COLLECTION OF WILD *HELIANTHUS ANOMALUS* AND *DESERTICOLA* SUNFLOWER FROM THE DESERT SOUTHWEST USA

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ABSTRACT

Genetic resources are the biological basis of global food security. Collection and preservation of wild relatives of important crop species such as sunflower provide the basic foundation to promote and sustain the crop. Acquisition through exploration is the initial step in the germplasm conservation process. There are 53 species of wild *Helianthus* (39 perennial and 14 annual) native to North America. An exploration covering 3700 km to the desert southwest US in June of 2015 led to the collection of five populations of *H. deserticola* (desert sunflower) and eight *H. anomalus* (sand sunflower) accessions. All populations were collected throughout the broad distributional range of the species. Based on sand sunflower's occurrence in desert sand dune habitats of Utah and Arizona, it frequently has been recognized as drought tolerant, with the largest achenes of any wild species and high oil concentration potential, and thus is a candidate for improving cultivated sunflower. Desert sunflower is a xerophytic annual species found in sandy soils on the floor of the Great Basin Desert in small populations in western Nevada, west central Utah, and along the border of Utah and Arizona. Population size, habitat, soil type, seed set, the presence of diseases and insects, and other wild sunflower species located near the collection sites were recorded for each population. This germplasm will be important now and in the future as a genetic resource to combat emerging pests and environmental challenges, helping maintain sunflower as a viable global crop and to preserve it for future generations.

Key words: Sunflower, Crop wild relatives, Wild species, Germplasm resources, Exploration

INTRODUCTION

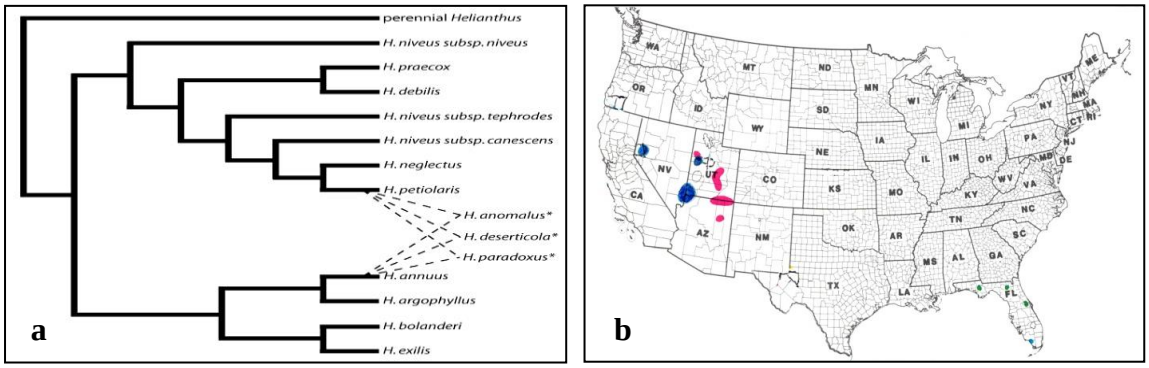
Collection and preservation of wild relatives of important crop species such as sunflower provide the basic foundation to promote and sustain the crop. Genetic resources are the biological basis of global food security, and acquisition through exploration is the initial step in the germplasm conservation process. There are 53 species of wild *Helianthus* (39 perennial and 14 annual) native to North America (Heiser et al., 1969; Schilling, 2006). The narrow genetic base of cultivated sunflower has been broadened by the infusion of genes from the wild species, which have provided a continuous source of agronomic and economic traits for cultivated sunflower (Seiler and Rieseberg, 1997; Seiler and Marek, 2011; Kane et al., 2013; Seiler and Jan, 2014). In a survey of the use of wild relatives in crop improvement over a 20 year period, among 13 crops of international importance, sunflower ranked fifth with seven traits incorporated (Hajjar and Hodgkin, 2007).

