2022 USDA SOYBEAN GERMPLASM COLLECTION ANNUAL REPORT

Soybean Breeder's Workshop - February 2023

The USDA National Soybean Germplasm Collection's mission is to be the most diverse and well-documented soybean germplasm collection in the world. We are the largest collection which freely distributes seed packets to individuals and organizations around the world as part of its responsibility to conserve and make available a wide range of soybean genetic resources for research, breeding, and educational purposes.

Summary

- Jess Fowler hired as an Agricultural Scientist Research Technician
- David Walker retired as Research Geneticist
- Purchased, installed, and trained on new color sorter
- Document digitization preparation is underway
- Management strategy for increasing and distributing GE accessions is ongoing
- -18C cold room upgrade would greatly increase the efficiency of the collection

Below is a summary table for the USDA Soybean Germplasm Collection:

Distribution		**Maintenance**	
Packets	19,163		
Accessions	11,679	Seed increases	2,027
Individuals	247	New accessions	59
Countries	20	Germinations	2,555
NSSL	0	Photos	3000+

Distribution

In 2022, the Collection staff distributed 19,163 seed packets encompassing 11,679 accessions from the Collection in response to 434 requests from 247 individuals in the United States and 20 countries. This high demand indicates the value from this collection and ability of the staff to fulfill orders. The Soybean Collection ranked 6th in 2022 for the total number of seed packets distributed across the entire National Germplasm System; behind only the Rice Collection, Small Grains Collection, and Plant Introduction Stations which each manage multiple distinct crop species.

The Collection includes many different types of soybean germplasm, such as landraces, wild relatives, and modern cultivars, and it is continually updated with new materials when the opportunity presents itself. Crop wild relatives are an important part of the Collection, as they can serve as a source of genetic diversity and novel traits that can be used to improve soybean breeding and genetics research. Most requests (18,034) come from *Glycine max* (soybean) and/or *G. soja* (wild soybean) every year. However, 15 requests for 1,129 seed packets of 920 *Glycine spp.* (perennial *Glycine*) accessions were also distributed in 2022. The Collection staff did not send any seed to the National Seed Storage Laboratory (NSSL). Backup seed samples have been set aside and will be sent to NSSL in the first half of 2023.

Staff – Urbana, IL

Jessica Fowler (Jess) was hired on 10/24/2022 to replace Clint Heimann as an Agricultural Scientist Research Technician. David Walker retired in April and filling this Geneticist position is underway.

Adam Mahan, Geneticist	100%
Benjamin Bartlett, Agronomist	100%
Jessica Fowler, Agricultural Scientist Research Technician	100%
Todd Bedford, Program Support Assistant	100%
Eric Moody, Agricultural Scientist Research Technician	100%
Vacant, Research Geneticist	100%
Gad Yousef, Biological Science Technician	100%
Nancy Sanders, Program Support Assistant OA	26%

Staff – Stoneville, MS

Rusty Smith, Research Geneticist	30%
Philip Handly, Agronomist	70%
Robert (Matt) Kersh, Biological Science Technician	90%
Hans Hinrichsen, Biological Science Lab Technician	20%

Seed increases

The availability of the Collection for distribution is an ongoing process that is ensured by replacing the seed in storage periodically. The Collection staff grew 2,027 accessions for seed replacement in 2022: 1,171 accessions at Urbana, Illinois and 856 accessions at Stoneville, Mississippi. A total of 1,740 accessions of *G. max*, 169 of *G. soja*, and 118 of perennial *Glycine*. Due to the current restrictions on travel due to the COVID pandemic, seed was not sent to Costa Rica nor Puerto Rico in 2022. However, seed was sent to Costa Rica (294 accessions) and Puerto Rico (56 accessions) for seed increases in 2023.

In Stoneville, 100 accessions of *G. soja* were planted for increase. Accessions of *G. soja* (69) and perennial *Glycine* (75) were increased in the greenhouse in Urbana. The University of Illinois leases greenhouse space to the USDA for these increases. Wild soybeans were grown inside an in-ground greenhouse room. This method replaces the insect-proof screen cage that is assembled in the field. Growing wild soybean plants in this manner prevents many insects and diseases that are common under field conditions, especially Potato Leafhopper in Central Illinois. Potato Leafhopper is not an issue in Stoneville, thus G. *soja* increases do not require screen cage protection. Perennial *Glycine* accessions are grown in a greenhouse room with blackout curtains that manipulate the photoperiod (daylight hours) received by the plants. Reducing the photoperiod is intended to induce flowering. Perennial *Glycine* species flower with anywhere between 10-14 daylight hours.

