Wild *Helianthus anomalus* and *H. deserticola* from the Desert Southwest USA: a Potential Source of Stress Genes for Cultivated Sunflower

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Abstract

The narrow genetic base of cultivated sunflower has been broadened by the infusion of genes from wild species, which continue to be a valuable source of desirable agronomic traits. *Helianthus anomalus* Blake is a wild annual species adapted to sandy dunes of the southwest USA. *Helianthus deserticola* Heiser is another wild annual species adapted to high desert areas of the same region. The adaptation of these species to harsh habitats makes them potential candidates for improving stress tolerance in the cultivated sunflower crop. Since seed of these species was not available in the USDA-ARS Sunflower Germplasm Collection, an exploration was undertaken in September, 2000 to collect populations for future research. Due to the extremely dry weather in 2000, only two populations of *H. anomalus* and one *H. deserticola* were collected. These collections are the first populations of these species added to the sunflower collection in over 20 years. Future research calls for introgression of the wild species into cultivated sunflower and evaluating the progeny for ecophysiological characteristics.

Media summary

Wild annual sunflowers from the southwestern deserts of the USA have the potential to improve stress tolerance in cultivated sunflower.

Key Words

Exploration, drought, ecophysiological, germplasm, genetic diversity.

Introduction

The genus *Helianthus* is comprised of 51 species with 14 annual and 37 perennial, all native to North America. Wild sunflower species have been a source for improving agronomic traits of cultivated sunflower (Seiler and Rieseberg 1997; Seiler 1992). There has been an increased interest in breeding cultivated sunflower for stress tolerance. *Helianthus anomalus* is a rare endemic species adapted to sand dunes and swale habitats in Utah and northern Arizona (Heiser 1958; Heiser el al. 1969; Thompson et al. 1981; Nabhan and Reichhardt 1983). Based on its occurrence in sand dune habitats, it frequently has been recognized as being drought tolerant and thus a candidate species for improving cultivated sunflower germplasm. *Helianthus deserticola* is another species identified as drought tolerant. It is a xerophytic 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 (Heiser et al. 1969). Molecular phylogenetic evidence indicates that *H. anomalus* and *H. deserticola* are stabilized diploid hybrid derivatives of two widespread species, *H. annuus* and *H. petiolaris* (Rieseberg 1991).

Unfortunately, due to the demand for the seed of these species and the difficulties of regenerating the original populations, seed from the USDA-Agricultural Research Service sunflower germplasm collection has not been available for almost 20 years. The objective of the present study was to undertake an exploration to the desert southwest USA to collect seeds of the two species and to make them available for future research.

Materials and Methods

The exploration took place from September 16 to September 23, 2000. The exploration covered 4100 km in three states: Utah, Arizona, and Nevada. Mature heads were collected from 10 to 100 plants within each population and bulked into a single sample. Herbarium specimens were deposited in the USDA-ARS wild *Helianthus* herbarium at Fargo, North Dakota. Seed 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 recognized distributional range of the species. Prior locations and generalized distribution maps were used to locate populations. 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

Two species, *H. deserticola* (Figure 1) and *H. anomalus* (Figure 2), were collected during the exploration.

Figure 1. (Left) *Helianthus deserticola*, Washington County, Utah. Note brown sandy soil and the associated sagebrush vegetation. (Right) *Helianthus deserticola*, Washington County, Utah. Typical plant with branching below and terminal heads.

Figure 2. (Left) *Helianthus anomalus*, Jaub County, Utah. Note white shifting sand dunes and cedars in the background. (Right) *Helianthus anomalus,* Jaub County, Utah. Typical plant with whitish stem and multiple heads with large, long bracts.

It had been 20 years since 25 known locations of the two species were last visited. For unexplained reasons, only three populations had seed baring plants in 2000 (Table 1).

Table 1. Species, location, habitat, and size of population collected during the exploration.

