project brought together scientists from a variety of institutions and countries. Many scientists made valuable contacts and connections with others in their field that they would not otherwise have eventuated.

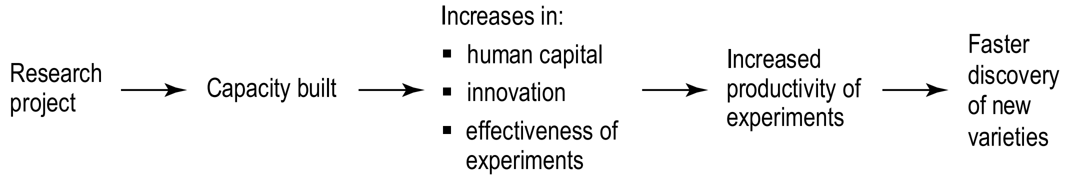

Figure 5. Benefit flows from capacity built. Source: CIE

Approach to estimation

The value of the capacity built in India was assessed using a survey conducted in India. The survey hoped to cover all the major participants in the research, such as the scientists, any participants in training courses and anyone involved in experiments or compilation of handbooks etc. A list of questions posed can be found in Appendix A. The survey was not able to cover all the scientists that participated in training in this project, as many of them had moved away and were not traceable. At least one participant from each of the three subprojects was surveyed.

The purpose of the surveys and interviews was to assess, first, whether capacity was built as a result of this project; second, how it has been utilised; and third, whether it was necessary and/or sufficient. This helps to determine what share of the benefits accruing from this project can be attributed to the capacity-building elements. For a thorough discussion of this attribution issue see Gordon and Chadwick (2007).

Survey results

The capacity built as a result of this project came through three main strands:

- biotechnology—the capacity to genetically transform was built
- crop breeding—the capacity for analysis of multi-environment trials was built
- modelling—capacity was built on the use of the APSIM–SORG model for Indian rabi sorghum.

Participants in all three types of training were interviewed and the feedback was mainly positive. The results of the survey and discussions showed that the training was directly related to the field of work or study of each of the participants surveyed. The most productive training appears to have been come from the biotechnology part of this project. In this part of the project, the most important aspect identified was training in the use of the PIG.

Interviews with those present at the PIG training showed that they valued it very highly and that they have since gone on to use the techniques learnt to conduct further experiments in the field. These experiments have led to development of stem-borer-resistant strains of sorghum (although these have not yet been developed to a stage where they are ready for distribution) and allowed further research to be conducted in other areas.

An additional advantage of the biotechnology training session was that it was held at ICRISAT and for a group of scientists. This meant that many participants were able to make contacts with other people in their field, thus leading to an increase in the national and international networks of participants.

The biotechnology subproject also delivered training to scientists that developed their capacity to conduct work in new areas of technology. For instance, *Agrobacterium* is now commonly being used to transfer genes in sorghum plants. There is a considerable skills overlap between genetic transformation by *Agrobacterium* and by particle inflow, and scientists were able to apply the skills they learnt as part of the ACIAR project to these newer methods.

Another key effect from the capacity built in biotechnology was that it led to an increase in interest in, and the number of scientists conducting, this type of work. It also led to further research grants in this field via the APNL grant. The APNL project finished in 2007 and has led to the development of strains of sorghum resistant to stem borer that are currently being trialled in field experiments. The scientists involved in biotechnology attribute their success in receiving and being able to manage the APNL grant in part to the training they received under the ACIAR project.

The modelling training received by Dr Kaul and Dr Kumar appears to have been less successful. Although Dr Kumar rated the training he received very highly, he was not able to apply the knowledge he gained about modelling to his work upon his return to India. This was a result of the constraints that he faced once home and, in large part, because the model was not widely applied due to the lack of funding for extension, which activity was not supported by the project.

Although all respondents to the survey rated the training they received very highly, and all agreed that their capacity was built as a result of the project, there appears to have been a break between the capacity built and the capacity utilised.

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia*. ACIAR Impact Assessment Series Report No. 48, July 2007

The capacity built in subproject 1 is still in use today, but the same cannot be said for subprojects 2 and 3.

The results of this survey, and discussions with many others that were involved in this project, found clear links between the capacity built and the development of the new pest-resistant varieties. The links were through:

- the skills and knowledge developed by the scientists on research methods and techniques
- the interest in and consequent funding for follow-on research into the resistant varieties
- the introduction of the PIG and its adaptation to provide an extremely useful tool for improving research productivity and allowing new methods to be adopted.

A large proportion of the project budget was taken up by training courses and workshops and scientists' visits. It is estimated that around 90% of the project budget was spent on these capacity-building activities.

In Australia, the impact of this project came from the identification of the characteristics of the CHS13R variety, and thus the benefits can be attributed to scientific discovery rather than capacity building.

Direct benefits from the technology

The benefits from this project are expected to flow as depicted in Figure 6.

The estimated benefits of this project to India are the future improvements in grain production and yields as a result of the new varieties arising from the training received in the biotechnology field.

The benefit to Australia is the earlier use of the higher-yielding CSH13R variety, which has a higher radiation-use efficiency.

Approach to estimation

The approach to estimation varies with the country and subproject that is being assessed.

Australia

The total benefits of this project to Australia are based on the assessment that the ACIAR project brought forward the identification of the benefits of the CHS13R variety by 5 years and that it increased the probability of successful adoption from 0.6 to 0.8. That is, if ACIAR had not funded the project, it would have been another 5 years before the hybrid came into use. Adoption is expected to take place fairly rapidly over 5 years (from 2011 onwards with the ACIAR-funded research and from 2016 without the ACIAR-funded research). Sorghum yield increases cumulatively by 4.5% through this period over and above the underlying trend. The estimation method is shown in Figure 7.

Historical data from 1961 to 2005 from the Australian Bureau of Agricultural and Resource Economics (ABARE) are used to (linearly) project the area of sorghum cultivation and 'underlying' sorghum yields between 2006 and 2025. 'Underlying' sorghum yields refer to projected future sorghum yields, assuming that the new high-radiation use efficiency (RUE) variety is never adopted. Using these 'underlying' sorghum yields, two future yield paths can be computed, one associated with the ACIAR-funded research project and another with the hypothetical alternative research project that takes place 5 years after the ACIAR-funded one.

