Researchers join forces to fight global threat to crops

PHOTO: MELISSA MARINO

Scientists around the world are working against the clock to build a genetic defence against a wheat disease that some fear could seriously destabilise global food security

Dr Paul Fox, ACIAR Crop Improvement and Management research program manager in New Delhi for the MAS wheat breeding program planning workshop.

BY MELISSA MARINO

A new variant of the ancient crop scourge, rust, is the target of a partnership between Australia and India to harness biotechnology in a bid to 'bullet-proof' wheat against this highly adaptable pathogen that has shown it can readily develop resistance to traditional genetic defences.

The emergence and steady spread of the new, virulent strain of stem rust fungus, Ug99, has heightened the urgency of the research to build new genetic resistances in wheat to protect against the pathogen, which is said to have the potential to not just reduce yields, but wipe out whole crops.

Named Ug99 after it was detected in Uganda in 1999, it has since spread on prevailing winds across the Red Sea to Yemen, and earlier this year was detected in Iran—far too close for anyone's comfort to the fertile Indo-Gangetic Plain of Pakistan and India, one of the world's most important bread baskets.

Although Ug99 is not yet known to be in Australia, it is important that breeding efforts ensure there is effective resistance in Australian wheat varieties. For India, which is at the front-line of a possible Ug99 incursion, the effort to build robust defences against it is of obvious and immediate importance.

Enter ACIAR and the Indian Council for Agricultural Research (ICAR) which, through a five-year marker-assisted selection wheat breeding program, are bringing together genetic resources of both countries to, among several objectives, boost resistance to Ug99 in wheat.

Dr Evans Lagudah from CSIRO Plant Industry, who is leading the Ug99 project within the broader joint program, says the aim is to avoid the use of just one resistance gene in wheat varieties. "It is to bring in genetic diversity, utilise different sources of plant resistance genes, use them in combination to ensure durable resistance against stem rust," he says.

It is a vision shared by Dr Paul Fox, ACIAR's Crop Improvement and Management research program manager, who says international collaboration will minimise the chance of any individual country releasing a variety with just one source of resistance.

"What you are doing then is potentially giving the pathogen a chance to mutate and overcome the resistance and that gene then becomes useless for the whole world," he says. "But if you had three effective genes in a resistant variety, the chances of getting simultaneous mutations to overcome the three genes is almost zero."

Of particular concern to scientists is that Ug99 can overcome many of the traditional resistance genes bred into wheat over decades to ward against stem rust, including the widely deployed resistance gene Sr31.

It has also shown a deft ability to mutate and overcome resistance genes such as Sr24, which at one point had protected against Ug99.

Resistance genes are facing further pressure with the spread of Ug99 to the Middle East—home to the barberry bush. This is an alternate host to stem rust, allowing the pathogen to survive after wheat is harvested and thus, evolve faster. And, while some scientists feel this evolution could result in pathogen strains with less virulence rather than more, no-one knows for sure what could arise.

Now, at a time when the world faces low wheat stocks, increasing demand, rising prices and predictions of global food shortages, most commercial wheat varieties are vulnerable.

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So as Ug99 knocks on the door of the bread basket of the subcontinent, scientists have stepped up their efforts against the disease, and the level of international cooperation. They are racing to breed wheat varieties with multiple sources of resistance from germplasm sourced from around the world before any spell of wet and humid weather creates the conditions for an epidemic.

The ACIAR–ICAR five-year program, whose Ug99 project is partnered in Australia by CSIRO Plant Industry and the University of Sydney's Plant Breeding Institute (PBI), is employing marker-assisted selection (MAS) to breed not only for boosted protection against rust and other diseases, but also for tolerance to drought and other environmental stresses, as well as improved quality.

MAS is a breeding technique employing 'molecular markers'—usually short fragments of DNA on specific regions of a chromosome near the target gene—which effectively 'flag' to breeders whether specific traits have been inherited. This means selection of traits is quicker and more efficient, which can potentially mean new varieties can be developed sooner.

The research will also feed into an escalating international response to Ug99, notably addressed this year by a $26.8 million Durable Rust Resistance in Wheat project involving researchers from 15 institutes worldwide and administered by Cornell University in the US under the umbrella of the Bourlag Global Rust Initiative (BGRI). Funding for the Durable Rust Resistance in Wheat project is being provided by the Bill and Melinda Gates Foundation.

While screening world wheat germplasm and developing markers for Ug99 resistance genes to complement the Australian–Indian research, the BGRI is also on the ground in Ug99 'hot spots' developing critical infrastructure, and research skills, and undertaking surveillance on the stem rust pathogen.

The global commitment will also be marked by the 11th International Wheat Genetics Symposium in Brisbane this August, featuring an ACIAR-sponsored session devoted to Ug99 involving all the key international players to formally coordinate the research effort.

Dr Fox says the aim is to develop a global action plan "so we can get the biggest bang for our bucks". He says international researchers will be ensuring there is no duplication and striving to have everyone's work as complementary as possible.

