SOILS AND CLIMATE GAIN FROM FERTILISER'S FLIPSIDE

An India–Australia research partnership is showing it is possible to produce more food while reducing fertiliser-related damage to the surrounding environment

BY GIO BRAIDOTTI

A project to help smallholder Indian farmers improve their fertiliser management could have an environmental spin-off half a world away in Australia by revealing the potential for urban green waste to lower Australian agriculture's emission of nitrous oxide, a significant greenhouse gas.

The project set out to help Indian farmers whose yields were chronically below expectations because the crops were taking more nutrient from the soil than was being provided by organic fertilisers alone. Supplementing the traditional organic fertilisers with chemical fertilisers rectified this and helped to stabilise the farming system practised by smallholder soybean and wheat farmers in the Madhya Pradesh state.

Australia provided the opposite scenario for examination—farming systems based almost exclusively on chemical fertilisers. It was found that Australia lacked sufficient understanding of the role that organic fertilisers could play in better managing soil nutrition. When the ACIAR team implemented improved organic fertiliser application—in trials on the Darling Downs—they were surprised to find that modifications made to their source of organic fertiliser, feedlot manure, led to decreased nitrous oxide emissions from the soil.

The modification was to add urban green waste to the manure—opening up the possibility of resolving two waste issues. The green waste increased the carbon component which locks nitrogen into soils.

The research has since delivered an

PARTNER COUNTRY
India

PROJECT DESCRIPTION: LWR/2002/032: Integrated manure nutrient management in soybean–wheat cropping systems on vertisol soils in Madhya Pradesh and Queensland

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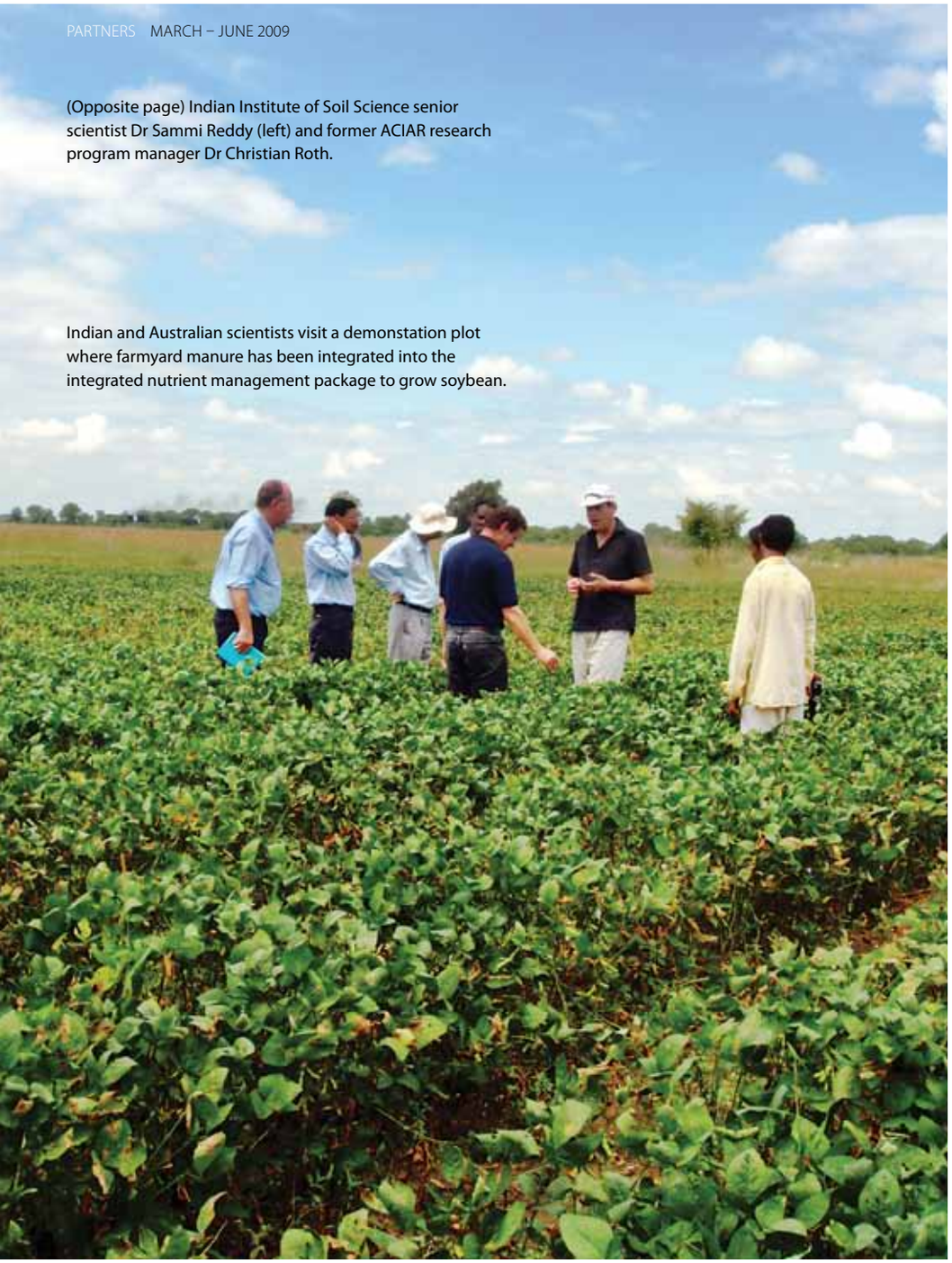