New accessions

The collection added 59 new accessions in 2022. These included 12 germplasm releases, 2 public cultivars, and 45 private varieties with expired plant variety protection certificates.

Testing new accessions for glyphosate resistance in the field is a quick way to identify plants that can tolerate the herbicide glyphosate and screen conventional seed lots for the presence of genetically engineered (GE) traits. In 2022, new accessions were planted in 4-row, 10ft long plots with a single row treated with glyphosate. The glyphosate treated single row is compared to the non-treated rows to observe the plant's herbicide response. If any of the plants in the treated row show little or no damage, it can be assumed that the seed lot contains glyphosate resistant seeds. In the case where some of the plants survive in a treatment row, 10 plants from the remaining three rows of the plot are sampled and subjected to a glyphosate strip test. Four of the plants with negative results are selected to plant in the field the following season. The plot that most resembles the correct variety – based on known descriptors – is harvested and used as the seed source for distribution.

Genetically Engineered (GE) seed

The National Plant Germplasm System (NPGS) has been working with USDA, EPA, and relevant germplasm curators to draft the necessary protocols for the safe maintenance and distribution of genetically engineered (GE) cultivars. GE cultivars need to be handled differently than non-GE cultivars (conventional and land-race soybean) to avoid contamination; implementing strict protocols for field planting, storage, handling of seed, cleaning, and threshing equipment will be necessary to prevent contamination of other accessions. GE cultivars are available to be added to the Collection when their patents and Plant Variety Protection (PVP) certificates expire. Including varieties expiring prior to 2023, 131 Roundup Ready soybean varieties are waiting to be added to the Collection and to be made publicly available. Over 300 GE cultivars will become available to the Collection through expired ex-PVPs in the next five years, and that number grows to over 900 GE cultivars over the next 10 years. The large number of GE ex-PVPs will put a strain on the operational protocols and cold-room storage capacity.

Germinations

Germination tests are an important for assessing the viability and quality of seed samples and for making decisions about when to regenerate a particular seed lot. By conducting germination tests on recently harvested seed, the collection staff can prevent poor quality seed samples from being sent for

backup or distributed for research or breeding purposes. Our germination tests assess the seed on three criteria; whether the seed germinates, is rotten, or is hard (i.e. didn't imbibe water).

In 2022, germination tests were conducted on 2,555 accessions. Germination tests for the remaining accessions grown in 2019 and 2020 were completed. Of the 2019 accessions, there was an average of 78% good seed that germinated, with an average of 5.2% rotten seed, and 1.2% hard seed. Of the 2020 accessions, there was an average of 75% good seed that germinated, with an average of 2.3% rotten seed, and 16% hard seed.

Database

GRIN-Global is a web-based software system developed by the USDA Agricultural Research Service (ARS) to manage germplasm operations. Data from the Collection is available in GRIN-Global to provide easy access to information about the collection. GRIN-Global provides a wide range of tools that can help users find the information and resources they need, including a "shopping cart" feature that allows users to easily request samples of the seeds they need for their research. This popular feature was used by seed requestors for 86% of the orders filled by Collection staff. This tool allows Collection staff to manage the request and ordering process in an efficient manner.

Research

Dr. Jeff Doyle and Dr. Jacob Landis, at Cornell University are conducting genetic analysis on perennial *Glycine* accessions from the Collection, with the goal of clarifying taxonomic classifications. This data will be used to better understand the evolutionary history and relationships of different perennial *Glycine* accessions, as well as to confirm species classification.

Dr. David Hyten, at the University of Nebraska, has continued a project to screen the Collection, with the goal to sequence the full genome of every soybean accession in the collection. This project is in the final steps of analysis and publication.

The Collection staff recently increased seed of several germplasm accessions for Impossible™ Foods, a company that produces plant-based meat alternatives. Large seed amounts were needed to screen accessions for specific variations in the protein quality, or quantity that they believe will improve the finished product of plant-based meat alternatives. Through this partnership, Impossible™ Foods will be providing information on carbohydrate composition for each accession which will be uploaded and made publicly available via GRIN-Global.

