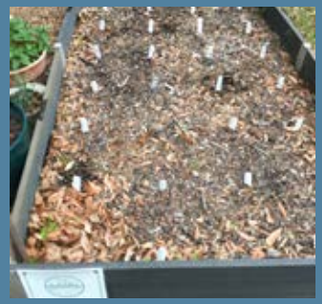
THE LAND INSTITUTE

2023 SEASON

Perennial Wheat

Civic Science Field Guide












PHOTOS: SUBMITTED BY 2022 SEASON PERENNIAL WHEAT CIVIC SCIENTISTS

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Welcome

Welcome to the second growing season of our perennial wheat civic science project!

In this multi-year effort, we are continuing to investigate **perenniality, disease,** and **community learning** through a decentralized project with roots in local landscapes across the country. This year's scientific data collection protocols are similar to last year's. We are making observations, submitting photos and data online, and hopefully harvesting seeds to put in the mail.

However, we are also adapting the project in a few ways in response to the challenges, opportunities, and insightful feedback realized last year. Multiple civic scientists faced problems with plot establishment and replanted perennial wheat seeds that may be sprouting for the first time this spring. We are offering more frequent, open-ended community calls to provide support and facilitate conversation. We are embedding community learning questions in the scientific datasheets, and providing an always-available feedback datasheet, to make it easier to share questions and reflections. And we are trying a new format and rhythm for our return of results by building an accessible "story-map" over the 2023 season.

Our relationships to perennial wheat plants are taking new forms, too. You can see one artistic example on this field guide's cover, provided by Kansas City-based illustrator Susan Flower. We're excited to see what stories, connections, and sensory experiences emerge through your care and curiosity in 2023.

Thank you for learning with us, perennially. Here's to another year of research together, testing and developing components of future diverse, perennial grain agricultures and cultures.

Onward!

How to Use this Field Guide

This field guide is designed to support you as civic scientists, both to help you learn and to facilitate high-quality data collection. Feel free to read the field guide cover to cover at the beginning of the season, or reference it as you're taking data throughout the season, or both!

Inside, you'll also find an outline of the purpose and plan of the project this season. Use this guide as a reference as you plan your season, visit your plot, and collect data. You may wish to consult it when talking to family, friends, or neighbors about the project.

In the back of this guide, you can find a reference section that explains concepts that will help you orient to the broader context of perennial grain agriculture research. For more educational resources, visit the "Resource" page on our project at CitSci.org.

Finally, the guide is accompanied by materials for harvest. Save this box! You will mail your grain harvest back to The Land Institute in the fall.

How to Care for Your Plot

Weeding

Weeding is the central part of maintaining the plot. We want to avoid any competition between weeds and perennial wheat plants that could affect their survival rate. Since the wheat plants have a one-foot distance between each other in our plots, there is plenty of open space for weeds to grow. The plant density is much lower than in an agricultural field where plants are grown much closer to each other, so once wheat plants attain a certain height, they are able to shade out the weeds.

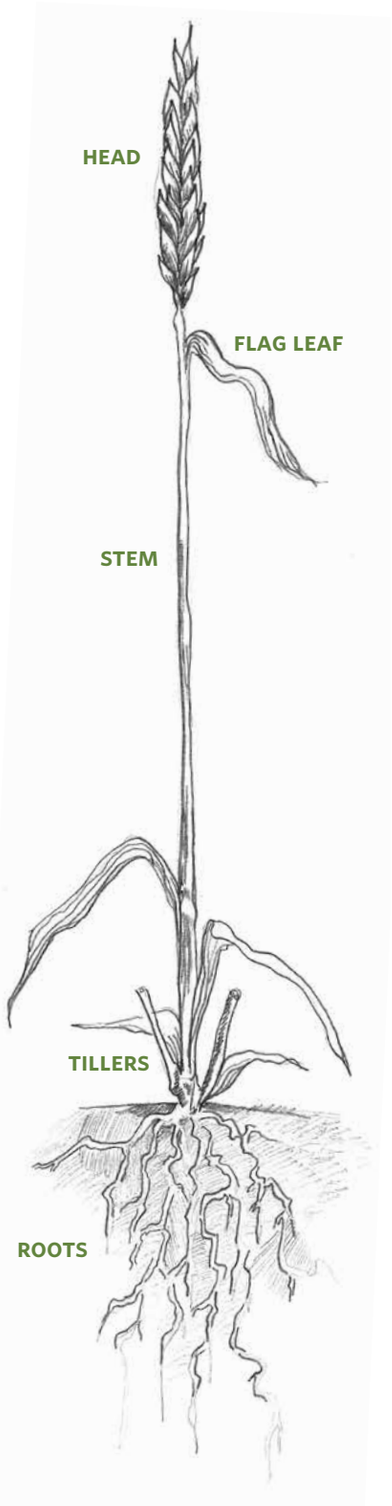
In our plots, weeding *at least once every two weeks* throughout the growing season is important to keep the weeds in check. You can use a tool like a hoe to remove weeds which are away from the wheat plants. For weeds very near the wheat plants, it is safer to remove those by hand so as not to accidentally harm the wheat plants, especially when they are small.

Watering

Regular watering is not recommended for wheat plants as natural precipitation is usually enough. For most wheat varieties, 15-20 inches of rain is enough to help it reach maturity. **When you notice that it hasn't rained for two weeks and the plants look stressed, you should water them.** We don't want to water the plants regularly, but we don't want the plants to die because of a lack of water.

Plant Tags

It's important that plant tags stay in place next to the corresponding plant. If your tag has blown away or degraded, replace the tag with a new one included in your season kit.



Plants & People

Get to know the plants and people involved in this perennial wheat civic science project. We join a long lineage of people who have grown and observed plants in their home spaces by participating in this project and process.

The plants in focus for this project are grain crops. Grains are staple foods with nutritional and cultural importance across the globe. By growing these grain crops side by side, their unique characteristics, structure, and development become visible.

Plants

Perennial Wheat: *xAgrotriticum*

Perennial wheat used in this study is a hybrid between durum wheat, most commonly known for its use in pasta, and intermediate wheatgrass. For more about the baking qualities of perennial wheat, read "Baking" on page 27.

In this project, the perenniality of this wheat variety is being tested across various geographies.

Intermediate Wheatgrass (IWG): *Thinopyrum intermedium, Cycle 5.*

Kernza® is a trademark name for grain harvested from intermediate wheatgrass, a deeply-rooted perennial plant first introduced as a forage crop in North America that is now being domesticated by The Land Institute and our collaborators as a perennial cereal grain for humans. Learn more at Kernza.org!

