Annual Report
Fall 2014

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Wes Jackson on the need to seize the moment

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— Wes Jackson
From his Prairie Festival address, Sept. 28, 2014

Small plots of sorghum and Kernza thrive in East Bank breeding fields at The Land Institute south of Salina, Kansas, where scientists are developing perennial grain crops.
About The Land Institute

The Land Institute, founded in 1976, is a nonprofit 501(c)(3) research and education organization funded by charitable contributions from individuals, families, organizations and private foundations. We are creating a new agriculture informed by nature’s ecosystems. Our scientists are developing perennial grain species to be grown in diverse mixtures that will require less fossil fuel, conserve soil and water, and weather the droughts and deluges that will become more frequent with climate change.

Contact us
2440 E. Water Well Road
Salina, KS 67401
(785) 823-5376
info@landinstitute.org

Leadership
Wes Jackson, President and Founder
Tim Crews, Director of Research
Jayne Norlin, Director of Institutional Advancement
Scott Seirer, Managing Director
Josh Svaty, Vice President

Spreading the word
Web site: www.landinstitute.org
Facebook: www.facebook.com/TheLandInstitute
Magazine: Land Report (published 3 times a year)
E-Mail newsletter: The Scoop, Signup at our web site
Annual event: Prairie Festival, Sept. 25-27, 2015

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Selected presentations
October 2013: Kansas State University, Center for Sorghum Improvement, “Breeding progress of perennial sorghum,” Manhattan, Kan. (Cox)
November 2013: Shaanxi Agricultural University and Yunnan Academy of Agricultural Sciences, multiple research presentations. Kunming and Yangling, China (Van Tassel), Cox, Crews, Wang.
November 2013: American Society of Agronomy Annual Meeting, “Progress in Developing Kernza Wheatgrass As a Perennial Grain” and “Developing Perennial Grains for Climate-Smart Agriculture,” Tampa Bay, Fla. (DeHaan)
February 2014: University of Kansas, Department of Ecology and Evolutionary Biology Seminar, “The ecological and evolutionary rationale for mimicking natural systems in agriculture,” Lawrence, Kan. (Crews)
March 2014: Iowa State University Sustainable Agriculture Program Lecture, “Current Efforts to Domesticate Perennial Grains,” Ames, Iowa (DeHaan)
May 2014: Cornell University, Crop and Soil Sciences Department Seminar, “Perennial Grain: Sustainable By Design” Ithaca, N.Y. (DeHaan)
August 2014: Organic Valley Dairy, Perennial oilseed field tour at the Odessa Demonstration Field Open House, Caiston, Wisc., (Van Tassel)
August 2014: Aspen Global Change Institute, Frontiers in Global Change Research, “Agriculture: driving global change for 10,000 years and still going strong,” Aspen, Colo. (Crews)
October 2014: American Association of Cereal Chemists Annual Meeting, “Grass to Grain: Sustainable food by design” Providence, R.I., (DeHaan)

Selected publications

Cover photo
Claire Trail and Jamie Bugel, who spent the summer in our fields as interns, use an aluminum cone to stuff hand-harvested stalks of perennial wheat into paper bags. The harvest from the individual plants will be analyzed for grain Crops, growth in the lab and seeds from promising plants will become candidates for future breeding.

Annual Report photography by Managing Director Scott Seirer

Goal: Developing relationships

By JAYNE NORLIN
Director of Institutional Advancement

The “consecrated constituency” we speak of so often includes families like the Simpsons and the Evaneses, whose combined support in 1976 significantly underwrote The Land Institute’s entire first-year budget. A review of our current donor list will show those names still among the 2,013 individuals and organizations supporting us last year. Our financial stability today is largely the result of this steadfast support. But if we want to thrive in the future — beyond the lifetimes of Land Institute pioneers — we have to consecrate a new generation of supporters. And that requires reaching out in different ways.

Last year we launched a new website and an official Facebook page. They shine a brighter light on our people and work, and tell us what you, our followers, are most interested in. Not surprisingly, it’s our work that attracts the most “clicks.” Take a look online and see interns and technicians harvesting perennial wheat, post-doc researcher Siva Damaraju looking for atmospheric nitrogen fixation in native grasses, and science director Tim Crews working with perennial rice researchers in the Yunnan Province of China. Your gifts support all this work — and more. Thank you!

