SUNFLOWER GENETIC RESOURCES

***Laura Fredrick MAREK*[1]**

[1] *North Central Regional Plant Introduction Station, Iowa State University and USDA-ARS, 1305 State Avenue, Ames, IA 50014 USA*

**lmarek@iastate.edu*

ABSTRACT

Sunflower (*Helianthus*) collections around the world play a critical role supplying germplasm for crop security and improvement. Sunflower is native to North America and this presentation focuses on the collection of more than 5000 cultivated and wild *Helianthus* accessions maintained by the United States National Plant Germplasm System (USDA-NPGS) genebank in Ames, IA with some discussion of other national collections. The NPGS cultivated collection, curated in Ames since 1948, contains landraces, cultivars, breeding lines, populations, synthetic varieties, and pre-breeding lines. Exciting new material includes a 288 member association mapping population as well as more than 300 pre-breeding lines containing DNA introgressions from 11 wild species. The USDA wild sunflower collection, started in Bushland TX in 1976, was transferred to Ames in 1985. Holdings include accessions representing all 66 extant wild annual and perennial sunflower taxa except one subspecies endemic to Baja California. The accessions were primarily sourced from wild populations in the US and Canada with some representation from naturalized populations around the world. With increased awareness of the value of crop wild relatives as sources offer traits and genetic diversity for cultivar improvement and to enhance crop security, we have emphasized collection of wild species to maximize representation of geographic and genetic diversity. A third of the wild germplasm holdings has been added in the past ten years including explorations in 2015 to increase representation of species from the western, southwestern and southern US. The NPGS collection is freely available for research and educational purposes although some restrictions are imposed by import regulations in receiving countries.

Key words: Sunflower, Genebank, Wild, Cultivated, Explorations

INTRODUCTION

The National Plant Germplasm System (NPGS) in the United States maintains and manages genetic resources for agricultural crops in the United States. The sunflower collection is maintained at the North Central Regional Plant Introduction Station (NCRPIS) in Ames, IA. The NPGS is an association of twenty genebanks (Fig 1) operating under the umbrella of United States Department of Agriculture Agricultural Research Service (USDA-ARS) united by common use of the Germplasm Resources Information Database (GRIN, GRIN-Global) and leadership from USDA National Program Staff in Beltsville, MD.

Most locations in the NPGS are partnered with a land grant university; for example, the station in Ames is a partnership with Iowa State University. There are four multi-crop plant introduction stations in the NPGS located in Pullman WA, Ames IA, Griffin GA and Geneva NY; a back-up storage and preservation research unit in Ft Collins CO (the National Laboratory for Genetic Resources Preservation); and 15 other repositories such as Sturgeon

Bay WI where the potato collection is curated, the National Small Grains Collection at Aberdeen ID, and College Station TX where the pecan collection is maintained. As illustrated in Figure 1, the stations cover a wide range of latitudes as well as temperature zones.

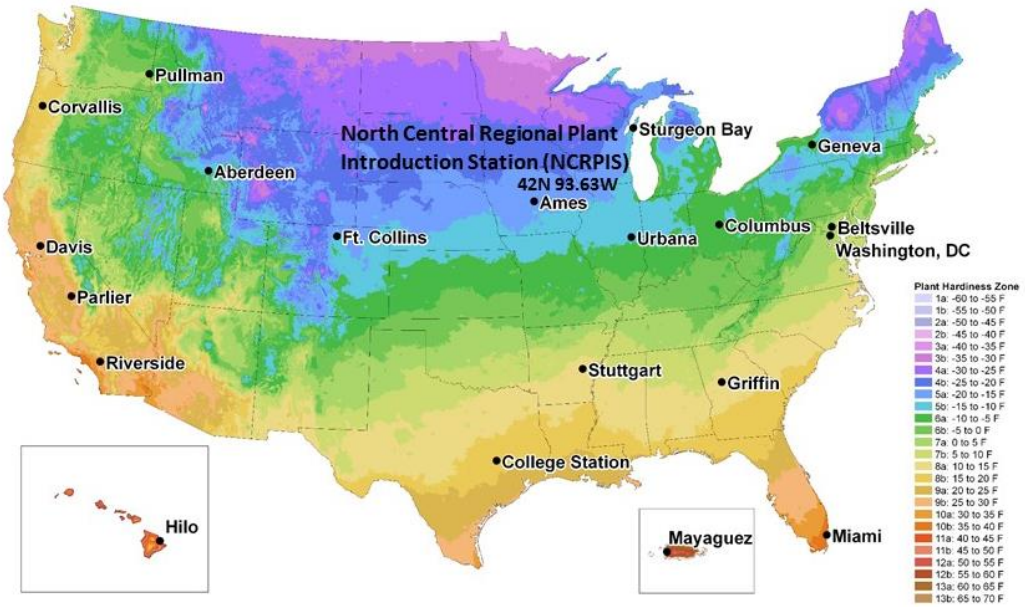


Figure 1: The 20 locations of the US National Plant Germplasm System positioned on the USDA's Plant Hardiness Zone map.

The NCRPIS is located in southwestern Ames on a little over 41 hectares of Iowa State University Experiment Station land at 42° north latitude, a comparable distance north of the equator as Edirne, Turkey although with greater average annual precipitation (910mm in Ames, 578mm in Edirne) and at a higher elevation (287 meters in Ames, 63 meters in Edirne). The NCRPIS is a joint project between the Agriculture Experiment Stations of the 12 North Central States, Iowa State University, and the USDA-ARS. There are five curatorial projects in Ames (amaranth, millets, quinoa, miscellaneous other crops; horticultural and medicinal crops; maize; oilseed crops; vegetable crops including carrots) and seven support and project teams (administration, entomology, farm maintenance and operations, information technology, pathology, management and distribution and storage of seeds, viability testing and the Germplasm Enhancement of Maize project).

