Land Report

Number 123, Spring 2019 · The Land Institute

About The Land Institute

MISSION STATEMENT
When people, land and community are as one, all three members prosper; when they relate not as members but as competing interests, all three are exploited. By consulting nature as the source and measure of that membership, The Land Institute seeks to develop an agriculture that will save soil from being lost or poisoned, while promoting a community life at once prosperous and enduring.

OUR WORK
Thousands of new perennial grain plants live year-round at The Land Institute, prototypes we developed in pursuit of a new agriculture that mimics natural ecosystems. Grown in polycultures, perennial crops require less fertilizer, herbicide and pesticide. Their root systems are massive. They manage water better, exchange nutrients more efficiently and hold soil against the erosion of water and wind. This strengthens the plants' resilience to weather extremes, and restores the soil's capacity to hold carbon. Our aim is to make conservation a consequence, not a casualty, of agricultural production.

LAND REPORT
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Land Report

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Cover

Influence of humans and other creatures and matters along the Smoky Hill River near Land Institute research plots in early spring. A two-foot tree branch cut neatly by saw or knife at each end and shaved of its bark. To make a tool, or to pass the time? Palmprints of raccoon. Wind on the water. A shore of sand, silt, and clay from erosion by wind, water, and farming. The river was high after autumn rainfall that was far above average. Though one should take care about crop predictions in meteorologically volatile Kansas, this might help make for a good growing year in our fields. Especially since, instead of annuals, we grow perennials, whose roots can take up more water. And rather than shipping soil to the riverbank, they will keep more it local, in the soil bank. Scott Bontz photo.

Olive trees on terraces in Palestine's West Bank. To hold soil on cultivated hills, farmers in this birthplace of agriculture must skillfully dry-set and maintain walls of stone. Aubrey Streit Krug photo.

Perennials in Palestine

Collaboration at a birthplace of agriculture

AUBREY STREIT KRUG AND BRANDON SCHLAUTMAN

How many different species of plants were we handed and prodded to eat, that sunny January Sunday in Palestine? Dozens, at least.

Before the road trip to the village there was breakfast in the city of Ramallah, with dipping dishes of hummus, olive oil, and zaatar – the mixture of wild thyme, or more properly the herb *Origanum syriacum*, with sesame and sumac.

Then when we arrived there were all the celery-like stems of greens gathered on the hillside, with flavors ranging from refreshingly watery to brightly tart. Between nibbles we sounded out the greens' names in Arabic: selek, khobbezeh, khorfesh. While foraging, we could see a hill named The Mother of Wild Pea, skip over the wall to where skyscrapers sit on Chickpea Plain, turn back to glimpse a Bedouin camp, and come to rest on young olive groves at the bases of eroded hills.

After a detour to find wild lupines, we came to a stone home in the village of Dayr Ballut for spiced rice wrapped in cabbage, seasoned chicken, salad with cucumbers and tomatoes, pita bread, citrus fruit, and more tea. The starter course was maybe the most remarkable – so many of the Palestinians we went on to meet told us what a treat we'd tasted. It was a yogurt soup with akkoub: the tender base of a spiny wild vegetable, carefully de-thorned, frozen, kept over from last season, and brought out for this occasion.

Akkoub, *Gundelia tournefortii*, is a perennial herbaceous plant native to Palestine. Perennial like the selek, like the *Origanum syriacum*, like the olives which come back year after year. The Land Institute's perennial project resonates in Palestine.

Our host for the feast, the woman who pressed the plants into our hands and onto our plates, was Amna Othman, a lifelong resident of this village who farms wheat and vegetables on the nearby rain-fed plain to support her family. She knows where to find and how to gather wild food plants. She saves seeds, too, and has brought a few wild akkoub plants into her garden to make gathering them more reliable and convenient. In her enduring relationship to her home place, Othman relies on perennial vegetation for food more than most people do.

Now, Othman's daughter is part of an effort to grow new perennials in Palestine, to help make a diverse perennial landscape that includes resilient and equitable human communities. Yusra Othman earned her master's degree in geography at Birzeit University and works for an agroecology project called Makaneyyat.

Makaneyyat is led by Omar Imseeh Tesdell. Omar is a Palestinian-American who grew up mostly in Iowa on an acreage, among typical Corn Belt farms.

He earned his bachelor's degree at Iowa State University and learned more about agroecology from faculty at the school's Aldo Leopold Center for Sustainable Agriculture. He completed his PhD in geography and sustainable agricultural systems at the University of Minnesota, where he studied the relationship between land and farming in Palestine. After graduation, he accepted a position as geographer and faculty member at Birzeit University, and started the Makaneyyat project.

Tesdell

In Arabic, "makan" is place, a set of relationships, "makaneyyah" a space, and "makaneyyat" its plural. Makaneyyat studies how social, economic, and political pressures affect culture and agriculture. Makaneyyat seeks to understand how landscape changes, and what can be done to shape change that benefits people and earth. That is, to apply agroecology to build human communities able to resist damage and to heal.

Cultivation is for Omar a kind of process philosophy, which says reality is not about timeless classical forms, about being, but about change, about becoming. This means working with the life force rather than seeking to dominate it. Makaneyyat's vision is to work with their connections (human and more-than-human) and technology (free and open-source software) to cultivate a new landscape in the ecosphere that can open up possibilities for this land community and for those in other parts of the world.

Makaneyyat's first efforts have been to describe plant occurrences as well as what plants mean and have meant to Palestinians and newcomers to Palestine. They have digitized landscape images and books about native wild food plants and agriculture in Palestine; this is for researchers to use like a search engine. They are also collecting plant specimens and conducting field work and interviews to start a wild food plant gene bank, to store plants' seed and tissue along with knowledge about plants. These two main initiatives are described on their website, makaneyyat.org/en/about-us/.

For the past four years, Omar has been coming to The Land Institute – which he describes as "rocket fuel for my imagination" – and participating in ecosphere studies conferences. In the last several years he has explored how perennial grain agriculture might transform landscapes, including human communities, in Palestine. While initially a thought experiment, now he's begun trials and domestication of new perennial crops.

In 2017 Brandon, The Land Institute's legume breeder, and oilseeds breeder David Van Tassel provided seeds for Omar to plant and manage. Brandon was particularly interested in trialing his Alborea, plants derived from crossing alfalfa – *Medicago sativa* – and *Medicago arborea*, a woody, perennial species native to Palestine and the Mediterranean region. To Brandon and Omar's delight, more than half of the Alborea lived through the summer dry season and into the next year of the perennial cycle. Brandon helped Omar make selections from these survivors for the 2019 growing season. He also sent seeds of perennial chickpeas and other Land Institute plants, including intermediate wheatgrass.

This January, we accepted Omar's invitation to travel to Palestine to learn about his "makan," to observe the agricultures

currently practiced, and to see his research plots. An original breadbasket of the world, Palestine is an apt place for humans to see the consequences of annual, tillage agriculture practiced for millennia on a highly erodable landscape, and to imagine the design of a new agriculture that could hold onto soil, with perennials grown in mixtures – nature's usual arrangement. In Palestine's West Bank, we were struck by the hillside terraces. We saw stones skillfully set to hold on to a precious resource, soil, and we felt the embodied work of generations. Before their agriculture drastically altered vegetation, perennials had done this work.