Processing Harvested Seed

An optical color sorter is a tool used to more efficiently separate moldy, diseased, and poor-quality seeds from good quality seed. This is done by using sensors that detect variations in color, shape, and size of seeds. The color sorter then uses a blast of air to separate the good seeds from the bad. A color sorter was installed, and Collection staff were trained on its operation. Previously, Collection staff would visually inspect and manually clean seed lots. This process can be time-consuming and in cases of highly diseased seed, it can take up to two hours to clean seed from a single lot. The operation of the color sorter has already improved the efficiency of the seed cleaning process and reduced the amount of time required to separate good quality seeds from bad quality seeds. Despite being down one technician for the majority of 2022, Collection staff still processed approximately 1,500 harvested seed lots this year.

There is still a critical backlog of seed cleaning that needs to be done. Seed lots from 2019, 2020, 2021, and 2022 Urbana production (approx. 4,000) remain to be processed and quality controlled.

Document Digitization

Over the course of a nearly seven-decade existence, the Collection has accumulated many historical documents, such as field notebooks, specification sheets, request orders, and other records. These documents can provide valuable information about the origin, history, and background of the accessions in the collection. However, these documents are deteriorating, and the information contained within them are difficult to access. Digitizing these documents and storing them in online repositories is an important step in preserving the information contained within them and making pertinent information more widely accessible. The Collection staff are working with the National Agricultural Library (NAL) and the University of Illinois Library to determine the best approach to preserving these documents.

Fatty Acid Evaluation

Fatty acid analysis is an important tool for evaluating the nutritional quality of soybean accessions, as it provides information about the types and levels of fatty acids present in the seeds. We have historically collected fatty acid compositional information on all accessions as part of our evaluation process. This information is then added to the GRIN database, making it easily accessible to seed requestors. Currently, we have a backlog of several thousand seed samples that require fatty acid analysis. Unfortunately, we have not yet found a suitable replacement since our previous collaborator ceased providing this service to us. We are actively seeking a new partner to help us address this backlog and continue our work to enhance the soybean collection.

Cold Room Seed Storage

The Collection needs a -18˚C cold room, in addition to current 4˚C cold storage, to meet current guidelines (FAO. 2013. *Genebank Standards for Plant Genetic Resources for Food and Agriculture*. Rome) for optimal long-term seed storage. Soybean seed, like most seed, can maintain high germination rates for many years when stored at -18˚C. This is evident from many of the backup samples that are stored at -18˚C at the National Center for Genetic Resources Preservation (NCGRP) and continues to test over 80% germination rate after more than 30 years of storage. By having a -18˚C cold room option, it increases the number of years that seed remains viable and thus reduces the opportunity for errors and contamination that can occur during packaging, planting, growing, and harvesting. Current procedures select accessions for seed increases when an accession becomes 10 years old, or when seed inventories reach a minimum threshold. This is based on the germination rate of the seed and the perceived degradation of seed germination in the current storage conditions. In 2022 at Urbana, roughly 90% of the accessions were selected for seed increases due to being 10 years old, and not because of low seed quantities. Improved cold room storage and increased capacity is an appropriate investment in the Collection to safeguard seed inventories more properly and to ensure climate-controlled space as the number of accessions increase.

The current cold room that houses the Collection needs refrigeration and dehumidification upgrades. The minimum standards for seed storage are 4˚C at 25-30% humidity. However, the current equipment reaches at best 8˚C and routinely reaches temperatures upwards of 12˚C in the summer. These temperatures can lead to enhanced seed deterioration, loss of germination rate, and fungal or insect

infestation. Upgrading the refrigeration system is crucial for the integrity and preservation of the Collection. Moreover, the current field laboratory housing the collection is greater than 15 years beyond its intended lifespan, which creates hesitation in spending capital on any improvements. This is becoming more important as the collection increases in size and personnel decreases as operating budgets remain flat. In the most recently passed budget (H.R.2617 - Consolidated Appropriations Act, 2023), Congress announced a fund of $500,000 towards deferred maintenance on USDA owned buildings at the Urbana, Illinois location (6 structures total), including the building housing the Collection. Discussions are ongoing, but the intent is to prioritize the refrigeration system upgrade (4℃, 25% humidity) and other critical deferred maintenance items of the soybean germplasm field laboratory.