The Oilseeds Project includes the sunflower collections as well as oilseed brassicaceae (the *Brassicas* such as canolas and rapeseed and miscellaneous new crop genera in the brassicaceae family such as *Camelina*, *Thlaspi*, *Crambe* and 20 others), flax, *Cuphea*, *Euphorbia* and a group of miscellaneous asters (36 genera). All of the support teams are critical to curatorial success and three in particular are described here. Our staff entomologist rears honeybees which are the primary pollinator for caged sunflowers as well as *Osmia* and alfalfa leaf cutter bees, bumble bees, and several species of flies. We have a plant pathologist on staff who inspects our fields and greenhouse plantings, conducts seed health testing, manages seed treatmenst, and issues the additional declaration statements often needed for international seed shipments. The viability team conducts germination testing on new accessions and regeneration lots before seed lots are stored as well as testing of distribution

lots at species specific intervals to help curators decide when seed lots need to be replaced with fresh seed.

THE SUNFLOWER COLLECTION AT THE NCRPIS, BASIC INFORMATION

It is the mission of the NCRPIS to expand the genetic diversity of priority plant genetic resource (PGR) collections, to improve associated information and information management tools that facilitate PGR conservation and utilization in research and crop improvement, and to provide these resources for research and educational objectives. The information presented will illustrated how that mission is fulfilled for sunflowers.

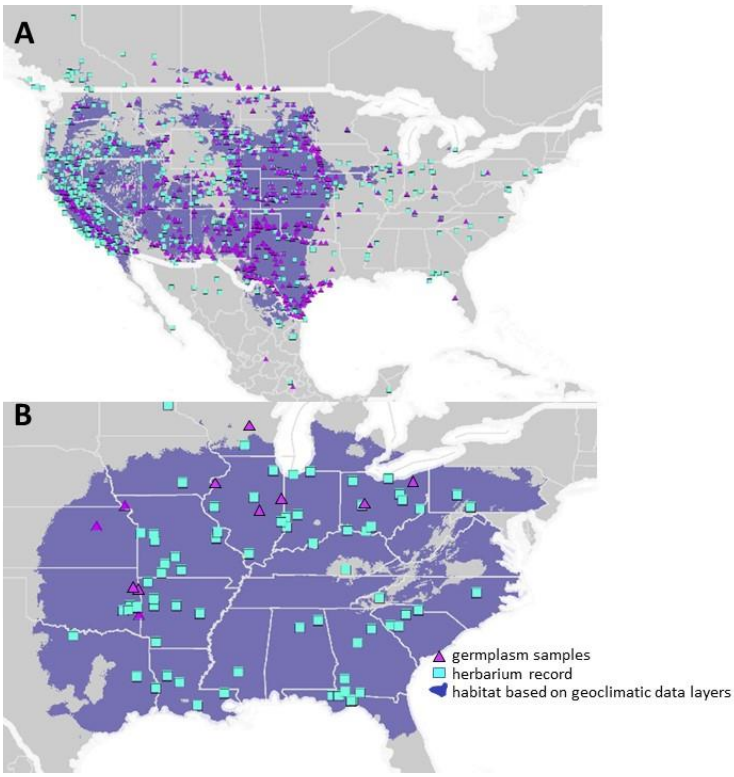
The USDA sunflower collection consists of a little over 5000 accessions, about 2500 cultivated accessions and 2500 accessions of wild species. As of May 2016, both groups were about 90% available for distribution.

The cultivated sunflower collection has been in Ames since the station opened in 1948 and consists of traditional open pollinated populations, North American native land races, inbred lines, composite and synthetic varieties, pre-breeding lines and an association mapping population (UGA-SAM1). The cultivated collection has been 90% or more available for distribution for many years.

The wild collection was transferred to Ames in 1985 from Bushland TX where it was initiated in the 1970s and where Dr. Gerald Seiler served the first curator. The wild collection contains samples from populations of all extant *Helianthus* taxa except *H. niveus* ssp *niveus* which is endemic to Baja California, Mexico as well as samples from naturalized populations in the US and around the world. The collection is curated as a living one; that is, seeds from active accessions can be germinated and plants will result. There had been less emphasis on the wild collection prior to 2004 when I became curator. Increasing species and accession availability, which was about 27% for all taxa except wild and cultivated *H. annuus* in 2004, became a priority. Increasing collection availability involves both regenerating seeds to distribution quantities and inactivating inviable accessions as well as collecting new samples to fill species and geographic gaps. About 700 wild accessions have been inactivated during the past 12 years when seed failed to germinate (primarily from the oldest original collections) during regeneration attempts.

EXPANDING GENETIC DIVERSITY IN THE NCRPIS WILD SUNFLOWER COLLECTION: UNDERPININGS

Identification of collection gaps involves comparing collected locations of existing accessions with known ranges and herbaria records which support potential active collection sites for species of interest. Rogers et al. (1982) published maps with range estimates for most of the wild *Helianthus* taxa, providing a starting point. The mapping group at the International Center for Tropical Agriculture (CIAT) in Cali, Columbia led by Chyrstian Sousa extended the concept of gap filling based on herbaria and germplasm sample records to include geoclimatic data layers (precipitation, temperature and soil characteristics, Kantar et al. 2015) and the resultant maps are intended to predict where populations could be expected to occur. For sunflower the soil data were critical to identifying species differentiation. As shown in Figure 2A for the direct progenitor of the crop plant, wild *Helianthus annuus*, samples and records overlap well and correspond to the areas of expected range based on the geoclimate data layers, although there are scattered geographic gaps across the US and gaps in Mexico and Canada.