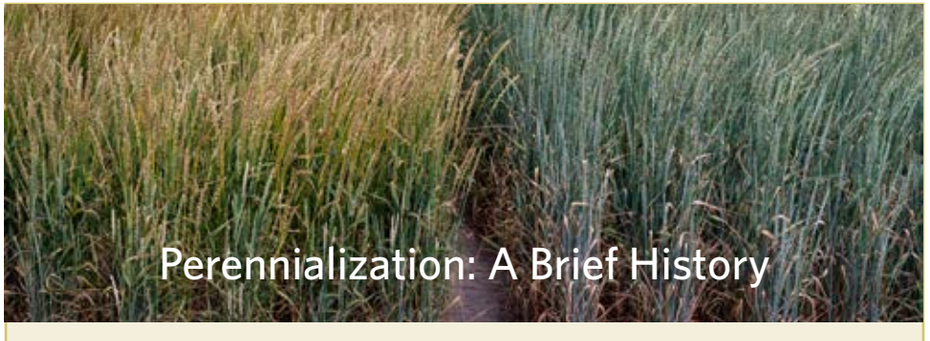
In this project intermediate wheatgrass is being planted as a "control" for perenniality. This means that the research team can compare perennial wheat's survival rates with intermediate wheatgrass.

Plant Pathways Toward Perennial Crops

In addition to noticing variations in appearance, it's helpful to note the pathways these grain crops have taken throughout history to grow in their present form in your plot this year.

Domestication starts with identification of perennial species (such as intermediate wheatgrass) that have one or more desirable attributes such as significant and consistent seed yield, synchronous flowering and seed maturation, or good seed retention (also called non-shattering). Large, diverse populations of the crop are grown out, and plant breeders select the best individuals for the traits of interest. These individual plants are then cross-pollinated, and the resulting seeds are planted to produce the next improved breeding population.

Perennialization is another method of breeding new perennial crop species that involves crossing an existing annual grain crop (such as annual wheat) with a wild perennial cousin. When successful, these "wide hybrid crosses" produce plants that maintain high seed yield and quality similar to the annual parent while inheriting the perennial lifestyle from the other parent.



Perennialization: A Brief History

Wheat has a long history of domestication as an annual grain crop. More recently, over the last hundred years, attempts have been made to perennialize wheat.

1920s — The earliest efforts date to the 1920s in Omsk, Russia.

1930s — N. V. Tsitsin performed the first successful cross in the 1930s between annual wheat and its perennial relatives.

1940s to 2000s — Since then, there have been efforts in Australia, China, and the United States to breed perennial wheat, including by Washington State University, Coit Suneson at the University of California-Davis, and Tim Peters. In addition to breeding a new perennial crop, inspiration for performing crosses between annual wheat and its perennial relatives comes from developing a dual-purpose grain and forage crop and hopes to transfer disease resistance from perennial relatives to annual wheat.

2001 — At The Land Institute, work on perennial wheat was started in 2001 by Stan Cox and Lee DeHaan.

2010 — In 2010, Shuwen Wang joined The Land Institute in a role dedicated to work on perennial wheat. In addition to testing and improving on perennial wheat lines developed elsewhere, new lines have been created at The Land Institute by performing thousands of crosses between annual wheat and their perennial relatives. Earlier efforts focused on using bread wheat as the annual parent. Good perenniality observed in a perennial wheat variety derived from durum wheat by Montana State University inspired the use of durum wheat in The Land Institute's breeding program, which has informed the cross between durum wheat and domesticated intermediate wheatgrass used in this civic science community.

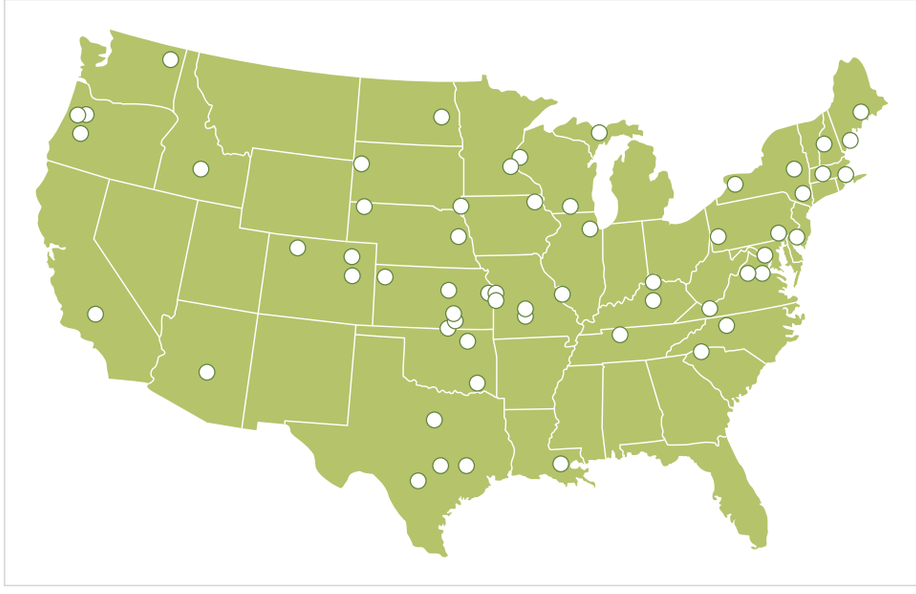
2020 — Shuwen Wang observed that the most current variety of perennial wheat was surviving two years in the research plots in central Kansas. It became necessary to test this variety's perenniality in various geographies, particularly arid regions. The idea of engaging civic scientists with this question was formed in 2020.

2021 — 106 civic science participants from across the US joined this collaborative research project.

2023 — 56 civic scientists continue to the participate in the project.

People

Civic Scientists



The Land Institute Researchers

Aubrey Streit Krug

Anna Andersson

Shuwen Wang

Maya Kathrineberg

Kathryn Turner

Yvonne Thompson

Lydia Nicholson

Reece Knapic

Our Perennial Wheat Civic Science Project

The Land Institute's civic science communities bring people together to learn as they grow, observe, care for, and study perennial grain crops. We are testing civic science as a method to gather scientific data across multiple locations and grow public participation and community learning.

The Perennial Wheat Civic Science community is exploring both social and ecological questions during this multi-year project. The three core question themes are:

Perenniality + Diseases + Community Learning

Perenniality

Is this variety of perennial wheat actually perennial? How many years does this variety of perennial wheat grow and produce seed? In which geographies does this occur?

Diseases

What diseases is perennial wheat susceptible or resistant to, and what is the severity? In which geographies does this occur?

Community Learning

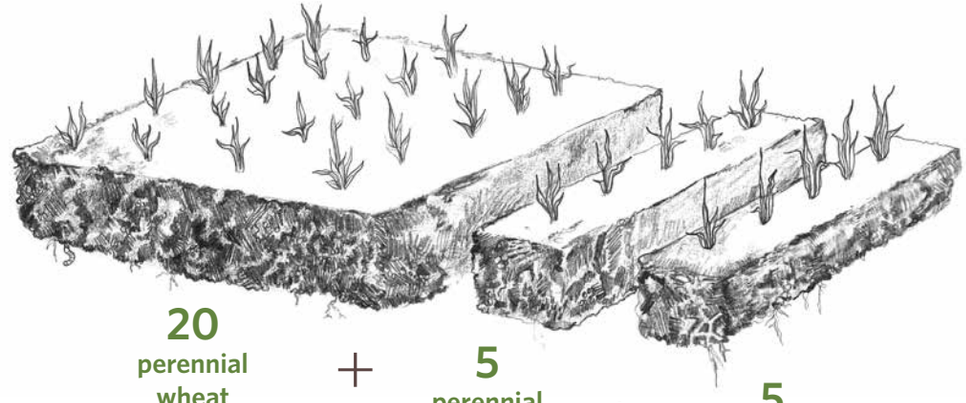
What do civic scientists and researchers learn through this project? What activities and materials support and sustain community learning? What knowledge and relationships are built, and who do they include?