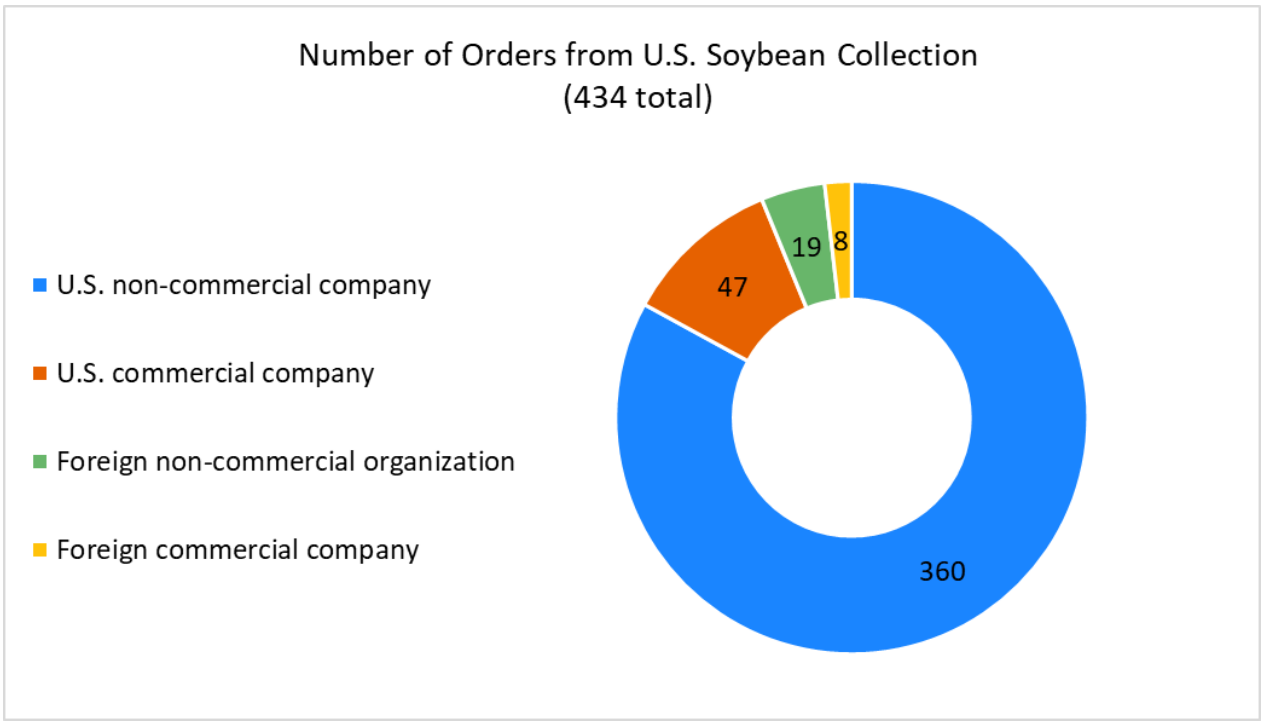
Summary inventory tables for each sub-collection in the USDA Soybean Germplasm Collection.