In the case of *H. hirsutus* (Figure 2B), although herbaria voucher records agree with the expected range based on geoclimatic data layers, there are no germplasm samples from the southern and eastern portion of the species range. This analysis helped identify a species in need of further collection to achieve a full range of sampling; *H. hirsutus* will be a target of a future collection effort.

Based on this kind of information, I planned two explorations for 2015, both of which are described because they represent very different environments and dramatically illustrate the diversity present within the genus *Helianthus*. Each exploration offered a unique perspective as to the value of filling gaps in a collection during these times of climate change. Dr. Seiler was my co-collector for both of the 2015 explorations.

Planning and preparing a plant exploration is a complex activity. First an infrastructure is established based on existing herbaria voucher records for the species of interest. Herbaria records tend to be ten to twenty or more years old. A second critical step is to contact botanists at universities, often starting with the herbaria directors, public lands (federal, state, city and county, such at the national forests and Bureau of Land Management scientists), and non-government organizations such as The Nature Conservancy and appropriate departments in tribal nations to accumulate information about extant populations and current year data. A key requirement for seed coming to the NPGS is that landowners are identified and any necessary permits obtained. We must be permitted to collect germplasm and the seeds must be distributable, generally without restrictions. Once locations of populations to sample are identified, determining a collection route usually involves the use of multiple maps. Topographical maps can be critical in the case of older voucher records which were made pre-GPS and which often relied on landmarks such as a cemetery or a church named on the topo maps but not in google or on Gazetteers. Roads can be re-routed and names can change, making finding the location of old records sometimes very difficult. And finally, the decision when to collect is made based on current year weather conditions along with information from local botanists. At each collection location passport data are recorded for entry into the NPGS database: latitude and longitude, description of the site including associated vegetation and how it was accessed, population size, and number of plants sampled, and images of the population and surrounding habitat are taken. In addition a voucher specimen is prepared for each population if possible. Sunflower specimens are currently stored at the USDA-ARS Sunflower and Plant Biology Research Unit in Fargo, ND.

2015 EXPLORATIONS: INCREASING DIVERSITY AND FILLING GAPS

Figure 3. 2015 sunflower collection explorations funded by the Plant Exchange Office (PEO), National Germplasm Resources Laboratory, USDA-ARS, Beltsville, MD.

The general areas of the 2015 sunflower explorations are indicted on Figure 3. A mid-June 2015 sunflower exploration to southeastern Utah and northern Arizona targeted *H. anomalus*, a species under-represented in the NPGS collection and of interest because of its success growing in a very dry habitat. Populations of *H. deserticola*, *H. petiolaris* ssp *petiolaris* and *H. annuus* were sampled as well. The US desert southwest has been experiencing more frequent and longer lasting droughts. Filling collection gaps before climate change affects long term *in vivo* survival of these crop wild relatives is a real consideration. For several years prior to 2015 this region had experienced severe drought. In 2015, however, southeastern Utah and northern Arizona received more than their average annual precipitation (178 mm) by mid-May and there was explosive plant growth. It was a very fortunate year to be exploring, although, as is typical, we did not find all expected populations.