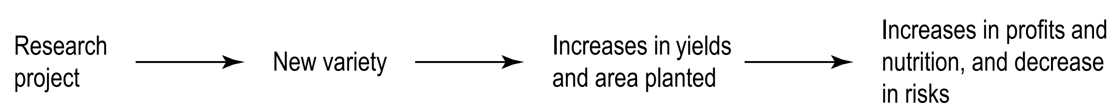

Figure 6. Benefit flows. Source: CIE

ABARE data on Australian sorghum producer prices for 1996 to 2001 are used. To compute producer prices from 2002 to 2025, the average of actual prices between 1991 and 2001 is used, and beyond this an annual inflation rate of 2% is assumed. Operating costs are based on 2002 Grains Research and Development Corporation (GRDC) data and, again, an annual inflation rate of 2% is assumed. The fixed costs are expected to be the same in the presence or absence of the ACIAR-funded research. As an approximation, the present value of implementation costs associated with the actual ACIAR-funded project and the later, hypothetical one are assumed to be the same.

This method evaluates the total benefits to Australia of this ACIAR project. These benefits accrued mainly from the scientific discovery that the CHS13R variety had higher radiation-use efficiency, and not from the capacity-building elements of the project.

India

For India, the benefits of this project can be attributed almost entirely to the capacity building of the Indian scientists through subproject 1, which enabled them to carry out further work in the genetic transformation of sorghum.

The benefits to this project will come through an increase in yield brought about as a result of the discovery of strains of sorghum resistant to shoot fly and stem borer. Although these benefits will have come mainly from the work conducted in subproject 1, the total project costs will be used in the analysis.

A supply and demand framework is used to conduct this analysis, as depicted in Figure 8. Data were collected on the unit cost of production and price of the best available and most widely planted variety of rabi sorghum currently available to farmers. These data form the basis of the estimates of the unit cost and price changes resulting from the new varieties. The predicted changes in price and unit cost were constructed using knowledge of the likely impacts of pest resistance as well as evidence from past releases of new seed varieties.

Pest resistance is shown to reduce the unit cost of production of sorghum. This is because the reduction in damage from insect pests leads to higher yields. However, while yields are higher, there are additional costs that partially offset the effect on per-unit cost of the improvement in yield. The labour cost of harvesting the sorghum per hectare will increase. The new varieties also require additional fertiliser. The cost of production of the Maldandi variety is estimated at 8,665 rupees

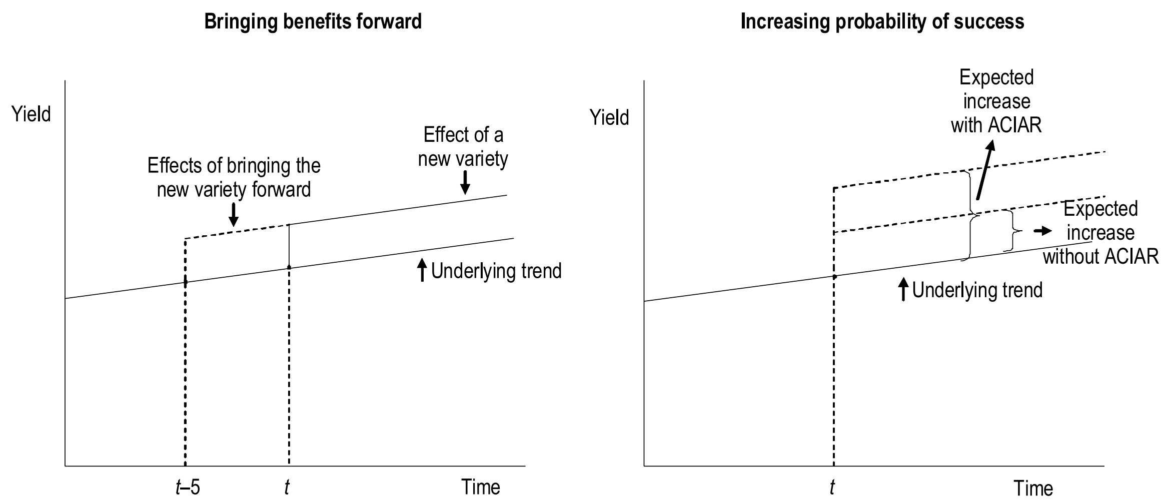

Figure 7. Bringing benefits forward and increasing probability of success. Source: Pearce et al. (2006)

per hectare. Introducing pest resistance will increase this cost to 9,108 rupees per hectare. The fixed costs are estimated to remain unchanged once the new varieties have been introduced.

The expected yield improvement from the new pest-resistant variety is 25% for each part of the plant—grain, stalk and by-product. This improvement is based on the current estimated cost to yield associated with loss from shoot fly, which would be eradicated.

Rabi sorghum is grown for a variety of purposes in India. The main purpose is use of its grain for flour, but the stalk and by-product are also of use for animal feed and fodder. Applying the estimated yield changes to the three components, and allowing for increases in the costs of production, gives a reduction in the unit cost of production of 2,561 rupees per tonne (around 16%). There is also expected to be a slight improvement in the quality of the grain, which would then attract a slightly higher price. The initial price is 11.5 rupees per kilogram, and it is expected that willingness to pay due to higher quality will raise the price to 12 rupees per kilogram. This is reflected by the shift in demand in Figure 8.

Assumptions used in quantification of the benefits

India

In order to quantify the benefits of this project in a supply and demand framework, a range of assumptions needs to be made about the current market for rabi sorghum in India, as well as the likely future impacts of the project. These assumptions are decided after reviewing all the available information on the subject to ensure that each assumption is as accurate as possible. Sensitivity analysis is also conducted to test the sensitivity of the results to changes in certain parameters used.

The key assumptions made are summarised in Table 3.