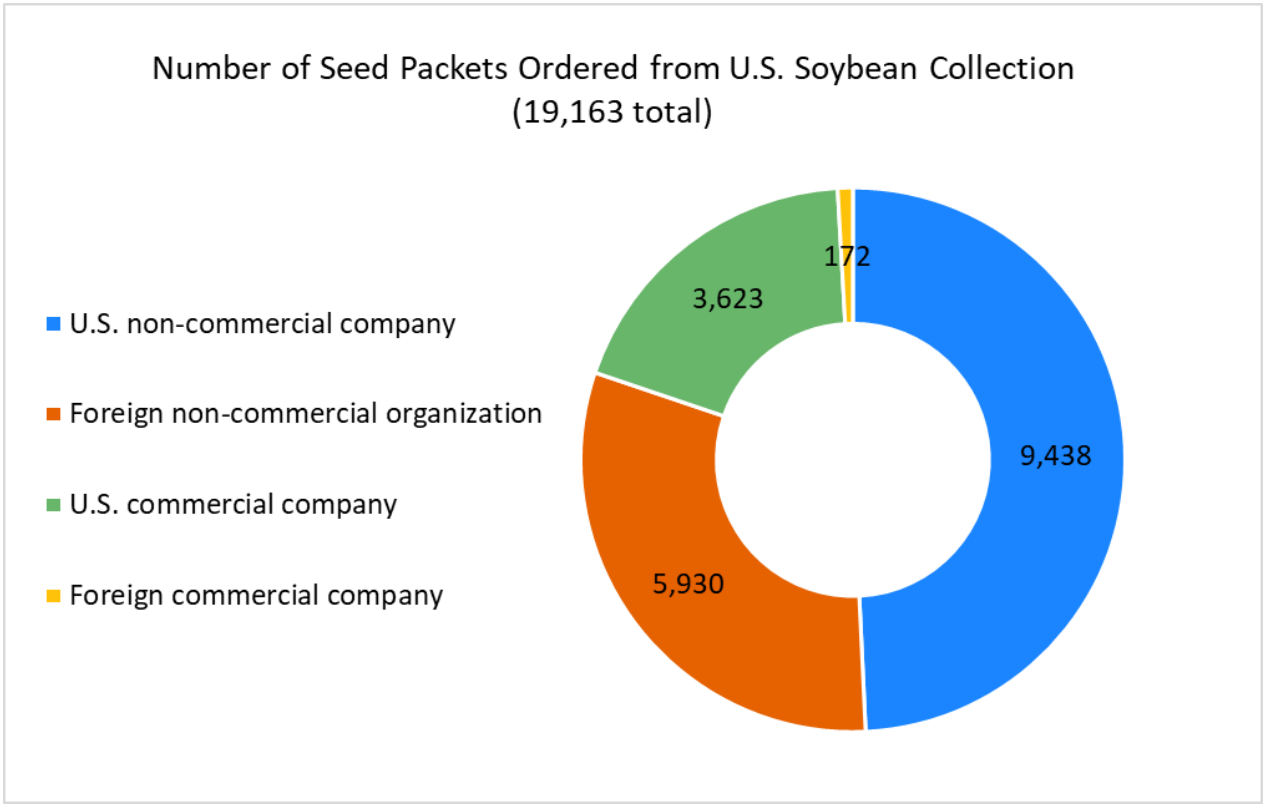
USDA Soybean Germplasm Collection Inventory	
Glycine max	17,553
Perennial species	1,213
Glycine soja	1,179
Private cultivars	783
Modern cultivars	565
Germplasm releases	311
Isoline - Clark	295
Old cultivars	208
Genetic types	197
Isoline - Harosoy	141
Isoline - Williams	102
Isoline - Other	66
Pigment mutants	47
Total	22,660

Glycine max	
Maturity Group	**# of accessions**
MG 000	144
MG 00	526
MG 0	1,162
MG I	1,776
MG II	2,279
MG III	2,221
MG IV	4,471
MG V	2,924
MG VI	1,642
MG VII	1,021
MG VIII	964
MG IX	874
MG X	109

Glycine soja	
Maturity Group	**# of accessions**
MG 000	165
MG 00	52
MG 0	54
MG I	61
MG II	95
MG III	50
MG IV	85
MG V	344
MG VI	172
MG VII	90
MG VIII	5
MG IX	2
MG X	4

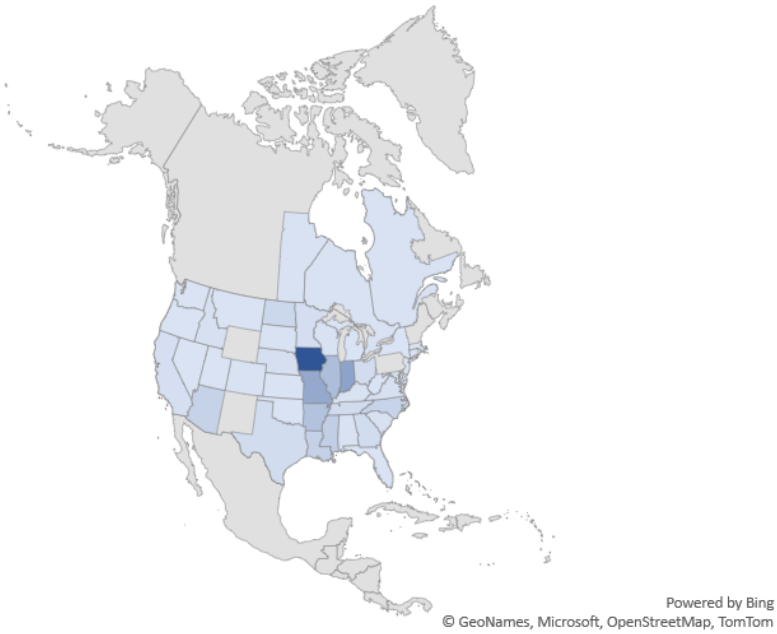
Perennial species	
G. tomentella	348
G. tabacina	184
G. canescens	151
G. clandestina	112
G. pescadrensis	68
G. latifolia	53
G. cyrtoloba	50
Glycine spp.	55
G. rubiginosa	37
G. microphylla	35
G. falcata	30
G. stenophita	27
G. argyrea	14
G. dolichocarpa	13
G. curvata	9
G. latrobeana	7
G. peratosa	7
G. syndetika	6
G. arenaria	5
G. pindanica	4
Total	1,215


