ADOPTION OF ACIAR PROJECT OUTPUTS

STUDIES OF PROJECTS COMPLETED IN 2000–2001

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Increasing the effectiveness of research on agricultural resource management in the semi-arid tropics by combining cropping systems simulation with farming systems research (LWR2/1996/049)

Peter Carberry

Collaborating organisations	Agricultural Production Systems Research Unit (APSRU), Australia; National Agricultural Research and Extension System (NARES), India, Zimbabwe, Malawi and Kenya; Tropical Soil Biology and Fertility Programme (TSBF), Uganda, Kenya and Zimbabwe
Project leaders	RJK Myers, ICRISAT, Zimbabwe; RL McCown and subsequently BA Keating, CSIRO/APSRU, Australia
Related projects	CS1/94/968, CS1/95/122, EFS/83/26, LW/87/35, LW/94/35
Principal researchers	P Carberry (APSRU), J Dimes and G O'Leary (ICRISAT)
Duration of project	1 January 1996 – 30 April 2001
Total ACIAR funding	$1,550,000
Project objectives	The project's goal was to develop a farming systems research capability in ICRISAT that combines simulation of crop production systems with agronomic experimentation and socioeconomic research and to use this capability to enhance ICRISAT's research on improved management of crops and production resources in the semi-arid tropics of Asia and Africa. In order to achieve its ultimate goal, the project aimed: (i) to train ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D (ii) to enhance APSIM to better enable simulation of the important cropping systems in the semi-arid tropics

	(iii) to develop a system for storage and retrieval of experimental data which efficiently serves simulation objectives (iv) to systematically compare APSIM simulations against field experiments to test model performance (v) in conjunction with experimentalists, to use APSIM to extrapolate experimental results in time and space (vi) in conjunction with NARS and NGOs, to apply APSIM in evaluating farmers' management options
Location of project activities	The project was originally based at ICRISAT Headquarters, Patancheru, Andhra Pradesh, India but was relocated to ICRISAT-Bulawayo, Zimbabwe in August 1999.

Overview

The ACIAR-funded collaboration on agricultural / resource modelling and applications in the semi-arid tropics (CARMASAT) project aimed at developing a farming systems research capability based on systems simulation. The resulting agricultural production systems simulator (APSIM) has proved its effectiveness in enhancing research on improved management of crops and production resources in the semi-arid tropics of Asia and Africa. While adoption by researchers is disappointing, the potential for APSIM remains high.

Project achievements

Over 160,000 smallholder farmers in Zimbabwe achieved 30–50% yield increases in their maize crops due to the aid-sponsored distribution of seed and fertiliser in the 2003–04 season. Key architects of this aid program readily attribute systems modelling within ICRISAT as being one source which supported the proposition of small doses of inorganic fertiliser applied in the lower potential regions of Zimbabwe. This outcome, and subsequent efforts, which focused on developing supply networks for small fertiliser packets in Zimbabwe and South Africa, represent a significant consequence attributable, in part, to the CARMASAT project.

In early 2005, a farming systems research capability based on systems simulation is well adopted within ICRISAT's research efforts in Zimbabwe and South Africa. However, such capacity is not employed more extensively — adoption within ICRISAT-India, other international agricultural research centres (IARCs)and collaborating NARES has been disappointing to date. Reasons for poor adoption vary from poor underlying skills, low credibility of models, to lack of institutional support.

The legacy of CARMASAT persists today within a range of current and planned research, development and extension projects being undertaken by ICRISAT and its collaborators. As commented by a funder of research in Africa: *"the seeds of past investment remain and returns will be gained in the longer term".*

ICRISAT and its NARES partners made significant progress in applying simulation models to agricultural systems R&D. Key achievements from the development of APSIM include:

- trained, active users who had applications of APSIM in their work plans, both in ICRISAT and NARES
- Following the enhancements made to APSIM, it was more widely used in the semi-arid tropics in India and Africa to help small-scale farmers
- Use of APSIM was enhanced through the use of experimental data sets applicable to India and Africa.
- Documentation of new APSIM modules and the results of research using APSIM were becoming available to other scientists through formal publications
- A web-based 'help desk' was established to support APSIM usage
- Linking of participatory methods to simulation improved on-farm participatory research methodology which increased the knowledge of the researchers, benefiting the NARES colleagues who have been trained in the improved methods, and helped the small-scale farmers in the study villages
- more than 30 papers were either published or were at an advanced stage of preparation for publication

The project succeeded in developing a new attitude to the use of modelling in research and extension in ICRISAT in India. This had started but needed to be developed further at African locations. A conclusion was that APSIM had become a valuable tool for research and extension in the semi-arid tropics. In the future, modelling applications will increase and diversify, and ICRISAT and APSRU could play a leading role in this. However, in a research environment with diminishing resources and on-going structural change, it took longer than expected to achieve these outcomes, and further efforts are required. ACIAR's investments in this and associated projects will undoubtedly be fully rewarded in the future.

