THE LAND INSTITUTE

2023 SEASON

Silphium

Civic Science Field Guide















PHOTOS: SUBMITTED BY 2021 & 2022 SILPHIUM CIVIC SCIENTISTS

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Welcome

Welcome to the 2023 season of growing and conserving silphium through civic science!

In this multi-year effort, we are continuing to **conserve seed, monitor plants for disease,** and **learn in community** through a decentralized project with roots in local landscapes across the country. This year's scientific data collection protocols are similar to previous years. We are making observations, submitting photos and data online, and hopefully harvesting seeds to put in the mail.

However, we are also growing to engage more silphium civic scientists in the research community. Some civic scientists will be planting and establishing new silphium ecotypes this spring. A few other civic scientists have been growing and isolating rust-susceptible silphium, and testing silphium in new environments, and we are integrating them and their work into this shared community.

This year we are offering more frequent, open-ended community calls to provide support and facilitate conversation across silphium civic science. 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 "storymap" over the 2023 season.

Our relationships to silphium 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, conserving and creating 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 envelopes 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: Plants don't like competing with other, taller plants for soil nutrients, water, or sunlight, therefore silphium plants should get weeded once weekly using something like a garden hoe, or by pulling larger plants by hand. Small plants around and between silphium plants can be managed by mowing (e.g. with a lawn mower or string trimmer).

Watering: In areas with regular rainfall, silphium plants may need no irrigation, but if plants look deflated or leaves are not standing upright, or if leaves begin to dry out, the plants must be watered immediately. This is especially important to ensure successful establishment after they are first planted.

Nutrients: After the first season, spring fertilizers can be applied to silphium plants using a turf spreader or by applying fertilizers in recommended amounts by hand. Composted manure or synthetic fertilizers sold for shrubs and trees will work well. Follow the directions for shrubs or perennial flowers.

Winter: In the winter, cut back any dead stems and leaves. You can mow right over silphium plants in the winter. The growing points for next spring are safely belowground.

Plants & People

Get to know the plants and people involved in this silphium civic science project. By participating in this project, we join a long lineage of people who have grown and observed plants in their home spaces..

Plants

Silphium integrifolium:

The Land Institute is developing *Silphium integrifolium*, a plant in the sunflower family native to the Great Plains and other parts of North America, as an oilseed crop. Silphium is a drought-tolerant perennial prairie plant being domesticated as an edible oilseed crop because of its deep, persistent root system and large seeds and flavor similar to its close relative, sunflower (*Helianthus annuus*). Plants in the Silphium genus are known and used by Native American tribes.

Silphium's taproot grows several meters deep, penetrating heavy clay soil that challenges other species. Silphium can access groundwater at depths of 4-6 feet, eliminating frequent irrigation and providing resilience in short-term droughts. Because it stays in row formation and uses water and nutrients at different depths, silphium is a strong candidate for intercropping systems and is expected to provide soil protection and carbon sequestration. Finally, silphium provides good habitat for earthworms, hoverflies, native bees, Monarch butterflies, and honeybees.

Long-term, the goal is for perennial silphium to partially replace annual oilseed crops such as sunflower, canola, and soy. Our near-term goals are to understand the agronomic traits (such as plant nutrition, field management practices, and harvesting methods) needed to reliably and consistently achieve current yield levels and to map silphium's performance (including survival, growth stages, and interactions with pests, pathogens, and pollinators) in a wide range of growing environments.

Plant Pathways Toward Perennial Crops

Domestication starts with identification of perennial species 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.

Silphium Domestication: A Brief History

1930s Ecologist John Weaver recorded *Silphium integrifolium*'s tendency to survive in drought seasons.

EARLY 2000s Domestication began at The Land Institute: David Van Tassel began collecting wild silphium seed and domesticating *Silphium integrifolium* as a perennial oilseed crop.

2001 Local silphium populations were observed to have large, good-tasting seeds and to perform well during seasonal or year-long droughts. The experimental plants grew much larger than plants in nearby prairies, suggesting that silphium is well-adapted to agricultural conditions.

2004 Early selective breeding focused on increasing the number of seeds in the head.

2012 Traits such as greater number of larger heads and seeds, heads that don't drop their seeds too soon, non-dormant seeds, and higher seed oil content were identified in the breeding program.

2014 Pests and pathogens started to affect silphium research plots in Salina in 2014. Plants in Salina, Kansas plots were infected with rust, leaf blotch, and a virus. A moth whose larvae are parasites of several silphium species also became a serious pest, with the colonization of heads approaching 100% in many situations. These pests and pathogens may be more common in more humid environments and only became common in Salina once researchers created favorable conditions and large populations of host plants.

2016-17 In response to the emergence of several serious diseases and pests, the team collected new wild germplasm and made hybrids between "elite" selections and wild silphium species and ecotypes.

