Out in the cold: Enhancing frost tolerance in wheat

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Wheat spikes from plants grown in the warm compared to plants subjected to a freezing treatment at the start of flowering. Credit: CSIRO

Rugging up against winter chills is a cozy and easy option for most of us. But our crops are facing frosts and freezing temperatures without the warmth of winter woolies. Frost poses a significant threat to agriculture, particularly in Australia's wheatbelt regions.

Plants have evolved to optimize the timing of their growth and flowering with seasonal light and temperature patterns. But climate change is beginning to impact these seasonal patterns.

Despite an overall warming climate, late spring frosts are occurring more

often than they used to. These frost events, especially during flowering, can drastically reduce wheat yields across the Australian cropping belt. Farmers are estimated to be losing hundreds of millions of dollars per year as a result.

Frost damage to plants

Any avid gardener or farmer knows that frost can be a plant killer. Crop scientist Dr. Fernanda Dreccer says frosts inflict damage on a cellular level to plants.

"When plants encounter cold or freezing nighttime temperatures, the lipids in their cell membranes compress," Fernanda says.

Lipids are fatty, waxy or oily compounds. They are an important part of the structure of cell membranes. Upon warming, these membranes often puncture, leading to dehydration and often irreversible damage.

"If this occurs during critical stages of plant development, like during flowering, critical structures can be damaged that affect the plants' ability to reproduce and produce grain," she says.

Building frost tolerance

Modeling suggests reducing crop frost sensitivity by as little as 1°C would increase growers' annual return by about $360 million.

Our research is tackling this problem in several ways. We're growing wheat cultivars under a range of environmental conditions, including mimicking exposure to frost. We're also investigating genes, metabolites (substances produced during metabolism), and plant structures to determine what makes wheat more or less sensitive to frost.

Metabolites and membranes

Fernanda's team is focusing on enhancing the ability of the plant's cell membranes to maintain flexibility. This quality helps plants survive frost.

Her research team is investigating what it takes for cells to remain hydrated under low temperatures.

"Membrane flexibility is determined by the plant's metabolite and lipid profiles, and we're examining genes and environmental conditions," Fernanda said.

The team hopes to understand the connection between the accumulation of metabolites and lipids, and how vulnerable wheat is to frost. They are also developing a non-destructive way to examine the metabolic composition of plant tissue.

Genes for frost tolerance

Senior principal research scientist Dr. Chris Helliwell and his team are tackling the problem using genomics tools.

The team is experimenting with precise exposure to freezing stress in controlled environment chambers. Through this work, they hope to identify genes or genetic regions associated with decreased frost sensitivity in wheat.

"We're targeting an early stage in reproductive development, which is particularly sensitive to frost," Chris says.

With more than 400 wheat varieties to test, this will take time. But Chris

says they will eventually identify markers for genes that control frost tolerance.

"Because it's difficult for plant breeders to select for frost tolerance, current varieties may or may not have those particular markers," Chris says.

"Once you know what they are, breeders can then select for the lines that have those markers in them as part of their breeding process."

Protective plant anatomy

Observations from the field suggest variations in plant structures—like the structure of different wheat spikes—may reduce sensitivity to frost damage at flowering.

Our chief research geneticist Dr. Greg Rebetzke and his team are investigating how much frost damages plants' reproductive structures. Greg is comparing unique wheat genetics looking for specific morphological and anatomical traits (features).

"These traits may provide greater physical protection or could reduce the formation and accumulation of ice crystals on newly-emerged wheat heads," Greg says.

"Identifying plants that produce these protective features provides another avenue to fortify wheat against frost damage."

Breeding frost tolerant wheat

All this research is helping to enhance frost tolerance in different varieties of Australian wheat. Our researchers hope to provide valuable

tools for plant breeders to improve wheat resilience during harsh frosts.

If successful, plant breeders will gain access to advanced selection methods and parental lines with lower frost susceptibility. Eventually, farmers will benefit from better wheat varieties that can withstand frost conditions more effectively.

Provided by CSIRO

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