The international nature of germplasm enhancement

Underlying the performance of elite crop varieties is an international network matching plant genetic traits to the challenges of farming in dry, hot, frosty, salty or other problematic growing conditions. Through this network, which includes a range of gene banks, opportunities to improve crops flow to researchers and breeders around the world. ACIAR works to facilitate the flow of material, which is especially important to Australia, where cropping industries are unusually dependent on exotic, imported species.

BY DR GIO BRAIDOTTI

In 1999 wheat crops in Uganda failed when a devastating disease long considered under control — stem rust — re-emerged in a more virulent form, which was to become known as Ug99. The breakdown of wheat’s immunity alarmed the world as the fungal disease inevitably spread along well-worn routes — to Kenya, Ethiopia, Sudan and Yemen.

The cause was the breakdown of the genetically based resistance built into wheat varieties in the 1950s — traits that were a cornerstone of the Green Revolution, protecting 90% of the world’s wheat varieties and 20% of the world’s total calorie intake.

But in Uganda the stem rust fungus re-jigged its DNA, trying out new genetic possibilities, and found a way to break down wheat’s in-built resistance. The resistance breakdown occurred at a time of declining interest and investment in agricultural science in the developed world.

It was Nobel laureate Norman Borlaug, nearing the end of his life, who raised the alarm and philanthropist Bill Gates who provided the funds to launch a response in the form of the Borlaug Global Rust Initiative (BGlR).

The BGlR is a research network that makes the best use of existing resources, funding researchers with specialist rust expertise wherever they exist. It developed facilities to screen the susceptibility of the world’s wheat varieties and to screen for resistant germplasm in Kenya, where Ug99 is prevalent. Breeders at the International Maize and Wheat Improvement Center (CIMMYT) then played a pivotal role, releasing Ug99-resistant wheat cultivars to affected nations funded by donors that included ACIAR.

However, breeders know that inevitably the stem rust fungus will evolve. The genetic recording will continue to erode away any new sources of resistance in wheat as part of a perpetual ‘arms race’ between fungal virulence and the immunity that breeders build into wheat.

Throughout the Ug99 response, Australia was the global black sheep. First, Australia’s problems with rust disease are so pervasive and potentially devastating that rust has long been a research priority and it received additional funding from ACIAR and the Grains Research and Development Corporation (GRDC) to deal with Ug99.

Second, the stem rust resistance built into Australian varieties often differed from the rest of the world (due to considerations for grain quality), with breeders preferring resistance traits (such as Sr2) that retained wheat’s effectiveness against Ug99.

Third, rust researchers at the University of Sydney Plant Breeding Institute (PBI) in Cobbity and CSIRO Plant Industry are looking for a way off the rust merry-go-round by taking rust resistance to a new, more durable level.

A crucial stepping stone towards this important objective involves isolating rust resistance genes and decoding the mechanism of action at the molecular level.

That goal was achieved in 2013 when a team led by Dr Evans Lagudah at CSIRO Plant Industry announced the isolation of Sr33—a stem rust resistance gene targeted because of its unusual ability to defend against all stem rust races tested, including Ug99. Sr33 can interact synergistically with other resistance genes (such as Sr2) to further raise the overall level of protection available to a wheat crop.

The importance of biodiversity

Like many plant genes of agronomic importance, Sr33 does not originate from the genome of domesticated plants. Rather it comes from a wild relative of wheat—a line of goatgrass (Aegilops tauschi) collected in Iran. It is a classic example that highlights the importance of collecting, conserving, sharing and exploiting the world’s crop genetic resources and of organisations, such as ACIAR, that promote these ideals.

Dr Tony Gregson, an Australian farmer and former chairman of Bioversity International, says ACIAR’s influence played an important role in developments such as the establishment of the Svalbard Global Seed Vault and the International Treaty on Plant Genetic Resources for Food and Agriculture. The treaty, which was ratified by Australia, implemented a multilateral system of access and benefit-sharing of genetic resources for 64 of the most important food and forage crops.

Important techniques to exploit these resources have also been developed with ACIAR assistance. This includes FIGS (Focused Identification of Germplasm Strategy), a technique that exploits information about the seasonal agro-climatic conditions where seed is collected to better select material likely to contain important traits. This includes the frost tolerance recently identified in field peas by Australian breeders from material collected in China by Dr Bob Redden while on an ACIAR project.
THE GENE THAT MADE A DIFFERENCE
When the call to action against Ug99 was issued, it is unlikely that even Norman Borlaug could have anticipated how far and wide the message would resonate.

In the home of the Green Revolution, a small 1.5-hectare tropical cropping farm on the banks of the Cauvery River in India would prove a leading player in the battle against Ug99.

Kuppusamy Periyannan and his wife, Subhulakshmi, are innovators in their farming community. While they have never participated in an ACIAR project, they understand something that developed nations can easily ignore—the vital role science plays in agricultural productivity to benefit the poor and their rural communities.