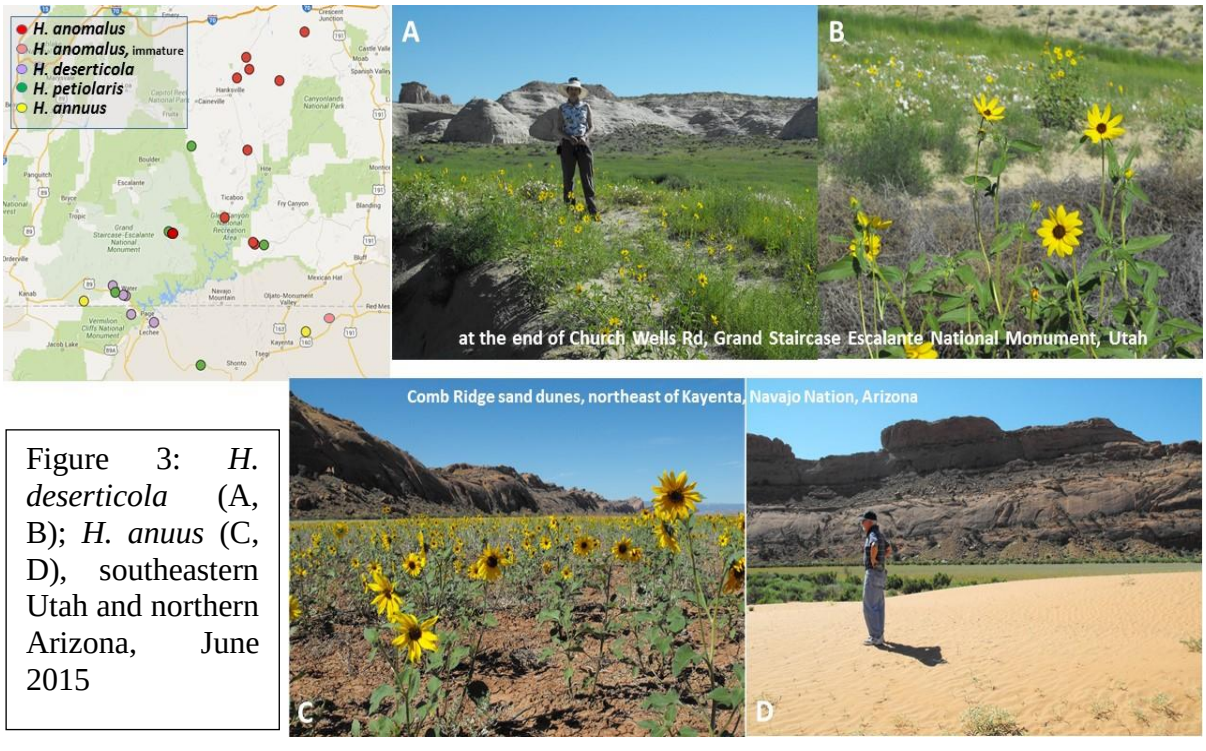


Figure 3: *H. deserticola* (A, B); *H. anuus* (C, D), southeastern Utah and northern Arizona, June 2015

Based on herbaria voucher records, we expected to find *H. anomalus* between Kanab, Utah and Page, Arizona. We did not locate any populations of the target species in this region but we did find *H. deserticola* (Fig 3, purple circles on map and images A and B) which added to genetic diversity in the NPGS wild sunflower collection for that species. We were also expecting to find *H. anomalus* in the Comb Ridge sand dunes northeast of Kayenta,

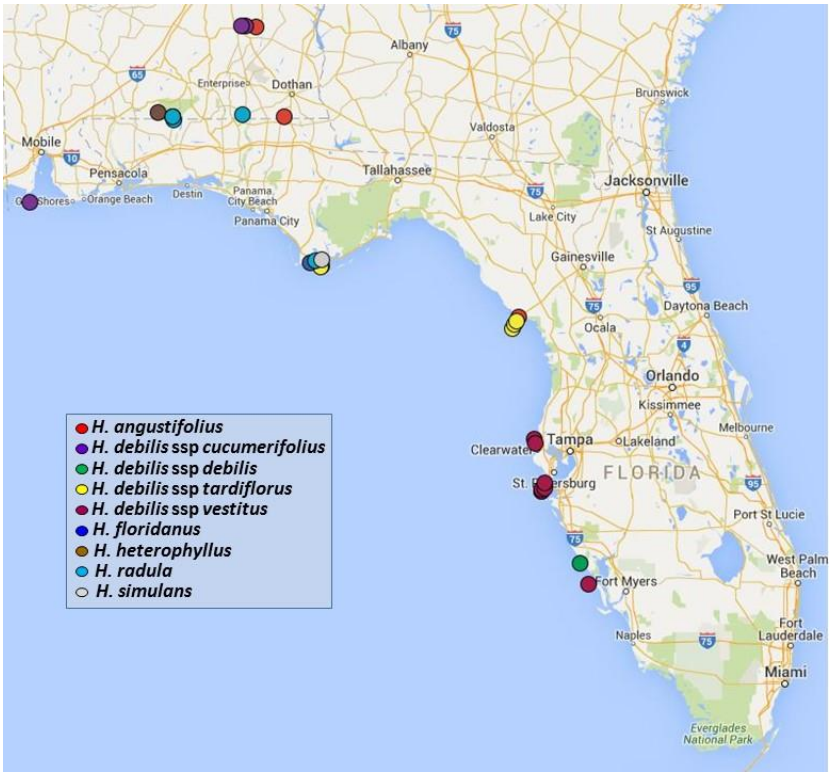
Arizona in the Navajo Nation. We observed an expansive population of *H. annuus* in the dried playa between the sandy dirt car track and the dunes but no *H. anomalus* plants in the dunes (images C and D, Fig 3.)

The first substantial populations of the exploration's target species, *H. anomalus*, were observed on the Nokai Dome plateau east of Lake Powell, Utah (Fig 4, image A; two populations) and eight additional populations were discovered and sampled as noted on the map (Figure 4, red circles on map). One unique feature of this exploration was that a freelance journalist, Nelson Harvey, accompanied us for two days. He was interested in crop wild relatives and their relationship to agriculture, a topic that seems to have had some presence in the popular press in the U. S. He had a professional quality camera and took many images which he agreed to share (Fig 4, images C, D and E). His article appeared in the Fall 2015 issue of Modern Farmer (N. Harvey, 2015).

Figure 4. *H. anomalus* in southeastern Utah, June 2015

The second exploration in 2015 took place in an area of the United States (Figure 5) where the climate concern is not drought but excess water due to rising sea levels and an increase in severe storms. This region of the United States continues to become increasingly urbanized, putting intense pressure on wild populations and creating some urgency to collect samples before populations disappear. In addition, revegetation work along the western coast and southern panhandle of Florida and southern Alabama often takes place without regard to use of appropriate endemic taxa. *H. debilis* ssp *debilis* is a popular species for dune stabilization and revegetation across the region despite it being native to eastern coastal Florida. As it is spread out of its traditional range, it has hybridized with the western coastal Florida subspecies *vestitus*. *H. debilis* ssp *debilis* and hybrids have been displacing *H. debilis* ssp *vestitus* in its traditional habitat (Bradley et al. 2004) which also lent some urgency to the second exploration. Valuable disease resistance traits have been transferred from several of the *H. debilis* subspecies to cultivated lines, notably resistance to infestation by the parasitic

plant *Orobanche cumana*, which was crossed into a cultivated background from the subspecies *tardiflorus* (Velasco et al. 2012). This discovery is especially interesting because *O. cumana* does not occur in the US. *O. cumana* is a primary concern in sunflower fields across many regions in Europe, Asia and now Africa and genetic resistance is the most reliable form of protection for the crop.