Number of Orders from U.S. Soybean Collection
(434 total)
U.S. non-commercial company
U.S. commercial company
Foreign non-commercial organization
Foreign commercial company
360
47
19
8

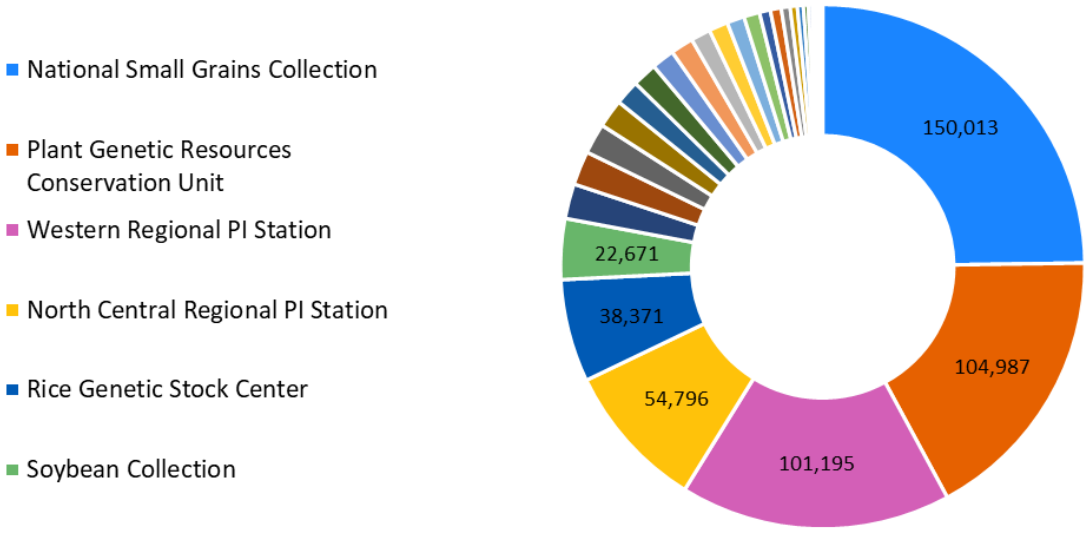

Number of Seed Packets Ordered from U.S. Soybean Collection
(19,163 total)
U.S. non-commercial company
Foreign non-commercial organization
U.S. commercial company
Foreign commercial company
9,438
5,930
3,623
172

Number of Orders from U.S. Soybean Collection

Iowa	3,735
Indiana	1,678
Missouri	1,525
Illinois	983
Arkansas	848
Mississippi	546
Louisiana	470
Arizona	450
North Carolina	433
North Dakota	329
Tennessee	208
Texas	188
Georgia	176
Ohio	172
Minnesota	142
Nebraska	105



Number of Accessions at U.S. NPGS Sites (605,483 total)



There is a significant amount of publicly available data for *Glycine* species, encompassing 180 traits and nearly 1 million observations. This data, compiled through the efforts of the Collection staff along with observations provided by seed requestors and through collaborations with public and industry partners, is summarized in the tables below.