Omar took us to the Natuf Valley: "one of the oldest areas of cultivation in the world – and you can tell." We saw the valley framed by the mouth of Shuqba cave, where archaeologists found evidence of Natufians eating grain, which might be among the earliest domestication. Natufians were sedentary hunters and gatherers, including of wild cereals and legumes, around 12,000-14,000 years ago; they were the predecessors of Neolithic agricultural communities. The weight and gravity of the damp cave walls, as well as the sky light visible through a circular ceiling opening, echoed the architecture of the churches we later visited. But unlike the adorned churches, with their streams of visitors, we were the only people in the unmaintained Shuqba cave that morning.

As Omar observes in the introduction to the short volume "Palestinian Wild Food Plants", "We Palestinians are a formerly agrarian society living amidst, some might say, the ruins of the agricultural revolution in its own origin place." Many of the staple crops that are native or ancient to this place – wheat, barley, chickpeas – are now imported from neighboring countries rather than grown on Palestinian terraces. Yet like the wild foods we foraged, which still linger in the margins, perennial tree crops have been selected and grown to fill the terraces, and they still provide for the people here.

In January – during the cool, rainy season – the almond trees were just beginning to bloom, and during our walks in the valleys near Ramallah we tasted fruit from the strawberry tree and pointed out carob and fig trees. But olive here is the perennial oil producer who must be met. Their durability and vitality astound. As Omar said, "They still intervene every fall to draw families in to pick the fruits and press the oil, keeping an ancient rhythm of life even amidst the fast-paced modern life in Palestine. Grafted on to wild olive rootstock, they have the ability to regenerate themselves and live for hundreds of years."

Many olive groves are managed through traditions of tillage. One grower that we visited, Fareed Tamallah, does not spray herbicide but tills beneath his trees twice per year, once in April to "remove the weeds so they didn't compete with the olives for water" and again in October to "open up the ground so it could absorb the rains." Tillage can become a vicious cycle: you till to remove the weeds, then because there is no ground cover and no rain, the soil, which is high in clay, bakes in the sun and becomes like a pot that is impermeable to water until more tillage.

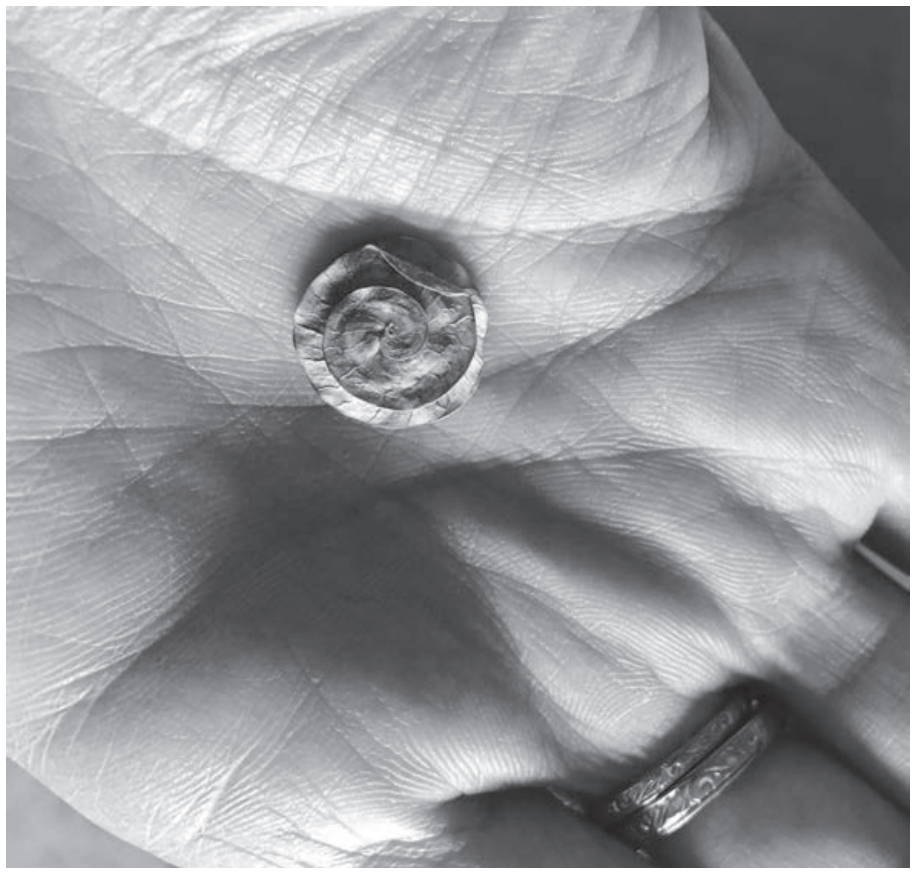
Fareed was interested in trying new things and was fascinated as Brandon pointed out among his trees the "weedy" wild clovers and *Medicago* species closely related to alfalfa. We dug up plants and looked at their nitrogen-fixing nodules.

Fareed took us to an abandoned olive grove that was overgrown with shrubs and no longer productive. He recalled how when he was younger, even though it was hard

work, he and his brothers liked to take over such abandoned olive groves. After they removed the brush it was easy to till the soil, which was exceptionally productive for the first couple of years. Those were the best soils to grow crops like wheat, barley, and chickpeas. As he spoke, Fareed started to realize that tillage could cause problems and that perennial soil cover could help rejuvenate soil fertility. Perennials might help limit evaporation of water from bare soils and help with capture of rainwater and dew.

Olive trees, with their perennial, reaching roots, have cultural meanings and ideological power in Palestine, the most contested holy land in the world. Some Palestinians point to these perennials to prove their agricultural use of land. Some Israelis have planted these perennials to assert their own relationships to land.

Traveling through Israeli-controlled checkpoints reminded us of how a powerful state shapes people's movements and influences how people perceive and relate



Medicago orbicularis, *or button clover. A local name for this wild plant means shepherd's bread, and people have eaten its seed for thousands of years. The Makaneyyat team would like to grow it for Mediterranean markets. It's an annual but gives credibility to the idea of domesticating alfalfa as a perennial grain legume. Aubrey Streit Krug photo.*

to plants. Due to the wall that separates the West Bank from Israel, Amna Othman has less access for gathering wild greens. The barrier restricts her from foraging for akkoub on land she had known and used for years.

Access to land is important to consider in designing research and envisioning applications. An ecospheric perspective challenges us to remember the human stakes of scientific work and to seek ecological solutions that come to terms with political, cultural, and ethical constraints and contexts. Recognizing social realities may help with transitions to, and the creation of, communities that feed themselves through perennial agriculture, both in the US and abroad.

During our visit, we discussed two kinds of new, soil-saving crops that could be developed to be grown under olive trees in Palestine. Both would be legumes, which fix nitrogen. One would be grazed, and the other would provide human food, like chickpea. Developing the first crop could build the longer-term research needed for the second crop.

There's something immediately sensible and compelling about companion plants in olive groves that could provide continuous soil cover and reduce the need for tillage. We met olive farmers who are already attempting various legume cover cropping and intercropping strategies – which were once common practices – such as with annuals like Faba beans, vetches, and berseem clover. Another member of the Makaneyyat research team, Sameer Khraishi, told us about his grandfather growing alfalfa, chickpeas, and soy under the olive trees. His neighbors' sheep and goats would come graze and add manure.