The elasticities of supply and demand were derived from past studies on the sorghum market and behavioural responses to price changes. These estimates come from data contained in the village-level studies conducted by ICRISAT.

The estimate of yield increase was based on numerous discussions with scientists and researchers in the field who all agree that shoot fly is one of the major problems affecting rabi sorghum yields at this time. Stem borer is

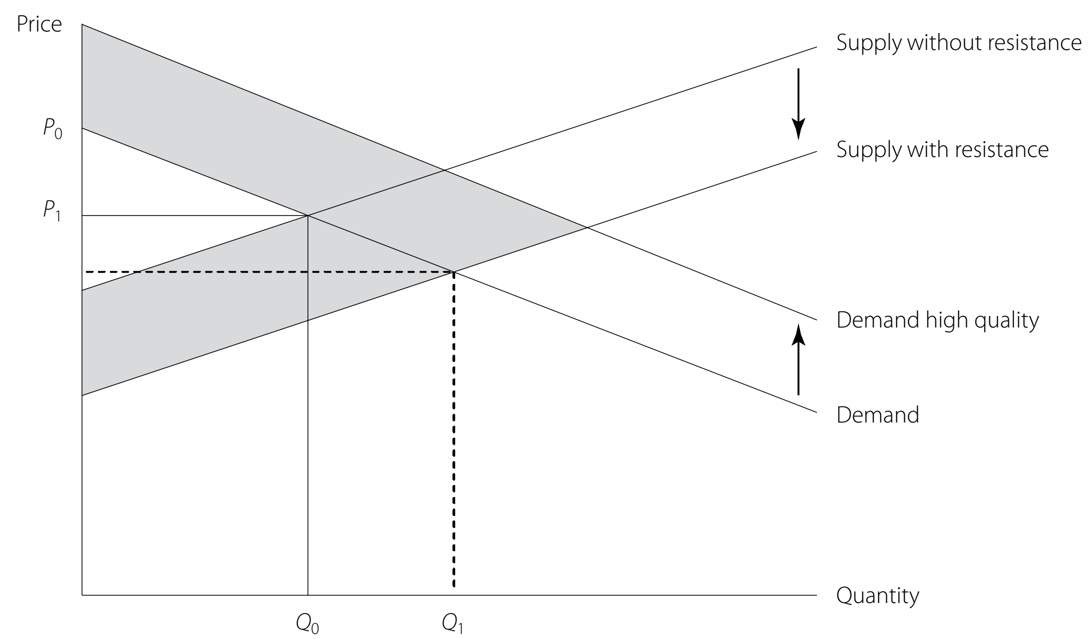

Figure 8. Estimation framework. Source: CIE

a secondary problem. The prevalence of shoot fly early in the rabi sorghum season means that farmers cannot plant their crop during the end of the rainy season when the soil is moist, and must wait until the start of the dry season. Shoot-fly resistance would enable farmers to plant rabi sorghum at the end of the rainy season without fear of infestation. This would greatly increase the level of soil moisture available to the crop at the time of planting and thus increase yields.

Shoot fly is, however, a much harder pest to target than stem borer. It is not as susceptible to *Bt* type toxins because it consumes only a very small part of the sorghum plant, and therefore the level of *Bt* toxin it consumes is not enough to kill the shoot fly before it has damaged the plant beyond repair. The reason for this is that the female shoot fly lays its eggs in the centre of the plant known as the meristem, and once the meristem is damaged the plant cannot grow. Stem borers only eat the plant leaves, which damages the plant but does not stop it from growing altogether. For this reason scientists estimate that it will take another 8–10 years for shoot-fly resistance to be effective in farmers' fields. Consequently, it has been assumed that shoot-fly resistant plants are not expected to be available until 2015.

A discount rate of 5% has been assumed, which is standard for ACIAR benefit–cost studies. A sensitivity analysis is conducted below to assess how the benefits vary when this assumption is changed. Since the benefits of this project accruing to India are measured in rupees, it is necessary to convert these values to Australian dollars. As all the benefits are still to arise, the 2007 exchange rate of A$1 = 34.43 rupees is used to measure future benefits in Australian dollars.

Table 3. Assumptions used in calculating benefits to India

Assumption	Value
Elasticity of demand	0.3
Elasticity of supply	0.8
Yield increase	25%
First year of anticipated benefits	2015
Discount rate	5%
Initial level of production of rabi sorghum	4,183,437 tonnes
Adoption maximum	75%

Source*:* CIE

With no discernable trend in area planted, it is assumed that the level of production would have remained constant at the average level 4,183,437 tonnes over the past 3 years in the absence of the project. Production area is constant due to the peculiarities of the land that rabi sorghum is grown on. Rabi sorghum is one of very few crops that can withstand arid soils. It is thus chiefly grown on marginal land where other crops would not grow. The area of production dedicated to sorghum is therefore fairly constant. There have been no yield improvements in this crop for many years, as shown in Figure 4.

It is thought that, due to remoteness and lack of information, not all farmers will be able to take advantage of the new varieties of pest-resistant sorghum once they come onto the market. Adoption will also take some time. We assume that adoption will commence at 10% in 2015 and will increase by a further 10 percentage points every year thereafter until 2021, increasing to its maximum level of adoption of 75% in 2022.

Based on these assumptions the present value of the benefits of shoot-fly and stem-borer resistance in rabi sorghum are estimated to be A$161 million. However, it cannot be said that the ACIAR project will be entirely responsible for these benefits, as many other aid agencies have been involved in funding biotechnology research on sorghum. Much more investment is required in the future if the benefits are to be realised.

To estimate the contribution of the ACIAR capacity building to this expected flow of benefits, two approaches are possible. One is to identify the total expenditure on all R&D related to the development of the pest-resistant variety. A second approach is to draw on the knowledge of the researchers and others involved to make an assessment of the contribution of the work to the overall achievement. This is the preferred approach where the work was necessary but not sufficient for the outcomes to be achieved, and it is felt that the contribution did indeed 'punch above its weight'. In attributing benefits to the ACIAR project, this second relative-importance approach was used. The benefits were apportioned on the basis of a subjective assessment made by the authors of the contribution of the project to the outcomes achieved.