Total observations for soybeans (*Glycine max*)

category_code	title	obs	category_code	title	obs	category_code	title	obs
CHEMICAL	ARGININE	5,530	DISEASE	Phytophthora Rot Race 30T	263	MORPHOLOGY	Lodging	17,556
CHEMICAL	CYSTEINE	5,530	DISEASE	Phytophthora Rot Race 31	145	MORPHOLOGY	LOWER LEAFLET RATIO	15
CHEMICAL	human allergen P34	13,304	DISEASE	Phytophthora Rot Race 33	113	MORPHOLOGY	Mottling score	14,411
CHEMICAL	Iodine number	2,820	DISEASE	Phytophthora Rot Race 38	65	MORPHOLOGY	Other leaf traits	1,060
CHEMICAL	ISOLEUCINE	5,530	DISEASE	Phytophthora Rot Race 4	1,472	MORPHOLOGY	Other plant traits	308
CHEMICAL	LEUCINE	5,530	DISEASE	Phytophthora Rot Race 5	791	MORPHOLOGY	Other seed traits	3,816
CHEMICAL	Linoleic	22,073	DISEASE	Phytophthora Rot Race 6	139	MORPHOLOGY	Pod color	19,352
CHEMICAL	Linolenic	22,072	DISEASE	Phytophthora Rot Race 7	2,991	MORPHOLOGY	Pod length	15
CHEMICAL	LYSINE	5,530	DISEASE	Phytophthora Rot Race 8	149	MORPHOLOGY	Pubescence color	18,259
CHEMICAL	METHIONINE	7,515	DISEASE	Phytophthora Rot Race 9	96	MORPHOLOGY	Pubescence density	18,697
CHEMICAL	Oil	22,165	DISEASE	Pythium ultimum	1,289	MORPHOLOGY	Pubescence form	17,758
CHEMICAL	Oleic	21,061	DISEASE	SOUTHERN STEM CANKER	119	MORPHOLOGY	Seed coat color	19,514
CHEMICAL	Other fatty acid composition	5,762	DISEASE	Soybean mosaic virus	15	MORPHOLOGY	Seed coat luster	18,224
CHEMICAL	Palmitic	21,061	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G1	236	MORPHOLOGY	Seed quality	17,662
CHEMICAL	Petiole Ureide	2,497	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G2	107	MORPHOLOGY	Seed shape of G. soja	15
CHEMICAL	Protein	22,165	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G3	236	MORPHOLOGY	Seed Shape of Glycine max	9,571
CHEMICAL	Stachyose	5,522	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G4	26	MORPHOLOGY	Seed weight	17,705
CHEMICAL	Stearic	21,061	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G5	107	MORPHOLOGY	Stem termination score	12,566
CHEMICAL	Sucrose	5,483	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G6	236	MORPHOLOGY	Upper leaflet length	15
CHEMICAL	THREONINE	5,530	DISEASE	SOYBEAN MOSAIC VIRUS STRAIN G7	236	MORPHOLOGY	Upper leaflet shape	15
CHEMICAL	TRYPTOPHAN	5,530	DISEASE	Soybean Rust Mixed	434	NEMATODE	Cyst Nematode Race 1	758
CHEMICAL	VALINE	5,530	DISEASE	Soybean Rust Red-Brown	102	NEMATODE	Cyst Nematode Race 14	2,548
DISEASE	Bacterial pustule	3,394	DISEASE	Soybean Rust Tan	3,084	NEMATODE	Cyst Nematode Race 2	234
DISEASE	Bean Pod Mottle Virus	427	DISEASE	Soybean Sudden Death Syndrome	6,861	NEMATODE	Cyst Nematode Race 3	12,805
DISEASE	Brown stem rot	4,031	GROWTH	Height	17,676	NEMATODE	Cyst Nematode Race 4	7,404
DISEASE	Frogeye C-32 Isolate	1,678	GROWTH	Stem termination type	18,195	NEMATODE	Cyst Nematode Race 5	11,627
DISEASE	FROGEYE RACE 11	108	INSECT	Beet armyworm	5	NEMATODE	RENIFORM NEMATODE	125
DISEASE	Frogeye race 2	2,652	INSECT	Corn Ear Worm	26	OTHER	Core Subset	3,102
DISEASE	Frogeye, unspecified race	115	INSECT	DEFOLIATION	339	OTHER	Image	4,119
DISEASE	NORTHERN STEM CANKER	1,467	INSECT	Leaf hopper injury	784	PHENOLOGY	Flowering	17,696
DISEASE	Peanut Mottle Virus	2,150	INSECT	Mexican Bean Beetle damage	5,046	PHENOLOGY	Maturity date	17,688
DISEASE	Phytophthora Rot Race 1	9,950	INSECT	Soybean Aphid Resistance	4,061	PHENOLOGY	Maturity group	18,259
DISEASE	Phytophthora Rot Race 10	623	INSECT	Soybean Looper	2,278	PHENOLOGY	Twining date	14
DISEASE	Phytophthora Rot Race 12	640	INSECT	Velvetbean caterpillar	126	PRODUCTION	Yield	17,521
DISEASE	Phytophthora Rot Race 17	2,227	MOLECULAR	MATURITY LOCUS E3	119	ROOT	ROOT FLUORESCENCE	795
DISEASE	Phytophthora Rot Race 2	432	MORPHOLOGY	Branching	2,153	STRESS	Chlorosis score	4,617
DISEASE	Phytophthora Rot Race 20	652	MORPHOLOGY	Early shattering score	16,063	STRESS	HIGH TEMPERATURE	520
DISEASE	Phytophthora Rot Race 25	2,834	MORPHOLOGY	Flower color	18,255	STRESS	Salt reaction	564
DISEASE	Phytophthora Rot Race 3	2,816	MORPHOLOGY	Hilum color	19,468			
DISEASE	Phytophthora Rot Race 30	115	MORPHOLOGY	Late shattering score	13,266			