The target taxa for the fall 2015 exploration were three subspecies in the *H. debilis* complex (*vestitus*, *cucumerifolius* and *tardiflorus*). Other species were collected if interesting populations were observed in unusual habitats or in regions for which there was not an existing accession in the NPGS sunflower collection.

Figure 5. Overview map of fall 2015 collection exploration to western Florida and southern Alabama

All collected populations of *H. debilis* ssp *vestitus* were on islands off the coast of western peninsular Florida. Four islands were accessible by causeway and/or draw-bridge; three required the rental of boats and captains. Of particular note was one of the three populations sampled on Egmont Key (Figure 6 image B). The population on the western side of the island, not previously vouchered and first noted by the state park biologist the week before we arrived, was in an area where the rising sea level (salt water) has killed palm trees. The sunflower population was expansive and healthy. The only mainland based population of *H. debilis* ssp *vestitus* we observed was in Oscar Scherer State Park but it was smaller than the size permitted for collecting (Figure 6, pale pink circle on map map) so we could not make a collection.

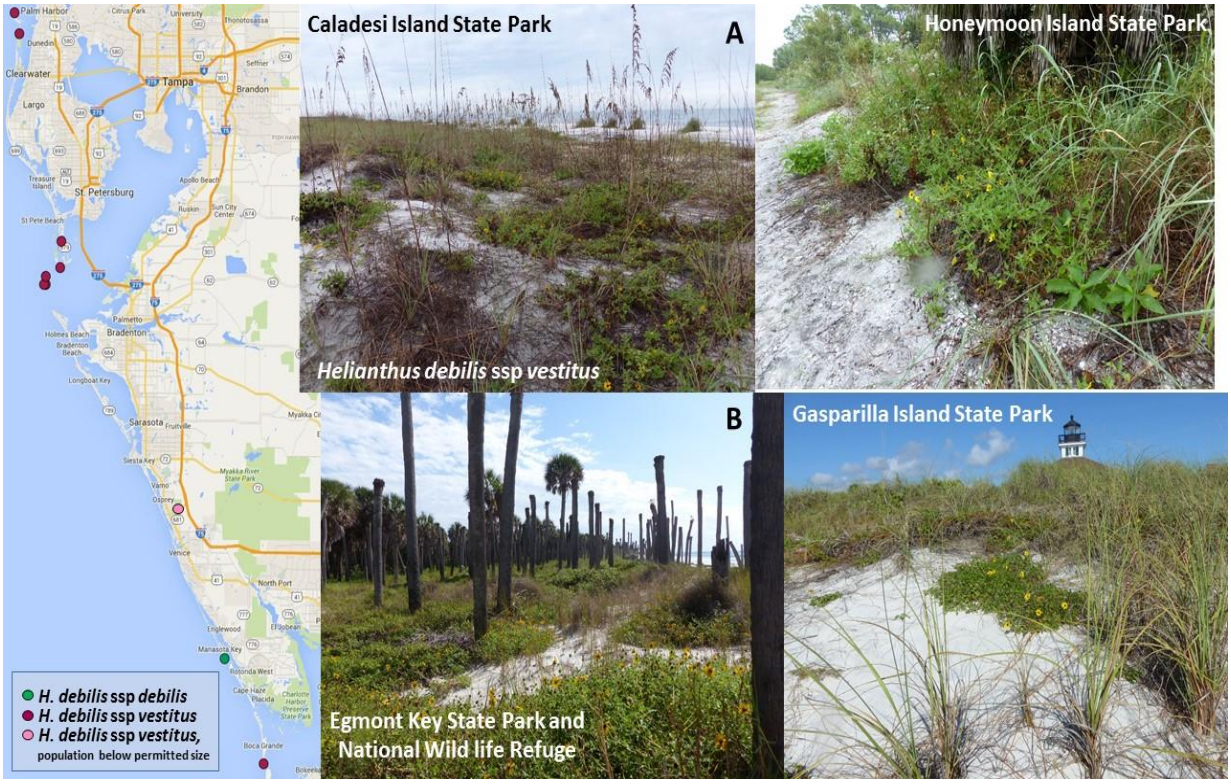


Figure 6. Collection area for *Helianthus debilis* ssp *vestitus*.

Figure 7. Collection area for *H. debilis* ssp *cucumerifolius* and *H. debilis* ssp *tardiflorus* and five additional sunflower species.

All the populations of *H. debilis* collected along southern Alabama and peninsular Florida were affected by the storm surge caused by Hurricane Patricia, initially the most intense tropical disturbance ever recorded, the week before we arrived. The hurricane ran aground into the mountains of western Mexico and did very little of the damage it was expected to cause, although it did cause a tidal surge across the Gulf of Mexico. Dauphin Island, Alabama was under water for about a week. Based on a herbarium voucher record, we expected a population of *H. debilis* ssp *cucumerifolius* in the general area of the street sign in Figure 7, image A. There were not plants visible at that location, although we did find a small population in a drier region some distance down the road (Figure 7, image B). St Vincent's Island, about 325 miles to the southeast of Dauphin Island and along the southern Florida panhandle was also largely underwater for about a week due to the Hurricane Patricia tidal surge. Extensive *H. debilis* ssp *tardiflorus* populations observed by the National Wildlife Refuge biologist just three weeks before the exploration were mostly destroyed; although we were able to collect limited numbers of seeds (Figure 7 image C).