The difference the project has made

During the course of CARMASAT, and subsequent to its termination, there were a number of examples where the project made a difference. Most of these examples relate to changes in research practice whereby a research question is addressed now by using participatory on-farm research and systems simulation. The big change is acknowledging the role of simulation in identifying research opportunities and in analysing the data from on-farm trials.

Example 1: On-farm monitoring and modelling of peanut sowing date and cultivar choice effects in the Pollachi region of Tamil Nadu, India.

Madhiyazhagan Ramadoss (Tamil Nadu Agricultural University, Aliyarnagar, India)

Researchers and extension officers collaborated with farmers to address peanut cropping and sowing decisions using on-farm experiments and cropping systems simulation in the Pollachi region of Tamil Nadu, India. The most influential variable affecting the peanut productivity in this irrigated region regards sowing date. During the 1998–1999 rabi (post rainy) season, three farmers' fields in villages in Pollachi region were selected and monitored. The APSIM model was used to simulate the effect of sowing date. The APSIM-peanut module simulation demonstrated close correspondence with the field observation in predicting yield. The model predicted that December sowing resulted in higher yield than January sowing due to a longer pod filling period, and this was confirmed by farmer experience. The farmers and extension officers became comfortable with their role as owners of the collaborative experiments and custodians of the learning environment.

In 2004, Mr Madhiyazhagan Ramadoss submitted a PhD thesis at University of Queensland on the topic of using the APSIM systems model to explore dryland maize within Australian farming systems. He recently returned to India as Assistant Professor (Agronomy) with the TNAU, Coimbatore, where he intends to establish a research program utilising systems simulation.

Example 2: Systems modelling and farmers' participatory evaluation of cropping options to diversify peanut systems in Anantapur region, India

V. Nageswara Rao, Piara Singh, Y. Padmalatha, and T. J. Rego (ICRISAT, Patancheru, India; Agricultural Research Station (ARS) of Acharya N G Ranga Agricultural University (ANGRAU), Anantapur, India)

Through systems simulation, peanut/short-duration pigeonpea intercrop systems were identified as the most suitable system for the rainfed Anantapur region. Farmer field trials were conducted during the 2000–2002 seasons to determine the adoptability of this system for the region. During these seasons, peanut yields were higher with sole peanut although system productivity was consistently higher with peanut/ short-duration pigeonpea systems. Short duration pigeonpea yields were higher compared to medium duration pigeonpea in the intercrop systems. Adoption of a peanut/short duration pigeonpea system by farmers in the neighbouring villages during the third cropping season

Bruce Pengelly

Following the enhancements made to APSIM, it was more widely used in the semi-arid tropics to help small-scale farms. After a workshop involving researchers and smallholder farmers in Zimbabwe, the farmers implemented and managed trials investigating manure and inorganic nitrogen interactions, legumes and their responses to phosphorus.

(2002), and better productivity in a severe drought year (2003) benefited farmers. Tools and methodologies employed in this study may well be utilised for similar situations in the semi-arid tropics. The use of simulation has potentially shortened the period of research prior to adoption by farmers.

Mr V. Nageswara Rao remains at ICRISAT, Patancheru, within a small crop modelling unit led by Dr Piara Singh. While this unit now concentrates largely on desk-top studies (eg yield gap analyses), Mr Rao has maintained his interest in combining systems simulation with on-farm research, with more recent efforts concentrated on exploring, with farmers and local NARES researchers in the Anantapur region, the potential application of seasonal climate forecasting. Through interviews with farmers and researchers who have collaborated with Mr Rao, it is clear he has achieved significant results from this effort. Without doubt, Mr Rao represents a strong advocate for the research approach and impacts which can be achieved from participatory research and systems simulation.

Example 3: Response of maize to low doses of manure and nitrogen in smallholder farms under semi-arid conditions

B. Ncube, S. Twomlow (ICRISAT, Bulawayo, Zimbabwe)

In 2001, a farmer group in the Tsholotsho district of Zimbabwe participated in the Linking Logics II activity where participative simulation generated farmer interest in on-farm experiments on the use of manure and inorganic fertiliser. Consequently, three seasons of experimentation have been conducted with about 35 farmers, which have demonstrated large maize yield gains from low doses of fertiliser (as little as 10kg N/ha).