This subjective assessment was made after lengthy discussions with participants involved in this project and sorghum researchers in Australia and India. These discussions highlighted three important factors to be considered when attributing benefits of this project:

- the very small relative size of the ACIAR project budget, compared with the other projects such as APNL, DFID and ADB
- the large amount of funding still required if shoot-fly resistance is to be achieved
- the roles of the ACIAR project as a catalyst and in generating the interest in sorghum biotechnology in India that led to the increase in funding.

Although data limitations meant that it was not possible to get precise estimates of the levels of funding involved in other aid projects to date, scientists shared the view that the ACIAR project, with a budget of $2.1 million, was a relatively small part of the finance received in this field (probably less than 5%). However, it was stressed by many that, despite the relatively small budget share of the ACIAR project, it should be given a proportionately larger attribution of benefits because it was the first project of its kind in this field, it generated a large amount of interest in transgenic sorghum, and it stimulated implementation of the other aid projects that followed. A number of scientists and researchers deemed 10% to be a fair estimate of the benefits attributed to the ACIAR project.

The capacity building by this project meant that the researchers in this field were able to secure the funding required to continue this research and had the skills to carry it out. This project was also responsible for renewing interest in a field that had seen very little activity for a number of years previously. It is considered that all of this benefit can be attributed to the capacity-building aspects of the project.

Attribution was determined following the guidelines set out in Gordon and Chadwick (2007). It was deemed by the researchers that the ACIAR project was necessary but not sufficient to achieve the outcomes, and a relative importance approach was used to determine the share of benefits from pest resistance that can be attributed to the ACIAR project. Capacity building in this project was deemed by the researchers to be sufficient by itself to have resulted in significant benefits. Thus, following Gordon and Chadwick (2007), full attribution was given to the capacity building activity.

Australia

The assumptions used in quantifying the benefits of this project to Australia are summarised in Table 4.

Table 4. Assumptions used in calculating benefits to Australia

Assumption	Value
Number of years discovery was brought forward as a result of project	5
Increase in the probability of success	0.6–0.8
Adoption profile	Maximum of 50% over 4 years
Yield increase	4.5%
Underlying sorghum yields	Linear projection of FAO data
Producer prices	FAO data from 1996–2001 inflated at 2% per year
Operating costs	Based on GRDC data
Fixed costs	Remain unchanged

Source: CIE

The assumption of the number of years the discovery was brought forward was made after consultation with various sorghum experts. They agreed that, without this ACIAR project, it would have taken longer to identify CHS13R as a highly productive strain and that any yield increases from this discovery would therefore have come about much later.

The yield increase is assumed to be 4.5%, which is an estimate based on discussions with sorghum researchers and the evidence from yield trials testing the new variety.[3]

Benefit–cost and the rate of return

Costs

The total cost of the project was $2.1 million over a 3-year period. The figures shown in Table 5 give the costs of the project for both the Australian and Indian sections combined.

Results

The results from the benefit–cost analysis are shown in Table 6 for each year estimated. The results are split by country. For the case of India, the total benefits resulting from introducing resistance to shoot fly and stem borer is shown in the second column. The third column shows the benefits that can be attributed to this ACIAR project, using the 10% attribution share discussed above.

India

The benefits are estimated from the 1996 value using a range of discount rates. An annuity value of the future benefits beyond 2026 was used to reflect the fact that these benefits are likely to continue accruing into the future. The benefits shown in Table 7 account for the total benefits of this project to India. As noted above, the capacity-building surveys led to the conclusion that all these benefits can be attributed to the capacity built through this project. Thus, the estimated benefits for this project from capacity building are A$161 million assuming a discount rate of 5%.

Australia

Using the assumptions described above, the benefits to Australia were estimated to be as shown in Table 8.

The benefits are estimated over a 30-year period from 1996 to 2025, under a range of discount rates.

Table 5. Estimated project costs (nominal Australian dollars)

	Year 1 (1996–97)	**Year 2** (1997–98)	**Year 3** (1998–99)	**Total**
ACIAR costs	244,545	268,542	275,650	788,737
QDPI	97,500	97,500	97,500	292,500
UQ	72,500	72,500	72,500	217,500
CSIRO	40,000	40,000	40,000	120,000
ICAR/NRCS	62,500	62,500	62,500	187,500
ICRISAT	100,000	100,000	100,000	300,000
GRDC	70,000	70,000	70,000	210,000
Total	687,045	711,042	718,150	2,116,237

Source: ACIAR

[3] Associate Professor Ian Godwin, pers. comm., 9 May 2006

Table 6. Results from the benefit–cost analysis

Measure	**India** Net benefits (A$)	**India** Net benefits from ACIAR (A$)	**Australia** Net benefits from ACIAR (A$)	**Combined** Net benefits from ACIAR (A$)
Benefit:cost ratio	818.1	80.9	18.8	100.7
Present value	1,634,822,096	161,683,820	37,668,698	201,350,729
Total	**6,553,050,279**	**653,417,264**	**104,433,219**	**759,947,999**
Year				
1996	−687,045	−687,045	−687,045	−687,045
1997	−701,798	−701,798	−701,798	−701,798
1998	−708,672	−708,672	−708,672	−708,672
1999	0	0	0	0
2000	0	0	0	0
2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	0	0	0	0
2008	0	0	0	0
2009	0	0	0	0
2010	0	0	0	0
2011	0	0	2,890,660	2,890,660
2012	0	0	8,947,321	8,947,321
2013	0	0	12,272,087	12,272,087
2014	0	0	14,155,891	14,155,891
2015	31,067,051	3,106,705	14,461,238	17,567,944
2016	62,134,102	6,213,410	12,341,715	18,555,125
2017	93,201,153	9,320,115	7,576,828	16,896,943
2018	155,335,256	15,533,526	5,115,591	20,649,117
2019	186,402,307	18,640,231	3,869,311	22,509,542
2020	217,469,358	21,746,936	3,948,248	25,695,184
2021	217,469,358	21,746,936	4,027,944	25,774,880
2022	233,002,884	23,300,288	4,108,398	27,408,686
2023	233,002,884	23,300,288	4,189,610	27,489,899
2024	233,002,884	23,300,288	4,271,581	27,571,869
2025	233,002,884	23,300,288	4,354,311	27,654,599
Continued	**4,660,057,674**	**466,005,767**		**466,005,767**

Sources: CIE and Pearce et al. (2006)

Sensitivity of estimates

India

The base case of the results was driven by various assumptions outlined above. To test the sensitivity of the results to some of these assumptions, a range of values is placed around several of the key assumptions. The share of the benefits attributed to the ACIAR project is allowed to vary between 5% and 15%, the time frame for successful adoption to vary from 2010 to 2020 and the yield improvements to vary from 20% to 30%. The values in the 'Medium' column in Table 9 represent those used in the main benefit–cost analysis. Table 10 gives the results of the sensitivity analysis.