It is an outlook that caused the Periyannans to highly value an opportunity they were denied—an education. They valued it enough to take out loans on their farm to educate their children but insisted that one, Sambasivam (‘Sam’) Periyannan, bypass popular courses in engineering or information technology (IT) in favour of agricultural science.

Sam Periyannan was subsequently responsible for cloning Sr33 while completing his PhD at CSIRO Plant Industry in Canberra, supported in part by an ACIAR scholarship.

“At the moment there is an IT boom in India and not many parents like their children to get into agricultural science,” Dr Periyannan says.

“They see there are opportunities after studying IT. But my parents were different. My father especially pointed me to agricultural science and it was the science’s links to farming that pushed me to try and excel at research.”

A plant pathologist by training, Dr Periyannan completed his PhD with assistance from ACIAR in 2011. He has chosen to stay at CSIRO as a postdoctoral research fellow to continue his work isolating two more novel stem rust resistance genes (Sr45 and Sr22).

For CSIRO, the isolation of Sr33 is a long-awaited innovation that radically changes the rules for breeders. Dr Lagudah says that it makes it possible to make informed, knowledge-based decisions as to which genes to combine to best thwart rust pathogens and obtain the most durable forms of rust resistance.

“We can even pre-combine genes and insert them—like a cassette of genes—into one site of the wheat genome, clearing the way for breeders to focus their crosses on combining beneficial yield and quality traits. The cassette could even include tolerance genes to stresses like salinity.”

It is a vision shared by ACIAR and the GRDC, which have both funded the CSIRO team, well before the existence of the BGRI.

“That support allowed us to gain the attention of the Gates Foundation, which then provided additional resources that accelerated progress towards identifying individual resistance genes,” Dr Lagudah says.

“Along the way we proved that it is possible to do sophisticated molecular work with wheat despite its large, cumbersome genome. In turn, that means we can attract more young scientists to risk working with wheat. So there is a spectrum of benefits from this kind of work: from research right through to the delivery of real world impacts.”

For Dr Periyannan, there is an additional benefit, one arising from ACIAR’s unique position as both an R&D funder and a research development agency.

“I’m so happy and proud that part of the work I do goes back to the farm—including smallholders and subsistence farmers in developing countries—through ACIAR’s work in India, Bangladesh and other countries,” he says.

“My own roots are with smallholder farmers...
and something that really interests me now is to get involved in an ACIAR project and to further my ties with ACIAR, perhaps by helping to train scientists from India, Nepal or Bangladesh, introducing them to gene cloning technology and DNA markers and how they can be applied to help farmers."

For the Sr33 discovery and many other contributions, Dr Lagudah and Dr Periyannan were both listed among researchers awarded the BGRI Gene Stewardship prize during the 2013 BGRI Technical Workshop in New Delhi, India. The award is given annually to scientists who contribute to responsible management of genetic resources of wheat.

The Australian researchers were selected for outstanding achievements in 15 areas, including developing programs for stacking resistance genes, creating molecular markers, strategic planning for durable, long-lasting, disease-resistant wheat varieties, highly effective training programs, willingness to share genetic resources, and strong efforts to clone resistance genes.

The winning researchers are based at three institutions—CSIRO Plant Industry, the University of Sydney and the University of Adelaide—which collectively form the Australian Cereal Rust Control team.

"The nominating credentials of each institution were so strong that the selection committee couldn’t pick one," said Sarah Evanga, adjunct professor of plant breeding at Cornell University, where the BGRI is administered. "Their spirit of collaboration was the inspiration for combining the nominations into one award.

"So much great work is being done at these Australian institutions. Their expertise, their collaborative spirit and their recognition of the importance of developing durably resistant varieties serve as an inspiration for rust scientists all over the world. With this award, we gratefully recognise the efforts of the Australian Cereal Rust Control Team." ■

ACIAR project: CIM/2007/084 and 064

**SHARED GERmplASM:** **A PILLAR OF AUSTRALIA’S GRAIN INDUSTRY**

**ACIAR ACTION** No less than 98% of the Australian wheatbelt is sown to varieties with genetic material derived from the genebank and breeding programs of the International Maize and Wheat Improvement Center (CIMMYT), one of the International Agricultural Research Centres (IARCs) operating to sustain global food security. The influx of CIMMYT germplasm into Australian wheat has lifted yields by as much as 10.5% in Queensland’s tropical cropping region and by an average of 4.6% across Australia. By the end of 2003, an estimated 193 Australian wheat varieties were found to incorporate CIMMYT genetics. But it is not just wheat that benefits. There are two other IARCs of particular importance to all phases of a typical Australian crop rotation—which might include wheat, barley, canola, lentils, faba beans and chickpeas. These are the International Center for Agricultural Research in the Dry Areas (ICARDA), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). ICRISAT adds an estimated $131 million in value for sorghum to Australian farms. Underscoring this value is the goodwill brokered by ACIAR on Australia’s behalf.