Diversity in the NPGS wild sunflower collection was increased significantly in 2015. Dr. Seiler and I sampled 48 different wild populations of 13 taxa over 15 days of collecting in two separate PEO funded explorations in vastly different parts of the United States. We also received a significant donation of 140 accessions of five wild annual species, from a collecting exploration targeted for habitat type and species funded by Dr. Rieseberg's lab at the University of British Columbia. Dr. Dylan Burge made the collections during a three month exploration in the western and southwestern US.

PROVIDING RESOURCES FOR RESEARCH AND EDUCATIONAL PURPOSES

Identifying gaps, planning an exploration and collecting seed comprise the first steps in providing genetic resources for research and educational purposes. The next steps involve ensuring that seeds are available for use as expediently as possible. A goal is to collect enough seed to allow for at least some immediate distribution and back up storage in Ft Collins. We also send seed for long term back up to the Global Seed Vault in Svalbard, Norway when inventory supports a transfer. It is not always possible to collect significant quantities of original seed, in which case the accession is tagged for regeneration. Some accessions with significant quantities of original seed are scheduled for regeneration to ensure availability of all taxa for international distributions: we cannot make disease declarations for wild collected seed. We also schedule regenerations when distribution lots fall below some minimum (usually 500 to 1000 seeds) or when viability testing indicates failing quality.

We use standard protocols for regeneration at the NCRPIS. In addition to growing sunflowers in Ames, we have an alternate grow out location in the central valley of California southeast of Fresno at the San Joaquin Valley Agricultural Sciences Center, USDA-ARS. Parlier has a much longer growing season than Ames allowing late flowering southern species to complete their life cycles and it is hot and dry during the summer more closely mimicking the conditions expected by species native to the desert southwest. All wild sunflower regenerations take place in screened steel cages with added pollinators (usually honeybees). Cultivated sunflowers are grown either in rows with head bagging and hand sib pollination or in cages (multi-headed restorer lines, accessions with few seed, open pollinated populations, others) with added pollinators.

NCRPIS CULTIVATED SUNFLOWER COLLECTION

Not surprisingly the sunflower collection at the NCRPIS has an international origin. Although the crop wild relatives are native to North America, cultivated sunflower breeding had its beginnings in Russia. The USDA started a sunflower collection some decades before there was a significant USDA supported breeding effort in sunflowers. The first accessions in the NPGS cultivated collection were donated from Argentina, Uruguay, Lebanon and Turkey (Table 1). Over time, fifty-nine countries including US breeders have made contributions. By the late 1970's the USDA breeding programs were generating populations and inbred lines for public release and inclusion in the genebank, and since 1990 the primary source of new cultivated lines has been the USDA breeding program although there have been significant donations from Spain and very recently from Canada.

Table 1: International Origin of the NPGS cultivated sunflower collection: donor countries and years donated.

Source	# of accession	date(s)	Source	# of accession	date(s)
Afghanistan	2	1954, 1978	Lithuania	1	1974
Argentina	46	1948 - 1998	Mexico	9	1981 - 1992
Australia	5	1976-1983	Monaco	1	1995
Austria	2	1954	Mongolia	2	1992
Brazil	2	1965, 1967	Morocco	1	1989
Bulgaria	14	1959 - 1992	Netherlands	4	1989, 1997
Canada	452	1962 - 1993, 2016	Pakistan	4	1959 - 1978
Chile	7	1960s, 1995	Paraguay	1	1995
China	22	1950 - 1995	Peru	1	1984
Colombia	3	1969, 1996	Poland	37	1962 - 2000
Cuba	1	1996	Portugal	2	1967, 1989
Czechoslovakia	3	1989	Rhodesia	3	1979
Egypt	4	1958, 1979	Romania	45	1969 - 1995
Ethiopia	6	1951	Russian Federation	71	1981 - 1992
Former Serbia and Montenegro	69	1978 - 1989	Serbia	4	1949 - 1979
France	25	1963 -1997	South Africa	11	1964 - 1971
Georgia	1	1974	Soviet Union, Former	152	1988 - 1992
Germany	46	1952 - 1997	Spain	118	1958 - 2005
Hungary	83	1956 - 1989	Sweden	1	1995
India	3	1989	Syria	2	1948
Indonesia	1	1954	Tanzania, Tanga	1	1960
Iran	61	1955 - 1995	Turkey	122	1948 - 1965
Iraq	10	1958	Ukraine	16	1959 - 1985
Israel	4	1954 - 2000	United Kingdom	3	1954, 1997
Italy	3	1978 -1989	United States	592	1964 - 2014
Jordan	12	1957, 1980	Uruguay	7	1948 - 1995
Kazakhstan	1	1974	Zambia	28	1981 - 1985
Kenya	17	1971, 1972	Zimbabwe	36	1985 - 1987
South Korea	2	2012	Unknown	49	1959 - 1992
Lebanon	1	1948			

The breeding effort in Fargo has traditionally focused on disease resistance, early maturity, and oil quality. Disease resistance and oil quality continue to be a focus although there are lines pending release carrying insect resistance, lines with low saturated fat and high oleic acid, and material with altered tocopherol composition (reduced alpha and increased gamma and delta tocopherols).

Two groups of core accessions have been identified within the cultivated collection. In the first, described by Brothers and Miller (1999), 113 accessions were determined to represent the diversity in the collection at that time based on passport data, morphological traits, oil quality traits and isozymes. In 2011, Mandel et al. described a set of 12 to 288 nested accessions using 34 SSR markers (two per linkage group) and the 288 lines were estimated to capture 90% of the diversity present in cultivated sunflower. The NCRPIS is also distributing one sunflower association mapping population, UGA-SAM1, developed at the University of Georgia and described in Mandel et al. 2013. The two sets of 288 lines are not identical but have a 67% overlap. 10% of the 288 lines in both the 2011 nested core set and the UGA-SAM1 population were provided by the INRA sunflower genebank as representing diversity in the French collection.

