



WATER DEPTH THE ROOT OF THE PROBLEM

Indo–Australian collaboration is allowing plant researchers to attempt something that has defied breeders for years—adapting the root system of wheat to better perform in drought

BY DR GIO BRAIDOTTI

When it comes to breeding wheat better able to cope with water scarcity, there is one particular problem that has been taunting agricultural scientists for years—accessing deep soil moisture.

Just as crops are about to flower and set seed, residual water in the soil is frequently out of reach of the deepest roots of current wheat varieties. Breeders know that if they could change the ‘architecture’ of the roots they could make that water available ... and, as a consequence, increase food production. Until recently the insurmountable problem was the technical complexity of screening and selecting for different kinds of root systems.

However, from 2009 an ACIAR-brokered

project is allowing breeders from India and Australia to pool resources to crack the root problem. The scientists are sharing germplasm, field trials at four Australian and five Indian sites, and trait-selection technology in a bid to help dryland wheat farmers worldwide produce more grain from the same amount of water.

The project is the first undertaken as part of the Indo–Australian Program on Marker Assisted Wheat Breeding (IAP MAWB) with ACIAR and the Indian Council of Agricultural Research matching funding.

Pilot field studies have been underway in India since the 2008–09 growing season. Some key sites used in these studies are located in the central and peninsular states, where wheat is grown entirely on soil-stored moisture acquired during the monsoon; this makes them especially suited to root physiology work. With

little rainfall to confound the study, the Indian team has near-ideal conditions to screen for variation in root architecture and evaluate its effects on yield.

Over the next four years, the Indian scientists from the Directorate of Wheat Research, the Indian Agricultural Research Institute and the Agharkar Research Institute will be working with Dr Richard Richards’s CSIRO Plant Industry team in Canberra and Queensland, with Dr Michelle Watt serving as Australian project leader.

The CSIRO team ranks among the world’s most successful at developing physiological tests that can detect—from among thousands of lines—plant attributes that can lift yields in dry conditions.

The team takes an idiosyncratic approach that avoids selecting for ‘drought resistance’

(Opposite page) Visiting a CSIRO field site to look at wheat establishment and root vigour are Dr Satish Misra (left) of the Agharkar Research Institute and Dr G.P. Singh (right) of the Indian Agricultural Research Institute. They were shown around by CSIRO's Michelle Watt (second from left) and Dr Richard Richards (second from right).

since resistance traits often allow wheat merely to survive drought. Instead CSIRO looks to improve 'water productivity', an approach developed by Dr John Passioura, CSIRO's renowned plant drought physiologist.

"One of the main factors limiting progress when it comes to breeding for dry conditions is inadequate 'phenotyping'—by which we mean the ability to characterise plant traits with the potential to improve water-limited yield," Dr Passioura says. "Almost all such phenotyping in the laboratory relies on screening plants for their ability to survive severe water stress, yet better survival rarely means better production."

By focusing instead on lifting production, over the years Dr Richards and his CSIRO colleagues have developed phenotyping technology that has resulted in the commercial release of new wheat varieties capable of remaining productive under a wide range of water-limited environments.

"The emphasis on water productivity is

important because it opens three avenues for pre-breeders to identify better-performing wheat germplasm," Dr Richards says. "We can look for traits that improve the amount of water the crop captures, or the efficiency with which the crop uses the water, or the partitioning of growth into grain (the harvest index). If you can improve any one of those three then you will improve yield under drought."

To date, phenotyping technology developed at CSIRO Plant Industry has primarily targeted above-ground plant features. However, researchers know that root traits also stand to drive water-productivity gains, and the project finally shifts water productivity phenotyping research 'underground'.

Impressive gains are thought to be possible by selecting for deeper roots at around the time of flowering and seed-setting. Dr Watt says that any water taken up about this time is directly used for grain production. "We have calculated that the uptake of an extra 10 millimetres can

contribute to an extra half a tonne of grain per hectare," she says. "So the deep-root trait has very high water productivity: a high conversion of water into yield."

Root length in mature plants, however, is extremely difficult to measure, especially when comparing water productivity in hundreds of wheat lines. It requires field plantings in real cropping zones and coring of the soil to a depth of two metres to physically measure the root system. Yet that is precisely what the Indian researchers are doing: coring at the ideal trial sites to find out how deep the roots penetrate in a wide range of elite wheat varieties, Indian

PARTNER COUNTRY

India

PROJECT: CIM/2006/071: Indo-Australian project on root and establishment traits for greater water-use efficiency in wheat

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'Stay Green' on the mark

By allowing breeding programs to bypass complex and time-consuming field trials at multiple sites and in different seasons, DNA markers are an attractive upcoming technology and ACIAR is promoting their development for traits that can help some of the world's poorest farmers.

Of particular interest is a trait that evolved in Africa that is likely to relate to an extremely efficient use of water, as well as differences in rooting. The trait was discovered in sorghum, a staple food for about 400 million people in 30 countries. Sorghum grain and straw (or stover) are also valuable as livestock feed in dry or marginal areas, such as parts of northern Australia and in the post-rainy season (Rabi) in India.