Another new strategy was to host a major gathering offsite — way offsite — in New York City. When New York Times food writer Mark Bittman proposed a public interview with President Wes Jackson and his good friend Wendell Berry, and New York-area board members offered to help, it was an opportunity we couldn’t let pass.

So on a rainy Friday night in April, Mark, Wes and Wendell took the stage of The Great Hall at Cooper Union, the same spot Abraham Lincoln famously spoke from in 1860. Thanks to generous board and foundation support, we offered the event for free and a large, enthusiastic crowd was on hand as the trio addressed questions about food, farming and climate change.

It was a magical evening. As a direct fundraiser, it was a modest success. As a friend raiser, it was a slam-dunk, introducing The Land Institute and our agriculture revolution to a host of new friends we invite to become newly consecrated constituents.

Will we do it again? You bet — maybe somewhere near you.
A new expression has become popular in relatively recent times. It is called “ecological intensification.” Agricultural scientists have heard the severe critique of the Green Revolution and, when possible, don’t want to make the same mistakes again. Diversity is called for, along with chemical reduction and more of nature’s services. Thus the new organizing term: ecological intensification.

Two camps seem to be emerging around the expression. One, while featuring more technological cleverness (precision planting, molecular tools, GMO’s), also includes greater use of rotations and cover crops to satisfy the biodiversity need. In this camp, a combination of agriculture engineers, molecular biologists, geneticists, and agronomists are gearing up to launch a more benign Green Revolution. Annual grains are still the “hardware.” What new “software” is being imagined seems likely, to those of us at The Land, to be of limited effectiveness. Grain fields need high nutrient retention. They need to accumulate organic matter and manage soil water. But once vegetation is cleared from the field, whether with the plow or herbicides, those necessary goals are hard to meet. Annual grain plants are not in the ground long enough for soil microbes and invertebrates to fully protect and enhance soil quality. And though soil erosion may be reduced somewhat, it won’t be nearly enough.

We believe society needs to embrace longtime considerations as well, and that distinction puts us in the other camp devoted to ecological intensification. We’re working to increase the variety of “new hardware” for solving the Problem Of Agriculture, which translates into a new paradigm. And we are not alone. An increasing number of scientists, but still a small minority, have chosen natural ecosystems as the highest standard for ecological intensification! This new hardware is winning the geneticists new colleagues, mostly young ecologists and evolutionary biologists eager to apply their knowledge and skills to grain agriculture. From their disciplines, billions of dollars’ worth of research results, accumulated over the past 150 years, stands ready to be applied.

Beyond the wide hybrids between current annual crops and their wild perennial relatives, our researchers have been both surprised and encouraged by the rapid genetic response to their selection involving two wild species: Intermediate wheatgrass and silphium, a relative of sunflower. The former became Kernza, our trade name, and the latter promises to be an important oil seed crop. The gains prompt us to do an extensive inventory of herbaceous perennials or shrubs that produce hard seeds. This effort will be coupled with analysis of what happened during the domestication of the annual grains, and from there we will explore how it could be repeated with wild perennial candidates.

The challenge will be less for some species than for others. Our plant breeders already are transferring knowledge from wheat and other related grains to Kernza. Lee DeHaan has found in Kernza what is called the q gene, which in wheat allows both shatter resistance and free threshing, and is increasing its frequency in all of his populations. We are living in just the right time to expect success sooner than was once imagined. New computational power makes possible the evaluation of large numbers of plants for intermating potential, and new genetic techniques will help us with that.

But any new crop will require more than breeding and genetics. Interdisciplinary teams will be necessary. Here, too, we have arrived at an opportune moment as a growing number of professionals in agronomy, plant pathology, soil science, food science, economics and social justice are joining our camp. They are recognizing that natural ecosystems are the best models for ecological intensification. This is exciting to us, knowing from the history of science that when two or more disciplines come together we can expect fruitful research.
Our sorghum is hitting the road

Here’s a dilemma for the breeder of perennial sorghum:
“Plants that survive the best are those that produce ample number of rhizomes,” said Stan Cox, who is breeding perennial sorghum at The Land Institute. “They also tend to produce more stems and smaller heads. That in itself isn’t necessarily a hindrance but those high-tillering plants also tend to waste a lot of energy on vegetative growth. The goal of all of these projects is to divert more of that above ground biomass into the grain.”