Helianthus anomalus (sand sunflower) is a rare endemic species adapted to sand dune and swale habitats in Utah and northern Arizona (Heiser, 1958, Heiser et al., 1969, Thompson et al., 1981; Nabhan and Reichhardt, 1983). It is a confirmed homoploid diploid hybrid species based on comparison of isozyme, nuclear ribosomal DNA, and cpDNA with its parental species, *H. annuus* and *H. petiolaris* that occupies an extreme environment relative to its parental species (Rieseberg, 1991; Gross et al., 2004; Ludwig et al., 2004)(Fig. 1a). *Helianthus annuus* is distributed throughout the central and western United States and typically inhabits heavy, clay-based soils. *Helianthus petiolaris*, the smaller of the two parental species, is distributed mainly through the central United States and inhabits sandier soils than *H. annuus*. The two parental species co-occur and often hybridize throughout their range. The species are all annual,

outcrossing, and have a haploid chromosome number of 17 (Heiser, 1947; Heiser et al., 1969; Rogers et al., 1982). *Helianthus anomalus* has been frequently recognized as drought tolerant, with the largest achenes of any wild species and high oil concentration potential (Seiler, 2007), and thus is a candidate for improving cultivated sunflower (Nabhan and Reichhardt, 1983; Seiler and Marek, 2006). It also appears to be more tolerant of nutrient stress than its ancestral parents based on a lower relative growth rate and higher nutrient-use efficiency (Brouillette and Donovan, 2011).

Helianthus deserticola (desert sunflower) is a xerophytic species found in sandy soils on the floor of the Great Basin Desert and distributed in small populations located in western Nevada, west central Utah, and along the border of Utah and Arizona, USA (Heiser et al., 1969) (Fig. 1b). It is also a homoploid diploid annual hybrid between two annual parental diploid species, *H. annuus* and *H. petiolaris* (Rieseberg, 1991, Gross et al., 2004). This species inhabits the desert floor, an extreme environment relative to its parental species (Gross et al., 2004) (Fig. 1a). Based on desert sunflower's occurrence in sand dune desert habitats, it frequently has been recognized as drought tolerant with high oil concentration potential, and thus a candidate for improving cultivated sunflower germplasm (Seiler, 1992; Seiler, 2007). Both species are excellent candidates for diversifying the genetic base of cultivated sunflower by enhancing oil concentration and quality improvement, as well as drought tolerance.

Figure 1a. Evolutionary relationships among annual *Helianthus* species. Homoploid hybrid species *H. anomalus* and *H. deserticola* are indicated with asterisks. Figure is redrawn from Gross et al., 2005, and based on combined nuclear ribosomal and chloroplast DNA data reported by Rieseberg, 1991; and, **1b.** Distribution of *Helianthus anomalus* (sand sunflower) in Utah and Arizona, and *H. deserticola* (desert sunflower) in Nevada, Utah and Arizona in the desert southwest US.



Unfortunately, very few populations of *H. anomalus* and *H. deserticola* have been collected and only a few are available for research purposes from the USDA-Agricultural Research Service, National Plant Germplasm System (NPGS) wild sunflower germplasm collection. Also, it is very difficult to regenerate the limited number of original seed from some of the earlier collected accessions. The objective of the study was to undertake an exploration to the desert southwest USA in Utah and Arizona in June to collect the winter-spring populations instead of the summer-fall populations previously collected in September-October of the two desert species, *H. anomalus* and *H. deserticola*, and preserve them for future generations to combat emerging pests and environmental challenges, helping to maintain sunflower as a viable and competitive global crop. The exploration was supported with funding from the Plant Exchange Office, National Germplasm Resources Laboratory, USDA-ARS, Beltsville, MD.

MATERIALS AND METHODS

The sunflower exploration for *H. anomalus* and *H. deserticola* took place from June 14 to June 22, 2015. Some populations were revisited in late July-early August 2015 to collect additional seed, and two additional populations without mature seed in June were collected. The exploration covered 3700 km in two states, Utah and Arizona. Seed heads were collected from 20 to 250 plants within each population

and bulked into a single sample. Herbarium specimens were deposited in the USDA-ARS wild *Helianthus* herbarium at Fargo, ND. The achene samples were deposited at the USDA-ARS North Central Regional Plant Introduction Station, Ames, Iowa, where they are maintained and distributed.