Australia

The base case results of the research are driven by various assumptions. To test the sensitivity of the results to some of these assumptions, a range of values is placed around several of the key assumptions outlined above. The increase in probability of successful discovery and adaptation as a result of the ACIAR-funded research project is allowed to vary between 0 and 0.4, the improvement in yield to range from 2.5% to 6.5%, and the number of years the project has brought forward key discoveries to vary from 2 to 8. The values in the 'Medium' column in Table 11 correspond to those used in the main benefit–cost analysis.

Table 7. Results of the benefit–cost analysis under varying discount rates: India

Discount rate	**Present value of costs** (A$m)	**Net present value of benefits** (A$m)	**Benefit:cost ratio**	**Internal rate of return** (%)
1%	2.07	1,874	902	19.2
5%	1.99	161.68	80.91	
10%	1.91	29.15	15.25	

Source: CIE calculations

Table 8. Results of the benefit–cost analysis under varying discount rates: Australia

Discount rate	**Present value of costs** (A$m)	**Net present value of benefits** (A$m)	**Benefit:cost ratio**	**Internal rate of return** (%)
0%	2.07	86.9	42.2	23.8
5%	1.98	39.6	20.2	
10%	1.89	15.9	8.5	

Source: CIE calculations

Table 9. Parameter values used in sensitivity analysis: India

Assumption	**Unit**	**Low**	**Medium**	**High**
Attribution	%	5	10	15
Yield	%	20	25	30
Start year		2010	2015	2020

Source: CIE

Table 12 shows the results of the sensitivity analysis. The net present value of Australian benefits from the research project ranges widely from A$3.6 million to A$97 million. The benefit:cost ratio varies between 1.8 and 49.0, while the internal rate of return lies between 11.1% and 31.5%. The minimum figures correspond to the case where there is no change in the probability of success of discovery and adaptation, the yield gain is 2.5% over 4 years, and the project brings forward key discoveries by 2 years. Conversely, the maximum figures correspond to the case where the probability of successful discovery and adaptation increases by 0.4, the yield gain is 6.5%, and the project brings forward discoveries by 8 years.

Distributional implications

The analysis also allows differentiation between the share of the benefits accruing to the producers and the share accruing to the consumers.

Total benefits accruing to consumers are estimated to account for 72% of the total benefits. Total benefits accruing to producers are expected to make up the remaining 18%.

Table 10. Results from sensitivity analysis: India

	Net present value of benefits (A$m)	**Benefit:cost ratio**	**Internal rate of return** (%)
Minimum[a]	24.3	18.3	11.38
Maximum[a]	186.8	373.4	30.28
Mean	84.5	166.6	19.70

[a] Assumes a discount rate of 5%

Source: CIE estimates

Table 11. Parameter values used in sensitivity analysis: Australia

Assumption	**Unit**	**Low**	**Medium**	**High**
Probability of success		0	0.2	0.4
Yield improvement	%	2.5	4.5	6.5
Years adoption brought forward		2	5	8

Source: CIE

Table 12. Results from sensitivity analysis: Australia

	Net present value of benefits (A$m)	**Benefit:cost ratio**	**Internal rate of return** (%)
Minimum[a]	3.6	1.8	11.1
Maximum[a]	97	49	31.5
Mean	35.9	18.1	23.5

[a] Assumes a discount rate of 5%

Source: CIE estimates

Environmental outcomes

The development of greater resistance to pests in sorghum, when it is achieved, will enable a reduction in the use of pesticides, with a consequent positive impact on the environment and a corresponding reduction in environmental risks.

In addition, improvement in the productivity of rabi sorghum will ultimately reduce water use in the southern states of India where irrigated rice has been responsible for the displacement of kharif (rainy season) sorghum areas. The higher supply of rabi sorghum will reduce the demand for rice.

In Australia, improvement in sorghum yields may increase ethanol production and reduce the dependence on non-renewable energy sources.

Social outcomes

As sorghum is often cultivated by poor farmers, an improvement in yield will have a positive economic impact that is expected to lead to significant social impacts. The reduction in the incidence of poverty should lead to better nutrition and considerably improved health outcomes. Some credit-constrained families may also be able to send their children to school when they previously could not afford to, thus leading to greater human capital accumulation.

Lessons

The key lesson learned from this project is the importance of continuity in projects involving capacity building. In the modelling subproject it was expected that further funding would be given to continue to develop the APSIM–SORG model for use in India. This extra funding would have enabled the model to be widely used in India and could have created some positive results. However, as the project was not extended, there was time to develop the model for only limited use. The capacity of one Indian scientist to use this model was built but this scientist was unable to find opportunities in which to use his training once he returned to India, and this capacity was not utilised.

Subproject 2 also suffered from a lack of continuity, as the two main scientists involved in the collation and analysis of the multi-environment trial database are no long working in this field. One of them retired shortly after the end of the project and the second was transferred to work in a different area. This has meant that the recommendations made as a result of the database analysis were not acted upon. Another key problem is that there existed strong opposition to implementation of one of the recommendations.