The NPGS cultivated collection contains a significant number of lines with introgressions from wild species. 138 accessions have a wild sunflower mentioned in their descriptive data field in GRIN; a more detailed assessment of the pedigree of all the inbreds and addition of that information to the GRIN-Global database is planned. Fifty-five of the introgressed lines were recently genotyped as described by Greg Baute (2015). Dr. Baute also developed and genotyped over 400 pre-breeding lines with introgressions from 11 wild species (Baute, 2015) of which 350 were recently received by the NCRPIS (May 2016).

INTERNATIONAL COLLECTIONS

Most of the countries which helped start the NPGS cultivated sunflower collection have continued to breed and develop their sunflower programs several of which are detailed in Table 2.

Table 2. Seven international sunflower collections with genebanks.

Country	Genebank Location	database	Treaty* status	accessions
Argentina	Cordoba	under development	signature only	~1350 op populations, inbred lines, naturalized populations, wild species
Canada	Saskatoon	GRIN Canada	contracting party	~600 cultivated and wild accessions 162 H. tuberosus accessions not databased
France	Toulouse	under development	contracting party	~6100 inbred lines, RILs, interspecific lines, op populations, EMS mutant population, wild species
Russia	St Petersburg	VIR PGR		~2800 cultivated and wild accessions
Serbia	Novi Sad	wild sunflowers	contracting party	3000 inbred lines and wild species
Turkey	Izmir	under development	contracting party	~400 oilseed and confectionary landraces
United States	Ames	GRIN Global US	signature only	~5000 op populations, inbred lines, interspecific lines, association mapping population, wild species

*The International Treaty on Plant Genetic Resources for Food and Agriculture

Sunflower breeding as an oil crop began in Russia more than 100 years ago and a search of the database at the Vavilov Institute of Plant Genetic Resources (VIR) in May 2016 indicated close to 3000 cultivated and wild species accessions in the genebank there. The collection is curated by Dr. Vera Garvilova (v.gavrilova@vir.nw.ru) who participated in a sunflower exploration in the United States in the 1980s. Use of sunflowers as more than a garden curiosity spread quickly throughout Europe and to South America and back to North

America. Sunflower breeding in Argentina began in the 1930s and the Instituto Nacional de Tecnologia Agropecuaria (INTA) genebank, located in Cordoba, contains a collection of approximately 1350 open pollinated populations, inbred lines, naturalized populations and wild species curated by Dr. Daniel Alvarez (alvarez.daniel@inta.gob.ar). Argentina was an original contributor to the establishment of the USDA sunflower collection (Table1). A collection of 400 Turkish oilseed and confectionary land races is maintained in Izmir by Dr. Ahmet Tan (a_s_tan@Hotmail.com). Turkey was also an original contributor to the NPGS sunflower collection (Table 1). The Institute for Field and Vegetable Crops, Novi Sad, Serbia has a long history in sunflower breeding and a strong interest in wild species. Scientists from Novi Sad participated in seven collection explorations in the United States during the 1980s through 1991. Their collection of wild species is available through a public database and the collection is curated by Dr. Sreten Terzic (sretenterzic@gmail.com). The French Sunflower Genetic Resources Center has recently been consolidated at the Institut National de la Recherche Agronomique (INRA) in Toulouse. Dr. Stephane Munos (crb.tournesol@toulouse.inra.fr) is the scientific curator with assistance from Marie-Claude Boniface and Nicolas Pouilly. The INRA collection has about 6110 lines including an EMS mutant population as well as recombinant inbred lines, open pollinated populations, inbred lines, interspecific lines and wild species. The group at INRA is developing a database and is expecting to be able to distribute seeds under material transfer agreements. The Canadian sunflower collection of about 600 lines is databased in GRIN Canada through Agriculture and Agri-Food Canada. The group maintains a substantial *H. tuberosus* collection which will be accessible online once their database migrates to GRIN Global Canada. Dr. Kessler (Dallas.Kessler@AGRI.GC.CA) distributes limited numbers of *H. tuberosus* accessions as tubers (all Canadian genebank materials are distributed under the SMTA) domestically and internationally.

SEED DISTRIBUTION FOR CROP SECURITY AND IMPROVEMENT

Sunflower is an Annex 1 crop under the International Treaty on Genetic Resources for Food and Agriculture which has effected exchange of germplasm: germplasm can be exchanged freely between contracting parties but under the terms of the standard material transfer agreement (SMTA). Countries with significant sunflower industries have varied in their response to the treaty: 129 countries are contracting parties to the treaty, nine countries have signed but not ratified the treaty, and about 50 countries have not yet participated. Of the countries discussed in the previous paragraphs, Canada, France, Serbia, and Turkey are contracting parties, the US and Argentina have signed but not ratified the treaty and Russia has neither signed nor ratified the treaty (Table 2). The US NPGS does accept germplasm under the SMTA and will distribute that germplasm under the SMTA. Currently there are two sunflower accessions with SMTAs attached, both land race lines received from South Korea in 2012.