The on-going activity at Tsholotsho currently forms the basis of a PhD thesis (University of Wageningen) being conducted by Ms Ncube. Her intention is to analyse the experimental results using APSIM.

Example 4: Workshops on harmonisation of farm operations with climatic information and crop models

K.P.C. Rao (ICRISAT, Nairobi) and G. Okwach (KARI, Katumani)

A two-day workshop was held with 26 smallholder farmers from Mwala Location, Machakos District, Kenya in July 2004. The participating farmers were exposed to systems information based on seasonal climate forecasts and systems simulation. This workshop was followed by two subsequent workshops attended by 50 farmers. The outcome of these workshops is a joint research proposal to ASARECA between ICRISAT and KARI to explore the further application of these systems tools in semi-arid Kenya.

> *"Farmers were excited and started asking for their own scenarios … we stopped at 6pm but the farmers still wanted to go on … it was the most exciting day of my scientific life"*
>
> **NARES scientist**

However, as at February 2005, 24 research/extension staff associated with the CARMASAT project (8 ICRISAT, 10 NARES, 3 IARC, 2 other) could be identified as having been trained in the application of APSIM and now were competent in its use. Of these probably only nine researchers would see APSIM as a key component of their current activities.

Given the first project objective of training ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D, roughly a 6% adoption rate (9 users out of around 140 trainees) can be regarded as low for close to 10 years effort. However, low adoption of simulation within agricultural RDE has been characteristic of these type of projects. Similar results were reported for the SARP and IBSNAT projects sponsored by the Dutch and US agencies in the 1980 and 1990s. Similarly, more recent efforts by ICAR in India to establish a crop modelling unit ended with few serious users of their INFOCROP model despite training of more than 150 scientists.

The question, "Why is there low adoption of APSIM (or other models) in agricultural RDE?" was posed to interviewees in this study. A number of reasons were proposed:

- NARES researchers/extension staff don't possess underlying skills in computer literacy, mathematics and university-based modelling courses to readily adopt modelling. Therefore, selecting collaborators for modelling activities needs to account for their affinity for modelling rather than accepting any comer (as most other projects do). In addition, the few who do become proficient, thus demonstrating talent, are poached into other jobs and careers.
- Learning to become proficient in modelling takes significant time, commitment and resources. Input data requirements for models are not readily available for new users and are costly to collect. In addition, one requires a reason to invest in becoming proficient in modelling and most trainees have not approached their training with specific reasons in mind.
- The perception amongst non-modellers is that models are not good enough to capture systems performance nor have modelling efforts to date demonstrated much benefit in either the research or smallholder farming domains. This perception is shared by donors.

> *"I don't believe the models"*
>
> **IARC researcher**

In addition to these more common issues, there were reasons proposed specific to the CARMASAT project:

- The initial APSIM licence arrangement, whereby APSIM distribution was controlled by APSRU and not made freely available to anyone, was seen as a significant barrier early in the project. This access policy differed from most other models and was seen as restrictive to the free transfer of scientific knowledge between researchers. Now that this policy has changed in order to make APSIM available to anyone who seeks a licence, the cost of the licence ($A2000pa) is seen as a barrier to most NARES.
- Modellers maintain loyalty to the 'camp' where they first trained and to the associated model. ICRISAT had a long association with the IBSNAT project and the DSSAT models and rivalry developed between this existing camp and the new CARMASAT project, especially in India.

> *"it takes a long time on a model to become proficient and so you need to stick with it. It is understandable that people will want to stick with a familiar model"*
>
> **ICRISAT scientist**

- Establishing new skills and technologies within an institution such as ICRISAT required management support. While CARMASAT initially received such support, the project was implemented at a time when ICRISAT was undergoing management and institutional change driven by declining resources. Consequently, the CARMASAT project within ICRISAT had high turnover of collaborating staff.

> *"we could have done more but needed institutional support"*
>
> **ICRISAT-India**

- CARMASAT spent too long early in the project concentrating on model development and therefore took too long to focus on applications. Most effort of the project in India concentrated on developing new modules (pigeonpea, millet, manure, soil P). While these themselves are significant achievements, relevant applications could have proceeded alongside development of these new modules.

