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The promise of perennials

Working through the challenges of perennial grain crop development

by Evan Lubofsky

It's early spring, and among a series of brown and barren crop fields, one field stands out. It's covered with a stand of lush green grass. It's a sight to behold

and while the grass may take on the appearance of a slender barley or rye, this species is different—it's intermediate wheatgrass, a perennial plant that will be grown for its seed, which will be harvested as grain and ultimately used for food.

Originally brought to the United States from Europe and Asia as a source of cattle forage, intermediate wheatgrass was first identified as a potential grain crop in the 1980s by the Rodale Institute, a non-profit agricultural research center in Pennsylvania. Rodale had been searching for a more sustainable crop that, unlike wheat, corn, and other annuals, could be planted once and harvested for years.

About 10 years and two cycles of selection later, Rodale handed the baton to the Land Institute, a non-profit sustainable agriculture research organization in Kansas, which has trademarked the wheatgrass Kernza and is currently breeding the grain in collaboration with a number of universities in the U.S. and Canada.

"We're really excited about Kernza and have started a large-scale agronomic research program based on intermediate wheatgrass," says ASA member Jake Jungers, a research associate in the Department of Agronomy and Plant Genetics at the University of Minnesota. "We're trying to figure out how to grow this perennial crop, to harvest seed from it and manage it in a way where we can have profitable seed yields for multiple years under

low management regimes. Based on the results we're getting, we think it could be a game changer on the perennial grain crop front."

The enthusiasm has spread. Scientists from a range of disciplines are collaborating on Kernza, including agronomists, soil scientists, botanists, geneticists, and food scientists. And it's not just the science community: food retailers, café owners, farmers, and even breweries have all jumped on the perennial bandwagon, hoping to see Kernza revolutionize agriculture as we know it today.

Sustainable Benefits

It's hard to argue with the advantages of a perennial grain crop like Kernza. By breaking the repetitive

The roots of the perennial grain crop Kernza (left) are much deeper than those of annual winter wheat (right), improving soil structure, decreasing erosion, and reducing the need for inputs, which in turn, helps curb pollution from leaching and reduces reliance on fossil fuel-burning farm equipment. *Photo by Jim Richardson and courtesy of Patagonia Provisions.*

plow-plant-harvest cycle of annuals, perennials reduce soil erosion caused by annual farming, and their deep roots help stabilize the soil. Fewer inputs are required since their roots can utilize water and nutrients much deeper than annuals. This not only makes perennials more drought resistant, but it helps curb pollution from leaching and reduces reliance on fossil fuel-burning farm equipment.

"Perennial grain crops represent one potential solution to manage soil and water resources a lot more effectively and ameliorate a lot of the negative consequences of crop pro-





While progress has been steady over the past two decades, the process of breeding intermediate wheatgrass is fraught with a number of challenges, including overcoming lodging (**above**) and small seed size (**right**). Photo above courtesy of The Land Institute and photo to the right courtesy of Flickr/Andrey Zharkikh.

duction today,” says ASA and SSSA member Steve Culman, an assistant professor and soil fertility expert with Ohio State University, who is collaborating on Kernza research. “No one’s guaranteeing that they are going to be the magic bullet that cures everything, but from a conservation perspective, it’s important that we continue to invest in these crops and at least try them out to see which ones are fruitful and which one’s aren’t.”

Breeding Challenges

Developing a crop that is small in stature and has the yield of annuals with the lifespan of perennials is a tall order and one that requires long-term commitment and substantial investment. According to Lee DeHaan, a plant geneticist with The Land Institute, while progress has been steady over the past two decades, the process of breeding intermediate wheatgrass is fraught with a number of challenges. Seed size, for example, tends to be small with intermediate

wheatgrass, particularly in dense fields. So, DeHaan and his colleagues have been working towards identifying and using the genetic variability for seed size.

“Increasing seed size is important since it makes harvesting easier, increases yield, and improves the endosperm-to-brain ratio,” he says. “We’ve been working towards increasing seed size in dense stands, but it’s been difficult, and we haven’t been able to make as rapid progress in this area as in others.”

Another trait that’s been slow-going for DeHaan and his team is making intermediate wheatgrass resistant to lodging—which is when crops fall over due to their tall statures and weak stem. Lodging can prevent seed heads from growing and producing grain. Lodging also makes harvesting difficult since grain ultimately needs to be removed from plants off the ground.

The main challenge here is dealing with the positive association between

crop height and yield; the crop needs to be tall enough for high yield, but not so tall that a slight breeze topples it over. Breeding for reduced height, according to DeHaan, will involve using molecular markers to identify regions of the genome that contribute to reduced height without limiting yield. Making progress in this area will likely rely on being able to select on the basis of these markers.

