

Keys to the gene bank

A treasure trove of yield-enhancing traits await crop breeders in the world's gene banks but gaining access will require unprecedented ingenuity and collaboration among curators, geneticists and breeders

BY DR GIO BRAIDOTTI

With farmers worldwide facing a need to double food production by 2050—and to do so with the same amount of land and less water—pressure is mounting on breeders to find a new generation of plant traits capable of boosting yields.

Considerable productivity gains are thought to be possible through breeding. In Australia, for instance, wheat yields in dryland areas have increased 3% annually—a rate that has tripled wheat production over a century. Scientists have attributed 30% of this overall gain to genetic improvements achieved through breeding programs.

Looking to the future, geneticists are attempting to track down the next generation of yield-improving traits, targeting characteristics that can help overcome common production constraints. Top of the list is greater genetic resistance to stresses such as weeds, pests and diseases, combined with tolerance to environmental constraints, especially drought, but also frost and waterlogging.

The consensus among geneticists is that stress-tolerance traits exist within the greater gene pool of cropped species. However, accessing those traits presents a number of problems that are being overcome, in part, with ACIAR's assistance.

Genetic resource scientist Dr Ken Street from the International Center for Agricultural Research in the Dry Areas (ICARDA) explains that, although breeders prefer to work with modern varieties and breeding lines,

gene banks contain two other sources of germplasm that contain much more biodiversity.

These are landraces (early forms of cultivated crop species that, unlike modern varieties, are genetically mixed and out-bred) and the wild relatives of cropped species, which are even more genetically diverse. Screening and testing this material for the needed traits, however, is expensive, time-consuming and requires growing out thousands of lines over several seasons. As a result, these resources have been underused in the past, a state of affairs that scientists are hoping to change.

"The assumption is that most of the modern breeding material has been pretty well looked over by breeders, and people now need new sources of genetic variation," Dr Street says. "Gene banks can provide the required biodiversity, but we need to make it easier for people to access and screen these genetic resources."

For agricultural science, that means three broad areas of innovation are required. ACIAR has been supporting collaborative research efforts on each front, says Dr Paul Fox, ACIAR's research program manager for crop improvement and management.

First, there is a need to collect and conserve crop varieties, landraces and wild relatives that otherwise face extinction. Second, techniques are also needed to make it easier, cheaper and faster to screen all these genetic resources for desirable traits. Finally, there is a need to centralise and integrate information about individual collections, facilitating its use by the broader scientific community.

PROTECTING BIODIVERSITY

Globally, there are an estimated six million specimens contained in more than 1,300 gene banks. Yet crop diversity has been vanishing from fields before it has been collected or dying in substandard gene banks due to chronic under-funding, says Dr Cary Fowler of the Global Crop Diversity Trust.

"These biological resources contain a huge amount of untapped and endangered diversity of inestimable value in helping agriculture cope, especially with climate change and population growth," Dr Fowler says.

More than a decade ago, ACIAR—in conjunction with the Grains Research and Development Corporation (GRDC)—recognised the need to assist conservation efforts. In addition to providing financial support to the gene banks associated with the centres of the Consultative Group on International Agricultural Research (CGIAR), specialised projects were launched in partnership with some of the world's most impoverished gene banks.

Dr Colin Piggin, from ICARDA, points to a 10-year ACIAR project that supported Dr Street's seed-collection missions in Central Asia and the Caucasus. The region is an important centre of origin for crops that are important to Australia, including wheat, barley, chickpea and lentil. However, since the collapse of the Soviet Union, the region's gene banks—including one of the world's oldest, the Vavilov Institute in St Petersburg—have fallen into disrepair.

"ACIAR funded a project to work with these countries to help rehabilitate their gene banks and also undertake joint collection missions with them," Dr Piggin says.



Dr Ken Street

PHOTO: BRAD COLLIS



Dr Cary Fowler

PHOTO: BRAD COLLIS



Dr Michael Mackay

PHOTO: REBECCA THYER

“If you think about the importance of conserving the legacy of biodiversity and retaining access to this material, it is monumentally important—especially for Australia. All our commercial food crops originate outside Australia, with the exception of macadamia nuts. By necessity we need the best gene banks and germplasm-screening technology available.”