Despite relatively few active users of APSIM within ICRISAT and collaborating NARES, the project succeeded in creating awareness of and appreciation for the contribution of modelling to RDE efforts. Senior management within ICRISAT universally were highly supportive of simulation modelling. In fact, concerns expressed by managers included the current over-commitment of their few modellers and the current demand for simulation analyses which remain unfulfilled.

There is a strong contrast between ICRISAT sites in India and Zimbabwe on how simulation is employed. ICRISAT-India appears to have reverted to using simulation in policy research projects (eg yield gap analyses) which were the stable application of modelling at ICRISAT prior to the CARMASAT project. Adoption of CARMASAT tools and approaches is therefore low — probably only 5% of activities run from the site. In contrast, ICRISAT-Zimbabwe has actively adopted the use of simulation within a farming systems research context. The impression is that most projects run from ICRISAT-Zimbabwe seek input from simulation and so adoption here is very high, approaching 80% of activities. The difference between sites can be explained by the shifting of the CARMASAT team from India to Zimbabwe in 1999.

> *"to be frank, when I started I was advised to be sceptical of models. Why take notice of them? Now I am convinced they work and are useful"*
>
> **ICRISAT-Africa scientist**

> *"absolutely, the small fertiliser dose effort was a key outgrowth of the modelling ... it indicated the highest returns and productivity gains were from low doses and this was confirmed in field trials"*
>
> **ICRISAT-Africa researcher**

> *"modelling has become an integral part of ICRISAT capacity in Africa ... modelling output has been an important part of many funding bids"*
>
> **ICRISAT-Africa researcher**

Little evidence could be found for active adoption of simulation analyses stemming from the CARMASAT project within the NARES in India, Zimbabwe or Kenya. While trained APSIM users exist in each of these countries, simulation effort concentrated around few users who have maintained strong linkages to ICRISAT or APSRU.

Project impacts

Community impacts

Few farmers in semi-arid areas of Africa use fertiliser and virtually none use recommended levels of application. Essentially, the formal fertiliser recommendations of national research and extension systems have been ignored by smallholder farmers in Africa's extensive semi-arid regions. Because of this, productivity gains from fertiliser use remain grossly under-exploited.

Over 160,000 smallholder farmers in Zimbabwe achieved 30–50% yield increases in their maize crops due to the aid-sponsored distribution of seed and fertiliser in the 2003–04 season. Most of these farmers were in the drier regions of Zimbabwe, where previous efforts had not included fertiliser. This initiative resulted in a short-term economic benefit for this large group of smallholder farmers in that particular season. This effort was to continue in the 2004–05 season but has been hampered by Government intervention. It is reasonable to predict a proportion of participating farmers would realise the benefits of applied N fertiliser and adopt this practice without subsidy. If so, the result would lead to economic, social and environmental benefits within these communities. Unfortunately this proposition could not be tested due to the current circumstances in Zimbabwe.

Key architects of the 2003 aid program readily attribute systems modelling within ICRISAT as being one source which supported the proposition of small doses of inorganic fertiliser applied in the lower potential regions of Zimbabwe. And modelling has become a core component within several follow-on projects within ICRISAT. Continued work on low fertiliser rates and engagement with agribusiness companies in southern Africa (Zimbabwe, RSA, Malawi, Mozambique) forms the basis of such effort. Already there are indicators of continued and widespread impacts with several agribusiness companies demonstrating interest in supporting fertiliser use by smallholder farmers.

A key recommendation from this review is to continue to support ICRISAT in its efforts to utilise its in-house systems modelling expertise to work with the private and public sectors in seeking greater adoption of fertiliser use in semi-arid Africa.

Brad Collis

The project succeeded in creating awareness and appreciation of the contribution modelling could make to agricultural research. The level of adoption has been disappointing but the potential remains high.

Capacity building and scientific impacts

The first aim of the CARMASAT project was to train ICRISAT staff and collaborators in using simulation modelling in agricultural systems R&D. Nine years hence, the outcome of this objective is a mix of success and disappointment. Success in that systems simulation remains an active tool and approach employed within ICRISAT centres in both India and Africa and the main legacy of CARMASAT, the use of the APSIM model, persists at most sites. Disappointment, because modelling remains a tool used only by a few devoted practitioners despite efforts at broad-scale training of staff from ICRISAT, other IARCs and NARES. Only within ICRISAT-Zimbabwe can systems modelling claim to be institutionalised through acknowledged key contributions to many projects run from this site. This outcome has been achieved due to the efforts of Dr John Dimes in providing simulation support and because his local managers, Drs Steve Twomlow and David Rohrbach, are strong advocates for systems modelling.