2016-19 Seeds were collected from various ecotypes in silphium's native range by Land Institute researchers to preserve the genes that are in wild populations. These plants could contain genes that could be helpful in silphium domestication.

2019 Controlled crosses between plants from the same ecotype were made, and were grown out in Salina.

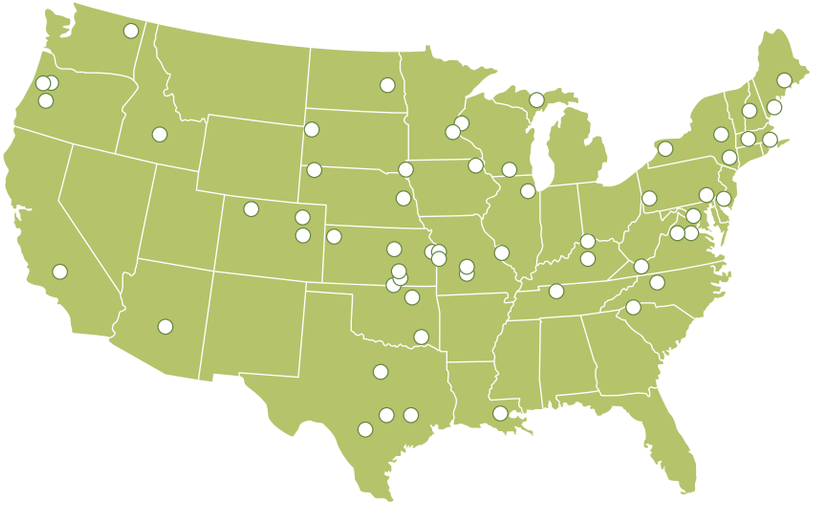
2020 In hopes of conserving 39 unique silphium ecotypes and testing the civic science method, the Silphium Ecotype Conservation civic science community was formed. 39 participants in 22 states planted various ecotypes.

2023 Silphium civic science community grew to include the conservation of germplasm of various Silphium species for ecotype conservation, isolating rust-susceptible silphium, and testing silphium in new environments.

Future After diversifying the breeding population, breeders will select for pest and disease resistance, larger seeds, reduced plant height, vigorous seed germination, and other traits that will make this crop easier to grow and harvest.

People

Civic Scientists



The Land Institute Researchers


Aubrey Streit Krug


Anna Andersson


David Van Tassel


Betsy Trana


Reece Kapnic


Kathryn Turner


Yvonne Thompson


Eric Cassetta

Our Silphium 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 silphium civic science community is exploring both social and ecological questions during this multi-year project. The three core question themes are:

Conservation + Monitoring + Community Learning

Conservation

How many ecotypes can be conserved and bulked to be used for further breeding efforts?

Monitoring

What diseases is silphium 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 silphium and improves our civic science method.

In the long term, we hope that by creating a broader network of people studying and caring for silphium, 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

Ecotype Isolation and Conservation

Why do we need to conserve ecotypes in isolation?

This project is designed to save and increase seed from specific Silphium ecotypes. The species involved in germplams conservation include *S. integrifolium*, *S. albiflorum*, and *S. laciniatum*. The Land Institute will maintain these distinct seed populations indefinitely, growing them out every few years to maintain fresh seed stocks. This seed can be used by researchers wishing to compare domesticated silphium with true wild silphium. Breeders in 20 or 200 years may need to screen these wild genetic resources if new diseases or other threats emerge. **Simply harvesting your seeds at the end of the season and sending them back is the core purpose of this project!**

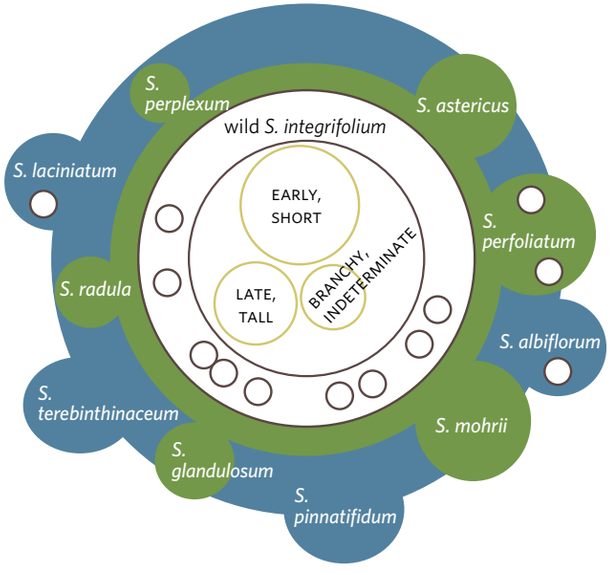
What is an ecotype?