All populations were collected from the restricted distributional range of the species, Utah and Arizona for *H. anomalus*, and Utah, Arizona and Nevada for *H. deserticola* (Fig. 1b). Prior locations, generalized distribution maps, and herbaria voucher records were used to locate populations in cooperation with local natural resource officials and botanists who provided valuable information about the current year population distributions and status of the two species. Landownership was determined and all necessary permits were obtained for seed collection and inclusion of the seed in the NPGS genebank. Population size (number and extent), habitat, soil type, seed set per head, and the presence of diseases, insects, and other wild sunflower species were recorded for each population.

RESULTS AND DISCUSSION

The exploration was successful in collecting 10 representative populations of *H. anomalus* from its distributional range in Utah and Arizona (Table 1). A single population of *H. anomalus* was located in Arizona, but the plants were just flowering and no seeds were collected. It had been 15 years since this species was last collected for the NPGS (Seiler and Brothers, 2003). Attempts to recollect this endemic species over the last quarter century have met with mixed results. In September of 2000, none of 12 populations collected in the October of 1980 could be relocated in the fragile sandy habitats (Seiler and Brothers, 2003). The species appears to be very sensitive to the prevailing fall-winter and spring-summer moisture conditions. The current exploration during June located numerous populations of sand sunflower probably due to the excessive spring rains in several parts of the species' distributional range.

Figure 2 shows the typical habitat of the only population of *H. anomalus* we located in Arizona. Unfortunately, only a few plants were observed with no mature seeds to collect. Figure 3 shows one of the diverse habitats in Utah where a typical *H. anomalus* plant with multiple branches and heads, light shiny green leaves, and whitish stems grows on top of sandy hummocks with the wind causing the sand to shift and appear as waves in the sand. Figure 4 shows the unique tap root that develops to help plants survive the constant shifting sand on the dunes. Figure 5 shows a unique habitat for *H. anomalus* in a draw on the steep slope of a shifting sand dune. Figure 6 shows dried white plant stalks from the previous season(s) confirming a persistent and thriving population.

The exploration was also successful in collecting five representative populations of *H. deserticola* from its distributional range in Utah and Arizona (Table 1). *Helianthus deserticola* was not collected in Nevada because of restricted access to the areas where the species occurs. In September of 2000, an attempt to recollect several populations previously collected in October of 1980 was not successful in the fragile sandy sagebrush habitat probably due to the extremely dry 2000 growing season, although one new population was discovered (Seiler and Brothers, 2003). As with *H. anomalus*, the species appears to be very sensitive to the prevailing fall-winter and spring-summer moisture conditions. The current exploration during June 2015 located several populations of desert sunflower mainly due to the excessive spring rains in several parts of the species' distributional range.

Table 1. *Helianthus anomalus* and *H. deserticola* identification number, elevation, location, habitat, and population size collected in June 2015.

Identification Number	Elevation (m)	Location	Habitat	Population Size
ANO-2810	1310	**Utah;** San Juan Co., SE of Cal Black Memorial Airport	Shifting sand dunes, roadside	200
ANO-2811	1450	**Utah;** San Juan Co., Nokai Dome Rd, SE of Halls Crossing	Shifting sand dunes, roadside	750
ANO-2813	1147	**Utah;** Garfield Co., Notum-Bullfrog Rd	Shifting sand dunes, roadside	1,000
ANO-2815	1769	**Utah;** Kane Co., Hole-in-the-Rock Rd, Grand Staircase Escalante National Monument	Shifting sand dunes, roadside	200
ANO-2817	1394	**Utah;** Garfield Co., unnamed draw into North Wash, west side of Hwy 95	Shifting sand dunes, steep slope	250
ANO-2818	1425	**Utah;** Wayne Co., Near Hanksville	Shifting sand dunes, roadside	200
ANO-2819	1661	**Utah;** Wayne Co., Lower San Rafael Rd	Shifting sand dunes	100
ANO-2820	1565	**Utah;** Emery Co., Hans Flat Rd	Shifting sand dunes	1,000
ANO-2821	1231	**Utah;** Grand Co, White Wash Dunes	Shifting sand dunes	1,000
ANO-2822	1532	**Utah;** Emery Co, west side of Hwy 24	Shifting sand dunes	1,000s
DES-2802	1214	**Utah;** Kane Co., Beside High Desert Lodge, Big Water	Sandy desert shrub pasture	750
DES-2803	1290	**Utah;** Kane Co., End of Church Wells Rd, Grand Staircase Escalante Natl. Monument	Sand dunes, near pasture	500
DES-2805	1261	**Utah;** Kane Co., Jacobs Tanks Rd, west of Grand Staircase Escalante National Monument visitor center	Sandy swale	500
DES-2806	1294	**Arizona;** Coconino Co., Vermilion Cliffs Natl. Monument; Ferry Swale Wash	Undulating swale wash, sandy soil	1,000
DES-2807	1295	**Arizona;** Coconino Co., Southeast of Page	Sandy roadside ditch	1,000

