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

Chloë Longmore and Jenny Gordon
Centre for International Economics, Canberra and Sydney

M. Cynthia Bantilan
International Crops Research Institute for the Semi-Arid Tropics

July 2007
The Australian Centre for International Agricultural Research (ACIAR) operates as part of Australia’s international development cooperation program, with a mission to achieve more-productive and sustainable agricultural systems, for the benefit of developing countries and Australia. It commissions collaborative research between Australian and developing-country researchers in areas where Australia has special research competence. It also administers Australia’s contribution to the International Agricultural Research Centres.

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Communications regarding any aspects of this series should be directed to:

The Research Program Manager
Policy Linkages and Impact Assessment Program
ACIAR
GPO Box 1571
Canberra ACT 2601
Australia

tel +612 62170500
email <aciar@aciar.gov.au>

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GPO Box 1571, Canberra ACT 2601


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

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. 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-useful state within this project, the project built the capacity for Indian researchers to achieve this objective.
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
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.

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.

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

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>Present value (PV) of costs</th>
<th>PV of benefits India</th>
<th>PV of benefits Australia</th>
<th>Benefit:cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A$m</td>
<td>A$m</td>
<td>A$m</td>
<td></td>
</tr>
<tr>
<td>1%</td>
<td>2.07</td>
<td>1,874.0</td>
<td>86.9</td>
<td>944.3</td>
</tr>
<tr>
<td>5%</td>
<td>1.99</td>
<td>161.8</td>
<td>39.7</td>
<td>100.7</td>
</tr>
<tr>
<td>10%</td>
<td>1.91</td>
<td>29.1</td>
<td>15.9</td>
<td>23.6</td>
</tr>
<tr>
<td>Internal rate of return</td>
<td></td>
<td></td>
<td></td>
<td>28.07</td>
</tr>
</tbody>
</table>

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