Can gene discovery methods halt the global march of wheat blast?

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Dr Sanu Arora and Professor Paul Nicholson of the John Innes Centre—leading the innovative research to combat wheat blast. Credit: Phil Robinson

An international research collaboration led by the John Innes Centre has used innovative genomic discovery methods to show how we might halt the emerging and highly destructive disease known as wheat blast.

In experiments researchers identified two genes that protected experimental wheat plants against exposure to the fungal pathogen Magnaporthe oryzae, which causes blast.

To make the discovery, the team used a technique called AgRenSeq, which allowed them to search for useful genes among a panel of heritage wheat varieties called the Watkins Collection. They also searched among wild grass relatives of wheat.

The Watkins Collection was collected from around the world in the 1930s and consists of more than 300 wheat lines or landraces containing disease-fighting diversity that existed in wheat before intensive breeding. Such collections of locally grown crops have, along with wild grass relatives of wheat, become a vital resource for researchers seeking genes that protect modern crops from emerging diseases.

Professor Paul Nicholson, a group leader at the John Innes Centre said, "We have made an important discovery on an emerging disease that threatens global food security and, in the process, highlighted the power of the Watkins Collection and the AgRenSeq genomic toolkit. Now our role is to interact with organizations such as (global research non-profit) CIMMYT to provide information on additional resistance genes and enable them to ensure that their breeding materials contain these genes so that they are protected against blast."

To identify resistance genes, researchers tested seedlings and spikes from the Watkins collection with specially modified isolates of the blast pathogen to identify which plants were resistant and which were susceptible to the fungus.

Then they used AgRenSeq, the gene discovery technique developed by

Dr. Sanu Arora a group leader at the John Innes Centre, to identify sections of the genome that showed gene activity in resistant plants.

This led to the identification of a resistance gene candidate Rwt3, which protects wheat by regulating an NLR gene. In plants NLR genes operate by encoding defensive proteins that detect pathogen effector molecules and trigger a protective response, like antibodies protect humans from infections.

The other gene discovered, Rwt4, is another defensive molecule called a tandem kinase. This gene was also found in the collection of Aegilops tauschii, a wild grass ancestor of modern bread wheat.

Glasshouse experiments using wheat plants in which the function of these resistance genes was lost showed they were susceptible to wheat blast isolates, confirming that Rwt3 and Rwt4 protected plants against blast.

The study, which appears in *Nature Plants*, also revealed that a version of Rwt4 termed Pm24 also protected plants against another significant disease of wheat, powdery mildew.

The method is potentially adaptable enough to find resistance genes that respond to geographically specific strains of the pathogen, says the research team. It offers proof of concept for how we might respond to emerging crop diseases by identifying resistance genes in heritage varieties or wild relatives and ensuring that these genetic barriers to disease are present in elite cultivars.

The collaboration, which includes groups from Japan and Saudi Arabia, now plans to make this information available to CIMMYT by providing genetic markers. These allow breeders to rapidly identify these genes in their collections and ensure that they include them in breeding blast resilient wheat cultivars.

Dr. Sanu Arora first author of the study said, "The disastrous effect of wheat blast in the wheat belts of South America, South Asia and Africa is a warning bell for Europe. We are not certain if this disease is already sitting on the horizon of Europe but the disease could potentially travel through human migration or seed import, therefore, it is critically important to defend this vital crop against the looming threat."

Dr. Jonathan Clarke, head of knowledge exchange and commercialization at the John Innes Centre, said, "This is a really good example of an international collaboration that is contributing to United Nations sustainability goals because global plant health is important to delivering food sustainability."

"A wheat kinase and immune receptor form host-specificity barriers against the blast fungus," appears in *Nature Plants*.

Wheat blast: A brief history

Wheat blast has left a trail of destruction across three continents since it was first reported in 1985 and is now regarded as a major threat to global wheat security. Consequently, the discovery and deployment of resistance genes against this pathogen are critical to mitigate this threat.

Caused by the fungal pathogen Magnaporthe oryzae, wheat blast, was first identified in Brazil in 1985 due to a "host jump" from ryegrass. The pathogen has since caused epidemics in Brazil's neighbors including Bolivia and Paraguay and further outbreaks have been reported in Zambia, India and Bangladesh.

Recent studies suggest that the host jump occurred because of a hybrid recombination of two species of the fungal pathogen. The search for resistant genes is urgent because modern wheat varieties have not been selected by breeders to include blast resistant genes in their programs.

The resistance genes in wheat Rwt3 and Rwt4 work because they recognize the pathogen genes PWT3 and PWT4 and consequently prevent infection. It has been proposed that the epidemics in Brazil occurred due to widespread cultivation of wheat lacking Rwt3 making them susceptible to ryegrass pathotypes.

Ryegrass pathotypes have also been associated with the outbreak of wheat blast in the U.S. This emphasizes the importance of maintaining Rwt3 and Rwt4 in wheat cultivars to prevent future host jumps.

More information: Brande Wulff, A wheat kinase and immune receptor form host-specificity barriers against the blast fungus, *Nature Plants* (2023). DOI: 10.1038/s41477-023-01357-5. www.nature.com/articles/s41477-023-01357-5

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