Makaneyyat is seeking native legumes to serve as perennial companions for olives. One of the most exciting candidates we came across on our tour was *Bituminaria bituminosa*, a drought-tolerant species already being considered as a forage legume far from its native range, in places like Western Australia.

Our trip's purpose was to meet the Makaneyyat team, and they were its highlight. These are the people who are doing the work, and their perspectives, knowledge, values, and life experiences guide the decisions. The collaborative team includes a group of students and part-time researchers, and is adding field workers, breeders, and partners like curators, farmers, community supporters, and owners of large food companies. Each offers different technical expertise, social capital, and potential to grow and deepen in shared work.

Along with Yusra Othman and Sameer Khraishi, the diverse research team includes Yara Dowani and Mary Deik, who, with Omar, work the domestication test plots, collecting data, harvesting seeds, and breeding plants. We spent a full day with them in the Makaneyyat office in Ramallah. Brandon helped them arrange to photograph seeds, and shared software to measure seed sizes and colors for selection and breeding. He also answered questions about breeding. Drawing on her experience coordinating the diverse team of collaborators who wrote and edited an Umó^{n}ho^{n} – Omaha – Native American language and culture textbook, Aubrey guided the Makaneyyat team through reflective conversations and exercises, helping the members share their motivations and identify their project roles based on their values and hopes for Palestine.

Traveling to Palestine to visit this fledgling domestication program brought us into relationship with a community with

powerful stories about the land, a place that has important capacities for plants and people: consider the range of wild and domesticated legumes, how philosophies of cultivation (or farming) have shaped the land, and the possibilities for educating more plant breeders.

Perennial agriculture has benefits for places far from our home in central Kansas, and while The Land Institute collaborates with researchers across the globe, the Mediterranean climate has not yet featured in perennial legume collaborations. Makaneyyat's work with perenniality in their part of the ecosphere – including the knowledge of plants practiced across generations by farmers like Amna Othman – has the potential to be adopted by farmers, communities, and researchers elsewhere in places like Australia, Southern Europe, Northern Africa, and California.

Streit Krug directs The Land Institute's ecosphere studies. Schlautman is the legume breeder.

Perennial Practice

AUBREY STREIT KRUG

1. Hold on. When the wind moves through, you'll make a song. When a single leaf finds you, edges serrated as a knife, how long can you cradle her?

2. Relieve yourself of certainty. Let soil horizons stretch as you stumble into patches beyond. Can you trace the source? And the source of the source? Can you get any deeper than mystery?

3. Don't true up. A perennial is not a perennial is not a perennial, the scientist intones. How many seasons will you need to learn the names of just one friend? Who remembers fluency?

4. Curl edges inward. Nap off the drought until sun and clouds pour into you. Light feeds what keeps you alive, which cannot come to light. Where could you go except home?

5. Compete together. Pay out your attention, play out your strategy. Exchange breaths – you will always be bound by cycles. Why not greet every so-called weed along the way?

6. Risk movement. Unlearn normal and ship the seed of an idea. Take faith as an experiment, over and over. When has your heart ever really opened into habitat?

7. Keep accounts. What you forage and hide away will eventually be ground up or down. Still you are asked to play. Will you come outside, will you make your first entry?

Extracts

I SHALL DISTINGUISH the environment as commons from the environment as resource. On our ability to make this particular distinction depends not only the construction of a sound theoretical ecology, but also – and more importantly – effective ecological jurisprudence. – Ivan Illich, "Silence is a Commons"

IF WE KNEW WHAT it was we were doing, it would not be called research, would it? – Albert Einstein

WHEN A SPIDER WEAVES a web, which seems separate from the spider's body, isn't her web as much a consequence of that spider's complexly interacting genotype as is the animal's body? – David P. Barash, "Through a Glass Brightly"

IN THE END, the most interesting thing about a conscience is how it answers, not whom it answers to. – Casey Cep, in a New Yorker review of books about atheism

"ROMANTICIZING THE PAST" is a familiar accusation, made mostly by people who think it's more grown-up to romanticize the future. – Paul Kingnorth, in Orion magazine

THERE IS NOTHING in the prospect of a sharp, unceasing battle for the bare necessities of life, to encourage looking ahead, everything to discourage the effort. – Jacob Riis, "How the Other Half Lives"

MORE CHOICE is meant to bring us more freedom (so says capitalism). And yet we're happier when we're bound. In fact, to be choiceless is the ultimate freedom. – Sarah Wilson, "First, We Make the Beast Beautiful"

AS OUR ISLAND of knowledge grows, so does the shore of our ignorance. – physicist John A. Wheeler

LIFE HERE WAS FLUSH with the soil, and to identify with it, one had to lie down and sleep for years on the muddy or dried-up ground itself. – Albert Camus, "The Growing Stone"

NEITHER KNIGHT, nor esquire, nor high-born nobleman, was here; but many of these humble sons of the hills had a consciousness that the land, which they walked over and tilled, had for more than five hundred years been possessed by men of their name and blood … – William Wordsworth, "A Guide Through the District of the Lakes in the North of England"

WITH COAL GONE, oil gone, high-grade metallic ores gone, no species however competent can make the long climb from primitive conditions to high-level technology. This is a one-shot affair. If we fail, this planetary system fails so far as intelligence is concerned. – Fred Hoyle, "Of Men and Galaxies"

WE ARE A DEMOCRATIC, egalitarian people who spend our days desperately trying to climb over each other. – David Brooks, The New York Times

Perennial lupins are among the legumes being evaluated as food seed producers and nitrogen-fixing companion crops for our perennial grains. In the legume room of The Land Institute's new greenhouse, bees are allowed – even needed, for pollination. Alfalfa mosaic virus is not. Scott Bontz photos.

Land Report shorts

A safe house for legumes

Before a legume could move into our new greenhouse this fall, the plant donated a bit of leaf to be tested for a disease called alfalfa mosaic virus. An outside lab put the tissue in solution, along with an antibody. If the virus was there, the antibody attached to it and changed the solution's color. Clear solution was a pass to the greenhouse. So it's a clean room.

Many legumes around The Land Institute, including soybeans and clover in lawns, carry the virus, whose infection reaches well beyond the family *Fabaceae*, to potatoes, tomatoes, tobacco, and hundreds of other species. Brandon Schlautman, our legume breeder, said that many of the clover plants in his breeding population have the virus. Symptoms include wilting, dwarfing, and cell death. But these can quickly disappear and leave a carrier looking fine. The virus commonly spreads by aphids.