> *"we have not been able to impress and convince colleagues on modelling ... while all say it is a useful tool, modelling has not contributed much ... we are yet to make a dent in on-farm applications"*
>
> **ICRISAT-India scientist**

> *"in IARC, there is no institutionalisation of modelling ... never a whole-hearted endorsement but rather a cautious acknowledgement of value"*
>
> **APSRU researcher**

> *"it's a management decision ... when there is competition for funds between field research and modelling, then modelling will fall out"*
>
> **IARC Manager**

Reasons for the low adoption of systems models in agricultural research, development and extension was discussed earlier. However, it is sobering to reflect on the lack of capacity building impacts achieved from the significant effort represented by CARMASAT and related projects. This is especially so when combined with past investments in trying to build capacity in systems thinking and simulation. The Kenyan Agricultural Research Institute has invested in training researchers in modelling since at least 1986 (funded by an ACIAR project) and yet in 2005 there are fewer than 10 modelling practitioners left in KARI despite continued funding support (from the Rockefeller Foundation). Likewise, crop modelling units established within the Indian Council of Agricultural Research and Zimbabwean Department of Research and Special Services both lasted less than five years. These efforts add to those documented in other large scale efforts to train researchers in systems modelling which have also largely failed to generate and sustain capacity in the area of systems modelling – (i) the Simulation and Systems Analysis for Rice Production (SARP) project[1], funded by the Dutch government, provided modelling training for rice-based farming systems in Asia, (ii) the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) Project[2], funded by the US Agency for International Development, developed and provided training in the DSSAT model, and (iii) the International Consortium for Agricultural Systems Applications (ICASA)[3] supports training in decision support tools and models.

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1 ten Berge, H.F.M., 1993. Building capacity for systems research at national agricultural research centres: SARP's experience. In: Penning de Vries F.W.T., Teng, P.S. and Metselaar, K. (eds.) Systems approaches for agricultural development. Kluwer, Dordrecht, pp. 515-538.

2 Uehara, G. and Tsuji, G.Y. 1991. Progress in crop modelling in the IBSNAT Project. In: R.C. Muchow and J.A. Bellamy (Eds.). Climatic risk in crop production: Models and management in the semi-arid tropics and subtropics. CAB International, Wallingford. p. 143-156.

3 www.icasa.net

The lack of widespread and sustained capacity in systems modelling stemming from the CARMASAT project is a disappointment felt by many associated with the project. However, some believe that this investment can still repay into the future.

> *"CARMASAT has been a net success and I'm glad we had it …but it is still an unfulfilled promise "*
>
> **ICRISAT scientist**

> *"the seeds of past investment remain and returns will be gained in the longer term"*
>
> **funder**

The scientific impacts of the CARMASAT project are impressive, manifest mainly through the development of added capacity to the APSIM model and associated publications. The CARMASAT project was responsible for initiating the development of four new APSIM modules:

- APSIM-SoilP – Probert, M. E., 2004. A capability in APSIM to model phosphorus responses in crops. ACIAR Proceedings no. 114, 92–100.
- APSIM-Manure –Probert, M.E. Delve, R.J. Kimani S.K. and Dimes J.P., 2004. The APSIM Manure Module: Improvements in Predictability and Application to Laboratory Studies. ACIAR Proceedings no. 114, 76–84.
- APSIM-Pigeonpea – Robertson, M.J., Carberry, P.S., Chauhan, Y.S., Ranganathan, R. and O'Leary, G.J., 2001. Predicting Growth and Development of Pigeonpea: A simulation model. Field Crop Res 71, 195–210
- APSIM-Millet – van Oosterom, E.J., Carberry, P.S. and O'Leary, G.J., 2001. Simulating growth, development, and yield of tillering pearl millet. I. Leaf area profiles on main shoots and tillers. Field Crop Res, 72, 51–66

All of these modules are available in the current release of APSIM (version 4.0) and are used in many research activities worldwide. These modules, and the science they capture, represent a significant contribution of the CARMASAT project beyond its own project timescale.

The CARMASAT and follow-on projects have generated more than 50 publications. This large publication output, as well as the continued use of APSIM, will likely influence future research investment worldwide.

Major users of the breeding G x E information are predominantly NRCS plant breeding programs and the associated institutions at state agriculture departments and agricultural universities involved in the AICSIP. As there are now more than 20 private seed companies in India (both national and trans-national companies) involved in producing and selling hybrid and inbred sorghum cultivars, this information will be used by some of them in designing and applying their variety trials.