An ecotype is a variety within a species adapted to specific local environmental conditions. Each participant in this project received a unique ecotype belonging to the Silphium genus. The various ecotypes vary subtly. The ecotypes have different morphologies (e.g. plant height, number of branches), variable climate adaptation (e.g. drought or heat tolerance, delayed flowering times), and will express resistance and susceptibility differently to biotic pressures in contrasting environments (e.g. increased fungal disease pressure in humid areas). Land Institute researchers collected them across diverse geographies.

Why are they in isolation?

The ecotypes are grown in isolation to ensure that silphium ecotype plants don't cross-pollinate with other ecotypes or already established wild populations in nearby surroundings. Pollinators can travel far distances and bring pollen from another silphium, which makes it hard to isolate plants in locations where silphium is native. This project aims to preserve these genes by growing individual ecotypes isolated from each other and outside of silphium's native range (except when the participant is located within the ecotype region being preserved).

What role do ecotypes serve in silphium domestication?

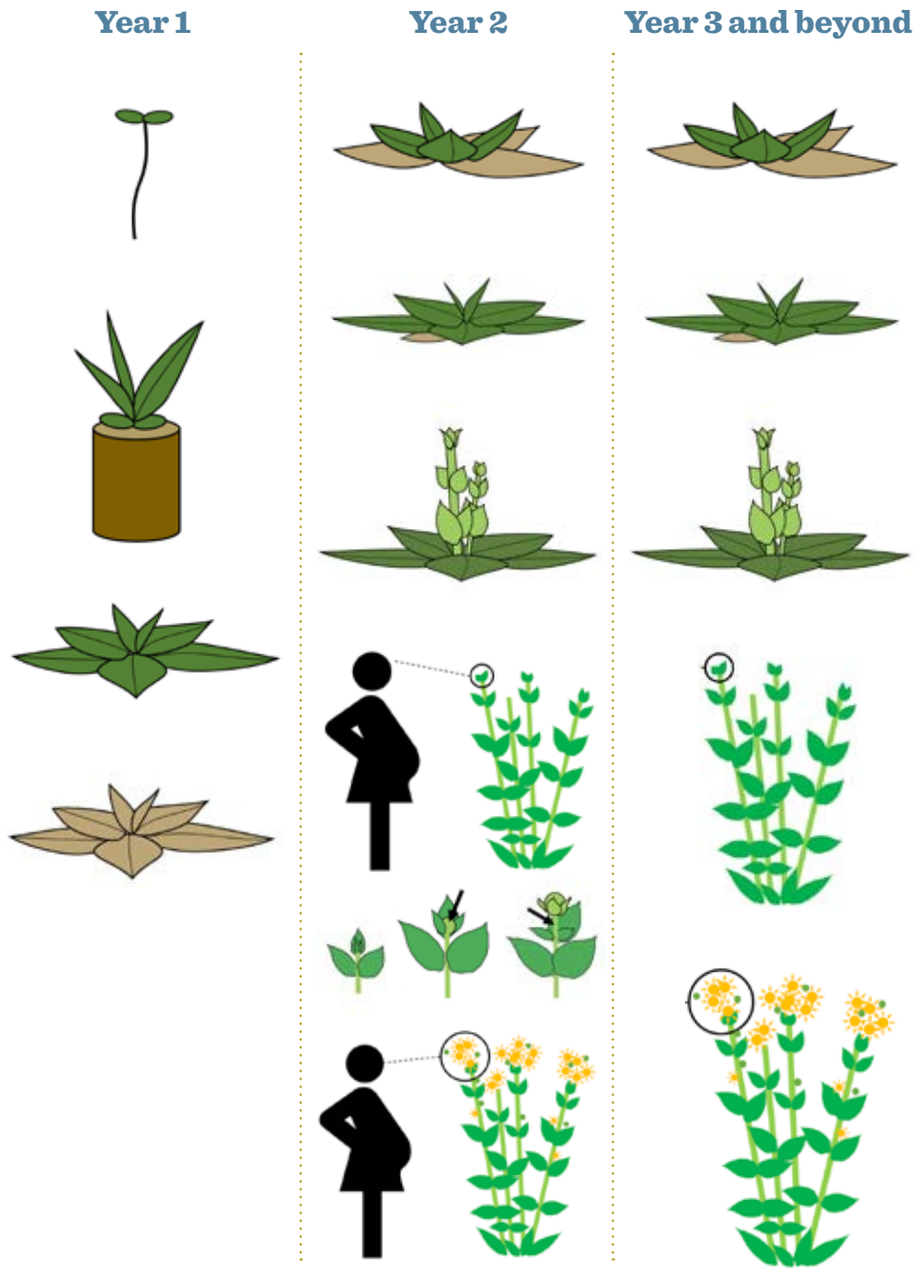


This visual features the various gene pools involved in domesticating *Silphium integrifolium*. The colored tiers indicate the projected likelihood of successful crosses between different ecotypes and species. Read more about where the ecotypes fit in the gene pool visual, and how your unique ecotype plays a role below! **Within these pools you can find the ecotypes you're stewarding by identifying the white unlabeled circles with brown borders within the wild silphium gene pool.** The yellow-bordered circles represent distinct breeding populations within the domesticated silphium gene pool.