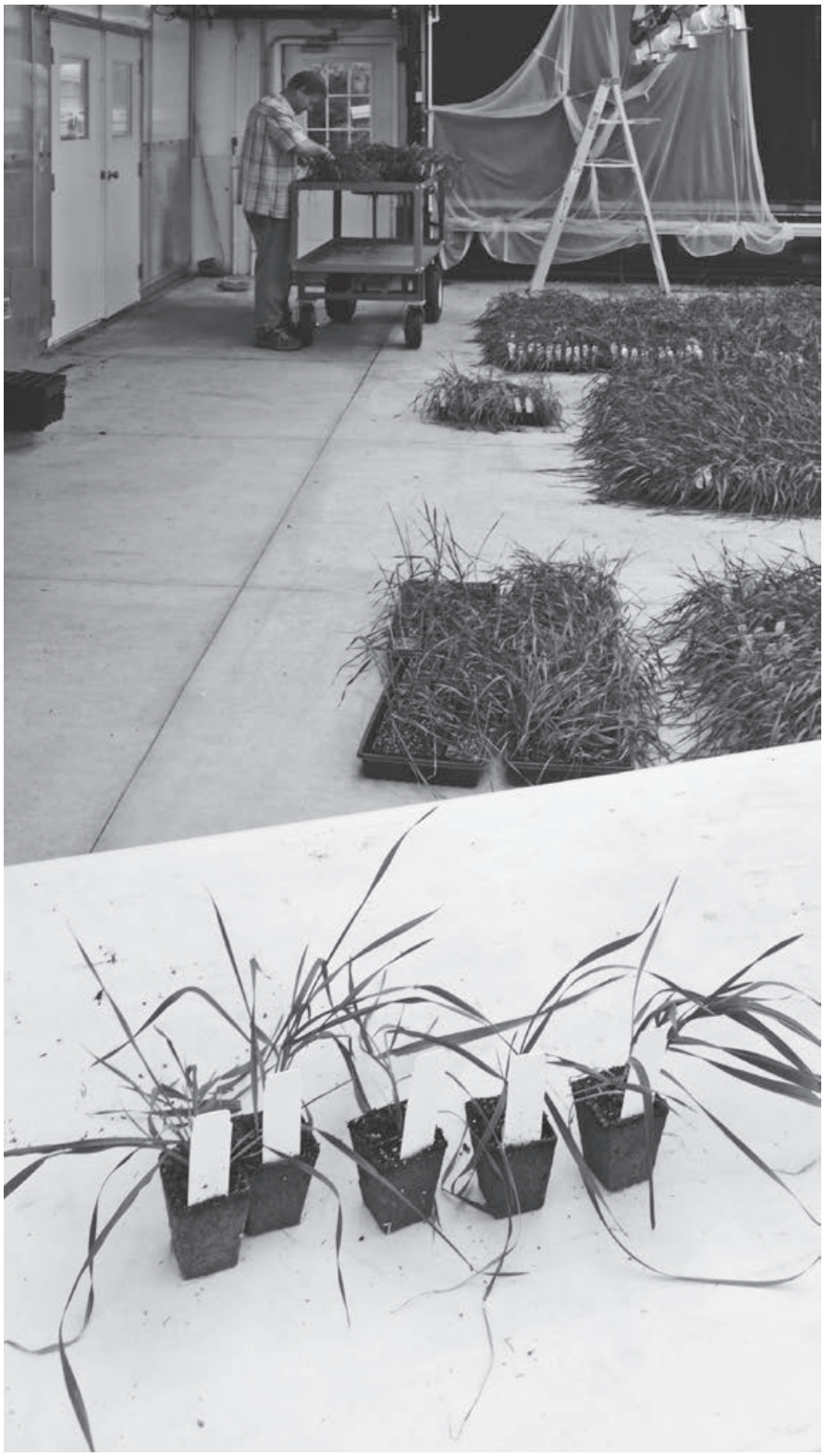
Our original greenhouse, built in the middle 1980s, is one big room, where the legumes grew along with wheat, sorghum, intermediate wheatgrass, and the sunflower relative silphium – all of our perennial food crops in the making. The large open space made it hard to control aphids. The new greenhouse is about double in size, and divided, so legumes have their own, protected room. For general disease and pest control, visiting the old greenhouse bars one from entrance to the new greenhouse that day.

"We will never be able to keep plants in the field free from viruses without developing genetic resistance", Schlautman said. "In the meantime, we need to have at least one clean place where we can keep selections and other valuable germplasm free from infection". He wants to buy gear to perform the antibody test and check the plants himself. This will not only screen and protect candidates 100 at a time, here, but also help speed selection for resistance.

Other legume developments: Schlautman and technician Spencer Barriball evaluated more than 2,000 plants from fields of alfalfa and a hybrid made by crossing alfalfa with a relative. They took cuttings from select plants and grew them over winter in the greenhouse. From about 20 plants they also propagated the legume seed crop candidate called sainfoin. This is another nutritious perennial forage crop, but not as thoroughly developed and understood as alfalfa. Schlautman is testing how to clone and grow it in a greenhouse. He and Barriball also oversaw the first year of a four-year study of alfalfa grown with one of our perennial grain crops, intermediate wheatgrass, in Kansas, Wisconsin, and Minnesota. This study seeks genetic variation to breed the legume for such intercropping.

Taking our crops commercial

Lee DeHaan's job with intermediate wheatgrass is to make it a perennial grain, and he's done well enough that demand from growers and food makers exceeds supply – and his time for getting seed to farm and market. For that we have hired a commecialization manager, Tessa Peters. "There's



never been a perennial grain that has needed a commercialization manager", Peters said, in a profile on The Land Institute website. "We are entering new territory … working to build a system that supports perennial agriculture beyond proof of concept".

From home in Missoula, Montana, Peters will screen and consult farmers, brewers, and food producers like General Mills to improve the supply of intermediate wheatgrass. The job includes finding growers who have the ability to plant and harvest a grass seed, and who understand that they are part of research on how best to grow it at field scale. Food makers also need to understand that they are researchers with a plant still on its way to a successful grain. How it performs in bread and beer might vary across farms and seasons, and so might its harvest dates and yields.

Peters

Before joining us in January, Peters worked for Organic Seed Alliance, helping growers with production and economic problems, and learning about the seed supply chain. She grew up in Gillette, Wyoming, earned a bachelor's degree in physics from Colorado State University, a bachelor's in agroecology from the University of Wyoming, and a PhD in plant breeding and genetics from the University of Wisconsin. Her husband works for the US Forest Service in Missoula. They have a two-year-old son.

