Activity 15

Genome Editing to Accelerate Pre-breeding Delivery of Improved Genetics

Lead Researcher
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KEY TAKEAWAYS

- **The leaf rust pathogen is constantly evolving and has overcome many of the current resistance genes**
- **This research explores using advanced biotechnology plant breeding methods for improving disease resistance in spring wheat varieties**
- **Researchers are using synthetic hexaploid wheat-derived populations where one-third of the chromosomes come from the wild relative species *Aegilops tauschii* to discover new genes to boost spring wheat tolerance to leaf rust**
- **10 backcross populations have been developed and screened**
  - The prime editing constructs were assembled, verified, and then transformed into the spring wheat variety 'Fielder' with new leaf rust resistance genes identified
- **Candidate wheat varieties with promising resistance to leaf rust were successfully tested in 2024**

This research activity, led by Andriy Bilichak of Agriculture and Agri-Food Canada (AAFC) in Morden, MB., aims to identify new genes to improve resistance to leaf rust in wheat and to transfer these genes into new, non-transgenic, wheat varieties to be grown by farmers in Western Canada. This research uses and builds upon previously developed and discovered wheat breeding material from research funded through Genome Canada (4DWheat) and the Canadian Agricultural Partnership (CAP).

Leaf rust can significantly reduce yield. Fungicidal crop protection products that are commonly used for wheat, primarily to control Fusarium head blight, are also effective against leaf rust. Genetic resistance is effective and nearly all wheat varieties currently have good genetic resistance to leaf rust. However, the leaf rust pathogen population is constantly evolving and has overcome many of the resistance genes currently used in Western Canada, and so the need to continuously incorporate new resistance genes into new varieties is important.

This research activity explores the potential of using advanced biotechnology plant breeding methods to improve disease resistance in spring wheat varieties for farmers in Western Canada. This has a high potential to lower crop protection use, decrease farmer input expenses, and slow pest resistance development for crop protection products. Furthermore, the global deregulation and acceptance of new plant breeding techniques, like gene editing, has provided an excellent opportunity to develop improved wheat varieties quicker and cheaper. Farmers will benefit from growing wheat varieties developed through new breeding techniques in the long term.

New wheat varieties targeted for Western Canada can be developed using the genetic diversity sourced from material that extends beyond those in popular commercially available varieties. Valuable genes can be identified in many species, including in the wild relatives of wheat, and these can then be transferred to new wheat varieties by using different plant breeding methods including the well-established method of making wide parental crosses to newer techniques such as genome editing.

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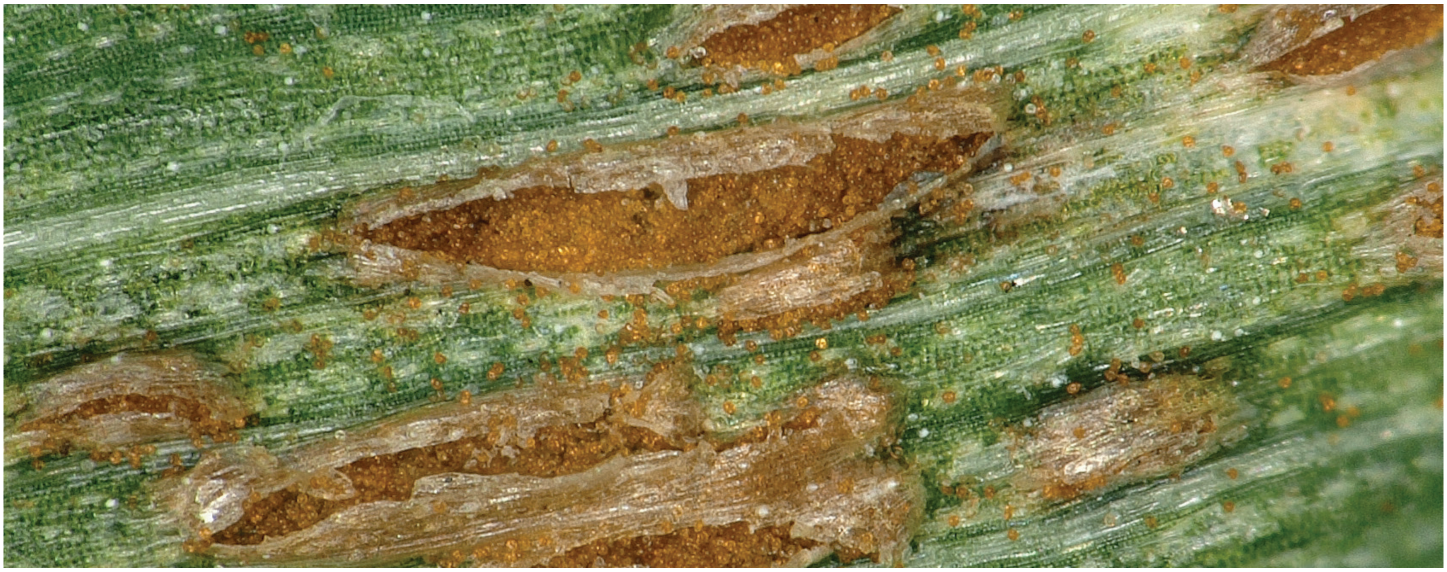

Leaf rust infection on wheat. PHOTO: BRENT MCCALLUM

Conventional breeding techniques, however, are usually cumbersome, not precise, and require greater resources like time, labour and money to transfer desired plant traits into new wheat varieties. For example, sometimes, when a conventional breeding method is used it's less precise because unwanted genes are transferred from a wild wheat relative to a new wheat variety, and this, in turn, requires a lengthier selection process, more field experiments, resources, and scientific expertise. Innovative and advanced plant breeding tools, like gene editing or cis-genic approaches, allow the precise transfer of an important gene or genes into new and improved wheat varieties in a timely, efficient, and economically robust manner.

However, before all of this can happen, beneficial genes must first be discovered to aid their plant breeding initiative. In this research activity, the genes within distant relatives of wheat are being explored, identified and tested. These researchers are using synthetic hexaploid wheat-derived populations where one third of the chromosomes come from the wild relative species *Aegilops tauschii* to discover new genes with the primary goal to boost spring wheat tolerance to leaf rust.

This research is being done at AAFC Research and Development Centres; Morden with Bilichak and Brent McCallum, Lethbridge, AB. with John Laurie and Ottawa, ON. with Sylvie Cloutier and Frank You.

To date, 10 backcross populations have been developed by Cloutier which were then mapped with hundreds of thousands of genetic markers with help from You. McCallum screened the 10 populations with different races of leaf rust, and the quantitative trait mapping was done by You. The genetic assemblies of the parental lines were completed by Cloutier and You, and Laurie tested many of the components of the cis-genic system, with further evaluations planned to begin shortly. The prime editing constructs were assembled, verified, and then transformed into the spring wheat variety 'Fielder' by Bilichak and new leaf rust resistance genes were identified.

Candidate wheat varieties with promising resistance to leaf rust were successfully tested in 2024 in disease nurseries in Morden. The breeding material was grown with leaf rust susceptible wheat lines were artificially inoculated with the fungus that causes leaf rust. Leaf rust develops on these susceptible wheat lines, producing wind-blown spores that infect surrounding test lines. These nurseries are also irrigated regularly to promote disease development. Additional leaf rust inoculum is blown into these nurseries from natural infection produced from infected wheat fields surrounding the field experiment. The combination of artificial inoculation by the susceptible rows, regular irrigation, and naturally occurring inoculum results in high levels of disease severity that these researchers use to evaluate candidate material.