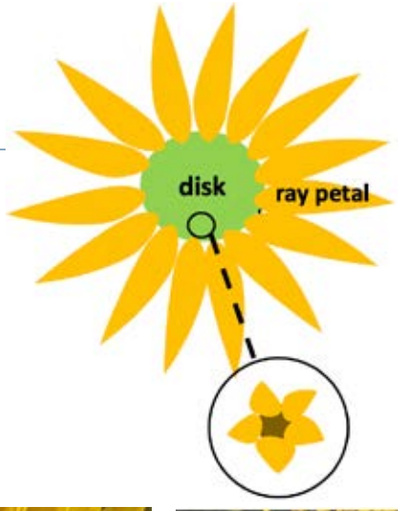
The white area represents the **primary gene pool**. The populations within this pool can be easily cross-pollinated by each other. Plants within this pool may look different and be adapted to different environments. The green area represents the **secondary gene pool**. These are different species of silphium that can cross-pollinate with *Silphium integrifolium*, but the crosses are difficult. Few hybrid seeds fill, and the hybrids may be somewhat sterile. The species *Silphium perfoliatum* (cup plant) is of special interest because it is being domesticated as a forage and bioenergy crop in Europe. We have made hybrids between *S. integrifolium* and *S. perfoliatum* and we are crossing the hybrids with each other. The hybrids may end up as a distinct type of domestic silphium.

The blue area represents the **tertiary gene pool**. These are wild silphium species that are reported to be almost impossible to cross with *S. integrifolium*. Rarely, hybrid plants may form, but they are expected to be completely sterile. However, we have not tested all of these reports. Furthermore, there are some modern techniques that can help increase the viability of hybrid embryos.