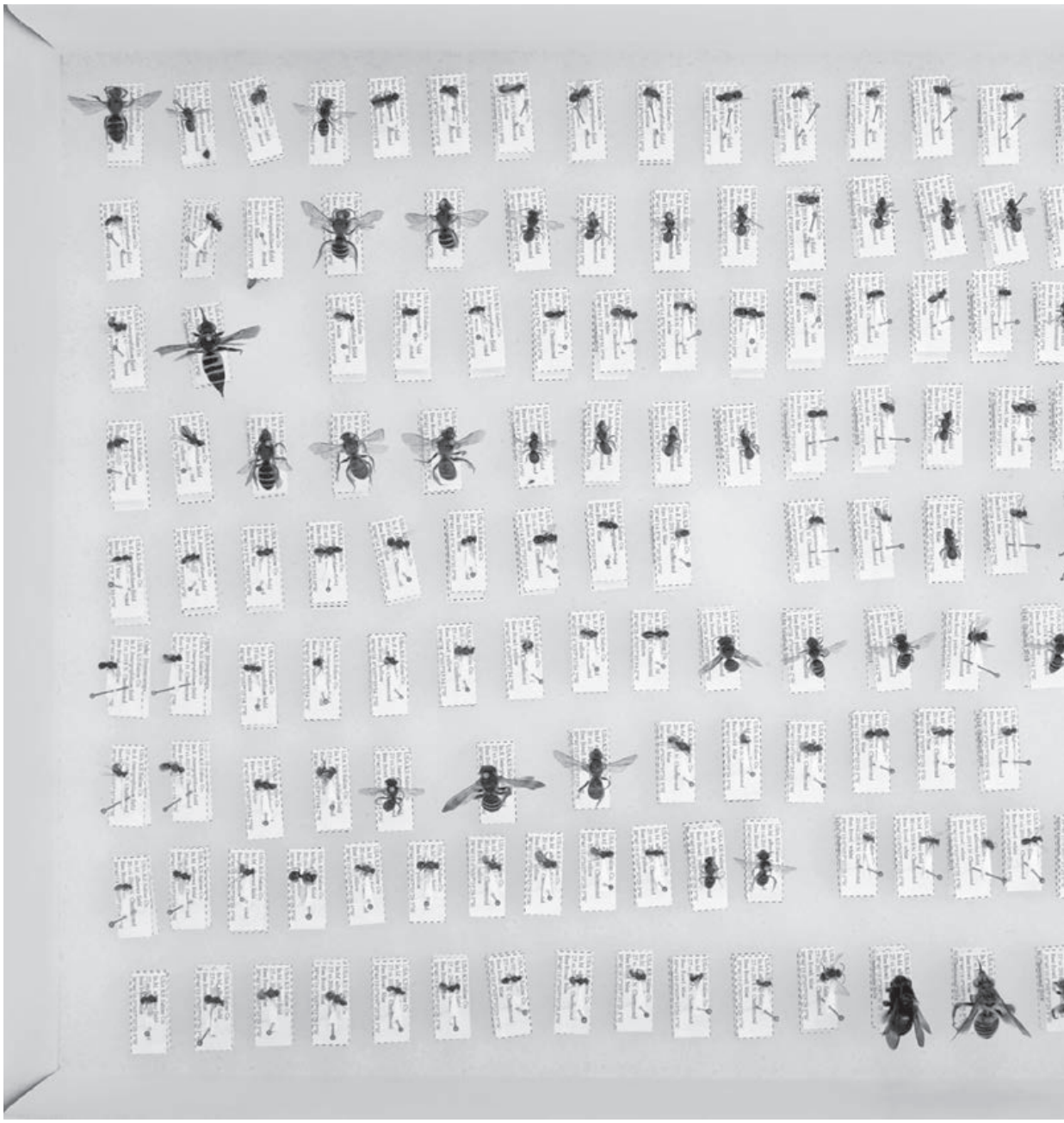
Intermediate wheatgrass is our crop closest to commercial success. Peters eventually could also take to market our other perennial food crops – sorghum, the sunflower relative called silphium, a legume, and perennial wheat.

Marking a blight

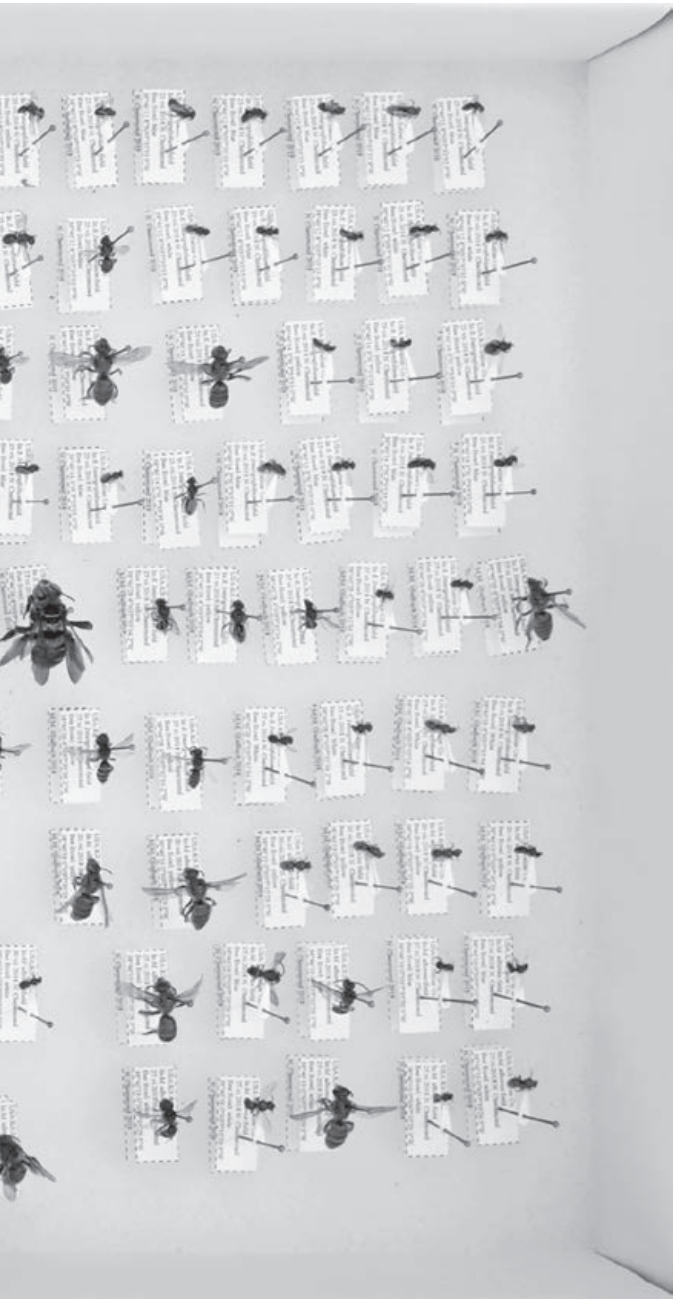
A fungus called Fusarium head blight, or head scab, shrivels the seed of wheat, barley, and oat. It also makes toxins that can sicken livestock, and in humans cause headaches, fever, and vomiting. A 2017 article in Molecular Plant Pathology said it is the world's most serious disease in wheat flowers. Epidemics strike about every four or five years, and US losses average about $3 billion. Fusarium also affects intermediate wheatgrass, one of the perennials that we're making a grain crop. As with wheat, breeding probably can't make wheatgrass entirely immune. But most wheatgrass plants are highly resistant. If Kathryn Turner, our crop protection geneticist, can find just the bottom 5 percent of candidate plants to cull their weak genes, we'll have quite a strong crop.

This isn't easy, because susceptibility depends not on one gene, but on environment and many small-effect genes. A wheatgrass type might be resilient one year but succumb the next. Turner's analysis from the field has found one helpful predictor, though it's far from a guarantee. That is flowering time. Earlier flowering might beat later humidity and warmer temperatures when the pathogen produces spores. With the help of Kansas State University

Facing page: Technician Marty Christians tends intermediate wheatgrass seedlings in the greenhouse last fall. Genetic analysis allows us to sample tissue from seedlings and predict how they will perform, rather than watch them grow for a year or more, only to still be uncertain what resulted from genes and what from environment.