In the near term, the purpose of this project is to build knowledge that advances the breeding of perennial wheat and improves our civic science method.

In the long term, we hope that by creating a broader network of people studying and caring for perennial wheat, we can help accelerate its scientific development and build the social and cultural conditions for a positive shift to diverse, perennial grain agriculture.

Project Design

30 Plants Total



20 perennial wheat + **5** perennial wheat, variety 2 + **5** intermediate wheatgrass

X **56** locations across the US

At least 3 plants of perennial wheat are needed to contribute meaningful data in the project!

Plant Tags

Each plant in your plot has a corresponding plant tag. These plant tags assist in identifying plants and are useful in data collection.

White stakes should be used for the perennial wheat and intermediate wheatgrass varieties planted in 2021. Blue stakes should be used for the second perennial wheat variety planted in 2022.

Protocols Timeline

Timing is approximate, may be different in your region!

	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT
Data Collection								
	Winter Survival	Season Feedback	Flowering	Photo Day	Harvest	Perenniality	Perennial Wheat Story	
	ESSENTIAL	ESSENTIAL	OPTIONAL	ESSENTIAL	ESSENTIAL	ESSENTIAL	OPTIONAL	
Logistics		 Packages Arrive EARLY APRIL				 Ship Harvest to The Land Institute BY SEPTEMBER 1		
Community Learning: In-Person and Digital			Monthly Community Calls					
			 Baking MAY	 Site Visits JUNE-JULY	 Site Visits JUNE-JULY			 Thank you! Return of Results Webinar OCTOBER 24

Timeline Components

Data Collection

This field guide is meant to help you with high-quality data collection. Data in this project include observations, photographs, numbers, locations, dates, samples, materials that are collected and harvested, and more quantitative data. The project also includes qualitative data shared by civic scientists and researchers through feedback, stories, conversations, messages, site visits, social media posts, forums, community calls, reflections, and other interactions. We collect, organize, and analyze data to investigate

How to collect data?

See the "Protocols" section, starting on page 21, for step-by-step instructions throughout the season! These steps help ensure the data collected meets scientific standards. Along with educational materials, repeated practice can help build skills to gather high quality data.

So follow the steps as best you can, reach out with questions and feedback so we can help, and know that you (like us!) are growing your skills now and for the next season, in the lifelong practice of learning.

Where to submit data?

CitSci.org

If you prefer to upload your data on a desktop, **visit CitSci.org to do so via the Perennial Wheat Civic Science project**. Here you can also access forums and multimedia resources.

TLI Civic Science App

Access datasheets and submit photos on your phone. The TLI Civic Science App is connected to CitSci.org and will upload your data. **Download the free app on your phone's app store by searching "TLI Civic Science."**

If you have problems logging in, accessing your account, or are receiving error messages on data submissions, contact **webmaster@citsci.org**.

Logistics

Mailing and packages:

Save the box you received in April to send your harvest materials back to The Land Institute. Your package includes a prepaid shipping label for returning materials in September. If you lose your label or need another, contact us, and we'll send you a new one.

Community Learning: In-Person and Digital

Webinars:

Webinars are interactive and allow civic scientists to meet other people across the country who are also engaged in learning about perennial crops. Researchers share civic science project results and provide knowledge about the broader context of perennial grain agriculture into which this civic science project fits.

Return of Results: Tuesday, October 24, 2023 at 7:00 pm CST.

Monthly Community Calls:

Join us for a community call the first Tuesday of every month at 7pm CST during the months of May – September. Civic scientists from a variety of projects will join an informal call to ask questions and learn from one another.

Regional Meet-ups:

Are you interested in gathering in person or virtually with other civic scientists in your region? Our team will be supporting those who would like to organize and host a regional gathering. E-mail us if you're interested.

Site Visits:

In June and July, our team will be asking select participants if we can make a visit to civic science plots to meet participants and their plants.

Project Communications

Forums

Access forums on CitSci.org to share your reflections about the project, ask questions, and connect with fellow civic scientists.

Newsletter

Each month during the growing season, you can expect an email newsletter from us. Monthly newsletters include results from the previous month, along with videos and materials to assist in your data collection and learning about perennial grain agriculture.

Social Media

Share your experience with other participants and the community at large by tagging **@thelandinstitute** and using the hashtag **#perennialwheatcivicscience**

Contact us:

civicscience@landinstitute.org
(785) 914-5262

StoryMaps

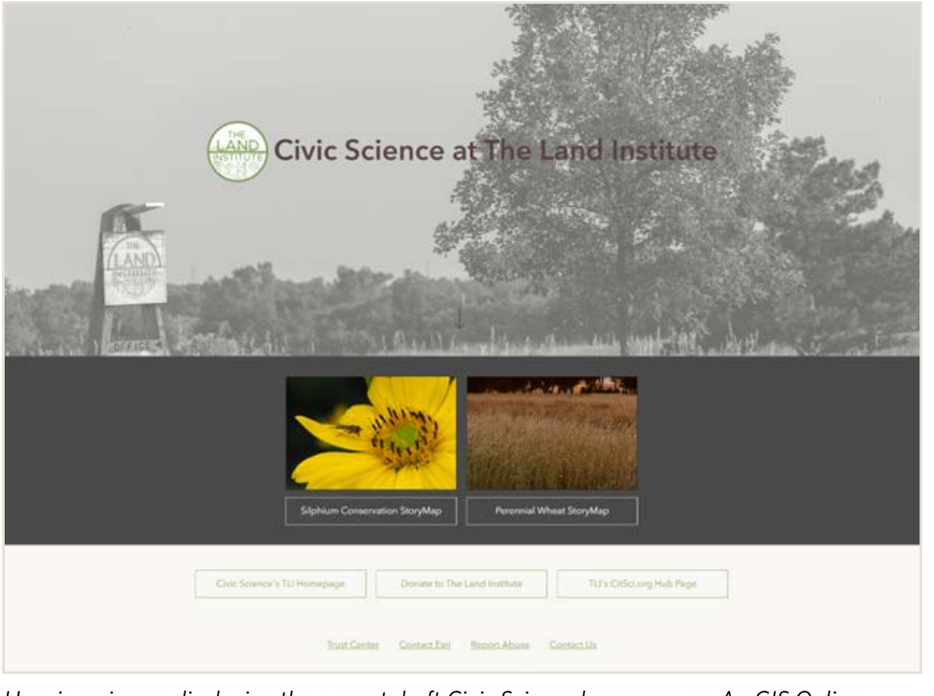
In 2023, we are testing a new way to share project results and stories with you as civic scientists, and with broader audiences. We are building an interactive ArcGIS StoryMap to communicate and visualize project data. Throughout the season, we will be updating the StoryMap with maps, stories, images, and news.