Wheat under cultivation on permanent raised beds demonstrates the value of good soil and water management.

The head of the Indian Agricultural Research Institute Department of Genetics, Dr K.V. Prabhu, who is also on the Australia–India MAS breeding program management committee, says productivity, waterlogging and the threat of Ug99 are key concerns for Indian wheat growers.

The partnership is an opportunity to address those concerns in advance and prepare, so the impact will not be as disastrous, he says. "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," he says.

Australia, although a small player in global wheat production, is in a strong position to help fight Ug99's spread. It has a long and successful record in combating rust through the 35-year Australian Cereal Rust Control Program (ACRCP) funded today largely by the Grains Research and Development Corporation and hosted by ACIAR Ug99 project partner, the University of Sydney's PBI, which is also home to an invaluable bank of knowledge and thousands of rust pathogen isolates dating back half a century.

ACIAR's other Australian Ug99 project partner, CSIRO Plant Industry, is the group behind the world's first cloned genes for plant rust resistance (in flax and maize) and has developed the acclaimed universal molecular markers that identify stripe rust and leaf rust

PHOTO: MELISSA MARINO

Australian Cereal Rust Control Program (ACRCP) head Professor Robert Park, from the University of Sydney's Plant Breeding Institute, at the MAS wheat breeding program planning workshop in New Delhi.

PARTNER COUNTRY: India

PROJECT DESCRIPTION: CIM/2007/064: Linking India and Australia to a global strategy for the Ug99 stem rust pathotype

CONTACT: Dr Paul Fox, fox@aciar.gov.au

resistance genes Lr34/Yr18, as well as markers for stem rust resistance genes including Sr24 and Sr31.

Also, and importantly, Australia has not bred extensively with the rust resistance gene Sr31, perhaps the world's most commonly used defence against rust and which Ug99 can overcome.

ACRCP head Professor Robert Park from the Plant Breeding Institute, who is also working on the Cornell project, explains that despite Sr31's global popularity driven by rust resistance and yield advantage, Australian breeders shied away from using it in milling wheats because of an associated defect known as 'sticky dough'.

This forced researchers and breeders to focus on other resistance genes to control stem rust. "Now we're in a very strong position to contribute internationally," he says. "Because we haven't used Sr31 we have a lot of useful resistance genes for stem rust in good, high-yielding varieties that other people can use."

Tests done in Kenya on 75 Australian cultivars showed around one third (29) were susceptible to the Ug99 strain that overcomes both Sr31 and Sr24. And now, joining forces with India will increase the potential for breeding varieties with even better resistance to Ug99.

India and Australia are a good match says Dr Fox, growing similar styles of wheat, but with important differences in their genetic backgrounds. "A lot of the genes India has been using for rust resistance are quite distinct from those Australia has been using so if we can come up with some combinations of genes from both countries they will be more robust than what either of us could come up with in isolation," he says.

In a key part of the current project, hundreds of varieties from Australia and India are being grown and screened for resistance against rust pathogens. The genomes of any resistant plant identified will be analysed and the genes that may be the source of that resistance identified. From there, molecular markers can be developed and used in breeding.

Already, the CSIRO team is busy developing markers for two known genes effective against Ug99—Sr13 and Sr22, two 'seedling resistance' genes that are quite strong but potentially can become short-lived when deployed alone.

Dr Lagudah says both of these genes exist in Australian varieties, but not in combination. They are in some Indian varieties but not in high frequency.

"The objective is to breed these two genes together as a 'package', ultimately into both Indian and Australian wheats," he says. "The advantage of having the two genes together is that it is much more difficult for a pathogen to overcome two genes than one at a time."

By using molecular markers, breeders will be able to identify specific regions of the chromosome that will always flag whether the Sr13 and Sr22 genes have been inherited in progeny without needing to wait for the plant to grow and express the genes' traits.

When the breeders make their crosses, they can select both genes and ensure the derived material carries both resistances. "Developing molecular tags is an effective tool that allows for the stacking of genes," Dr Lagudah says.

In the longer term, the researchers will also characterise and locate partial resistance but longer lasting 'adult plant resistance' genes that may be present in the Australian variety Hartog, and stack those with seedling resistance genes.

The stem-rust resistance genes could also be stacked with the molecular-tagged stripe and leaf-rust resistance genes Lr34/Yr18, further boosting resistance. These genes, that are always inherited together, not only provide broad-spectrum resistance to leaf and stripe rust, but have also been shown to enhance the level of stem-rust resistance genes in some wheat cultivars, Dr Lagudah says. "So the idea is to use genes like Lr34/Yr18 as the backbone upon which you build."

Although the advantages of building robust defences against Ug99 are clear in countries, such as India, that are geographically close to places where the pathogen is known to have spread, Australia too, will directly benefit from the research.

"We need to be aware of these exotic threats and do pre-emptive breeding," Professor Park says. "Ug99 may never turn up in Australia, or it might already be here. It's not a foregone conclusion but we have to make sure we have effective resistance in our material and stay engaged with the global community." ■