Figure 7 shows the typical habitat of a population of *H. deserticola* located in southern Utah. While this species shares some of the habitat types of *H. anomalus*, the main difference is that it is found on the floor of the Great Basin desert in sandy soils interspersed mainly with sagebrush and other desert shrubs. Figure 8 shows one of the diverse habitats where *H. deserticola* grows in sandy soils and hummock type of topography near desert shrubs. Figure 9 shows typical plants with multiple branches and heads, dull green leaves and darker greenish-red pubescent lower stems. Figure 10 shows the unique habitat in an undulating swale wash in sandy soil among the desert shrubs. Figure 11 shows a unique habitat of *H. deserticola* scattered in a sandy pocket on an undulating swale wash underlain by shale rock.

Figure 2. Gerald Seiler standing next to the largest *Helianthus anomalus* plant in a very small population found near Dennehosto, AZ in a shifting sand dune. Only found a few plants were found with no mature seed to collect.

Figure 3. *Helianthus anomalus* (ANO-2810) on hummock sand dunes in San Juan County, UT, SE of Cal Black Memorial Airport. Notice the wave pattern in the sand from the wind shifting the sand in the dunes. Typical plants with multiple branches, light shiny green leaves, and whitish stems.

Figure 4. Population ANO-2813 in Garfield County, UT along Notum-Bullfrog Rd in shifting sand dunes near roadside. Notice the distorted exposed roots that developed to anchor the plant in the actively shifting sand dunes.

Figure 5. Population ANO-2817 in Garfield County, UT, North Wash, west side of Hwy 95, with sunflowers growing in a draw of a steep slope of a shifting sand dune.

Figure 6. Laura Marek collecting seed in population ANO-2813 in Garfield County, UT. Along Notum-Bullfrog Rd, in shifting sand dunes. Note the dead white plant stalks from previous season(s).

Figure 7. *Helianthus deserticola* (DES 2802) in Kane Co., UT near Big Water UT in a typical desert shrub habitat interspersed among the shrubs in open sandy areas.