The Land Institute's Civic Science ArcGIS homepage can be found at: **civscitli.maps.arcgis.com.** Scroll down to see all current project StoryMaps. You can also access the StoryMap via the monthly newsletter and the CitSci.org project.

ArcGIS Online is an online geographic information system (GIS) tool that is used for managing, analyzing, and displaying geographic data. StoryMaps is one of the programs offered in ArcGIS Online. It allows us to build web pages that create and display maps alongside story-driven content.

StoryMaps are openly accessible and will be viewable by researchers, civic scientists, and the public. Data and content on the StoryMaps will be de-identified unless the civic scientist has given direct consent to have identifying information included. Geographic coordinates used in the mapping are kept at a coarse scale, so they are not identifying. We are happy to attribute content with your permission. Please contact us if you would like credit for a photo or another form of attribution, or if you would like to share a story specifically for inclusion in the StoryMap.

Here is a sample of mapping content you could expect to see. This particular map is using perennial wheat flowering dates tracked by civic scientists.



Here is an image displaying the current draft Civic Science homepage on ArcGIS Online.

Reminder of Informed Consent

Participation in submission of scientific and sociocultural data through these protocols is voluntary, but encouraged. Resulting knowledge will inform our work as a project research team, and we will regularly report what we are learning back to you as the perennial wheat civic science community.

Members of the research team know civic scientists' identities, but details about your identity will only be known to the community to the extent that you choose to share. The research team will not disclose any personally-identifying information about you in publicly-available forms unless we seek and receive permission from you first.

For more information about how results will be of benefit and be used, and about confidentiality, please look at the informed consent you signed at the beginning of the project (a copy is available in the project resources on CitSci.org) and reach out with any questions.

Protocols

A protocol is a standardized set of steps that all participants will follow in completing data collection in this research project. Protocols help ensure high-quality data collection.

The following protocols are in chronological order. The headings will help you connect your contribution to the **core research questions** this project is exploring and show if the activity is **essential** or **optional**.

Datasheets

When submitting your data on CitSci.org or the app, **find the datasheet that matches the protocol name bolded at the top of each protocol page in the field guide.**

If you'd like to share information about your plants or your plot that doesn't already fit into one of the datasheets, submit your updates through the **"Plant Update"** datasheet. Here you can report events such as hailstorms, herbivory, or other interesting observations worth sharing!

Season Feedback

What is supporting your learning and engagement, and how can we improve?

COMMUNITY LEARNING
ESSENTIAL

Timing

April and ongoing, whenever you have feedback and ideas to share

Getting Started

We ask you as civic scientists to share feedback to help us improve this project and to inform future civic science efforts. Your feedback supports our collective learning. When you share what is working well, we can learn what to sustain and grow. When you share challenges, questions, and ideas, we can learn how and why to change.

Protocol

1. Access the season feedback datasheet anytime at:
   airtable.com/shr8ot6LlZisDMTEl

   You can also scan the QR code to access the story datasheet:

2. Enter your feedback and click Submit.

Going Deeper

Your feedback is essential in helping us understand civic scientists' experiences and the impact of civic science. Feedback is most helpful when we can understand what's going on, and if we aren't sure we understand, we may wish to reach out to you to gain clarity or context.

We look for patterns across feedback in the group. We also look for infrequent but important responses that highlight where we need to improve. Your honest answers provide important data for designing civic science projects, materials, and opportunities and research opportunities for civic science.

Winter Survival

Were your plants affected?

PERENNIALITY
ESSENTIAL

Timing

March - April, depending upon your region; see below

Your plants might look like this at this stage!

Getting Started

The last frost date has passed for most of the continental USA in April. It's time to note how many plants are starting to turn green and grow again. The green plants have survived the dormant winter period and are ready to grow back in spring. Wheat plants can emerge from winter dormancy after the average temperature over 14 days is above 41°F or 5°C. We want to identify how many plants have survived the coldest months of the year after having emerged in the fall through this data collection.

Protocol

1. Identify the range of last frost date in your region using the guide map:

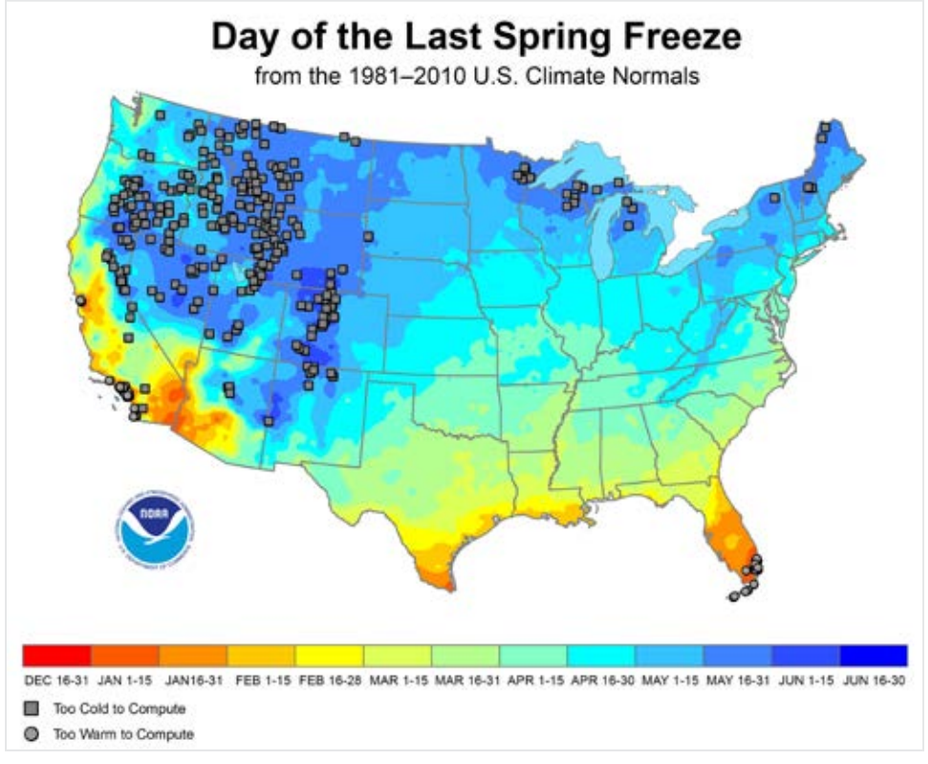
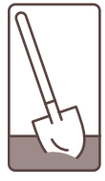


IMAGE: HTTPS://WWW.NCDC.NOAA.GOV/NEWS/WHEN-EXPECT-YOUR-LAST-SPRING-FREEZE

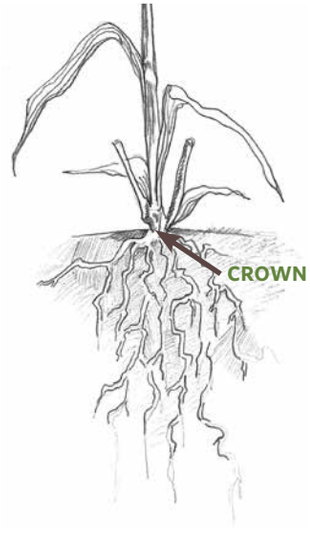
2. Make the observation **a week after the last date** from the range you obtained from the map.
3. Identify the perennial wheat plant tag numbers with **at least three green leaves**.
4. Confirm that **only one plant is emerging** from each plant tag. If you see two plants emerging from one plant tag location, remove one of the plants.
5. **Take a photo** of your plot.
6. Enter data!
7. **Log on to CitSci.org** and access the TLI – Perennial Wheat Civic Science project.
8. Click the **Add Data** button to find and open the datasheet titled Winter Survival.
9. Enter your answers and click **Submit**.