The most interesting finding from this impact assessment is that the quality of the training received was rated very highly by those who received it but the capacity built from this training was only rarely translated into capacity utilised. The area in which capacity was utilised was in biotechnology. The main reason that outcomes were achieved through this subproject is that further funding was received in this area. The extension of funding allowed the scientists involved to continue using the skills they had learnt and to develop them further.

No further funding was received to conduct modelling or to continue refining and using the multi-environment trial database, and thus benefits from these two projects appear to have been zero for India.

Literature consulted

ACIAR 1998. ACIAR project CS1/1994/968, 'Overcoming production constraints to sorghum in rainfed environments in India and Australia', annual report 1997–98. ACIAR: Canberra.

— 2007. Project summary for project CS1/1994/968. At: <www.aciar.gov.au/project/CS1/1994/968>. Accessed 17 January 2007.

— n.d. Report of the review of project CS1/1994/968, 'Overcoming production constraints to sorghum in rainfed environments in India and Australia'. ACIAR: Canberra.

Finer J.J., Vain P., Jones M.W. and McMullen M.D. 1992. Development of the particle inflow gun for DNA delivery to plant cells. Plant Cell Reports 11, 232–238.

Gordon J. and Chadwick K. 2007. Impact assessment of capacity building and training: assessment framework and two case studies. ACIAR Impact Assessment Series Report No. 44.

Likert, R. 1932. A technique for the measurement of attitudes. Archives of Psychology 140, 1–55.

Pearce D., Monck M., Chadwick K. and Corbishley J. 2006. Benefits to Australia from ACIAR-funded research. ACIAR Impact Assessment Series Report No. 39.

Seetherama N. and Godwin I. 2004. Sorghum tissue culture and transformation. Science Publishers: India.

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia.* ACIAR Impact Assessment Series Report No. 48, July 2007

Appendix A Survey questions

The survey questions used in this study were largely based on those taken from the tracer study carried out by the Effective Development Group (EDG) as discussed in Gordon and Chadwick (2007). Responses were recorded on a five-point Likert (1932) scale. Some of the questions from the original tracer survey were modified or removed entirely as they were not relevant to the training received in this instance.

The questions asked are detailed below:

Relevance

- The topics of the activities were directly related to my field of work at the time

Quality

- The trainers were knowledgeable and provided information of a good quality
- I found participating in the activities difficult due to my level of English
- I found the activities well structured and content well focused

Capacity built

- I increased my capacity to conduct high quality research
- I acquired new or improved laboratory or other technical skills
- I acquired new skills for managing research projects efficiently and effectively
- I better understand issues and principles in my field and resources I can access to assist in my research
- I acquired new ways to approach work problems
- I learned new or improved ways of communicating with networks within my field

Capacity utilised

- I was able to apply the knowledge/skills gained to my work
- I continue to use the knowledge/skills gained
- I increased my professional collaboration with organisations both nationally and internationally
- I have trained others in the skills I learned
- I was able to secure additional resources to expand or enhance my research
- The networks made during the project have enabled me to produce better research outputs
- The technologies/knowledge/skills gained from the project enabled me to perform better at work
- As a result of the project I was able to carry out more productive experiments

Outcomes

- I was offered a promotion/greater responsibilities as a result of the training I received as part of this project
- I have pursued other work opportunities in the field I was trained in
- As a result of what I learned and have applied I gained greater satisfaction form my work
- The organisation I work for increased its research and development outputs as a result of this project
- The project added to the quality of the research that the organisation produces
- The project increased the speed at which advances were made in the rabi sorghum field

Appendix B Survey response example

An example of the responses received to the questionnaire is given below. Face-to-face interviews were held with the questionnaire respondents to allow for clarification of the questions or for the consultant to seek further details on the answers given. Table B1 is an example of a survey response.

Table B1. Example survey responses

Name ....

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Details
Relevance						
The topics of the activities were directly related to my field of work at the time	x					
Quality						
The trainers were knowledgeable and provided information of a good quality	x					Carl Rathus, one of the best available people at the time for transformation, had very good knowledge of transformation techniques at the time. Has now left the profession
I found participating in the activities difficult due to my level of English					x	
I found the activities well structured and content well focused	x					

Table B1. (continued)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Details
Capacity built						
I increased my capacity to conduct high quality research		x				That training was not science, it was how to use the gun, there was no science in that, but it did increase capacity to use the gun and conduct research with it
I acquired new or improved laboratory or other technical skills	x					Was a new technique at the time which he learned and used
I acquired new skills for managing research projects efficiently and effectively		x				Was new and not managing projects
I better understand issues and principles in my field and resources I can access to assist in my research	x					
I acquired new ways to approach work problems	x					Acquired the gun which was useful
I learned new or improved ways of communicating with networks within my field	x					Increased his contacts with people as interacted with others in the workshop
Capacity utilised						
I was able to apply the knowledge/skills gained to my work	x					Still use particle inflow gun for research in finding other genes, although not in Bt genes
I continue to use the knowledge/ skills gained	x					
I increased my professional collaboration with organisations both nationally and internationally	x					
I have trained others in the skills I learned	x					Went on to teach use of the gun to others, every year students come in and learn the new techniques, have trained at least 3 others per year in use of the gun
I was able to secure additional resources to expand or enhance my research	x					Because of the gene gun, was able to receive APNL funding

Table B1. (continued)

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Details
The networks made during the project have enabled me to produce better research outputs		x				At the time of initiation, could not have solved each other's problems as it was new tech to all but the networks were maintained and used later, Ian Goodwin, Emma Mase, key contacts made
The technologies/knowledge/ skills gained from the project enabled me to perform better at work	x					
As a result of the project I was able to carry out more productive experiments	x					Increased productivity as was able to use the guns for particle inflow, they then were able to use the guns for other causes, have also used it for other crops, university etc use gun for other purposes
Outcomes						
I was offered a promotion/greater responsibilities as a result of the training I received as part of this project		x				At the same time was initiating agro-bacterium system so conjunction of the two led to increase in responsibilities, initiated the APNL project afterwards and was involved in that as a result of the training, as a co-principal investigator
I have pursued other work opportunities in the field I was trained in	x					APNL project was used with the same gun, and now for another project using the same gun at the moment
As a result of what I learned and have applied I gained greater satisfaction from my work				–x		Has not led to the scientific results that had been hoped for so in that way it is disappointed, success rate is less for particle inflow than for *Agrobacterium*
The organisation I work for increased its research and development outputs as a result of this project				–x		At the same time other projects were initiated and this was also a factor, R&D outputs were not increased as a result of this project
The project added to the quality of the research that the organisation produces						The project added to the quality of the research but did not change it in itself
The project increased the speed at which advances were made in the rabi sorghum field						

