More frequent and severe droughts are regarded as the single biggest threat to the world's supply of arable farmland.

Scientists rally to the challenge of a DRYING PLANET

PHOTO: EVAN COLLIS

The world's leading drought specialists gathered in Shanghai recently to advance global research into more water-efficient and drought-tolerant crops

BY DR GIO BRAIDOTTI

There is a consensus among agricultural scientists that water scarcity is currently the most persistent reason for rural poverty and the single greatest factor determining crop yields.

Adding to that strain, agricultural scientists are faced with the need to double crop production by 2050 using current water availability. As part of the global effort to meet the challenges posed by water scarcity, scientists from around the world met in Shanghai for the Interdrought-III conference to step up drought-related research efforts in agronomy, plant breeding, genomics, transgenics and water management.

Six hundred agricultural scientists at the conference, including Australian researchers and their collaborators involved in ACIAR-funded projects, rated drought as the biggest threat to food production in developing and developed countries. The conference was hosted by the Shanghai Academy of Agricultural Sciences and the Shanghai AgroBiological Gene Centre.

The purpose of the meeting, said one of the fathers of drought-stressed-plant physiology, Israel's Dr Abraham Blum, was to respond to the plight and the need of farmers all over the world, including poor smallholders, whose livelihoods are constantly threatened.

One of the most significant responses to the many challenges posed by water stress has occurred in China. Dr Blum said China was defying trends in the developed world by massively boosting spending on agricultural R&D.

A dozen presentations by Chinese researchers demonstrated the breadth of the drought work being undertaken. Government start-up projects there are linking scientists with farmers to create a "second Green Revolution" based on more efficient and ecologically sound uses of water resources in conjunction with water-efficient farming systems and crop varieties.

Dr Peng Shigi from the Chinese Ministry of Agriculture provided a snapshot of the state of China's water resources. She explained that the development of irrigated agriculture had played an important role in China's agricultural development (only 30% of grain is produced by dryland farming). Today, 70% of China's total annual water supply is used in irrigation.

However, with urbanisation and rising living standards the amount of water needed for domestic and industrial use is on the rise, straining the nation's already overdrawn resources. More frequent drought events are further adding strain and rendering once-arable land desert. The ministry estimates that if left unchecked, the effects of pollution, climate change and land degradation will make drought events more frequent and catastrophic.

"Agricultural production suffers the threat of severe drought," Dr Peng said. "The direct reduction of grain output has (already) reached 20 million tonnes a year. Water savings and raising the efficiency of water use in agriculture is an important guarantee for agricultural development in the future."

Dr Zhang Qifa from Huazhong Agricultural University explained that past agricultural practices emphasised yield above all other considerations and led to the unsustainable use of nitrogen and phosphorus fertilisers and the indiscriminate use of pesticides, which added water-quality issues to overstrained water supplies.

"The Government is now calling for a second Green Revolution based around more sustainable farming practices, with Chinese scientists mandated to increase production while using less inputs and making more efficient use of water," Dr Zhang said.

Chinese agricultural scientists are targeting opportunities provided by both agronomy and plant breeding for water savings and efficiencies. Molecular breeding technology in particular is being scaled up and includes GM technology to test and deploy genes associated with 'drought tolerance' traits. These efforts are targeting both irrigated and dryland areas.

On the land management front, Dr Peng described three core strategies:

- Improve dryland production, especially by applying conservation farming techniques, recycling field run-off and making more water-efficient crops available—a strategy currently seeing sorghum heavily promoted to farmers by the Chinese Ministry of Agriculture.
- Limit the amount of water used in irrigated fields in ways that maximise yields. This approach is seeing drip irrigation, deficit irrigation (DI) and partial root drying (PRD) optimised for use in grain and horticultural production systems across China.
- Consideration for the needs of natural systems where competition between agriculture and natural ecosystems is leading to encroaching desertification.

Australia is already well advanced in many of these techniques and, through ACIAR, is helping their wider adoption in developing countries where there is growing momentum to adopt water-conserving farming techniques. Collaborative research projects are helping to adapt existing techniques such as zero-tillage and stubble retention, drip irrigation, DI and PRD for use in China, India, Bangladesh, Syria and Iraq.

On the breeding front there are major pushes to identify plant traits that improve water-use efficiency (WUE), especially in cereals.

Promising levels of genetic gain have been achieved, especially in maize, rice, pearl millet and wheat, with researchers from the centres of the Consultative Group on International Agricultural Research (CGIAR) playing leading roles. Once again, Australia is involved in a number of ways: through funds provided by ACIAR to the centres, through the involvement of Australian scientists, and in collaborative R&D projects.