DeHaan also views breeding for sustained yield as a trouble spot that still needs a great deal of work. With Kernza, grain yield looks pretty good the first year, excellent the second year, but begins to plummet in Years 3 and 4 as the stands become more dense.

“Sustained yield in a dense stand is difficult to breed for because the best way to measure it would be to plant genetically uniform dense plots and measure their yield for numerous years,” DeHaan says. “This requires resources and time. I’m looking for shortcuts, such as genetic markers that may be linked to sustained yield, and identifying traits that could predict sustained yield, such as reduced tillering or increased stem diameter.”

One option that potentially sidesteps some of the breeding issues is hybridizing annual wheat with perennial wheatgrass vs. domesticating a brand new crop. But according to DeHaan, hybridization is like gambling—there are no guarantees—whereas domestication is akin to long-term investing.

“The hybridization route might be a shortcut because you can use the genes of the domestic crop directly in the new perennial crop,” he says. “However, like many shortcuts, it may not turn out to be much shorter in reality. Making wide crosses involves a lot of genetic problems, which can be difficult to resolve. You may make a sudden breakthrough that solves a major issue, so you could have a great crop quickly. Or the problems could be so difficult that they will take a lifetime to solve.”

Dig Deeper

Read more about this topic in these journal articles:

- Soil and Water Quality Rapidly Responds to the Perennial Grain Kernza Wheatgrass. See <http://bit.ly/2dLUQs4>
- Establishment and Optimization of Genomic Selection to Accelerate the Domestication and Improvement of Intermediate Wheatgrass. See <http://bit.ly/2dLVbes>

Management Issues

Beyond breeding challenges, growing perennial wheatgrass presents formidable management challenges to contend with. For example, proper fertilization is a delicate balancing act that makes it tricky to apply just the right amount of nitrogen. There needs to be enough nitrogen to boost grain yields but not so much that the plants grow too tall and fall over.

Row spacing is another issue. When perennial plants become too crowded and rows become too dense, they don't produce as much seed. After four or five years of growth, the plants mesh together in sod-like fashion, making it almost impossible to tell that discrete rows ever existed. Good for weed control and soil protection; bad for yields.

"Perennials seem to sense how dense the area is—as if they are responding to environmental cues," Jungers says. If a stand becomes sod bound, we see fewer and fewer of the plants that seed. Yields start to drop during Year 3, and then in Year 4 and beyond, they drop dramatically."

According to Jungers, there are a number of approaches being taken to solve the plant density/spacing issue. He and his team are experimenting with tilling out strips in crowded stands and even spraying herbicides in strips to interrupt the inter-row spacing of the plants and make more room.

"We are looking at ways to maintain stand density from the start to sustain grain yields, but also looking at ways to fix old stands that have become less productive."

A Path Forward

Breeding and management challenges aside, perennial grains are moving forward. More than 200 ac of Kernza have been planted throughout the U.S. and beyond, and adventure clothier Patagonia is investing in the crop as part of its recently established sustainable food business venture, Patagonia Provisions. In October, Patagonia Provisions announced the release of the first commercially available beer to be made with Kernza, Long Root Ale.

"We're at an exciting point right now because we've partnered with Patagonia Provisions, and we're growing 120 ac of Kernza for them in conjunction with a group of farmers in northern Minnesota," Jungers says.

Beyond Patagonia, however, the economic drivers for perennial grain development have been limited. Certain wheatgrasses have been eyed for biofuel production, but cheaper oil and gas prices in recent years have tempered excitement around these so-called energy crops and stagnated their development. But Jungers does see a commercial path forward: he feels leveraging Kernza as both a grain crop and a source of cattle forage could give growers an alternate revenue stream and reduce risks if the grain market isn't fully developed or experiences volatility.

"With intermediate wheatgrass, there's a lot of vegetative biomass growth in the early spring and in the fall after harvest," he explains. "All this leafy green ma-



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terial would be nutritious forage for cattle. A dual-use crop and forage system would give farmers more options and make the crop more economically viable."

According to Culman, while there's been solid, steady progress with Kernza, those looking to bear fruit overnight can forget it. He says a great deal of work still remains in taking the grains from farm to table—something he's optimistic about.

"In some ways, perennial grains have traditionally been relegated to being a pretty far out, radical idea," Culman says. "But the reality is that there's a lot of scientists from all over working on this right now—it's not some pie in the sky dream, and progress is being made. Do we have a long way to go? Of course, we do. But if you look at the 50 to 60 years of intensive breeding and billions of dollars that went into corn, you quickly realize that you can't expect a lot of progress without the investment."

E. Lubofsky, contributing writer to CSA News magazine

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