If fewer than 3 plants survived at your location, you do not need to collect additional data.



Going Deeper

What is happening with the plants that causes winterkill? What does this mean in various geographies?



As the temperature decreases during fall, wheat plants start getting ready for winter dormancy by reducing the moisture in the crown and slowing the overall growth. The crown is the base of a grass plant that connects the roots and the shoots.

This process is called cold acclimation. When the fluctuations in temperatures are extreme, as we observe with climate change, plants can experience below-freezing temperatures even before they are acclimated to cold, leading to their death. In spring, as the temperatures rise, the new leaves emerge from existing tillers and new tillers from the crown, leaves lengthen and start to become erect. Tillers are lateral shoots that grow from the crown and the main shoot. Signs indicating that the plant is moving from the vegetative phase to the reproductive phase include leaves becoming erect and elongating the stem.

The plant will progress through the various stages. Tillering that occured in fall can continue in spring, leading to stem elongation and eventually heading when the seed head comes out.

Genetic differences in plants (their genotypes) as well as environmental differences can lead to winterkill. For example, some plants have better cold acclimation than others, and in some places sudden spells of cold weather can occur before plants are acclimated.

Why did we plant these plants in the fall?

Wheat plants are vulnerable to extreme heat or cold when in the reproductive phase of growth. That's why they remain in the vegetative phase of growth until they have experienced a certain duration of cold days. This growth habit is called the winter growth habit.

Undergoing cold duration is called vernalization which signals to the plants that it's safe to transition to a reproductive phase which includes flowering. A vernalization requirement is an adaptation of wheat plants to survive the harsh winter in temperate regions. Wheat plants also sense the length of the day and flower only when the days are getting longer. This is called photoperiod sensitivity. The combination of vernalization requirement and photoperiod sensitivity ensures that the winter has passed and it's spring when the plants can safely flower. Planting wheat plants in fall gives them a head start in spring, and they mature before the summer heat sets in.

Baking

What is your experience baking with perennial wheat?

COMMUNITY LEARNING

OPTIONAL

Timing

April – May

Getting Started

Two punds of flour is included in your season start kit.

What do we know about perennial wheat flour?

The perennial wheat flour included in your kit was grown in 2022 in Salina, Kansas, and milled as a whole grain at The Land Institute and sifted using an #40 sieve with larger holes. This means that the seed's bran is included, resulting in whole wheat flour.

The variety of perennial wheat growing your plot and making up this flour is a cross between durum and intermediate wheatgrass. Durum is traditionally used in pasta and crackers, and intermediate wheatgrass is known to have a sweet, nutty flavor profile when milled.

Wheat Quality Analysis tests on this variety have shown high protein content. Additional baking quality analysis is underway.

Protocol

1. Share about your experience!
2. We'd love to hear about what you observed about the sensory experience of baking, cooking and tasting perennial wheat. These observations are simply for fun!
3. Submit your photos and notes from your home baking and cooking on CitSci.org datasheet titled Baking with Perennial Wheat.

Flowering
When did your perennial wheat plants flower?

PERENNIALITY
OPTIONAL

Timing

May – June

Getting Started

The flowering date helps us estimate how long it would take for wheat plants to mature. When the wheat plants flower, they are very susceptible to extreme cold or heat. A later flowering date means higher chances of the wheat plant to experience extreme summer heat, potentially resulting in its death. We also want to see if the flowering date varies with geographical location.

Fig. 1

Fig. 2

Protocol

1. Observe your perennial wheat plants throughout the month of May.
2. When you see the flag leaf has developed on the shoot, you'll know that flowering is near. [Fig. 1]
3. When you notice the first seed head has fully emerged from the flag leaf, the plant has flowered! The seed head is the collection of wheat flowers where the seeds will eventually appear. [Fig. 2] No need to record the flowering dates of intermediate wheatgrass.
4. Record the date and report in datasheet titled Flowering.
5. It's ok if you missed the first flowering date, just report the date when you notice that at least one perennial wheat plant has flowered.
6. Take a close up photo of the emerged seed head you are reporting about.
7. Upload the perennial wheat plant's flowering date to CitSci.org or TLI Civic Science App.
8. Repeat these steps for the next two perennial wheat plants that flower in your plot. In total you'll record three flowering dates, using three separate data sheet submissions.

This photo of intermediate wheatgrass illustrates what you can expect to see as the grasses in your plot flower. Note that each species' flowering will look slightly different!

Going Deeper

We would like to have the flowering date of three plants for statistical purposes. Don't worry if you notice the fully emerged head a few days late. Once you see a fully emerged head, check the plot every day until you have a flowering date for three plants.

Did you know? The wheat plants in your plot are anemophilous or wind-loving. These plants use the wind to shed their pollen rather than rely on insects or animals to carry their pollen. Because they don't need to attract insects for pollinators, you won't notice any fragrance, nectar, or petals on these flowers. The flowers that have emerged from your wheat plants are small, non-petaled, and colorful.

Disease Photo Day

Are your plants affected?

DISEASES
ESSENTIAL

Timing

June 4-9, 2023

Getting Started

Disease Photo Day

This data collection will help identify what diseases affect plants in various parts of the country. civic scientists will help contribute new data on perennial wheat's susceptibility to Fusarium head blight and stem and leaf rust.

By identifying the diseases that affect perennial wheat we can see the disease range throughout the various geographies, and the susceptibility of the perennial wheat you have growing in your plot. If plant breeders develop more resistant strains through breeding, there could be less need for fungicide application, and less inputs which is beneficial economically and environmentally. As plant breeders and civic scientists work to develop the perennial wheat at The Land Institute, researchers want to understand what variants are found so that we can improve this perennial crop and also learn how it will fit into current annual wheat growing regions.

Protocol

1. Visit your plot on June 4-9, 2023.
2. Review the disease pictures below:

Rusts

Leaf Rust

Stem Rust

Stripe Rust

Fusarium Head Blight

Spot Blotch

Bacterial Leaf Streak

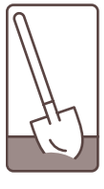
3. **Do any of your plants have symptoms that look like this, or other symptoms that you're not sure about?** Identify infected stems and leaves on your perennial wheat plants that exhibit signs similar to the pictures above. No need to keep track of which plants you're observing!