(Opposite page) Indian Institute of Soil Science senior scientist Dr Sammi Reddy (left) and former ACIAR research program manager Dr Christian Roth.

Indian and Australian scientists visit a demonstation plot where farmyard manure has been integrated into the integrated nutrient management package to grow soybean.

improved soil-management strategy capable of closing the yield-gap in a sustainable way in India, and in Australia, helping lessen their contribution to climate change.

Underlying all these gains is a better understanding of soil fertility and the impacts that managing this natural resource have on food production, the environment and the economy of farming communities.

Coming together for this ACIAR project was the prestigious Indian Institute of Soil Science (IISS), the University of Queensland and the Queensland Department of Natural Resources and Water (NRW). Partnering the soil scientists was a highly respected farmer-support non-government organisation (NGO), the Bharatiya Agro Industries Foundation (BAIF).

Dr Christian Roth, previously research program manager with ACIAR, says that traditionally, Madhya Pradesh's smallholders use manure to fertilise their crops but that not enough of this organic material is available to achieve maximum soybean and wheat productivity. "We knew at the outset there was going to be a need to add inorganic fertilisers," he says. "The problem with that approach is that you need to know which particular nutrients are missing in the soil."

IISS senior scientist Dr K. Sammi Reddy says Madhya Pradesh's soils are vertisols—black, well-structured soils of volcanic origin, but with 30% or more clay content—which crack and shrink during the dry season and swell during the monsoon.

Smallholders grow soybean during the monsoon season, contributing to a harvest that accounts for 75% of India's total soybean production. A wheat crop follows, grown mostly on soil-trapped moisture. Although cropping is undertaken on areas of just two to 20 hectares, these smallholders are important food producers for India.

Dr Reddy says that despite farmers' efforts to fertilise their crops, these farming systems are nonetheless in "negative nutrient balance"—crops are taking more nutrients from the soil than are being returned by the application of manure.

In response, the scientists joined forces with farmers to run trials that diagnosed the soil's nutrient deficiencies, down to individual micronutrients. These on-farm experiments identified deficiencies in phosphorus, sulfur and zinc, in addition to the nitrogen deficiency that farmers already knew about.

"We also analysed farmyard manure pits in different villages and found that the method used to produce manure leads to the loss of nutrients," Dr Reddy says. "At stake is about 40% of nitrogen, 23% of phosphorus and 36% of potassium put into the pits as organic materials such as animal dung, household refuse and ash."

Between the low manure application rate, the nutrient loss during composting and the depleted soils, average soybean yields are just 1.2 tonnes a hectare—half to a third of the yield potential, according to crop simulation and field experiments.

INTEGRATED NUTRIENT MANAGEMENT

To close this yield-gap, scientists set about looking for a fertiliser regime that could remediate soil fertility without causing harm to either the environment or the farms' economic sustainability, given world-wide volatility in input costs, such as fertiliser and energy.

The solution involved combining the farmyard manure with an inorganic fertiliser selected to supply the missing nutrients, especially sulfur and zinc. Because the approach combines organic and inorganic treatments, scientists refer to it as integrated nutrient management (INM).

"It wasn't just about telling farmers you need to fertilise, it was about the need to target the missing nutrients in a sustainable way," Dr Roth says. "You can get a big response simply by providing the missing nutrients."

On-farm trials were undertaken to compare the performance of various fertiliser treatments and determine the optimum rate of application. These succeeded in nearly doubling average soybean yields with three different fertiliser regimes.

Biological fertiliser improves outlook for rice farmers

Among ACIAR efforts directed at improving soil-management practices, a project in Vietnam has demonstrated it is possible for rice growers to use less environmentally harmful forms of fertiliser while improving crop performance and reducing farm costs.