CGIAR's International Maize and Wheat Improvement Center (CIMMYT) has achieved impressive results in maize using a selection technique called managed stress screening (MSS). The project, which has been running for 12 years, targets farmers in Africa and is headed by Dr Gary Atlin and Dr Marianne Bänziger.

The value of CIMMYT's protocol was formally tested in 2001–02 when its MSS-selected varieties were compared with those produced by other seed producers, including Monsanto.

"These were large experiments and the CIMMYT maize showed a 12–18% yield advantage over other varieties when tested in low-yielding environments," Dr Atlin said. "The yield differences were smaller but persisted in higher-yielding conditions. It seems unlikely that molecular markers or transgenics delivered the same gains for the time and money invested. So this breeding protocol works very well."

An agreement is now in place that will see CIMMYT's maize germplasm combined with Monsanto's drought-tolerance gene technology and field tested in Africa. The deal will see technology fees on any resulting varieties waived for African farmers.

Furthermore, the protocol has been adopted by the CGIAR's International Rice Research Institute (IRRI) to develop drought-tolerant rice varieties using field sites where water stress can be managed by draining and irrigating as needed. About 900 rice lines have been tested and IRRI has identified germplasm that yields 50–100% higher under drought stress.

"The CIMMYT and IRRI breeding programs have demonstrated that gains in drought tolerance from MSS are subsequently expressed in the target farming environment," Dr Atlin said. "Generally, MSS in maize and rice has proven adequately repeatable as a breeding strategy on a single-site basis."

Molecular breeding technology is also being applied. For drought, this primarily involves mapping regions of the genome associated with improved WUE, followed by either the development of molecular markers to facilitate selective breeding or gene discovery to develop GM varieties.

At Huazhong Agricultural University, Dr Zhang's team is using two genes identified by IRRI to change the performance of Chinese rice to common water stresses. These are the *Sub1* gene, which provides rice plants with tolerance to submergence underwater during flooding, and the *Saltol* gene, which provides a measure of tolerance to saline water. Projects are also underway to locate genes associated with drought tolerance and a dozen such genes are currently undergoing testing in an extensive transgenic program.

At the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), impressive gains have been made using the most drought-tolerant cereal crop—pearl millet—in collaboration with India's Central Soil Salinity Research Institute, the All India Coordinated Pearl Millet Improvement Project and the Institute of Biological, Environmental and Rural Sciences in the UK.

Pearl millet is the staple cereal and fodder crop grown in the hottest, driest regions of Sub-Saharan Africa and the Indian subcontinent, but Dr Rattan Yadav said that post-flowering drought stress consistently and drastically reduces yields and yield stability. However, a single discrete site in the pearl millet genome has now been identified that can account for 32% of yield variation seen between varieties during terminal drought.

"This site is associated with maintaining yield, biomass and harvest index under drought and in delaying leaf rolling," Dr Yadav said. "It also provides an added advantage under salt stress."

Similar mapping approaches are underway in wheat, durum, barley, sorghum, peanuts, cotton, chickpeas and common bean. Australia is involved in some of these efforts, with projects at the Australian Centre for Plant Functional Genomics, CSIRO Plant Industry and Queensland Primary Industries and Fisheries.

Most of the advances have come from measuring root and leaf characteristics long known to be associated with drought tolerance, Dr Blum said. However, he added that relatively few new drought-tolerance traits have been identified since the 1970s. The most valuable is carbon isotope discrimination—a technique developed in Australia and used by Dr Richard Richards and Dr Greg Rebetzke's CSIRO Plant Industry teams to develop more water-efficient wheat varieties.

Addressing delegates in Shanghai, Dr Rebetzke presented the next generation of wheat WUE traits under development at CSIRO. These include early shoot vigour, reduced tiller numbers, and the replacement of dwarfing genes that are more compatible with WUE.

"We sought an alternative dwarfing gene and found one (*Rht*) that reduces height without reducing seedling growth," Dr Rebetzke said. In adapted backgrounds, the early vigour trait is now associating with yield increases of 7–16%, reaching as high as 38% under some circumstances."

The Shanghai conference was the third time in 12 years that scientists have met under the Interdrought banner, with prior meetings in Montpellier, France, in 2001 and Rome in 2005. Because of the growing urgency surrounding drought and a drying climate, the period between conferences is being reduced to three years, with Interdrought-IV scheduled for Perth in 2012. ■

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