Silphium Growth Pattern

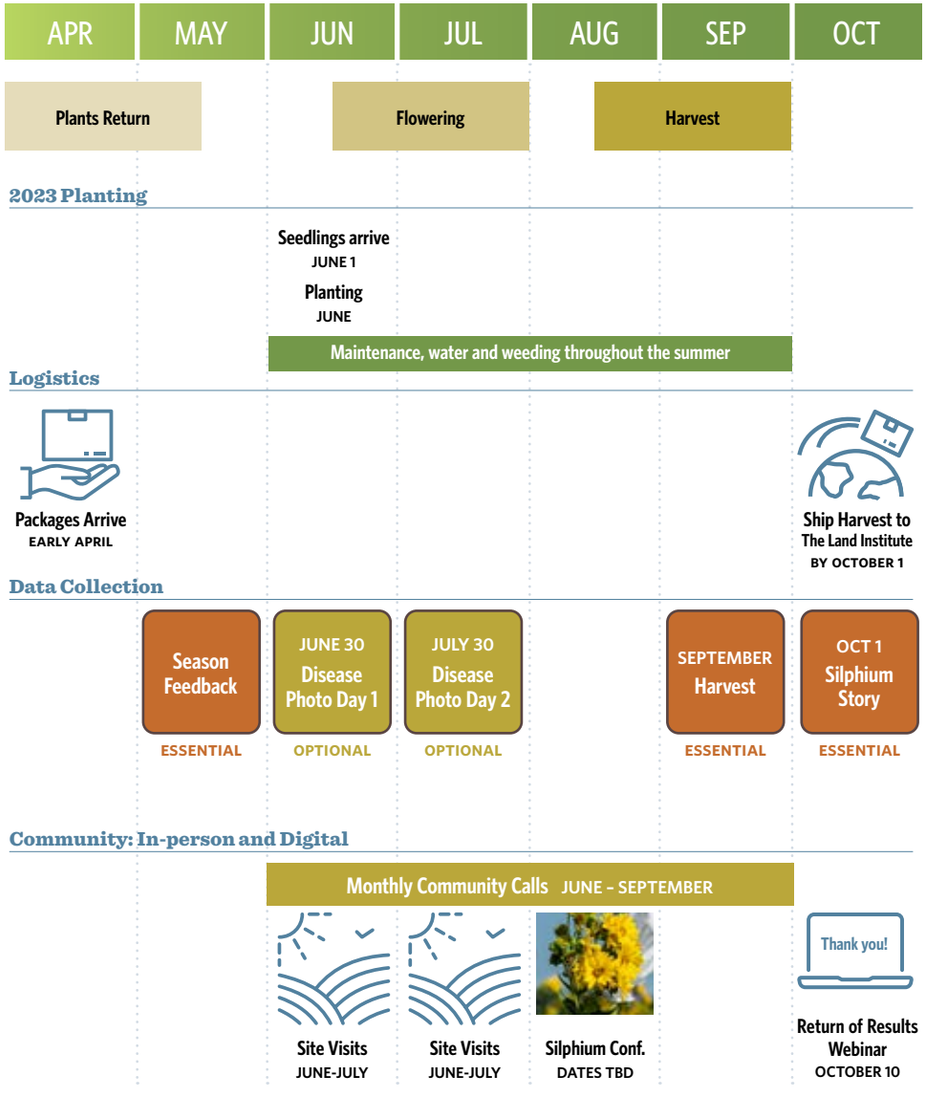


Flower Development



Season Timeline

Plant development varies depending on region and ecotype!



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 the project's research questions.

How to collect data?

See the "Protocols" section, starting on page 23, 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 Silphium Conservation Community 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:

If your plants are setting seed this year, 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 October. 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 10, 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 June – 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:

Our team will be contacting select civic scientists to ask if we can visit you and your plots and plants this summer.

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 **#silphiumcivicscience**

Contact us:

civicscience@landinstitute.org
(785) 914-5262

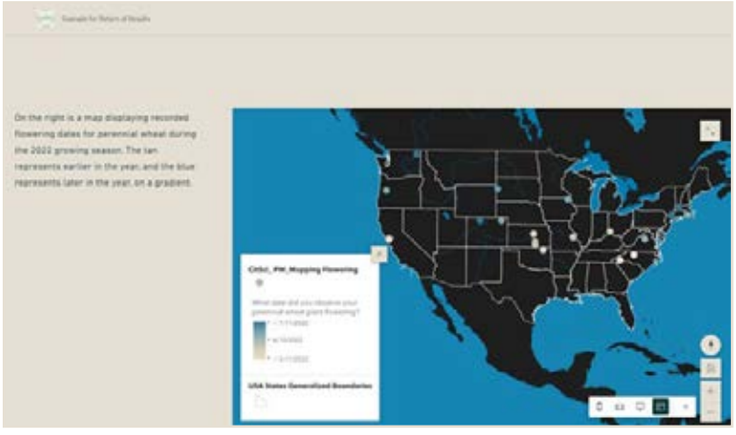
StoryMaps

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.

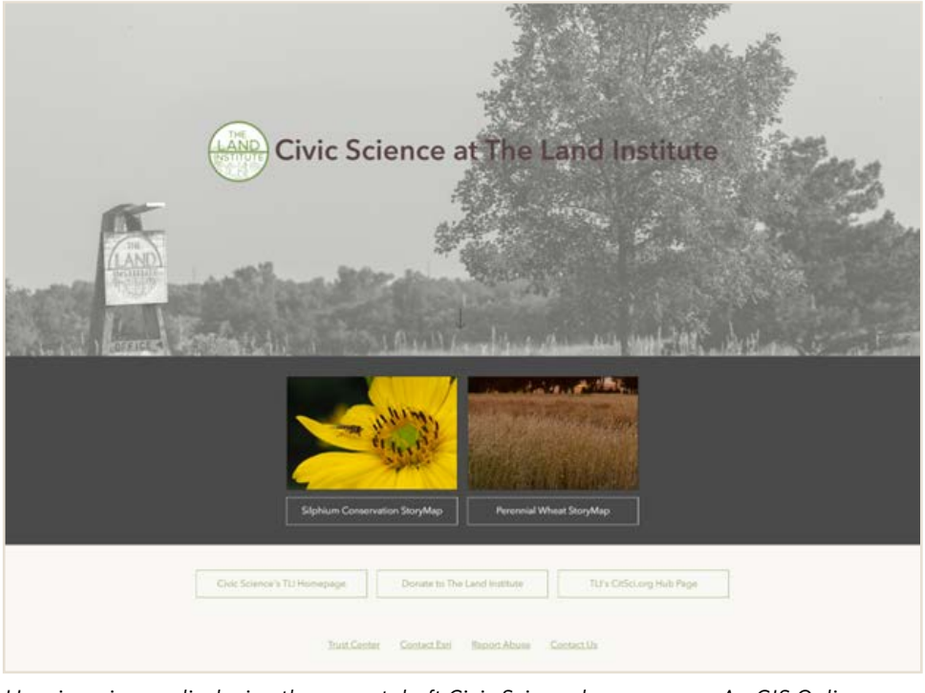
The Land Institute's Civic Science ArcGIS homepage can be found at: **civscitli.maps.arcgis.com.** Scroll down to see all current project StoryMaps. You can also access the StoryMap via the monthly newsletter and the CitSci.org project.

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.

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/shr8ot6LIZisDMTEl

   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.