Source: CIE

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia.* ACIAR Impact Assessment Series Report No. 48, July 2007

Appendix C Stem borer and shoot fly

One of the main aims of this project was to try to incorporate pest resistance to shoot fly into rabi sorghum. Shoot fly was chosen as the main pest to target because it is currently the pest with the largest negative impact on rabi sorghum yields. The reason for this is that the shoot-fly population increases during the kharif (wet) season. Were it not for shoot fly, farmers of sorghum in the rabi season would be able to plant their crop immediately after the harvest of the kharif crop. However, the high shoot-fly population at the end of the kharif season means that farmers must wait for about 2 months until September before planting the rabi-season crop, so as to avoid the very high yield losses that would be caused by the high shoot-fly population in July.

The problem with planting in September as opposed to July is that soils are then much drier. Planting in July would guarantee better moisture content in the soil and would lead to faster growth and higher yields of the sorghum crop. Eliminating shoot fly would enable farmers to plant earlier in the season, when the soil is wetter, and this would lead to higher yields.

Stem borer is currently not a large problem for rabi sorghum farmers as it does not do great damage to their crops, and achieving resistance to stem borer alone would not provide a large benefit to them. However, if scientists are successful in developing shoot-fly resistance in rabi sorghum, the earlier planting season will mean that rabi sorghum will also become susceptible to greater damage from the stem borer. It is thus important to ensure that any new sorghum varieties are resistant to both pests.

This project failed in its aim to create sorghum resistant to the shoot fly, the main reason being that there are many scientific difficulties involved in targeting this pest. These include problems in rearing shoot-fly larvae in vitro, meaning that testing becomes very difficult. Another barrier to developing shoot-fly resistance is that *Bt*-type genes are not appropriate for this kind of pest.

Bt genes insert a toxin into the plant that is safe for human consumption but deadly to the pest. In the case of the stem borer, the pest will ingest enough *Bt* toxin from eating the sorghum and will die before it can greatly damage the sorghum plant. The difference with the shoot fly is that it lays its eggs inside the sorghum plant and the larvae eat the meristem, or growing tips, of the plant after hatching. The levels of toxins ingested by the larvae are not great enough to kill them before the meristem is eaten and the sorghum plant is irreparably damaged.

Scientists are currently working on trying to find the appropriate method of inserting resistance to shoot fly into the sorghum plant. Some progress has been made but a lot more work needs to be completed before this process is finished.

Stem borer is much more straightforward and many advances have been made since the ACIAR project. A stem-borer-resistant variety of sorghum has been created and it is currently undergoing small-scale trials to ensure that the levels of resistance it presents to stem borer are high enough. If these trials are successful, larger, multi-environment trials will commence and it may be only another 1–2 years until stem-borer-resistant strains of sorghum arrive in the farmers' fields.

Therefore, although pest resistance to stem borer has been achieved in sorghum, this will not be of great benefit until shoot-fly resistance is also achieved, as stem borer is currently not causing large crop losses in rabi sorghum.

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia*. ACIAR Impact Assessment Series Report No. 48, July 2007

Appendix D
List of persons interviewed/consulted

- Dr Cynthia Bantilan, global theme leader, institutions, markets, policy and impacts, ICRISAT, Hyderabad
- Dr Ian Godwin, associate professor, School of Land, Crop and Food Sciences, UQ
- Professor Graeme Hammer, professorial research fellow (crop sciences), School of Land, Crop and Food Sciences, UQ
- Dr C.L.L. Gowda, global theme leader, crop improvement, ICRISAT, Hyderabad
- Dr K.K. Sharma, principal scientist, biotechnology, ICRISAT, Hyderabad
- Dr Fran Bidinger, principal scientist, genetic resources and enhancement program, ICRISAT, Hyderabad
- Dr Belum S. Reddy, principal scientist in sweet sorghum research, ICRISAT, Hyderabad
- Dr B.S. Rana, formerly Director, NRCS, India
- Dr Seetherama, Director, NRCS, India
- Dr H.C. Sharma, principal scientist, biotechnology, ICRISAT, Hyderabad
- Dr S.L. Kaul, scientist, NRCS, India
- Dr Ravi Kumar, principal modeller, NRCS, India
- Dr S.V. Rao, ICRISAT, Hyderabad
- Dr Tom Hash, principal scientist, molecular breeding, ICRISAT, Hyderabad
- Dr Viserada, NRCS
- Krishna, NRCS

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia.* ACIAR Impact Assessment Series Report No. 48, July 2007