After more than 10 years of careful selective breeding, we’re having success.
“In the past year, we completed the three-year retrospective study where we took lines that were used as our original foundation of the breeding program back in 2002, and selections that were made in 2006 and 2009, and compared them,” Cox said. “That’s a short time for a breeding program. For just sheer grain yield, there has been a significant increase. And it was achieved without losing perenniality.”

But in some instances, sorghum perenniality turns on cold tolerance, and there are many parts of the world where the temperate climate means these plants are strongly perennial.
“We’re not throwing away material that is more productive and more like a crop plant but doesn’t have the cold tolerance to survive here,” Cox said. “It may offer opportunity to get perennial sorghum sooner in another environment.”

So we have plants being grown in Mali, Ethiopia, Uganda, South Africa, as well as the Yunnan province of China, and several locations around the United States.

As with our other breeding programs, we are accumulating genomic information about the plants we breed, which promises to help us positively identify key traits in successive generations.
Relocating these plants to other parts of the world isn’t without its challenges.
“You take a variety from one part of the world where it may do very well, and it’s almost certain it won’t do as well if you take it to the other side of the world.”

— Stan Cox

No. 12F620: A survivor’s tale

Its name — 12F620 — is as innocuous as its appearance. Shuwen Wang has pulled up a photograph of a perennial wheat plant on his laptop. The image is of a modest-looking clump of a plant, one that looks remarkably like the other plant clumps nearby.

“I am most excited about this,” Wang says carefully.

It turns out looks can be deceiving. In 2010, Wang planted about 2,000 perennial wheat hybrids, the products of crossing annual wheat and wheatgrass. By the end of the summer, 843 of the plants had survived — 12F620 among them. It was special because it regrew like Kernza, and set decent seeds by itself.

This combination — perenniality and grain yield — has been one of the greatest challenges in breeding perennial wheat. For the most part, gains in one are accompanied by losses in the other. 12F620 appears to be a real exception.

“We are trying to find out if some genes have mutated,” Wang said.

Many other developments have been promising. Wang recently compared the yield of 30 genetically stable perennial lines from The Land Institute with seven perennial wheat lines from other institutions, as well as Kernza and two varieties of annual wheat.

Our highest yielding perennial plant was 70 percent of annual wheat; four were at least 50 percent. And they were shorter than the perennial wheat from other institutions, desirable because shorter plants mean less energy was used to produce stalks and they tend to remain more upright.

But our plants matured earlier than the others. After harvest, new tillers emerged but reached the critical reproductive stage too quickly, while the weather was too hot, and died.

“New shoots coming up from regrowth should stay vegetative so as to get through hot summer and cold winter. Nearly all the current perennial wheat lines do not behave in this way,” Wang said. “This problem can be solved with genetic means, as indicated by 12F620.”

Wang believes he is zeroing in on the genetic markers that can identify the pattern of flowering time, a key trait for adaptability in any grain crop.

In the past four years, Wang and his associates have made many crosses between various wheat and wheatgrass species. Progenies derived from durum wheat and Kernza crosses look most promising in terms of perenniality and grain yield. Wang is planning to grow hundreds of thousands of plants next fall in order to find the superior progenies. Germplasm of this kind has been shipped to researchers in Canada, Sweden and China so they can make selections suited to their locations.

Many questions remain unanswered, but with novel breeding materials in the field and experiments underway, Wang is optimistic — if not effusive — about the future.

“It’s something that could be exciting in two or three years,” he said.
Exploring the deep secrets of nitrogen

Long, long before responsible parents started instructing their children in the merits of saving for a rainy day, plants were doing that with nitrogen. Plant biologists have dubbed this “luxury uptake” — storing nitrogen the plant will use later.

“Many plant species might have this mechanism, which could be perceived as inefficient in traditional plant breeding programs,” said Tim Crews, director of research at The Land Institute. That may be one explanation for why the trait appears to be absent from many modern crops.

But this behavior may be necessary if we are to have crops that don’t require infusions of fertilizer. Filling grain heads takes a timely supply of nitrogen.

“It’s another thing when you have a two- or three-week window when grain is filling, with a lot of nitrogen demand.”

Learning more about the exchange and regulation of nitrogen has become the focus of new experiments at The Land Institute.