Species	*Identification Number*	*Location*	*Habitat*	*Population Size*
H. deserticola	AMES-26094 DES-2345	Washington Co., Utah, Anderson Junction	Sandy desert sagebrush	250
H. anomalus	AMES-26095 ANO-2346	Jaub Co., Utah, Little Sahara Recreation Area, White Sands Campsite	Shifting white sand dunes	200
H. anomalus	AMES-26096 ANO-2347	Jaub Co., Utah, Little Sahara Recreation Area, Jericho Picnic Area	Upper slope of shifting white sand dune	250

It had been extremely dry in most of the areas explored, with no evidence of the species being present in the fragile sandy habitats.

The potential value of the two desert species may be in their ability to adapt and survive stresses in arid environments. Rosenthal et al. (2002) studied 24 morphological and 18 ecophysiological traits of *H. anomalus* and *H. deserticola*, and their parents, *H. annuus* and *H. petiolaris*. For *H. anomalus*, the environmental factors that are most limiting to plant growth and survival are sand dunes that are constantly moving and low nutrient availability, particularly inorganic nitrogen. *Helianthus anomalus* did have higher leaf nitrogen than either of its parental species (Rosenthal et al. 2002). Schwarzbach et al. (2001) observed higher water content per leaf area and more succulent leaves in *H. anomalus*. The succulent leaves might better withstand sand abrasion. They also observed that *H. anomalus* maintains a larger temperature difference between air and leaf temperature than its parents. Thus, it appears to be able to keep its leaves cool, or possibly avoiding the high sand and air temperature characteristic of sand dunes. In wild populations of sunflower, *H. anomalus* does tend to have a well-developed tap root and fewer lateral roots than its parental species (Schwarzbach et al. 2001). Many of these characteristics have potential value for cultivated sunflower, if they can successfully be transferred into a cultivated sunflower background.

Helianthus anomalus has the largest seed and the highest oil concentration of any of the wild sunflower species. Large seed and rapid seedling growth characterize dune plants and is thought to represent adaptations for avoiding burial by moving sand. These characteristics will facilitate breeding when the wild species germplasm is transferred into cultivated sunflower.

Helianthus deserticola grows in stabilized sandy soil on the desert floor. Desert annuals typically germinate only after heavy seasonal rains and then complete their reproductive cycle quickly. Traits associated with this strategy include rapid growth rate, rapid flowering, reduced height at maturity and high rates of photosynthesis and stomatal conductance. Rosenthal et al. (2002) observed that this species grows rapidly compared to its parents, *H. annuus* and *H. petiolaris*, and buds and flowers

significantly earlier than either parent. As with other annual sunflowers, *H. deserticola* displays high rates of photosynthesis and stomatal conductance, both values in the range of the parental species (Schwarzbach et al. 2001). Rosenthal et al. (2002) also observed that *H. deserticola* had a reduced boron uptake, and may be useful for enhancing boron toxicity tolerance in cultivated sunflower.

Ecophysiological characteristics of wild *H. annuus* and *H. petiolaris,* the two parental species of the annual desert species have also been examined. Sobrado and Turner (1983a) compared tissue water relation characteristics and biomass productivity in two cultivars of *H. annuus* and two wild species (*H. nuttallii* and *H. petiolaris*) under field conditions. Water deficits induced a major reduction in leaf area development and dry matter accumulation in all species. A water deficit also induces a significant decrease in the osmotic potential at full turgor and decreases the turgid to dry weight ratio in cultivated lines, but not in the wild species.

Water relations and stomatal responses in cultivated sunflower and one wild species, *H. petiolaris*, under conditions in which rate of drying (moisture level) could be controlled and manipulated was reported by Sobrado and Turner (1983b). They concluded that cultivated *H. annuus* and wild *H. petiolaris* differ in their ability to osmotically adjust to water deficits. They demonstrated a strong correlation between osmotic potential at full or zero turgor and the turgid to dry weight ratio in leaves. They suggested that changes in cell size may play a role in osmotic adjustment and drought tolerance in sunflower.

Mechanisms enabling plants to survive stress have been selected during evolution, not all of which fully maintain a plant's productive processes. Research and characterization of physiological mechanisms of stress in wild sunflower are just beginning. Drought tolerance is very complex, involving many interrelated factors. All indications are that the ability of sunflower to withstand stressful environments is controlled by a number of genes, and the multilocus nature of these characteristics imposes limits on subsequent manipulations.

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