The NPGS distributes germplasm without charge and generally without restriction except that intellectual property rights cannot be applied to germplasm as it is received; some breeding and selection must be undertaken first. In addition, the US Fish and Wildlife Service puts restrictions on species that are on its Threatened and Endangered Species list which includes three sunflower species: *H. paradoxus* (threatened), *H. schwenitzii* (endangered) and *H. verticillatus* (endangered). The NCRPIS is currently permitted to distribute *H. paradoxus* accessions under the conditions that any plants raised and their derivatives cannot be commercialized and all research must occur in a laboratory or greenhouse. The US Treasury Department imposes sanctions on trade with some countries; these do not allow for seed distribution although there can be exceptions for humanitarian purposes.

The primary restrictions on seed distribution, however, are imposed by the importing countries. Frequently a phytosanitary certificate is required to accompany a seed shipment and some countries require an import permit. It is common for countries with sunflower industries to require that any cultivated sunflower seed shipped be either declared free from downy mildew or be treated for that pathogen. Our staff pathologist inspects our regeneration fields, removes any diseased plants, and he can make many declarations based on those observations. Sometimes our pathologist is required to perform seed testing to meet import requirements. Resource limitations, both seed inventory amounts and pathology group time and expense, generally limit the number of accessions that can be tested to not more than 30 on an order. Testing results are entered into the GRIN Global database and hold for that accession as long as the distribution lot remains the same. There are times we cannot meet requirements by either testing or field declaration and then the seeds cannot be sent unless the requester can receive a waiver from the relevant agency in his/her country.

Ordering germplasm from the NPGS takes place through the Germplasm Resources Information Network (GRIN) Database, which migrated on November 30, 2015 to GRIN Global. Unless the requester has ordered since November 30, 2015, the first step in the ordering process is for the requestor to set up a GRIN Global online profile which can be done by selecting My Profile at the GRIN Global home page (http://npgsweb.ars-grin.gov/gringlobal/search.aspx) and following prompts. An order can then be set up under the "Accession" sub-menu on the home page, using a shopping cart style of ordering, unless the requester is interested in accessions which are not available when it is necessary to contact the curator.

The distribution process from the NCRPIS is straight forward (Figure 8) but the length of time to complete the process varies depending on the number of accessions requested and whether the request is domestic or international and if international, if there are import restrictions, and sometimes other factors. Plan for at least two months for receipt of international orders.

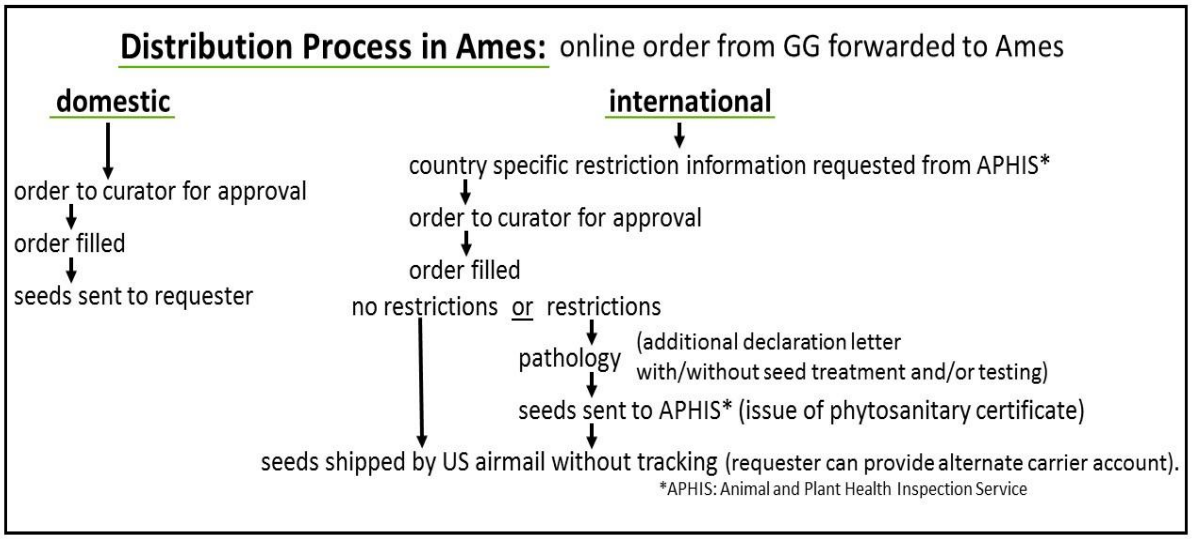


Figure 8: Schematic representation of seed distribution from the NCRPIS, Ames.

During the five year period from 2011 to 2015, 24,600 sunflower seed packets were distributed from the NCRPIS in 755 orders, 20% of which were sent internationally to 40 countries. The seed packets were split approximately 2/3 (16,000) cultivated accessions and 1/3 (8,600) wild sunflower accessions. About 50% of the wild packets were wild *H. annuus*

and 50% all other wild taxa. Demand for wild sunflower accessions has increased over the past 10 years as more accessions and all taxa have become available.

CONCLUSIONS

The USDA sunflower collection has had an international origin, beginning in 1948 with donations from agricultural programs in Turkey, Argentina, Syria, Uruguay and Lebanon. In subsequent years, 54 additional countries have made important contributions. The USDA sunflower breeding program, underway in the 1970s, began contributing inbred lines to the collection in the 1980s. Now the USDA sunflower collection is able to make significant resources available to the international community both cultivated germplasm as well as the substantial collection of all wild sunflower taxa (except *Helianthus niveus ssp niveus*) which we continue to expand to ensure maximum geographic and genetic representation. Sunflower crop wild relatives provide a valuable genetic resource which, along with a significant collection of cultivated accessions, the NPGS maintains and distributes free of charge for scientific and educational purposes.

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