“We have started an experiment to understand the nutrient limitation of an intensively harvested native prairie, because I think that’s a more valid comparison for how nutrient limitation will be experienced in a perennial agroecosystem,” Crews said.

Legumes are long recognized for their ability to fix atmospheric nitrogen, but a round of experiments launched a year ago by post doc Siva Damaraju at The Land confirms that a number of non-legumes do a similar thing.

“We have definitely seen evidence of non-legume nitrogen fixation in perennial sorghum and Hopi annual maize,” Crews said. Analyses are ongoing. “We’re trying to determine how important it is, from a quantitative perspective. Are they just going to fix 2 kilos per hectare per year, or 20, or 100?”

Polycultures achieve their resilience and efficiency by virtue of integration of many living organisms, a symbiotic web that leaves few resources that weeds can exploit to get a foothold. Effective intercropping requires complementary arrangements.

“The idea is that you have different resource requirements,” Crews said. “Two different plants might be more compatible next to each other than two of the same plants that have exactly the same resource requirements.”

One experiment launched this year by (continued on next page)
Nitrogen fixation occurs in Hopi corn, but how?

University of Kansas Ph.D. student Maged Nosshi looks at isotopes found in adjacent plants to determine the depth from which they are drawing their water. Nosshi has been looking at resource portioning with respect to water. Water closer to the surface has higher concentrations of the isotope O-18.

“He is doing O-18 isotope work to try to determine where in the soil profile these two plants get their water from, if one’s shallow and one’s deep,” Crews said.

Taking measure of silphium

Do silphium plants that get ahead early, stay ahead?

David Van Tassel, who is responsible for breeding perennial oilseed plants at The Land Institute, noticed that within days of germinating, there is noticeable variation in the length of the silphium seedlings’ roots. Silphium is a perennial plant, a member of the sunflower family.

“I placed just-germinated seeds between sheets of paper and recorded the shoot length as the seedlings grew for the next few days,” Van Tassel said. “At the end of the season, I will note which plants grew most vigorously — number of leaves, stem thickness, time of flowering, biomass — and see if there is any correlation with seedling growth rates immediately after germination, or with the number of days taken to germinate.”

If a correlation exists, it could have important implications.

“We may be able to pre-screen thousands, or even millions, of seedlings very cheaply, discarding the weaker plants before we invest in them the considerable resources — time, labor, space — required for field evaluation,” he said. Annual crop seedlings grow much more vigorously than most perennials, but Van Tassel and colleague Lee DeHaan suspect that this difference has more to do with mutations that have accumulated in the genomes of perennials than their lifespan. Overcoming this history using strong selection could make perennial grains much easier for farmers to establish, but could also indirectly improve the perennials’ performance throughout their lifecycle.

Silphium is emerging as a newly re-discovered star of the sunflower family. During the exceptionally hot, dry summer last year a stand of silphium plants commanded his attention. Unlike the wilting plants around them, they showed no signs of stress. During the Dust Bowl years, the botanist John Weaver remarked on this very same trait.

It has surprised us in other ways. Organic Valley, a cooperative based in La Farge, Wisconsin, has partnered with us to research growing it there. In 2013 we took nearly 2,000 silphium seedlings to Wisconsin, expecting to see many perish in the colder winter (it is nearly 5 degrees — more than 300 miles — north of us). Nearly all survived.

One of our summer research assistants, Elizabeth Peuchen, now in a chemistry Ph.D. program, spent several days chemically analyzing seeds from dozens of our silphium plants at the USDA sunflower research center in Fargo, N.D.

“We have not fully compiled the results, but the trends are pretty clear,” Van Tassel said. “Silphium oil is very similar to sunflower oil. Like sunflower oil, it is high in polyunsaturated fatty acids, but contains very little of the highly desirable omega-3 fatty acids. The good news is that it appears to have none of the toxic fatty acids found in some seeds.”

Van Tassel recently delivered a much larger quantity of silphium grain to Organic Valley for oil extraction using their new food-grade press. “I’m very curious to find out how the oil tastes,” he said. “We’d also like to begin learning if it readily substitutes for standard vegetable oil in recipes, especially recipes using Kernza.”
In search of elusive haploids

Less can be more, but getting less can also be a formidable challenge in the world of genetics. The cells of most living things have two sets of chromosomes — one from each parent. That helps ensure genetic diversity in offspring, but sometimes you want to ensure certain characteristics are passed on. A plant with only one set of chromosomes — a haploid — would make that much easier, but to call haploids rare would be understatement.