Disease Photo Day 1: Viruses & Downy Mildew
Are your plants affected?

DISEASES
OPTIONAL

Timing

June 30, 2023

Getting Started

This data collection will help identify what diseases affect plants in various parts of the country. Civic scientists will help contribute new data on silphium's susceptibility to **viruses and downy mildew.**

By identifying the diseases that affect silphium we can see the disease range throughout the various geographies, and the susceptibility of the silphium you have growing in your plot.

Protocol

1. Visit your plot on June 30, 2023. If you're not home that day, submit as close to this date as possible.
2. Review the disease pictures below:
3. **Do any of your plants have symptoms that look like this, or other symptoms that you're not sure about?** For more examples of these pathogens and the ranges of severity, reference the photos in the section titled "Going Deeper."

Viruses

Silphium viral symptoms on upper leaves - vein banding (pronounced, light colored leaf veins) and twisted, narrow leaf tips.

Severe silphium viral symptoms - very narrow, wiry, sometimes twisted leaves with no flower bud development

Downy Mildew

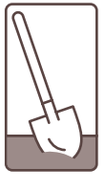
Downy mildew on underside of leaf (small, fuzzy, grey angular spots)

4. **If YES, take a photo** of a 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.

   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 silphium can thrive without rust or head blight, and we'd love to know where those places are located!



Going Deeper

Downy Mildew

caused by the fungal pathogen *Plasmopara halstedii*

Size of pustules: ~2 mm (0.08 inch) in diameter initially, but can spread to cover the whole leaf

ID tips: Fuzzy white or grey angular lesions, give the diseased spots a "downy" appearance. This disease is more common on the underside of leaves, close to the ground.

Downy mildew is a fungal disease of the *Silphium* genus. It can be identified by its white "downy" growth on the underside of the leaf and corresponding chlorotic (pale, yellow) spots on the upper side of the leaf. *P. halsedii* requires cool temperatures (15-23°C/59-73°F) and a high relative humidity (>85%) to infect the plants.

This disease may have a small effect of reducing grain yield or reducing seedling establishment, particularly in cool environments where there is high humidity. We've observed downy mildew in The Land Institute's silphium plots in Kansas in early spring and late fall, but infection has not occurred every year and the infection levels have been very low. Downy mildew (caused by *Plasmopara halstedii*) affects a wide range of plants in *Asteraeceae* (the sunflower family) — including ragweeds, thistles, fleabanes, sunflowers, lettuces, coneflowers, goldenrods, and ironweeds to name a few — as well as plants in the genus *Verbena*.

Silphium Clear Vein Disease

caused by species closely related to Dahlia endogenous plant pararetroviral sequence (DvEPRS)

ID tips: Twisted or wiry leaves, sometimes with a bent leaf tip. These symptoms are usually most pronounced near the top of the stalk in second year plants that are bolting.

We are in the process of determining whether silphium plants are infected with DvEPRS or another viral strain that is closely related. Symptoms of this disease in silphium include vein banding (lighter color along the veins), leaf distortion (constriction and twisting), and stunting (shortened plant height). Symptoms may be present at any time during the growing season when the plants have bolted.

This virus can prevent flowering in extreme cases. This is one of the most severe diseases in silphium and can result in high yield losses. It is possible that only some of the stalks of a plant will display viral symptoms.

Silphium Clear Vein (SCV) Rating Scale

This scale is provided to help you identify the signs of Silphium Clear Vein Disease on your plants. There is no need to rate the severity of your plants' symptoms on your datasheet. Instead, this scale is provided to help you spot varying severity levels of the virus.

0 Normal. Leaves dark green and broad. Leave edges may exhibit serration and leaf tips slight narrowing or pinching.


1 Clear or chlorotic leaf mid veins, mild twisting, cupping, leaf tip curling and pinching.


2 Large, clear or chlorotic mid vein, leaf tip pinching, light cupping, yellowing at leaf tips.




3 Large clear mid vein, pronounced toothed edges, mild cupping, mild twisting, pinched tips.

4 Large clear mid vein, leaf twisting, sometimes twisted apical meristem.

5 Toothed or serrated leaf margins, large clear mid vein, severe leaf cupping, twisting, wrinkling, pinched or yellow leaf tips, or helical twisting of unexpanded leaves at the shoot apex.

6 Narrowed leaves becoming lanceolate, large clear mid vein, twisted leaf tips or helical twisting of unexpanded leaves at the shoot apex.

7 Narrow leaves becoming lanceolate-linear, large veins comprise a substantial amount of the leaf area and are chlorotic or clear, pronounced twisting or serration of leaves. Remaining leaf areas becoming pale or browning

8 Very narrow, wiry leaves becoming linear, large clear or chlorotic veins, twisted leaves with necrotic tips.

9 Extremely narrow, wiry linear leaves; the mid vein essentially comprises the entire leaf. Some leaves or stems may be necrotic. Stalk apices deformed and apical meristem may abort, halting further stalk growth; lateral branching may result (as seen here).