4. **If YES, take a photo** of a stem and/or leaf that resembles the pictures above and submit your observation on the Disease datasheet on CitSci.org or TLI Civic Science App. If the Crop Protection Genetics team sees something that is of interest from these photos, they may reach out and ask for a leaf sample to include when you send your harvest materials back to The Land Institute in September.

   Important when photographing stems and leaves!

   - Make sure the leaf is living (has some green tissue) and is flat rather than rolled or wrinkled.
   - Make sure that the photographed image is zoomed in to focus the majority of the frame on one leaf, and is well focused.
   - Make sure the lighting is even on the whole frame; often, direct sunlight is not the best for photographing plants. Pictures of shaded portions of plants or photographs taken on overcast days better distinguish pathogen symptoms.

5. **If NO, report your observation** by the Disease datasheet on CitSci.org and note that you don't see signs of disease. Absence of disease is also very useful information! There are some environments where perennial wheat can thrive without rust or head blight, and we'd love to know where those places are located!



Going Deeper

What types of disease affect wheat?

90% of plant pathogens are fungi. Besides fungi, plants are also affected by viruses and bacteria. On wheat plants, disease symptoms are evident on various parts of the plants such as the head, the stem, and the leaves. Different crop species and varieties are susceptible to different diseases and if affected, the yields and quality of the grain can suffer. These diseases can spread from the soil, the air, and from other plants that are infected. Some examples of the diseases that affect wheat are:

Rust diseases: fungus that affects stems or the leaves

Rusts in perennial wheat are caused by three fungal pathogens that can drastically reduce the grain yield and grazing quality of the crop. The rust spores can travel long distances and can infect many cereal grains including barley, oats, rye, annual wheat, perennial wheat, and intermediate wheatgrass, though we have not observed any leaf rust or stripe rust infection on intermediate wheatgrass in our research so far. For disease to occur, the spores must fall onto a susceptible plant host, and have adequate humidity and moderate temperatures for germination, which may not occur in all seasons or growing regions of the civic science trial.

Fusarium Head Blight: fungus that produces toxins in grain

Fusarium head blight is caused by the fungal pathogen, *Fusarium graminearum*. This pathogen can infect the developing grain of many small grains, including perennial wheat, annual wheat, intermediate wheatgrass, barley, and rye. Infection occurs when environmental conditions are favorable, ideally between 20-25° C with high moisture or humidity occurring during pollination and grain fill. This pathogen can produce multiple mycotoxins, including deoxynivalenol (DON) which is toxic to humans and livestock, limiting the utility and value of the grain. Infection may be visible on the heads of the plants, resulting in a bleached appearance before the head senesces. Pink-orange fungal mycelia can sometimes be observed on the heads. Infected kernels can appear pink, dark grey, or chalky white.

What can plant breeders do about disease susceptibility?

Introduce resistance genes! Intermediate wheatgrass is known to have resistance to Fusarium head blight, leaf rust, stripe rust, and stem rust. Because perennial wheat is a hybrid between intermediate wheatgrass and annual durum wheat, the fusarium head blight resistance has been introduced to prevent infection into annual wheat varieties that usually suffer. Additionally, strains of pathogens that infect annual wheat may be more common due to its widespread global production and limited genetic diversity.

Harvest:
How much did your plants produce?

PERENNIALITY AND DISEASES
ESSENTIAL

Timing

July, with exact timing based on location; due by September 1, 2023

Getting Started

You can expect your perennial wheat to mature in July in many places. When harvesting, it's important to harvest when the head is completely dry but not yet dropping its seeds or "shattering." Make sure the heads are fully brown with no sign of green. If there is moisture in the seed heads, they may mold in transit. You can also do a bite test where you take out a seed from the head and try to bite it. If the seed has hardened and is hard to bite, it's ready for harvest.

Perennial wheat plants will mature first, followed by intermediate wheatgrass plants. You will harvest perennial wheat plants during the first harvest. Two weeks later, you will harvest the intermediate wheatgrass during the second harvest.

Protocol

1. Locate harvest materials: scissors, tape, plant number stickers, harvest bag, and measuring stick.
2. Take a photo of your plot prior to harvesting.
3. Measure the height of three of your perennial wheat plants. Height of the plant is the vertical distance between the ground where the roots are and the top of the seed head of the tallest tiller.

4. **Harvest: Perennial Wheat**
   - **a.** Locate the two perennial wheat varieties growing in your plot. You will harvest from each plant individually. It is important to keep the heads of each unique plant separate from the other plant heads.
   - **b.** Cut the stem of one perennial wheat plant using scissors approximately 6 inches below the head. Repeat this step until you've harvested all the heads from one plant.
   - **c.** Using tape, gather the stems together and tape them together.
   - **d.** Find the harvest bag with the correct species and plant number labeled in your harvest kit that matches the plant you've harvested, and apply it to the tape around the stems.
   - **e.** Take a photo of one of the perennial wheat bundles in your hand—no need to repeat this step when harvesting from remaining plants.
   - **f.** Place the bundle of stems in the corresponding labeled brown paper bag provided.
   - **g.** Move on to the next perennial wheat plant, and repeat these steps until you've harvested all mature perennial wheat plants.
   - **h.** Return any unused labels with the harvest materials.

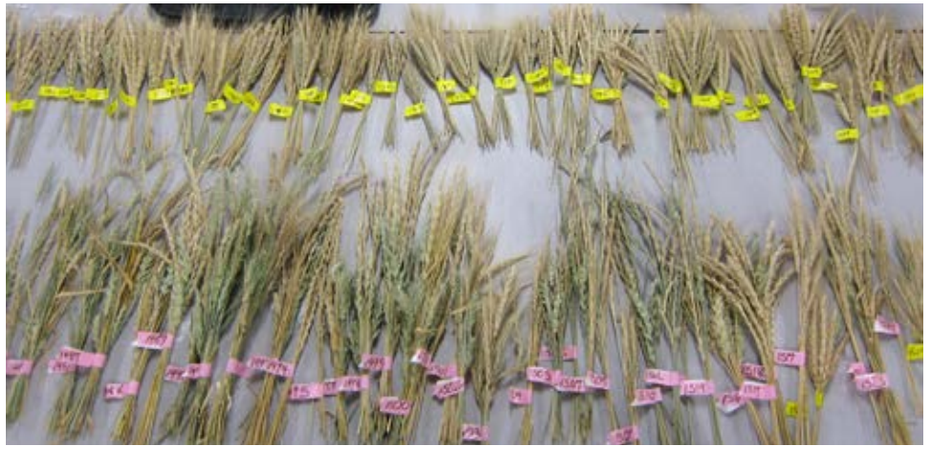
6. **Enter data!**
   - **a.** Log on to CitSci.org and access the TLI - Perennial Wheat Civic Science project.
   - **b.** Click the Add Data button to find and open the datasheet titled Harvest.
   - **c.** Enter the three measured heights of the plants and upload your harvest photos. Click Submit.