IMPACT ASSESSMENT SERIES

No.	Author(s) and year of publication	Title	ACIAR project numbers
1	Centre for International Economics (1998)	Control of Newcastle disease in village chickens	8334, 8717 and 93/222
2	George, P.S. (1998)	Increased efficiency of straw utilisation by cattle and buffalo	8203, 8601 and 8817
3	Centre for International Economics (1998)	Establishment of a protected area in Vanuatu	9020
4	Watson, A.S. (1998)	Raw wool production and marketing in China	8811
5	Collins, D.J. and Collins, B.A. (1998)	Fruit fly in Malaysia and Thailand 1985–1993	8343 and 8919
6	Ryan, J.G. (1998)	Pigeon pea improvement	8201 and 8567
7	Centre for International Economics (1998)	Reducing fish losses due to epizootic ulcerative syndrome—an ex ante evaluation	9130
8	McKenney, D.W. (1998)	Australian tree species selection in China	8457 and 8848
9	ACIL Consulting (1998)	Sulfur test KCL–40 and growth of the Australian canola industry	8328 and 8804
10	AACM International (1998)	Conservation tillage and controlled traffic	9209
11	Chudleigh, P. (1998)	Post-harvest R&D concerning tropical fruits	8356 and 8844
12	Waterhouse, D., Dillon, B. and Vincent, D. (1999)	Biological control of the banana skipper in Papua New Guinea	8802-C
13	Chudleigh, P. (1999)	Breeding and quality analysis of rapeseed	CS1/1984/069 and CS1/1988/039
14	McLeod, R., Isvilanonda, S. and Wattanutchariya, S. (1999)	Improved drying of high moisture grains	PHT/1983/008, PHT/1986/008 and PHT/1990/008
15	Chudleigh, P. (1999)	Use and management of grain protectants in China and Australia	PHT/1990/035
16	McLeod, R. (2001)	Control of footrot in small ruminants of Nepal	AS2/1991/017 and AS2/1996/021
17	Tisdell, C. and Wilson, C. (2001)	Breeding and feeding pigs in Australia and Vietnam AS2/1994/023	
18	Vincent, D. and Quirke, D. (2002)	Controlling *Phalaris minor* in the Indian rice–wheat belt	CS1/1996/013
19	Pearce, D. (2002)	Measuring the poverty impact of ACIAR projects—a broad framework	
20	Warner, R. and Bauer, M. (2002)	*Mama Lus Frut* scheme: an assessment of poverty reduction	ASEM/1999/084
21	McLeod, R. (2003)	Improved methods in diagnosis, epidemiology, and information management of foot-and-mouth disease in Southeast Asia	AS1/1983/067, AS1/1988/035, AS1/1992/004 and AS1/1994/038
22	Bauer, M., Pearce, D. and Vincent, D. (2003)	Saving a staple crop: impact of biological control of the banana skipper on poverty reduction in Papua New Guinea	CS2/1988/002-C
23	McLeod, R. (2003)	Improved methods for the diagnosis and control of bluetongue in small ruminants in Asia and the epidemiology and control of bovine ephemeral fever in China	AS1/1984/055, AS2/1990/011 and AS2/1993/001
24	Palis, F.G., Sumalde, Z.M. and Hossain, M. (2004)	Assessment of the rodent control projects in Vietnam funded by ACIAR and AUSAID: adoption and impact	AS1/1998/036
25	Brennan, J.P. and Quade, K.J. (2004)	Genetics of and breeding for rust resistance in wheat in India and Pakistan	CS1/1983/037 and CS1/1988/014

IMPACT ASSESSMENT SERIES <CONTINUED>

No.	Author(s) and year of publication	Title	ACIAR project numbers
26	Mullen, J.D. (2004)	Impact assessment of ACIAR-funded projects on grain-market reform in China	ANRE1/1992/028 and ADP/1997/021
27	van Bueren, M. (2004)	Acacia hybrids in Vietnam	FST/1986/030
28	Harris, D. (2004)	Water and nitrogen management in wheat–maize production on the North China Plain	LWR1/1996/164
29	Lindner, R. (2004)	Impact assessment of research on the biology and management of coconut crabs on Vanuatu	FIS/1983/081
30	van Bueren, M. (2004)	Eucalypt tree improvement in China	FST/1990/044, FST/1994/025, FST/1984/057, FST/1988/048, FST/1987/036, FST/1996/125 and FST/1997/077
31	Pearce, D. (2005)	Review of ACIAR's research on agricultural policy	
32	Tingsong Jiang and Pearce, D. (2005)	Shelf-life extension of leafy vegetables—evaluating the impacts	PHT/1994/016
33	Vere, D. (2005)	Research into conservation tillage for dryland cropping in Australia and China	LWR2/1992/009, LWR2/1996/143
34	Pearce, D. (2005)	Identifying the sex pheromone of the sugarcane borer moth	CS2/1991/680
35	Raitzer, D.A. and Lindner, R. (2005)	Review of the returns to ACIAR's bilateral R&D investments	
36	Lindner, R. (2005)	Impacts of mud crab hatchery technology in Vietnam	FIS/1992/017 and FIS/1999/076
37	McLeod, R. (2005)	Management of fruit flies in the Pacific	CS2/1989/020, CS2/1994/003, CS2/1994/115 and CS2/1996/225
38	ACIAR (2006)	Future directions for ACIAR's animal health research	
39	Pearce, D., Monck, M., Chadwick, K. and Corbishley, J. (2006)	Benefits to Australia from ACIAR-funded research	FST/1993/016, PHT/1990/051, CS1/1990/012, CS1/1994/968, AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
40	Corbishley, J. and Pearce, D. (2006)	Zero tillage for weed control in India: the contribution to poverty alleviation	CS1/1996/013
41	ACIAR (2006)	ACIAR and public funding of R&D, Submission to Productivity Commission study on public support for science and innovation	
42	Pearce, D. and Monck, M. (2006)	Benefits to Australia of selected CABI products	
43	Harris, D.N. (2006)	Water management in public irrigation schemes in Vietnam	LWR2/1994/004 and LWR1/1998/034
44	Gordon, J. and Chadwick, K. (2007)	Impact assessment of capacity building and training: assessment framework and two case studies	CS1/1982/001, CS1/1985/067, LWR2/1994/004 and LWR2/1998/034
45	Turnbull, J.W. (2007)	Development of sustainable forestry plantations in China: a review	
46	Monck M. and Pearce D. (2007)	Mite pests of honey bees in the Asia–Pacific region	AS2/1990/028, AS2/1994/017, AS2/1994/018 and AS2/1999/060
47	Fisher, H. and Gordon, J. (2007)	Improved Australian tree species for Vietnam	FST/1993/118 and FST/1998/096
48	Longmore, C., Gordon, J., and Bantilan, M.C. (2007)	Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia	CS1/1994/968

From: Longmore, C., Gordon, J., and Bantilan, M.C. *Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia*. ACIAR Impact Assessment Series Report No. 48, July 2007

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Assessment of capacity building: overcoming production constraints to sorghum in rainfed environments in India and Australia





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