Total observations for wild soybeans (*Glycine soja*)		
category_code	**title**	**obs**
CHEMICAL	human allergen P34	1,118
CHEMICAL	Linoleic	1,243
CHEMICAL	Linolenic	1,243
CHEMICAL	Oil	1,243
CHEMICAL	Oleic	1,243
CHEMICAL	Other fatty acid composition	182
CHEMICAL	Palmitic	1,243
CHEMICAL	Protein	1,243
CHEMICAL	Stearic	1,243
DISEASE	Bean Pod Mottle Virus	117
DISEASE	Phytophthora Rot Race 3	448
DISEASE	Soybean mosaic virus	182
GROWTH	Height	182
GROWTH	Stem termination type	1
INSECT	Beet armyworm	425
INSECT	Soybean Looper	379
INSECT	Velvetbean caterpillar	408
MORPHOLOGY	Flower color	185
MORPHOLOGY	Hilum color	939
MORPHOLOGY	LEAFLET SHAPE OF GLYCINE SOJA	1,060
MORPHOLOGY	LEAFLET SIZE OF GLYCINE SOJA	1,060
MORPHOLOGY	Lower Leaflet Area	1,036
MORPHOLOGY	Lower Leaflet Aspect	1,049
MORPHOLOGY	LOWER LEAFLET RATIO	182
MORPHOLOGY	Other leaf traits	38
MORPHOLOGY	Other plant traits	3
MORPHOLOGY	Other seed traits	299
MORPHOLOGY	Pod color	1,003
MORPHOLOGY	Pod length	182
MORPHOLOGY	Pubescence color	185
MORPHOLOGY	Pubescence density	1,001
MORPHOLOGY	Pubescence form	270
MORPHOLOGY	Seed coat color	1,040
MORPHOLOGY	Seed coat luster	185
MORPHOLOGY	Seed shape of G. soja	185
MORPHOLOGY	Seed weight	182
MORPHOLOGY	Upper leaflet length	182
MORPHOLOGY	Upper leaflet shape	182
NEMATODE	Cyst Nematode Race 1	1,078
NEMATODE	Cyst Nematode Race 3	545
NEMATODE	Cyst Nematode Race 4	1
NEMATODE	Cyst Nematode Race 5	547
OTHER	Core Subset	81
OTHER	Image	1,847
PHENOLOGY	Flowering	1,246
PHENOLOGY	Maturity date	1,245
PHENOLOGY	Maturity group	185
PHENOLOGY	Twining date	182
STRESS	Chlorosis score	21

Total observations for perennial *Glycine*		
category_code	**title**	**obs**
CHEMICAL	Bowman-Birk Inhibitor	560
CYTOLOGIC	Chromosome number	861
DISEASE	SCLEROTINIA STEM ROT	777
DISEASE	SUDDEN DEATH SYNDROME	754
MORPHOLOGY	Adventitious roots	319
MORPHOLOGY	Leaflet arrangement	291
MORPHOLOGY	Upper pubescence type	290
MORPHOLOGY	Upper terminal leaflet length	265
MORPHOLOGY	Upper terminal leaflet shape	292
MORPHOLOGY	Upper terminal leaflet width	293
NEMATODE	Soybean Cyst Nematode Race 3	490
OTHER	CORE SUBSET	115
OTHER	IMAGE	3,008