10 Necrotic leaves and stem apices. Symptoms are not known to cause root or crown mortality but may effectively eliminate aboveground vegetative and reproductive functions during a season when symptoms are severe.

Disease Photo Day 2: Rust & Blotch

Are your plants affected?

DISEASES
OPTIONAL

Timing

July 30, 2023

Getting Started

This data collection will help identify what diseases affect plants in various parts of the country. Civic scientists will help contribute new data on silphium's susceptibility to **viruses and downy mildew.**

By identifying the diseases that affect silphium we can see the disease range throughout the various geographies, and the susceptibility of the silphium you have growing in your plot.

Protocol

1. Visit your plot on **July 30, 2023**. If you're not home that day, submit as close to this date as possible.
2. Review the disease pictures below:

Silphium Rust

Orange Rust

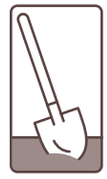
Black Leaf Blotch


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 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 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.

   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 silhpium can thrive without rust or head blight, and we'd love to know where those places are located!



Going Deeper

Silphium Rust

caused by the fungal pathogen *Puccinia silphii*

Size of pustules: <1 mm (0.04 inch) – 2.5 mm (1 inch). The largest pustules have been observed on stems.

ID tips: The spores are attached firmly and do not dust off. Lesions form on both the underside and top side of leaves and on the stems.

Silphium rust has appeared as early as April, but typically the infection peaks in July. Development of this disease is dependent on moisture for spore germination. Pustules can appear on leaves, leaf veins, and stems. The color of lesions can be yellowish-orange, bright orange, brick red, or chocolate brown, and may mature to cinerous black and grey later in the growing season. High humidity and temperatures around 20° C (68° F) enable spore germination and infection.

Rust lesions on the leaves greatly reduce the photosynthetic capacity of the plant and can result in lower head weights and yield reduction. Stem infection also has been linked to lower seed weight. Very severe infections may prevent flowering and seed production. This rust caused by *P. silphii* is expected to occur throughout the central US and is one of the more common and severe diseases of silphium. Silphium rust caused by *P. silphii* infects plant species in the Silphium genus, including *S. perfoliatum*, *S. lacinatum*, and *S. terebinthinaceae*.

Severity Scale: We use the severity scale (0-100%).


2%


5%


10%

20%

50%, 85%, and 100%

Lesion Color Range

The color of the *P. silphii* rust lesions can vary widely, from yellow to orange very early in the infection, to brick red, brown, black, and eventually grey as the rust matures.

Orange to yellow

Brick Red

Brown

Black

Grey

Location of Rust on Leaves

Often the rust will develop on the underside of the leaves first, but not always. If the lesion spreads, it can grow through the leaf and appear on the other side, too.

Tops of leaves where lesions are developing below

Bottom of leaves

Shape of Rust Lesions

Rust typically has rounded edges and a raised surface (or indented, if looking at the other side of the lesion). However, sometimes rust and the tissue it kills can have a more angular appearance that resembles other diseases.

Angled rust damage along leaf vein connected to a rounded and raised rust pustule.

Rust on Other Parts of the Plant

P. silphii infects the leaves commonly, as well as other parts of the plant like the stems and heads. The youngest plant tissue around the developing heads is usually the location where new rust infection spreads later in the season.

Young stem rust lesions

Silphium with rusty stems and bracts (green leaves surrounding the flowers)

Rust on silphium stems (image on the left) can easily be confused with the damage made by boring insects (image on the right). Silphium rust will often be darker and will have no evidence of boring into the stem.

Newly formed rust pustules on the top of the stem

Orange Rust

caused by the fungal pathogen *Coleosporium terebinthinaceae*

Size of pustules: <1 mm (0.04 inch) – 2 mm (0.08 inch) in diameter

ID tips: The spores are very loosely attached to the underside of the leaf and easily dust off when mature. The clusters of spore form very small pustules smaller than the head of a pin.

Orange rust caused by *C. terebinthinaceae* is a relatively recently observed disease in our research plots in Salina, KS in the late summer-fall and has been very localized. In places where it occurs, it can spread quickly through wind dispersal of the spores. The clusters of spore form very small pustules smaller than the head of a pin. The color of the spores is usually bright orange, but can be yellow or dark red.

This species is expected to be more common in the southeastern US, but has been documented as far north as Pennsylvania. We have also observed it in research plots in Texas, and native prairies in Illinois and eastern Kansas. It's likely a widespread disease but has unknown agronomic impact on seed yield. This species also infects other *Asteraceae* species including annual sunflower, but is not considered an important pathogen of annual sunflower. It reproduces asexually on silphium species and uses species in the *Pinus* (pine) genus to complete the other spore stages of its life cycle.