A new biofertiliser technology has been developed by Vietnamese partners and the University of Sydney as part of an ACIAR project headed by Professor Nguyen Thanh Hien in Vietnam and Professor Ivan Kennedy in Australia. The innovation was achieved by combining lower inputs of urea and phosphorus fertiliser with specific microorganisms that increase the amount of nutrients available to plants. The new 'inoculant biofertiliser' is called BioGro.

Research and field experiments with several hundred rice farmers in northern and southern Vietnam found that when the microorganisms are present in a crop's root zones, seedlings in rice paddies inoculated with BioGro require at least 50% less fertiliser than non-inoculated plants.

"The norm in Vietnam is about 100 kilograms of nitrogen fertiliser per hectare," Professor Kennedy says. "With the cost of this input roughly tripling in the past two years—largely as a result of the volatility of oil prices—the development of BioGro has the potential to help alleviate rural poverty and reduce hardship for some of Vietnam's 30 million farmers."

Farmers also report that the inoculated plants are tougher and more resistant to fungi and insects, while scientists see potential to mitigate negative environmental impacts associated with fertiliser use.

"Excess nitrogen from fertilisers enters the environment, pollutes water and accelerates global warming through the production of nitrous oxide," Professor Kennedy says.

Since the project's completion in 2008 it has attracted the World Bank's attention, receiving a US$200,000 award from its Global Development Marketplace. The award was shared by Dr Phan Thi Cong from the Institute of Agricultural Sciences for Southern Vietnam in Ho Chi Minh City and Professor Ivan Kennedy and Dr Michael Rose from the University of Sydney.

The World Bank award aims to scale up project outcomes to reach more farmers. A parent company is expected to franchise provincial factories in Vietnam, providing them with the mother culture to produce BioGro. A viable supply chain is also being created to link the factory with farmers.

A key component of this ongoing activity involves technology and skills transfer. The University of Sydney's Dr Michael Rose is continuing his former association with the project as an AusAID Youth Ambassador, helping to ensure quality control of the microorganism cultures. During 2009, two young Vietnamese graduates will join him in Sydney, funded by AusAID's Australian Leadership Awards Fellowships, to learn these sophisticated quality-control techniques.

The winning recipients in 2008 of the World Bank's competitive grant program, the Global Development Marketplace, including Professor Ivan Kennedy (second from left) and Dr Phan Thi Cong (fourth from left).

While 100% inorganic fertiliser yielded 2.1 t/ha, similar yields (2.2 t/ha) were obtained with just 50% of the recommended rate of inorganic fertiliser combined with 5 t/ha of farmyard manure. The further use of *Rhizobium* inoculation also proved beneficial, yielding 2.3 t/ha. Economic analysis found that integrated nutrient management produced the highest net returns (13,457 rupees a hectare) and benefit-to-cost ratio (1.28) to the farmer.

With technical solutions on hand, the project next faced its second, more daunting challenge. With agriculture the mainstay of Madhya Pradesh's economic life, about 71% of the state's 60 million people are directly engaged in agriculture. Reaching all the farmers needing assistance with their soybean and wheat crops seemed an insurmountable problem, but one that ACIAR was determined to tackle from the outset with a project designed to facilitate extension.

"Experience tells us that often research organisations are not the best placed to ensure knowledge generated by research is actually adopted on farms," Dr Roth says. "The novel element in this project is that ACIAR broadened the partnership to include an NGO that could extract the greatest extension benefit from farmer participation in the R&D trials."

The NGO selected for the project was BAIF, one of India's larger community-based organisations specialising in creating self-employment opportunities for rural families.

Despite the best intentions, Dr Roth says trials and field days in the first year tended towards traditional academic approaches. These came unstuck when confronted by farmers who deal not with single productivity issues but holistic field realities. Indian and Australian scientists alike look back and recall that the academic approach simply did not work.

"To their credit, the scientists were more than willing to analyse what went wrong and fix it—that became the turning point," Dr Roth says.

Dr Reddy says a method was identified to run field trials in participatory ways that promote extension to farmers. Called the 'mother–baby trial' (MBT) method, Dr Reddy's commitment to its implementation saw him attend an MBT training course in 2006 at the International Rice Research Institute in the Philippines.

He says the 'mother trial' is the initial researcher-driven trial undertaken on-farm to generate statistically robust data. In the next phase, the most promising treatments are selected and with the technical assistance of BAIF, these smaller, 'baby' trials are replicated by the farmers on their own farms. Baby trials serve to generate more data while allowing farmers to experience, choose and refine which treatment best suit their needs.

The crucial role played by BAIF was to provide the capacity to run high-quality baby trials on a scale that stunned Australia's project leader, Dr Neal Menzies.

