BREAKING NEW GROUND IN BREEDING WHEAT FOR DISEASE RESISTANCE

Take a technological breakthrough, add a fortuitous break, and you may get the ingredients for another breakthrough. Can a gene that makes rice immune to rust, the worst disease of wheat, point the way to new strategies for wheat to fight disease?

Last year, Alessandro Pellegrineschi, a cell biologist with CIMMYT, considerably raised the transformation rate of wheat—the percentage of wheat plant clones that successfully incorporate a new gene and associated traits through genetic engineering.*

Transformation rates are critical to the successful use of genetic engineering for plant improvement. Low rates greatly reduce the likelihood of producing a viable plant with a selected gene and trait. High rates produce more viable plants and give researchers and breeders more materials with which to experiment.

A BREAKTHROUGH IN EFFICIENCY

By mid-1999, Pellegrineschi had taken wheat transformation efficiency rates from an average of 0.2% to 0.9–1.0%, a five-fold increase. He did this by making incremental improvements in the transformation protocol, such as using "cleaner" DNA, optimizing selection standards for embryos, and identifying key environmental conditions for the mother plants of the embryos used in the transformation process.

Although encouraged by his results, Pellegrineschi was far from satisfied. His goal was a 5% transformation rate. "Shooting" 1,200 wheat embryos with a 5% transformation rate every week would produce 60 transformations, enough to test one gene construct and produce at least one viable plant capable of transferring the trait to its progeny. Over the course of a year, this would allow scientists to insert more than 50 different genes into plants—providing a lot of new material for breeders.

Twelve months after setting his target, Pellegrineschi and his team far exceeded their ambitious aim. Wheat transformation rates of 6–7% are now the norm at CIMMYT, and some elite lines exhibit average transformation rates between 10 and 15%. “The biosafety greenhouses are full,” says the researcher, “so we can now focus on other issues.”

A Fortuitous Break

Lee Jang-Yong had just attended a seminar in early 1999 at CIMMYT by the Deputy Director General of the Korean National Institute of Agricultural Science and Technology, an institute under the umbrella organization of Lee’s sponsor, the Rural Development Administration. Eun Moo-Young had given a presentation in which he touched upon a gene in rice—the receptor-like protein kinase gene—that might help explain rice’s immunity to rust diseases.

Interest in Eun’s aside about the gene was fairly low. CIMMYT develops wheat and maize, not rice. As in most advanced research institutes, in CIMMYT at that time genetic engineering for wheat was more promise than reality. The large size of the wheat genome and a lack of knowledge about the response of the plant in tissue culture severely constrained advances.

While the gene faded off the radar screens of some in the audience, it sparked an interest in Lee. He followed up on the matter with Eun, who agreed to provide the gene to CIMMYT for research. Lee knew of no successful transfer of a gene from rice to wheat before, and in fact he was not sure if anyone had even tried it. But because Lee was working in that special international mix of scientists and expertise which one finds at CIMMYT, he knew of Pellegrineschi’s accomplishments in boosting wheat transformation rates and decided to approach him.

As Pellegrineschi recalls, “Lee told me he had this interesting rice gene and he thought it could be important for developing rust resistance in wheat. I hadn’t heard of the gene before. Lee created a gene construct here at CIMMYT and we quickly kicked off some transformation work.”

The initial results were striking. Plants were infected with one of the more virulent races of rust found in Mexico. The transformed plants showed “only spots of necrosis, reflecting only a modest infection,” compared with highly lethal infections on the control plants. Pellegrineschi and Lee were ebullient over their results but also recognized their own limitations in this area. They were not comfortable with their disease inoculation skills, and neither researcher considered himself a pathologist by any means. It was time to call in another expert.
A Breakthrough for Wheat Disease Resistance?

“I was very excited to see the results,” says CIMMYT wheat pathologist Ravi Singh, “because it’s the first time I’ve seen before my eyes that transformation can provide this kind of resistance.”

Singh, who has studied rust for 20 years, is quick to point out that while the gene comes from rice, which exhibits immunity to rust, he thinks it unlikely that it will confer the same level of resistance to wheat. He explains that there are two types of rust resistance: hypersensitive or race-specific resistance, which is based on a “major gene,” and non-race-specific or “slow rusting” resistance, which relies on the accumulated effects of numerous minor genes.

In race-specific resistance, a gene elicits a response to a specific race(s) of rust and fights it by killing the tissue in the immediate area of the infection, thus denying the pathogen a source of food (rust feeds only on live tissue). While this sort of resistance sounds ideal, it holds up only for three to five years. Slow rusting resistance, on the other hand, allows the rust pathogen to continue feeding on live cells but fights it within the cells, meaning that infection is reduced to a level that does not seriously damage the plant or reduce yields. This type of resistance is not subject to breaking down, although crop losses can be significant when a rust epidemic is severe.

Singh, who is now conducting more elaborate tests with the transgenic plants, says that they exhibit resistance responses closely resembling race-specific responses, so he doubts that this single gene represents a magic bullet (with truly novel characteristics) against the disease. Nevertheless, more experimentation is needed to confirm this supposition, and even if the gene turns out to be race-specific, it could still be a valuable asset when stacked or pyramided with other major or slow-rusting genes within a wheat line.

The real breakthrough with great potential impact, according to Singh, lies in the process itself. “A lot of effort in conventional breeding goes into looking for and transferring alleles and genes. The exciting aspect of this [wheat transformation process] is the fact that if we can identify something in rice that can be expressed in wheat, we can now investigate moving other genes with known functions into wheat. Traits such as heat tolerance, or resistance to fusarium head scab in durum wheat, would be invaluable.”

Experiments and research strategies are already in place to determine if the rice gene can help produce resistance to a wide diversity of rust races as well as a host of other wheat diseases, including fusarium, yellow rust, helminthosporium, and septoria. “We are producing adequate supplies of seed and plan to test more widely,” says Singh. “It looks like this will be quite an exciting year.”

Researchers at the Right Place, Right Time

Lee and Pellegrineschi share that sentiment and are quick to attribute the advance to the international research environment of CIMMYT. Lee notes that little work on wheat is carried out in Korea, and none of it employs transformation. “Even with this gene in hand,” he observes, “it is pretty unlikely that anyone would have thought of using it with wheat.”

“It was the right place and the right time,” Pellegrineschi says with a grin. “Our two projects crossed inside CIMMYT, and that’s why we’ve been able to have this rapid progress. Working back in our labs at home—in two different institutions in two distant parts of the world—it would have taken a long time to achieve this, and actually, it might never have happened. Now we have immediate collaboration and something to show for it. This doesn’t happen just anywhere.”

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