Bees collected from our fields last year by technician Edy Cheremond and intern Megan Gladbach. This year we want to identify every bee species that visits plots that will test what perennial crops might make good field borders. Cheremond also will note which insects come to hunt herbivores. For more, see story at right.



researcher Jared Crain, Turner progresses more quickly by matching field results with variation in DNA sequences called markers. Relating more than 20,000 markers with how plants perform, they built a computer model that uses environment and genetics to predict which plants in the next generation will be susceptible to infection. Last fall, rather than wait for a seed head to mature – and still face environmental fog – the breeding program was able to evaluate tissue from plants as mere seedlings.

There's no need to identify the genes that make a plant susceptible to *Fusarium*. Researchers need only see that particular sums of markers lead there. This process is called genomic selection. Though progress with *Fusarium* resistance still won't be as quick as with simpler traits, the sequencing technology lets us characterize chromosomes of plants by the hundreds and makes breeding faster and surer.

Testing life on the edge

The federal government's Natural Resources Conservation Service encourages farmers to border their fields with prairie, a mash-up of native perennial species. The perennials control erosion, and some attract pollinator insects. But these wild medleys often take years to suppress the weeds that go with planting. What if farmers still planted border perennials, but in less of a hodgepodge, with more confidence in seeing them quickly up and running? And what if they used select species that could become food seed crops, meanwhile making good forage for animals? The Land Institute and Kansas State University will try to answer these questions with a $50,000 NRCS Conservation Innovation Grant. Ebony Murrell, who leads our crop protection ecology, last fall over-

saw transplanting to 18-by-18-foot, single-species plots the seedlings of two legumes, alfalfa and sanfoin, and two sunflower relatives, *Silphium integrifolium* and cup plant. To compare, there's also wind-pollinated intermediate wheatgrass, and a prairie mix of three grasses and six forbs. The plots are repeated in four locations across our land in Saline County, Kansas.

The questions to answer: What kind of ground cover do each of the crops provide? How does the forage quality compare? How does forage quality balance with attractiveness to pollinators? Murrell and her technician, Edy Cheremond, also will attempt to identify every species of bee that visits. "That in itself will be valuable", she said. "We really don't know the relative abundance of these species", or what each is pollinating. The researchers also will note which beneficial insects come to hunt herbivores.

Murrell wants the study to last at least three years. At our Prairie Festival in fall of 2020, visiting farmers will be invited to survey the plots and say which plants appear to have what they want in border crops, and how The Land Institute and K-State could promote them with farmers.

Sorghum surprises

The beginning of perennial grain sorghum comes by crossing annual crop sorghum with its wild, perennial relative, *Sorghum halepense*. The hybrids usually have no rhizomes, or only few. These underground, overwintering stems of a perennial typically show up in later breeding generations. But among the more than 800 hybrids made last year, a surprising 300 or so made rhizomes. This suggests that descendants will be rich in rhizomes and perenniality. Even better news: this year's rhizomatous first-generation hybrids also looked more domesticated than those in previous years, and some had much bigger seed. This was because, after repeated backcrossing to grain sorghum parents, these plants carry an increased share of genes for crop-like traits.

Researcher Pheonah Nabukalu is exploring whether their chromosome sets were simple, diploid pairings, as in crop sorghum, rather than the quadruple sets typically found in our perennials, which complicates and slows breeding. The spring 2018 Land Report told how Nabukalu and fellow researcher Stan Cox got another, pleasant surprise: three-fourths of the hybrids first grown out back in 2014 were diploids. They're still trying to figure out how this happens.

Even with The Land Institute's new, taller greenhouse, which accommodates the usually towering hybrids, there wasn't enough floor space for all of the rhizomatous plants that Cox and Nabukalu want to grow. Last fall, as in 2015 and 2016, the overflow of seed was planted in tropical Puerto Rico.

The tropics are home to the sorghum midge, an insect that can regenerate in nine days and quickly blast a seed crop. Last year in Puerto Rico there was no problem with midge, and it had never ventured much north of Oklahoma. But in 2018 it socked farms from central to western Kansas, and didn't miss our plots. We recovered enough seed from superior rhizomatous plants to sow this year. See the facing page for more about sorghum.

She helps make an oilseed crop

Sydney Schiffner is the new research technician for silphium, a sunflower relative that we're developing as a perennial oilseed

Toward a map of sorghum

In our new greenhouse, Pheonah Nabukalu staples a bag to the head of a perennial sorghum plant. The bag shields pollen from other plants, to ensure this one pollinates itself. Of this 'selfing' there've been 12 generations. After four to six more, each of some 300 plants in the program will be inbred enough that its seed should produce a uniform stand. Then performance across different plots coupled with genetic comparison will sort nurture from nature, yielding a map that allows Nabukalu to take a seedling's DNA and predict how the plant will turn out. This will greatly speed selection and improvement of the new crop.

Technician Sydney Schiffner counts stem internodes of silphium in The Land Institute's new greenhouse. She also took weekly measurements of leaves and plant height. The perennial oilseed plant was raised in pots varying in size from 1 to 65 gallons, in search of an optimum belowground space for aboveground growth. Ideally the plant will flower in the first year, to speed selection and breeding. Flowering has typically come in the second year. Schiffner found that in big pots plants grew several times larger, and sent up flower stems. The drawback of big pots is they eat greenhouse space. The sweet spot turns out to be 25-30 gallons. *See the facing page for more about silphium.*

crop. Only a handful of people in the world have worked with silphium this way, and Schiffner was already one of them. For her master's degree, received last year from the University of Minnesota, she tested the best ways to plant and fertilize silphium. She also participated in our yearly silphium conferences. Her degree is in applied plant sciences, with a focus in agronomy. Her bachelor's degree, also from Minnesota, is in ecology, evolution, and behavior, with a minor in statistics. Schiffner's home place is rural Becker County, in upper western Minnesota. For her staff profile on our website, she is asked what book she would write, and says this: "It would either be about drag queens from RuPaul's 'Drag Race', or a type of meta-analysis of how ecology and agriculture have interacted and clashed from the past and into the present".