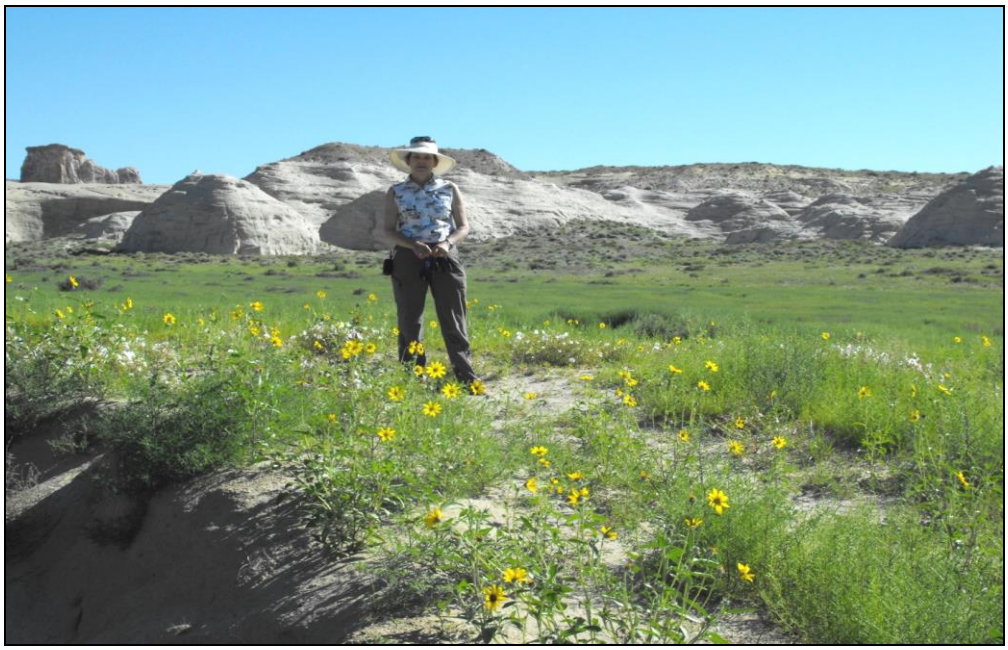


Figure 8. Laura Marek collecting seed of population DES 2803 in Kane Co., at the end of Church Wells road, west of Big Water, UT. Note the different habitat with more grayish sandy soils and hummock type topography in the background near desert shrubs.

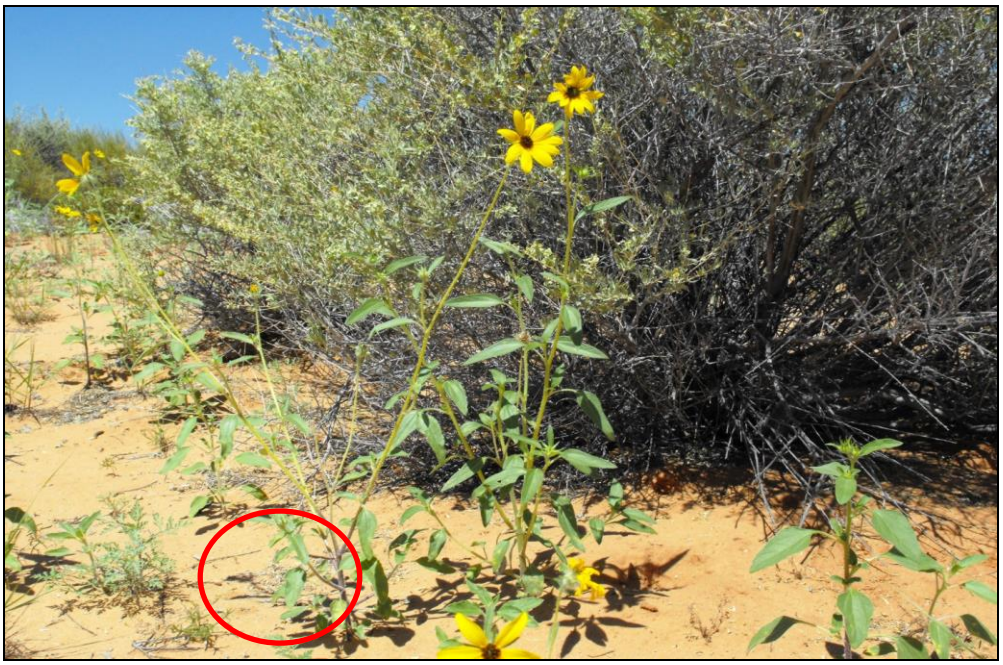


Figure 9. Population DES-2805 in Kane Co., UT, along Jacobs Tank Rd, west of the Grand Staircase Escalante National Monument (BLM), sandy pocket among the desert shrubs. Typical plant with multiple branches, dull green leaves, and darker greenish-red pubescent lower stems.

Figure 10. Population DES-2806 in Coconino Co., AZ, Ferry Swale Canyon, Vermillion Cliffs National Monument (BLM) in an undulating swale wash in sandy soil among the desert shrubs.

Figure 11. Gerald Seiler collecting seed of DES-2806 in Coconino Co., AZ, Vermillion Cliffs National Monument (BLM) in sandy soil in the undulating swale wash among the desert shrubs. Note the white shale outcropping in the background that underlies this area.

CONCLUSION

The addition of 10 *Helianthus anomalus* and five *H. deserticola* populations to the NPGS wild sunflower germplasm collection represents the first germplasm of these species collected Utah and Arizona in almost 15 years. The added populations are important as a genetic resource to combat emerging pests and environmental challenges, helping to maintain sunflower as a viable and competitive global crop and to preserve it for the future generations.

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