7. **Wait approximately 2 weeks and repeat** the harvest steps for intermediate wheatgrass—no need to submit data on CitSci for the intermediate wheatgrass harvest.
8. **Send the harvest materials back** to The Land Institute with the prepaid shipping label provided in your season start-up kit as soon as you've harvested, and **at the latest, September 1, 2023**.

Going Deeper

Analysis

After completing the harvest of all three wheat species in your plot, send your materials back to The Land Institute. Once the heads have arrived, the perennial wheat research team will thresh or remove the seeds from the hull, weigh and measure them, and test their fertility. The grains will also be analyzed for grain toxins and estimate yield of individual plants.

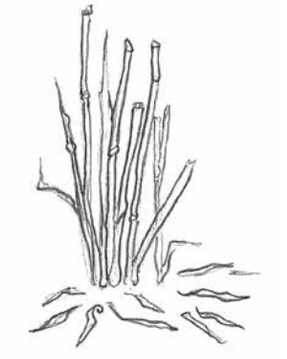


Perenniality

Are your plants still living?

PERENNIALITY

ESSENTIAL



Timing

End of August

Getting Started

For a plant to be perennial, it has to show regrowth after the sexual cycle, and this is what we are going to assess this month. If we see regrowth after harvest, that is an encouraging sign of perenniality.

Post-sexual cycle regrowth is a necessary first step towards perenniality. Annual wheat doesn't regrow after harvest, and the plants die after the first sexual cycle, which ends with the maturation of seeds.

Protocol

1. Visit your plot during the last week of August.
2. Identify which of your perennial wheat plant tags are showing signs of regrowth.

   Signs of regrowth include greening of the vegetative growth at the base of the plant.
3. Enter data!
   - **a.** Log on to CitSci.org and access the TLI - Perennial Wheat Civic Science project.
   - **b.** Click the Add Data button to find and open the datasheet titled Perenniality.
   - **c.** Enter your answers and click Submit.

Story:
What is your perennial wheat story so far?

COMMUNITY LEARNING
ESSENTIAL

Timing

September and anytime you have a story to share; multiple submissions are welcome

Getting Started

Through this season of experience with these plants, we're excited to hear your story. You could share a moment or memory that stands out to you, an interesting conversation you had with a neighbor or friend, a reflection about an insight you realized, a photo that encapsulates your story of civic science, or something you were inspired to create. Simple text is good, and so are images, poems, songs, videos, maps, and more.

Protocol

1. Access the story datasheet anytime at:
   airtable.com/shrItYuZgCI19P3OS

   You can also scan the QR code to access the story datasheet:

2. Enter or upload your story and click Submit.

If you have a story to share that you can't enter into the datasheet, please email it to us at civicscience@landinstitute.org.

Going Deeper

Stories help us get a richer picture of the community learning impacts of civic science and investigate and improve our approach.

We gather stories not only from civic scientists but also from ourselves as researchers. We have observed that civic scientists and researchers enjoy, and benefit from, hearing each others' stories.

We recognize that stories are told in many places across the project, including emails, phone calls, forums, webinars, newsletters, and social media. That's great! And we also want to provide this dedicated opportunity to help invite everyone to share their story.

Sharing stories is the last step of data collection for the 2023 growing season! After this, our civic science research team will be synthesizing final results to share back with you, and applying what we learn to the design of the 2024 growing season and beyond. Congratulations and thank you for completing this year with us. Stay tuned for more observation and evaluation in future years as this project continues!

Reference

What is The Land Institute?

Founded in 1976, The Land Institute is a non-profit research organization that seeks to reconcile the human economy with nature's economy, starting with food. By working to ignite a global reinvention of agriculture, The Land Institute is developing diverse, perennial grain agriculture that functions within nature's limits and where humans flourish as members of a thriving ecosphere. In this future, agriculture regenerates the soil, water, and air on which all life depends. The agriculture we seek will equitably provide for human needs within ecological limits over the long term.

The Land Institute is working to develop an ensemble of perennial cereal, legume, and oilseed crops and perennial cropping systems that nourish people, build and hold soil, use water efficiently, reduce reliance on fossil fuels and chemical inputs, and sequester carbon. We collaborate with research partners and advocates worldwide to advance perennial grain crops, ecological intensification of perennial grain cropping systems, and socioeconomic transition and cultural transformation for a perennial future.

Where is The Land Institute?

The Land Institute headquarters is located near the Smoky Hill River outside of Salina, Kansas, U.S., in the homelands of the Kaw, Pawnee, Osage, and other Indigenous nations. In the long view, we are newcomers to this place. Our Civic Science program staff and research benefit from access to this land, knowledge, and resources due to settler colonialism and ongoing systems of oppression. The Land Institute is committed to responsibly repairing harm and building mutually beneficial relationships with members of the land community here in Salina and across the ecosphere. Therefore, civic science collaborators are humans and members of the more-than-human living world of plants, soils, creatures, water, and air. We work toward a more just perennial future for all.

Why Perennials?

Perennial plants grow year after year, reducing the need for annual tilling, planting, and weeding. Annual crops grow once and are then harvested and terminated, requiring farmers to repeatedly till the soil to plant new seed. Tilling creates the ideal environment for weeds, which compete with crops for sunlight, nutrients, and water, especially when the crops are seedlings. These weeds then must be suppressed or killed chemically or mechanically. This constant soil disturbance releases significant amounts of carbon, which become the planet-warming greenhouse gas CO^2 in the atmosphere. Tilling also causes soil loss, nutrient leakage into water supplies, and changes in soil organism communities that damage soil health.

Perennial crops are robust. They protect soil from erosion and improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and contribute to climate change adaptation and mitigation. Overall, perennial crops help ensure food and water security over the long term. Many fruit, forage, some vegetable crops, including fruit trees, alfalfa, grapes, asparagus, and olive trees, are perennials crops that communities have grown for thousands of years. The Land Institute is adding perennial grains, legumes, and oilseed crops to the list. Perennial crops can free farmers from the treadmill of economic instability by significantly reducing the need for costly inputs and minimizing tillage and planting operational expenses. This new perennial "hardware" for agriculture stands to catalyze a rich culture around food production and supply chain development. Research is emerging to understand the social and economic strategies needed to support these new agricultural systems.

Why Grains?

Grain crops are the staple foods of humanity, providing more than half of modern society's food calories and occupying two-thirds of the cropland. Several non-grain crops—potato, sweet potato, cassava, yam, plantain, breadfruit—serve as the primary staples in particular regions and contribute carbohydrates to the global food system. However, the global production of grains is much higher, and grains are considerably more likely to enter the international market because they are small, hard, dry, and therefore more manageable and economical to transport. They are far less delicate and perishable than most fruits, vegetables, and tubers. Combined with their small size, these attributes allow grains to be handled and stored in pipes and tanks almost like a liquid.