New crop, new pest tactics

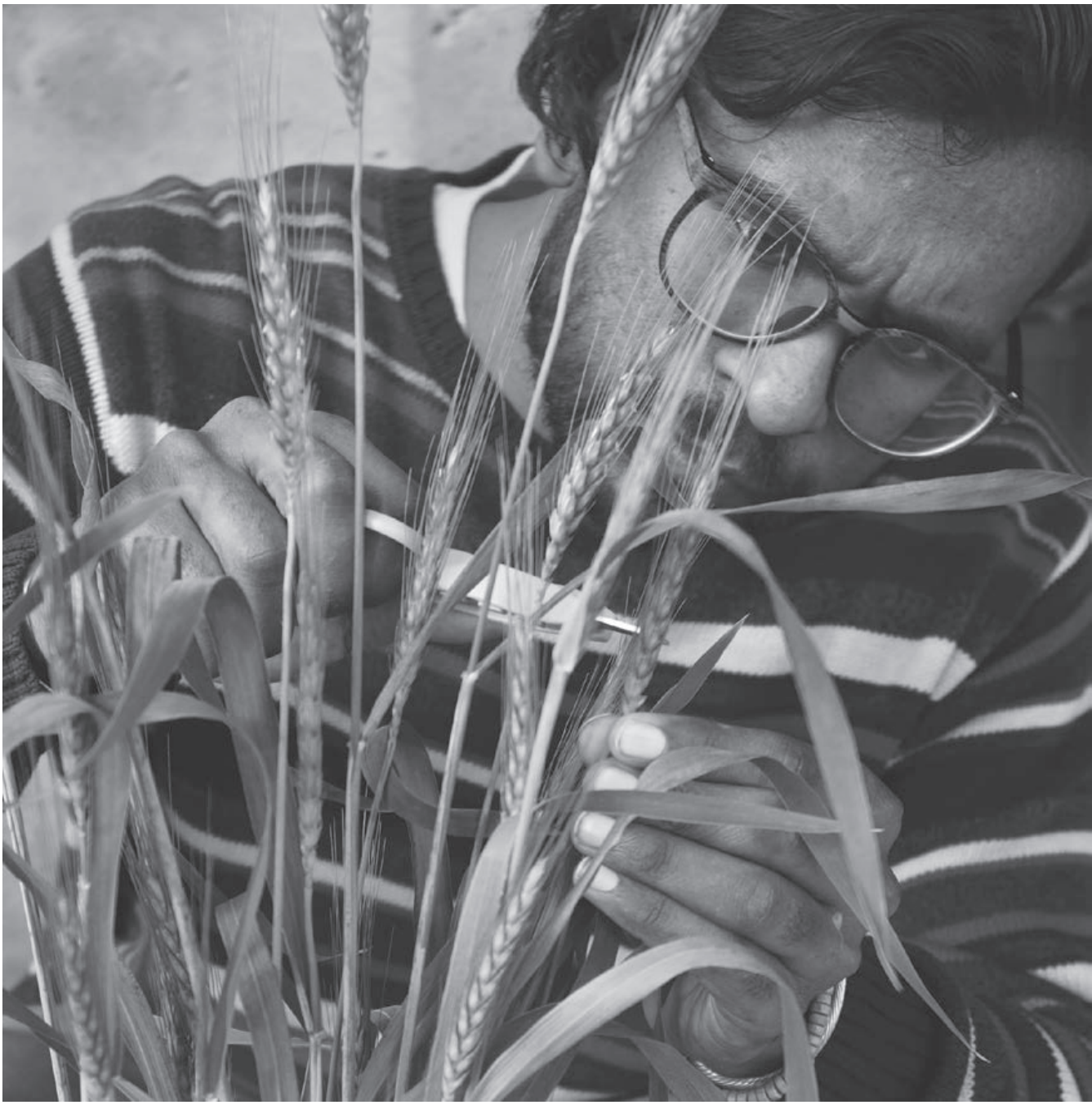
Silphium, the perennial oilseed crop in the making, last year again suffered heavy insect damage in its heads, stems, and crowns. But our researchers Ebony Murrell and Edy Cheremond, along with Jarrad Prasifka, a USDA entomologist in Fargo, North Dakota, identified perpetrators and began testing ways to manage them. Prasifka discovered our biggest pest, *Eucosma giganteana*. This moth's caterpillars eat both flower heads and root crowns, but only in the *Silphium* genus. Since silphium is a new crop, managing this pest demands research and novel means. Cheremond developed an artificial diet and reared caterpillars to adulthood for lab study. He and Kelsey Peterson, a PhD student at the University of Minnesota, are developing a way to test plants for resistance.

Sexual lures might also limit damage. This is the work of a new collaborator, Rob Morrison, of the USDA in Manhattan, Kansas. He studies the moth's sex pheromone. We hope to use this chemical signal to trap or confuse moths and deter mating, while sparing pollinators, predators, and other benign insects.

At The Land Institute we halved caterpillar numbers in silphium root crowns by applying nematodes, which are naturally occurring predatory roundworms. We also sprayed flowers with an insect growth regulator called methoxyfenozide. This affects only the destructive caterpillars, not predators, pollinators, or soil organisms. It cut eucosma colonization by 90 percent, equaling the previous strategy of spraying flowers with the insecticide permethrin and covering them with bags. "This research provides exciting possibilities in 2019 for managing eucosma in an environmentally friendly way, and allowing our silphium breeding program to progress", Murrell said.

Argentinian colleagues Alejandra Vilela and Luciana González-Paleo discovered that cutting silphium stems back in the spring makes them bush out in a way that could improve harvest. They trimmed the silphium for a different reason, but also noticed that the plants became shorter, and that some produced fewer, larger, and more uniform heads. We would need to breed plants that thrive under this somewhat severe treatment. But it might quickly achieve crop form.

Tolerance to clipping also helps for study of silphium grown among other crops. A small-scale farmer in Argentina has already sown silphium with annual rye. He cut the rye for hay, along with some grain. The rye had suppressed weeds, and the first-year silphium seedlings looked good. Rye will be replanted, and the next harvest could include flowered silphium.



Technician Piyush Labhsetwar plucks the anthers from annual bread wheat, so the flowers won't self-pollinate. Later he'll apply pollen from perennial intermediate wheatgrass. This is the first step toward making perennial wheat. Last year wheat breeder Shuwen Wang achieved perennial plants that appear to breed true – their offspring are of consistent form. This enables three studies, described on the facing page.

Wheat, soils, weeds, genomes

Six years after starting a hybrid by crossing annual durum wheat with perennial intermediate wheatgrass, last summer Shuwen Wang had plants that could not only be expected to live for at least two years, but which also looked like a pure line – plants so similar that offspring should keep to form instead of varying wildly like the first generation. From this promising collection, Wang and his technician, Piyush Labhsetwar, harvested more than 13,000 seeds, and in fall these were sown. Come summer they may have as much as 200 times as much seed. The harvest will serve three studies for furthering the crop and how it is grown.

Former Land Institute intern Siwook Hwang wants to compare how the two parent species and the hybrid affect their home, the soil. Perennials dominate natural vegetation, which makes for better soil than does annual cropping – more soil organic matter, better storage of water and nutrients, less soil loss. Hence our aim to perennialize grain agriculture. We're just starting to learn how perennial grains will affect the underground world, and how best to farm them. In a study proposed for his doctorate at Colorado State, Hwang would compare across the three plant types the architecture of roots, what the roots give soil, and which microbe communities develop. He wants to find the belowground strengths of wheatgrass and see what is passed down to perennial wheat. He also wants to study what happens by adding a legume, to fix nitrogen.

In another study, Wang and Labhsetwar will try combinations of different weeding machinery and fertilizer timing to improve wheat survival. Until now, after harvest in year two the weeds have moved in fast and shaded out crop plants. By that time in summer the wheat appeared malnourished, but Wang feared that fertilizing would make the weed problem worse. He hopes to improve mechanically knocking back weeds so he can improve his crop with feeding.

Research technician and tractor driver Adam Gorrell will continue using a tine weeder, which effectively rakes out little weeds between crop rows but has not done so well with heavier growth in summer. So he will add a new device, the finger weeder. This is like two small spoked wheels without rims, turning opposite one another in the soil, and so close that they can take out weeds practically in the wheat row itself. It will demand of Gorrell careful driving. Fertilizer timing will vary from a few weeks before harvest, at harvest, and a few weeks after.