Black Leaf Blotch

caused by the fungal pathogen *Colletotrichum dematium*

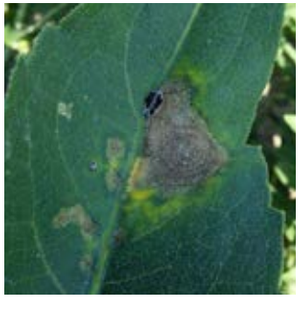
Size of pustules: 2 mm (0.08 inch) – 4 cm (1.6 inch) in diameter, often coalescing to cover greater areas.

ID tips: Lesions often have concentric rings and spread along the leaf veins, past the diameter of the main lesion. The lesions are usually visible on the upper and lower sides of the leaves.

Colletotricum dematium (synonymous with *Colletotricum silphii*) is a fungus that typically colonizes damaged or senescing tissue but can also be parasitic on some species. Leaf infection occurs in warm conditions with prolonged high humidity.

In silphium, this pathogen causes dark brown and black lesions on the leaves. Often the lesions have a concentric pattern of rings that look similar to tree rings. Sometimes the leaf veins beyond the perimeter of the lesion are also black. Severe infections can result in premature senescence of all the leaves on a plant. Black leaf blotch has been the most severe foliar pathogen of silphium in our research plots at The Land Institute in 2018 and 2019, when high rainfall has coincided with warm temperatures in the late summer.

Colletotricum dematium has a large range of potential hosts; a few examples include spinach, onion, tomato, soy, and alfalfa.



Harvest:
Help bulk the seed of your specific ecotype!

PERENNIALITY AND DISEASES
ESSENTIAL

Timing

August – September

Getting Started

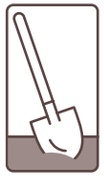
You can expect your silphium to mature during the months of August to September, depending on the region. When harvesting, it's important to harvest when the head is completely dry but not yet dropping its seeds or "shattering."

Protocol

1. **Harvest:**
   - **a.** Keep an eye on your silphium as they mature, in the "Going Deeper" section you'll find photos of plants progressing towards maturity.
   - **b.** Use a scissors to harvest the mature heads.
   - **c.** The plant heads should look like this!
   - **d.** Make sure to harvest the mature heads as the season progresses until you have harvested all the heads from your plants.
   - **e.** 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.
   - **f.** Return the seed in the envelopes included in your welcome packet.

2. **Enter data!**
   - **a.** Log on to CitSci.org and access the TLI - Silphium Conservation Community project.
   - **b.** Click the Add Data button to find and open the datasheet titled Harvest.
   - **c.** Enter your photos and click Submit.

3. **Send your 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, **October 1, 2023.**



Going Deeper

Typically, seed head maturity moves from green seed heads, to mature seed heads (yellow and browning), and then onto shattering heads.

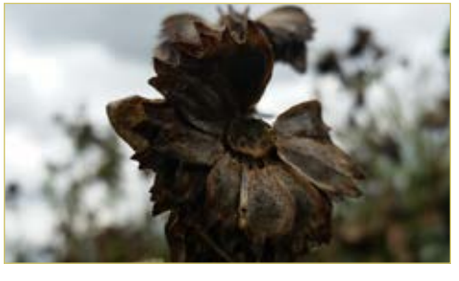
Immature silphium heads have a green color.




Mature silphium heads tend to have a yellow or brown color.




Silphium heads that have shattered are very dark and are beginning to lose their seed. Seed shattering happens when seed falls away from the heads as the plant dries down. We avoid harvesting these heads because we want to ensure that we collect the full amount of seed when harvesting seed heads.




Silphium integrifolium stems typically have a large maturity gradient, meaning that the heads that develop first are also those that have the largest seeds and mature first. Lower heads are typically brown, while the upper heads are much smaller and green, because they are immature. This maturity gradient is visualized in the picture at right.

Analysis

Once you've completed the harvest of all the silphium seeds in your plot, send your materials back to The Land Institute. Once the heads have arrived, the silphium research team will thresh or remove the seeds from the hull, weigh and measure them.

Story:
What is your silphium 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 silphium 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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Aubrey Streit Krug, Director of Ecosphere Studies

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Visual Design: Linsey Sieger, Third Sector Creative

Map Content: Reece Knapic

Notes















PHOTOS: SUBMITTED BY 2021 & 2022 SILPHIUM 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**
- [ ] **Disease Photo Day #1**
- [ ] **Disease Photo Day #2**
- [ ] **Harvest Silphium**
- [ ] **Submit Your Silphium Story**

Establishment Checklist

- [ ] **Seedlings Arrive: June 1**
- [ ] **Planting: June**
- [ ] **Maintenance, Water and Weeding: Throughout the Summer**

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