“We looked at something like 40,000 seeds last year and found 12 twin seedlings. Of those 12, one was a haploid,” said Lee DeHaan, who is domesticating Kernza (intermediate wheatgrass) at The Land Institute. “Next year I plan to screen thousands more for twins and hopefully find more haploids.”

Finding haploids accelerates progress toward plants with desired characteristics. “The end result of all this is we might be able to get a semi-hybrid variety that is more predictable,” DeHaan said. “We have a lot of trouble with crossing two good plants and getting bad plants. In a perennial stand, I believe this is going to be much more important, because if you have a few kind of bad plants that make lots of stems but not very much seed, then you have planted a weed in a field. This is one explanation for decline in yield over time — bad plants overtake the good ones.”

And we have found many good ones. “Two and a half cycles of selection pretty much doubled the yield,” DeHaan said.

A study at the University of Minnesota compared Kernza to Rush (a popular variety of intermediate wheatgrass grown for forage), switchgrass and corn, grown in five locations. The average grain yield of Kernza was twice that of the popular intermediate wheatgrass. And besides producing grain that can be used as food for humans, Kernza produced as much non-grain biomass as switchgrass.

But the crucial difference is that the perennials protect the soil after harvest; once the corn stover is gone the soil becomes vulnerable. “That really exposes the soil to erosion and degradation,” DeHaan said. “With perennials … you can remove all the residue every year and actually improve soil quality at the same time.”

Our Kernza begins to flower

Bread made with Kernza flour is served at the Prairie Festival.

Technician Adam Gorrell pilots a combine through a ripe field of Kernza.
Financially, strong year booked

By SCOTT SEIRER
Managing Director

Fiscal 2014 was another strong year financially for The Land Institute.

But let the numbers speak for themselves: We raised $4.7 million, which is 67 percent more than our revenue budget. We spent $2.7 million, slightly less than was budgeted. Our assets grew by 24 percent, to $14.3 million. And our operating reserve stood at 16.6 months of budgeted spending, up from 15.3 months in the prior year. We have no debt.

Our revenue number was boosted significantly by the gift of 230 acres of land near Lawrence from Jim and Cindy Haines. With that property, valued at $1.7 million, we’re beginning development of a satellite research center in a cooperative agreement with the nearby University of Kansas. This will allow us to further our plant breeding and ecology work and also work with and train students and future scientists in the merits of an agriculture based on perennial grains.

It is financial strength that allows us to expand research at our Salina home, too. We’re hiring new researchers, post-doctoral students and technicians. And we’re increasing our research capacity by adding facilities, equipment, technology and land. Last spring, we added a plastic-covered hoop house to the greenhouse, giving us space to protect and nurture greater numbers of young plants destined for transplanting in our fields. In October, we added field space by purchasing 70 acres just across the road from our breeding plots south of Salina.

Financial strength is the base on which we build our research program. It provides the means to fund our mission, and it provides us a sense of optimism as we create the perennial plants that will revolutionize agriculture. We invite you to look more deeply at our financial strength by examining our audit, which is posted on our website.

Spirituality explored at festival

Widely divergent views on religion and spirituality, so often divisive and so often a catalyst for violence, can find common ground when it comes to the environment. That was a common theme among speakers at the 2014 edition of the Prairie Festival, staged in The Land Institute’s Big Barn in late September.

“Morality does not have to be grounded in religion,” said one of the speakers, Ted Burk, chair of the Environmental and Atmospheric Sciences Department at Creighton University in Nebraska. We can — and must — come together to protect our life-sustaining environment.

The Prairie Festival drew a crowd of 694 from 37 states and six foreign countries. Besides the speeches, participants kicked up their heels at our barn dance, joined a sunrise prairie walk to see native plants, enjoyed artwork and music, participated in a sunrise yoga class, and dined on a chuck wagon-style bison stew dinner. And they learned about our work. More than half of festival visitors signed up for an optional walking tour, led by scientists, of our perennial grain research plots.

Plan to attend next year

Prairie Festival 2015 is set for Sept. 25-27. Watch our web site for information and, come summer, an online registration form. Join us.
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Wes Jackson on the need to seize the moment

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