Hundreds of domesticated plants produce edible seeds, but only a few dozen have ever been considered grain crops. Some experts equate grains with cereals—grain crops from the grass family. Today, grains are defined as crops that resemble the first domestic cereals, rice, and wheat, especially in the way they are harvested. The seeds typically dry on the plants before harvest and are harvested and threshed en masse. Grain crops are grown and processed primarily for the seeds, and grains are valued primarily for providing the staple nutrients: starch, fat oil, and protein. The closer a plant is harvested and used like the archetypal grains, the more often it will be described as a grain crop.

The scale of grains on the landscape and in the human diet presents an immense opportunity to transform the global food system from extractive to regenerative. Perennial grain crops protect soil from erosion, improve soil structure, increase ecosystem nutrient retention, carbon sequestration, and water infiltration, and contribute to climate change adaptation and mitigation. We imagine a future where new perennial grains cover the world's agricultural soils and feed the global population.

Why Intercropping & Polycultures?

At The Land Institute, we are working to combine plantings of complementary perennial species in "intercrops" or "polycultures" and examine the critical functions of natural systems into agriculture: nutrient retention, carbon sequestration, soil regeneration, and other indicators of soil health. Additionally, researchers are learning to use crop diversity paired with biological control agents to manage pests and pathogens in our perennial crop systems.

Plant diversity is important because it helps keep populations of plant-loving insects and diseases in check. When species with different resource requirements grow together, their diversity enhances productivity by efficiently using sunlight, water, and nutrients.

Perenniality is important because the vegetation lives for many years. Soil is not only protected against erosion, but it builds and accumulates organic matter. As a result, deep-rooted perennial plants can access nutrients and water that escape the reach of annual plants.

With future intercrop systems, called polycultures, The Land Institute hopes to incorporate the benefits of diversity seen in nature and supplant the need for commercial inputs like fertilizers and pesticides. Combining perenniality and diversity in grain agriculture may achieve higher levels of ecological intensification than researchers previously thought possible, effectively addressing many problems inherent in annual agriculture like severe pest outbreaks, soil erosion, nutrient leakage, and soil organic matter loss.

What is Civic Science at The Land Institute?

The Land Institute's civic science communities bring people together to learn as they grow, observe, care for, and study perennial grain crops. Civic science weaves together science, story, and community.

We are testing civic science as a transdisciplinary method to grow diverse, perennial grain agricultures and cultures. Civic science projects are designed to broaden and sustain public participation and social learning, and to gather meaningful scientific data across multiple locations for use in plant breeding and ecology. Agroecological data and new relational stories, experiences, and knowledge gained by civic scientists and researchers may shape the development of a perennial future.

The Land Institute launched its first pilot civic science community in 2019, collaborating with research teams in plant breeding, ecology, and ecosphere studies. We have convened four cohorts so far, with multiple projects active today, and new projects and experiments in the works. We maintain a waitlist for people interested in joining future perennial civic science communities.

Why is the program called Civic Science?

We were first inspired to name our work civic science by artist Carmen Moreno, who introduced us to this term. We call public participants in our projects civic scientists. Civic science involves scientific data collection as well as the study of learning outcomes in an experimental process that involves both researchers and participants. In the literature, civic science is part of the broader field of research known as citizen science. There are active conversations in citizen science about its name and questions of inclusiveness. In addition, there are dialogs about the common classification of public participation in science projects on a spectrum from contributory to collaborative to co-created. (For relevant publications, and to learn more, see the resources posted in our project at CitSci.org.)

Naming our work as civic science helps us accurately represent the contributory and collaborative nature of our current project designs while leaving room for our program and future projects to evolve. Our civic science project designs acknowledge that perennial grain agroecology arises from us as researchers and not independently from communities who come to us with research questions or who co-create those questions with us at the start. We also appreciate the tradition of civic agriculture and the chance to connect our program with that tradition.

Finally, etymologically, the word civic points to what individual members of society do, the rights and obligations they have, and how their behavior affects others. Perhaps civic science can help us come together to experiment with ways of learning and behaving that help develop a just, diverse, perennial grain agriculture and culture.

Citations & Gratitude

For more information, please check out the resources posted in our project at CitSci.org (including a list of relevant publications!) and The Land Institute's website at landinstitute.org. The reference material above is adapted from the The Land Institute website, our internal Civic Science Lab Manual, and the 2012 entry on grains by David Van Tassel and Duane Schrag published in the *Berkshire Encyclopedia of Sustainability*.

Our Civic Science program continues to evolve through collaboration, relationship-building, and ongoing learning. This field guide names several key people on the inside back cover, and many more deserve credit due to their help and contributions in discussing and informing the research approach and in proposing and realizing experimental projects:

- Colleagues across The Land Institute, ranging from research staff to administrative support and leadership; visiting scholars and temporary staff, including interns, research residents, and post-bacs
- Domestic and international collaborators, particularly the Ecosphere Studies community and New Perennials Project
- Academic colleagues, particularly those in the Citizen Science Association and the Association for the Study of Literature & Environment
- Visitors and friends of The Land Institute who discussed civic science on tours with us and who have expressed inquiry and interest; all the supporters who make possible all the work of The Land Institute
- Grant proposal collaborators, advisors, and reviewers
- Many researchers who we have never met, whose books and articles have informed our understanding of what we can build on and contribute to, and similarly challenged and inspired us in fields including citizen science, participatory research, agroecology, ethnobotany, data science, agricultural extension, feminist studies, and Indigenous studies
- Finally, the most important acknowledgment goes to the people who join us as civic scientists. Those who invite perennial grains into their homes, backyards, farms, and gardens, who try new tasks and give us feedback, and do the work of caring and learning together for varying lengths of time, but perennially in relationship with plants and places. Thank you!

How This Guide Was Made

This perennial wheat field guide was developed in winter 2021-22 through a collaborative effort led by The Land Institute's Civic Science Program. The most recent edition, published in 2023, includes updates to protocols and team members as the research and team has evolved. Our team first discussed in depth the purpose of the field guide, last season's field guides for other perennial grain civic science projects, and feedback we received from civic scientists about their needs and interests. In 2022, we decided to revise and simplify our field guide structure, including the organization of protocols, and to include more visuals. We made this decision after consulting with collaborating researchers and designers. The field guide then went through an iterative process of drafting, commenting, revising, and reviewing. Below we list everyone who has contributed, in alphabetical order by last name, and the various roles they played.

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Notes

PHOTOS: SUBMITTED BY 2022 SEASON PERENNIAL WHEAT CIVIC SCIENTISTS

2023 Season Checklist

Reference this (chronological) season checklist as you progress through the 2023 growing season. Note that some of these tasks are optional. Engage in a way that feels exciting and manageable to you!


ESSENTIAL


OPTIONAL

- [ ] **Share your feedback about the season: anytime**
- [ ] **Count the number of living plants in your plot**
- [ ] **Bake with perennial wheat!**
- [ ] **Record the first flowering date**
- [ ] **Disease photo day: 6/4-6/9/23**
- [ ] **Harvest perennial wheat**
- [ ] **Harvest intermediate wheatgrass**
- [ ] **Count the number of living plants in your plot**
- [ ] **Submit your perennial wheat story**

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