A third study will compare how this perennial wheat sets seed in different fields and conditions. Results will be compared with chromosome counts. Although the plants look much the same, their genomes vary. Over generations, some lines have lost a few wheatgrass chromosomes. Past perennial wheats have produced best with 56 or 42 chromosomes. Some of Wang's new plants have more than 56. He wants to see if the best yields match a particular count.

Though these hybrids can live two years, they aren't strongly perennial. Instead of lying dormant through the summer after harvest, in the second year they quickly regrow, which exposes growing tips to heat damage. Wang, Labhsetwar, and a colleague at Oklahoma State University are trying to change a gene apparently responsible. Meanwhile, plants well nourished with fertilizer may actually lay back a little on summer regrowth.

Have experience, want more

Land Institute internships usually last three to six months. Most interns have earned bachelor's degrees or will within a year. They may already have their sights on grad school. For those not quite decided, this winter we began the research residency program. Residencies will last one to one and half years. Most participants will have been Land Institute interns who want deeper work with perennial grains and agroecology.

Among our first residents is 2018 intern Abigail Han, of Arlington, Virginia, who is majoring in crop and soil science at Virginia Tech. Here she studies the genetics of kura clover, which could provide continuous ground cover and, as a legume, provide nitrogen to other crops it's grown with. "Thinking about how we can go with the flow of nature instead of constantly fighting against, like we usually do in conventional farming, enchants me", she says in a profile on our website.

Eric A. Cassetta, of Prescott, Arizona, was another 2018 intern. He majored in biological sciences and minored in philosophy at Arizona State, and is helping us understand the pathogens in silphium, our perennial oilseed crop. "The work here caught my attention because it has a beautiful blend of sustainability and applied scientific research, two of my passions", he said.

A third 2018 intern, Alex Griffin of New York City, is studying biology, with a focus on plant sciences and ecology, at Williams College in western Massachusetts. Here she'll study protecting silphium, looking at diseases and beneficial fungi among silphium roots. She's attracted by the potential of perennial grain polycultures, and also "because I wanted to work with and learn from scientists, educators, and thinkers who embrace difficult questions, love land and place, and are committed to building a more just world".

Cassetta

Detrixhe

Han

Griffin

Rena Detrixhe grew up near Russell, Kansas, and earned a fine-arts degree from the University of Kansas. She was not a Land Institute intern, but is a resident for our relatively new effort, ecosphere studies. Her website, renadetrixhe.com, describes

Facing page: Artist Rena Detrixhe is The Land Institute's research resident for ecosphere studies. Resident is a new job here, for longer, deeper work than an internship. Our other residents work in crop research. Here, from finely ground Oklahoma soil Detrixhe creates her Red Dirt Rug Monument, whose iterations have shown in cities from Santa Fe, New Mexico, to Roanoke, Virginia. Mark Andrus photo.

her work as exploring "relationship between humans and the more-than-human world". For an example, see page 24. Her work here concerns agriculture, memory, grief and healing, and Great Plains history. She'll also help in the crop plots, and sow a polyculture plot for her research.

Long-timer moves on

Sheila Cox, who worked as a Land Institute technician for almost two decades, left in March to live with and care for her grandmother in Georgia. Beginning in 2000, she did field work for us while earning a bachelor's degree in biology at the University of Kansas. She joined us full-time in 2005 to help develop sunflower relatives and sorghum. She will return this summer to help with planting.

Cox

The rise of perennial rice

Rice developed by Land Institute collaborator Fengyi Hu has become the most commercially advanced perennial grain in the world, with about 7,400 acres – more than 11 square miles – planted in Yunnan Province, China. Three of our researchers made an annual trip to Yunnan University last fall, and toured remote smallholdings where farmers are trialing hybrids of annual rice and perennial rice. One type has rivaled the yields of annual rice over several years without replanting. This is in irrigated paddies, not yet on dry, upland fields, where it may prove more valuable for stemming erosion. This year plantings are to extend to Laos, Cambodia, Vietnam, and Myanmar. African researchers reported that Yunnan rice has done well in Uganda before any breeding for adaptation to that place. Our research director, Tim Crews, said the perennial rice was delicious.

Growing a Green New Deal

Reform versus revolution, realistic versus radical – these are false dichotomies, Land Institute President Fred Iutzi and former University of Texas journalism Professor Robert Jensen argue in proposals to flesh out the Green New Deal, only a resolution in the US House. In an online essay for Resilience, they propose two paths that are "politically viable today but also point us toward the deeper long-term change needed" for agriculture's crucial role in the deal. These paths are 1) job training to help repopulate the countryside and change how farmers work, and 2) developing perennial grain crops.

The writers challenge capitalism and the industrial worldview with two core beliefs about what's needed for humans to live sustainably: 1) People are not just labor-machines, nor just customers; an economic system should make work meaningful, equitable, and fulfilling, and make communities healthy. 2) The more-than-human world – what we typically call "nature" – cannot be treated as nothing more than a mine and a dump.

In preface for how to repopulate the countryside, Jensen and Iutzi write, "Today one hears of how rural America and its people are ignored, but a more accurate term would be exploited" – rural America is a colony. "Agricultural land is exploited, as are below-ground mineral and water resources, typically in ecologically destructive fashion.

He keeps us looking good

Scott Hamilton checks alignment of pulleys after replacing a fan belt in the original Land Institute greenhouse. Hamilton is our new facilities and grounds technician. Preparing him for the job were 20 years in construction and eight years in landscaping. He also grew up in Salina, appreciated our reputation, and lives a mile away.

Meanwhile, recreation areas are 'preserved', largely for use by city people". They say the Green New Deal should support programs to expand farming and farm-related occupations in rural areas. This would be part of preparation for the more labor-intensive sustainable agriculture needed for "land-conserving communities and healthy regional economies". For an example they offer the Minnesota-based Land Stewardship Project's training programs, which include a workshop for clarifying participants' motivation to farm and, with help from an experienced farmer, identifying resources and needs. There's also a one-year program for those ready to start a farm, whether or not they own land, and a two-year course for farmers needing guidance for long-term success. To read the essay, go to resilience.org and search for "Growing a Green New Deal".

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MEMORIALS

Mary Castielo, from Michael R. Johnson · Strachan & Vivian Donnelley, from John Hoskyns-Abrahall · James P. Duggan, from Eileen Duggan · Avenell Harms, from Duane K. Harms · C. Dale Johnson, from Michael R. Johnson · Mitch Mathis, from Charlene Mathis · Larry J. Nelson, from Michael Robinson · William R. Phelps, from Patricia Phelps · William H. Rebholz, from Edward & Adelaide Jacobson · Harry L. Westoff, from Evelyn and Gordon Maxwell · Laura Ingalls Wilder, from Elizabeth Greene

THE LAND INSTITUTE

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Eric Cassetta, a research resident at The Land Institute, cuts leaves from a silphium stem to make a clone. He'll attach a clamshell container filled with potting soil in which the plant will root. In the early steps of domestication as a perennial oilseed crop, silphium's genes remain wildly diverse. With genetically identical plants we can more clearly see how influences like soil makeup and pests affect their growth. When we find plants with desired traits, such as disease resistance and large seeds, cloning allows us to make multiple copies. For more about silphium, see page 21. For more about the new research residency program, see page 25. Scott Seirer photo.