Breeding programs have changed some of their breeding and selection practices. For the AICSIP, rationalisation of testing locations is not easy but three separate zones for *rabi* sorghum are now recognised (a rationalisation of the five target environments identified by this project). The predominant factor in differentiating these zones is soil depth, with shallow, intermediate and deep soils characterising the three zones. Overall, the breeding focus is on these three zones, with the recognition that in all cases there is a need to shorten the duration of the crop. This is most marked for shallow soils, such as those in Maharashtra, where the stated aim for breeding programs is to select for lines of 100–105 days to flowering, which is 10–20 days earlier than the most commonly grown varieties and hybrids.

Major users of the APSIM-SORG model include the research institutions at QDPI, CSIRO and UQ in Australia, and scientists at NRCS and ICRISAT in India. Information gained from the r*abi* seasonal conditions have extended the utility of the model for a wider range of soils and environments.

Project impacts

Community impacts

Major community impacts will only be possible with the delivery of mechanisms of shootfly resistance in *rabi* sorghum. This will require further research and there are great opportunities to develop new initiatives to continue this collaboration.

The greatest community impact from the delivery of shootfly resistance will be economic. It would confer the ability to plant earlier, which will enable farmers to improve the use of the available soil moisture and result in higher productivity and security of production. Earlier plantings would mean that farmers would also be more likely to benefit from the application of N fertilisers, and hence would see the benefits of investment in better crop management. An additional impact of shootfly resistance will be that sorghum will become more attractive as an alternative for *rabi* sowings and it would be highly likely that the area sown to sorghum in India would increase.

Capacity building and scientific impacts

Indian scientists now have the capacity to genetically engineer sorghum. This has been instrumental in allowing progress to be made under the APNL biotechnology program. The biotechnology building at NRCS has benefited from equipment gained from the ACIAR-funded project. The Indian researchers are in the process of developing molecular markers and genome analysis which will greatly enhance their capacity for sorghum genetic improvement.

The capacity building has involved scientific visits between Australia and India and a number of Indian scientists have been trained in skills of plant genetic engineering, retrospective analysis of breeding trial data, genotype x environment analysis, and the development and application of crop simulation models.

The breeding programs overseen by the AICSIP umbrella are being updated with the knowledge gained from this project. There are however some obstacles to progress, but there is resolve within NRCS and ICAR to make the necessary changes to improve the breeding efficiency of *rabi*, *kharif* and forage sorghum breeding programs.

Seed companies are now heavily involved in the production of hybrid sorghums in India. More than 20 companies are involved in sorghum seed production, many in direct cooperation with ICRISAT and the AICSIP. These companies are benefiting from the research findings of this project.

A major scientific impact of the project has been the growth in interest in sorghum genetic engineering research in India, which was non-existent at the beginning of the project. In addition to the continued work on stem borer resistant lines with Bt genes (funded by APNL), NRCS has formed new linkages with other groups. These include the linkages with CRIDA (aimed at improving drought resistance traits), GB Pant University (improving *rabi* sorghum roti-making quality and shelf-life) and Osmania University (drought resistance traits and grain mould resistance). There are also projects at Tamil Nadu Agricultural University and ANGRAU developing sorghum transformation techniques. Finally, two seed companies are collaborating on sorghum transformation.

The APNL project has been focussed on the use of genes such as chitinase to overcome stalk rots and grain mould, and the use of Bt for stem borer. The stem borer work is well advanced, and much of the success for this project has come from the ACIAR-funded research. The ACIAR-funded project has enabled infrastructure and expertise to build up, and the Indian national system has taken up the technology with gusto. There is evidence that the transfer of Dr Seetharama from ICRISAT to NRCS has helped this to happen. Conversely, it also appears that this has been a loss to ICRISAT and currently almost all the transgenesis research at ICRISAT is focused on pigeonpea and groundnut under the guidance of Dr KK Sharma.

Scientists at NRCS, NRCPB and ICGEB are very interested in developing a new proposal with UQ to develop shootfly resistant sorghums. We have had discussions on the potential use of small peptides aimed at Dipteran proteases to prevent shootfly larvae from completing their life cycle. ICGEB has been involved in developing this technique to control malaria mosquitoes. We will also explore the potential to down-regulate the sorghum volatiles which attract female shootflies to the young seedlings. This would also involve collaboration with entomologists at DPI&F.