"BAIF said they could run baby trials on 100 different farms—and we were happy for them to try—but I did not believe they could achieve that many. They actually got 95 baby trial results in one season, which is a stunning effort. It really is a remarkable demonstration of what an

A compost pit prepared by farmers from the village of Rangai as part of the integrated nutrient management project.

effective outreach group they are."

Farmers from the villages of Sanchi, Rangai and Kamapar who took part in the ACIAR project report predominantly good experiences from their interaction with the IISS–BAIF team. Of seven farmers contacted, all intend to continue with the fertiliser treatment. "Integrated nutrient management has shown very good results and production has increased considerably," says Mr Ranjeet Verma, who farms about eight hectares in Sanchi.

BENEFITS NOT ONLY IN SOIL NUTRITION

On the extension front, each farmer reports actively helping others improve soil nutrition, something Ms Sanjay Verma of Rangai says takes place primarily through discussions—"the sharing of views"—among farmers. All report seeing changes in their village as a result.

"There is an increase in technical know-how regarding agricultural practices and an understanding of the importance of micronutrients," Mr Ranjeet Verma says. "So in the village we are experiencing increased production."

However, when listing benefits not a single farmer restricts the list to soil fertility. Mr Ram Manohar Verma cites the availability of improved varieties with the formation of a seedbank in Rangai village; other farmers talk about improved pesticide application or the availability of manure through structures at the village level.

"When farmers see a field, they see a whole lot of problems and are not just focused on the one issue targeted by the research project," Dr Roth says. "So another project impact made possible by the closer contact between researchers and farmers was a broadening-out of inquiry."

This resulted in solutions to recurrent waterlogging of the soybean crop and a method of preparing and storing manure that avoids nutrient loss.

The enthusiasm farmers have expressed for the research partnership has amazed the scientists who have come to view this response as the project's most spectacular outcome.

"For me, I'm a boffin," Dr Menzies says. "I work in a laboratory. So seeing all these social and cultural dynamics in the research and development system that is helping smallholders—that is something special. If extension efforts continue then this is a project that could potentially have huge impacts."

BAIF's Dr Somnath Roy says farmers are keen to continue with the project and he would like to see Madhya Pradesh's smallholders receive ongoing support: "Madhya Pradesh is a state with 11 agro-climatic zones and each requires at least one chance to get to know the technology in a farmer-friendly way."

With BAIF keen to continue disseminating the integrated nutrient management message, the organisation is seeking operating funds from its own donor base, which includes state and national governments. To help BAIF shore up its case for integrated nutrient management, ACIAR provided additional funding in 2009 for a different district to run a further 100 baby trials.

With the technical side of the project at an end, the scientists and ACIAR are quietly confident that ultimately this is a project with the potential to have impacts well beyond the original participating villages. However, India is not the only beneficiary.

AUSTRALIAN BREAKTHROUGH

Dr Menzies says there is an Australian component to this project relating to agricultural uses of manure from livestock feedlots, particularly on the Darling Downs in Queensland. It was formulated to take advantage of IISS expertise in the re-use of organic waste in agriculture. Dr Menzies says Indian expertise exceeds anything available in Australia, where organic waste mostly ends up in landfill.

Dr Ram Dalal from Queensland's NRW explains that in Australia about one million tonnes of feedlot manure is generated a year, more than half of it in Queensland. Although some of this manure is used as fertiliser for cropping, the practice was running into problems.

"What we found is that farmers were using 20 to 50 t/ha," Dr Dalal says. "That creates problems of high nitrate and phosphorus levels in soils, which can cause a pollution hazard for groundwater, rivers and even the Great Barrier Reef. Additionally, up to 10% of nitrogen is lost as a greenhouse gas—nitrous oxide—that is 298 times more potent a threat to climate than carbon dioxide."

The scientists wanted to reduce the rate of nutrient release from the manure and decided to mix it with a carbon-rich but nitrogen-poor material to tie up free nitrogen in the soil. They selected green waste compost—the material produced by city councils from managing parks and pruning trees. Australia-wide each year, three million tonnes of green waste is generated and disposed of in landfill, Dr Dalal says.

In a surprise discovery, the mix of manure and green compost was found to reduce emissions of nitrous oxide by up to 60%.

Given that 80% of nitrous oxide is produced from agriculture, even a 50% reduction of agricultural emissions would stand to make a substantial difference as agricultural science faces its greatest challenge ever: doubling food production from the same amount of land while reducing environmental impacts.

"There is a real need to understand nitrogen and learn to use it as efficiently as possible," Dr Menzies says. "The work we did on this project was directed at finding solutions for precisely this challenge."

Dr Roth says he is delighted with the outcome. "ACIAR is always happy when we have such potentially large impacts," he says. "Given the real breakthrough we saw in India, it is then extra special to demonstrate a reciprocal benefit to Australia." ■