Dr Paul Fox, ACIAR's crop improvement and management research program manager, says that Ethiopian sorghum lines that can fill grains and mature even through terminal drought are of particular interest. The tolerance is due to a trait called 'Stay Green', in which a few leaves stay green long enough to provide the starch needed to fill grain.

"Stay Green was identified in several sorghum lines, including one called 'pineapple top', a low-yielding plant type that is not suited to commercial cultivation," Dr Fox says. "So we have a project to use the DNA markers of Stay Green and insert them into varieties that farmers are commonly growing. This will allow breeders all over the world to move Stay Green into more productive sorghum varieties."

The project is being undertaken in a partnership between India and Australia headed by Dr Vincent Vadez and Dr Tom Hash from the International Crops Research Institute for the Semi-Arid Tropics, in India. Participating from Australia are the University of Queensland and Queensland Primary Industries and Fisheries, which are working with India's National Research Centre for Sorghum and the International Livestock Research Institute.

Field activities started in India during the 2008–09 Rabi and will continue through to 2012, involving the Queensland researchers who are working on predicting the possible effects of Stay Green on yield across environments using crop simulation modelling.

The researchers know that Stay Green is a complex trait involving many genes, gene interactions and gene-by-environment effects. Cracking the molecular and physiological basis of a major drought-tolerance trait stands to deliver potentially enormous benefits in the long run, and not just for sorghum breeders.

"If we understand a drought-tolerant trait like Stay Green in sorghum, then the potential exists to use those genes and markers, and their related mechanisms, in other major food crops such as rice, wheat or maize, and that could have huge impacts on food security," Dr Fox says.



PHOTO: EVAN COLLIS

Dr Paul Fox, ACIAR's research program manager for crop improvement.

PARTNER COUNTRY

India

PROJECT: CIM/2007/120: Improving post-rainy sorghum varieties to meet growing grain and fodder demand in India

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PHOTO: BRAD OULS

Dr Richard Richards

"That's the great thing about the collaboration with India—there is a huge benefit from doing the work jointly."

– DR MICHELLE WATT



(From left) CSIRO's Dr Michelle Watt shows Dr Satish Misra and Dr G.P. Singh a screen for root vigour at a project workshop in Canberra, in September 2008.

landraces and experimental CSIRO germplasm.

"A deep-root project on this scale has never before been attempted," Dr Watt says. "That is the great thing about this collaboration with India: they have the best field conditions to correlate root architecture and water productivity."

To make the most of the R&D opportunities, CSIRO intends to test the possibility of using simpler phenotypic tests to substitute for coring the soil. Under consideration is the use of thermal cameras to measure leaf temperature—a trait affected by the root's ability to make water available for transpiration by the leaves. Called 'surrogate traits', these substitution measurements offer immense benefits to breeding and research programs alike, but they first need to be rigorously validated under real field conditions.

"This ACIAR project can help validate the new technology because we are going to couple these measurements with direct coring and physical observation of the roots," Dr Watt says. "If these quick leaf measurements hold up in the field they could prove very useful for optimising water productivity and could

become surrogate traits that are very attractive for use by breeders."

Besides deeper roots, CSIRO is also planning to test for a whole suite of other water-productivity traits, including a plant adaptation that can increase the amount of water that crops can capture. CSIRO has previously developed wheat lines that undergo very rapid early shoot growth, a trait that allows crops to establish quickly and which, by providing ground cover, minimises evaporation from exposed soil. This shoot trait helps to conserve soil moisture.

"At CSIRO we found that if we select for more vigorous early shoot growth we can also adapt varieties to perform better under conservation farming systems, where stubble from the previous crop is retained and the soil is not tilled to conserve soil moisture," Dr Watt says.

The CSIRO germplasm was developed as part of Dr Richards and Dr Greg Rebetzke's water productivity pre-breeding program and is being made available to the Indian collaborators for further field evaluation. Also making their way to India are wheat lines that use the *tin* (tiller inhibition) gene to reduce the production of kernel-bearing tillers (or stems).

Dr Watt explains that the extra tillers tend to produce smaller kernels under dry conditions, and for Australian farmers this can incur a price penalty. The *tin* trait also offers a way to redirect the plant's energy away from tiller production and into root growth, allowing the plant to access extra water for grain production.

As each of these water-productivity traits are validated in the field over the next four years, new opportunities are being generated to benefit dryland wheat farmers, including stacking individual traits to consolidate breeding gains.

"That's the great thing about the collaboration with India—there is a huge benefit from doing the work jointly," Dr Watt says. "CSIRO has screening methods and is developing simple surrogate traits for complex developmental selections. India has the best field conditions to study root architecture and water productivity. And both countries hold some really interesting germplasm. Together we can realise the potential of these resources that ultimately provide a platform to identify important genes and develop molecular markers to make selective breeding far easier." ■