Since those early ACIAR projects, the Global Crop Diversity Trust—with support from Australia’s GRDC—has launched the largest-ever initiative to rescue and conserve endangered landraces and wild relatives of crop varieties. As a consequence, gene banks are set to become bigger and much more genetically diverse. That makes retrieving needed and novel traits from the world’s seed collections even more complex, Dr Street says.

CRACKING THE GENE BANK CODE

Working with Dr Michael Mackay, a fellow Australian genetic resource scientist, Dr Street recently demonstrated it is possible to dramatically improve breeder access to genetic traits stored in the world’s gene banks.

A technique called FIGS (Focused Identification of Germplasm Strategy) has already helped pre-breeders identify long-sought-after traits, such as resistance to barley net blotch, powdery mildew, Russian wheat aphid and sunn pest.

“Basically, I am using ecological principles to restrict the number of plants that breeders

have to screen from thousands to hundreds,” Dr Street says.

“The idea is to choose a small set containing the most useful possible genetic variation. FIGS does that by applying to gene banks the same selection pressure exerted on plants by evolution.”

Another approach with huge potential to simplify use of genetic resources is marker-assisted selection (MAS). Dr Fox says markers make it possible to do away with elaborate, expensive and time-consuming field and laboratory tests normally needed to determine whether plants contain genes known to be beneficial. Instead, a sample of DNA taken from plant cells is tested rapidly and directly for the presence of desired genes.

ACIAR is backing the development of markers through a number of projects, including a MAS wheat-breeding project undertaken as a partnership between India and Australia. Dr Fox says the two countries face similar agro-climatic production constraints and often have complementary breeding expertise. The project is bringing together genetic resources from both countries to improve wheat resistance to various stresses, including rust pathogens and drought.

The research is also contributing to an escalating international response to Ug99—a new rust strain capable of devastating many cultivated wheat varieties.

India’s Dr K.V. Prabhu, from the Indo-Australia Marker-Assisted Wheat Breeding Program, says these kinds of partnerships

provide an opportunity to address production concerns in advance and prepare together. “This is a frank partnership on a scientific basis, looking at the strong points that both countries have and using those on a shared basis.”

BIOINFORMATION AND THE GENE BANK PUZZLE

As innovation makes it ever more viable to harness genetic resources in breeding programs, Dr Fox says vast amounts of information are going to be generated. However, in the absence of a centralised database and communication among researchers, this bioinformation may stay fragmented, preventing the realisation of its true value to breeders.

In the early 1990s ACIAR anticipated the need for a centralised database capable of integrating information about genetic resources. Dr Fox says support was provided to a CGIAR centre in Mexico, the International Maize and Wheat Improvement Center (CIMMYT), to kick off the development of such a database. The result was ICIS—the International Crop Information System.

“ICIS makes it possible to collate data about breeding, evaluation and utilisation of genetic resources from diverse worldwide sources,” Dr Fox says. “The open source code software supports applications designed to store and query pedigrees and trait data that are essential for breeders.”

ICIS has already facilitated discoveries in Australia relating to agriculturally valuable genes that went undetected in past breeding programs. The information is being mined from the large datasets generated by routine breeding programs in conjunction with pedigrees accessible through ICIS. For instance, Dr Howard Eagles of the University of Adelaide is tracing the impact of a gene introduced to Australia from India by William Farrer in the 19th century.

“There is now real interest among those wheat breeders who are grappling with breeding for the hot, dry springs we often have in Australia to critically re-evaluate Indian wheat lines,” Dr Eagles says.

Taken together, the R&D push around genetics, gene banks and bioinformation are helping to more fully integrate biodiversity into the agricultural R&D pipeline, creating bridges between gene banks, the pre-breeding community and breeding programs.

Dr Fox says that trying to achieve these goals independently at the national level is simply wasteful. “Solving these problems is best done in partnership, with progress shared among partners, especially developing countries whose genetic resources are making it all possible.” ■