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Wild annual *Helianthus anomalus* and *H. deserticola* for improving oil content and quality in sunflower

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Abstract

Within the past decade, the desire for alternative sources of fuels, chemicals, and other industrial materials has received increased attention. Sunflower (*Helianthus annuus* L.) oil has the potential to be improved for nutritional and industrial purposes through selection and breeding. The narrow genetic base of cultivated sunflower has been broadened by the infusion of genes from wild species, resulting in a continuous improvement in agronomic traits. The genus *Helianthus* is comprised of 51 species and 19 subspecies with 14 annual and 37 perennial species. Interest in using wild species in breeding programs has increased, but concerns about the introduction of low oil concentration and quality from the wild species persist. Two annual desert species, *Helianthus anomalus* Blake and *H. deserticola* Heiser, are excellent candidates for increasing oil concentration and enhancing quality based on their adaptation to desert environments. The objective of this study was to collect achenes of *H. anomalus* and *H. deserticola* from the desert southwest USA and assess their potential for improving oil concentration and quality in cultivated sunflower. The sunflower collection took place from 16 to 23 September 2000 and covered a distance of 4100 km in three states: Utah, Arizona, and Nevada. The only *H. deserticola* population collected had an average oil concentration of 330 g/kg, whereas the two populations of *H. anomalus* had an oil concentration of 430 and 460 g/kg, the highest concentration recorded in any wild sunflower species. The linoleic fatty acid concentration in the oil of *H. anomalus* populations was uncharacteristically high for a desert environment, approaching 700 g/kg. A linoleic acid concentration of 540 g/kg in *H. deserticola* was more typical for a desert environment. *H. anomalus* has the largest achenes and the highest oil concentration of any wild sunflower species, and the same chromosome number ($n = 17$) as cultivated sunflower. These features will facilitate the introduction of genes from this wild annual progenitor into cultivated sunflower. The lower saturated fatty acid profile in this species is also a desirable trait offering the potential to reduce saturated fatty acids in cultivated sunflower. Further research will be needed to determine the inheritance of the fatty acids and oil concentration. Other agronomic traits will need to be maintained during the introgression of these traits into cultivated sunflower oil.

Keywords: Sunflower; Oilseed; Oleic acid; Linoleic acid; Palmitic acid; Stearic acid

1. Introduction

Interest in potential non-food uses of renewable resources has increased in recent years. Vascular plants produce many compounds and secondary metabolites, one of which is oil. Although oil concentrations of up to 37 g/kg have been reported in whole plants of wild

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sunflower (*H. annuus* L.), the achenes are the primary storage tissue for oil (Seiler et al., 1990). The oil that accumulates in the achenes of wild and cultivated sunflower is composed of triacylglycerols that exist in the liquid form at room temperature and have a low melting point. The fatty acid composition of the achene oil determines its end use suitability.

Sunflower oil is a source of fatty molecules that can be used as reagents for chemical modifications (Girardeau et al., 2000; Leyris et al., 2000). Sunflower oil also has excellent nutritional properties. It is practically free of significant toxic compounds and has a relatively high concentration of linoleic acid. This polyunsaturated fatty acid is an essential fatty acid (not synthesized by humans), and is the precursor of gamma-linolenic and arachidonic acids (Dorrell, 1978). Sunflower oil can be used in the manufacture of lacquers, copolymers, polyester films, modified resins, and plasticizers when there is a price advantage to the manufacturer. The high concentration of linoleic acid and very low concentration of linolenic acid mean that despite the moderate iodine number of 125–140, it has good drying qualities without the yellowing associated with high-linolenic acid oils (Dorrell and Vick, 1997). It can also be used in the manufacture of soap (Suslov, 1968). Emulsifiers and surfactants from fats and oils are already used in formulating pesticides (Pryde and Rothfus, 1989). In addition, with the development of high-oleic sunflower hybrids, sunflower oil has become a more important feedstock for the oleochemical industry, of which the cosmetics industry is a major user (Luhs and Friedt, 1994).

Several reports have been published evaluating sunflower oil and its blends with diesel as a fuel (Morrison et al., 1995). It is estimated that if a farmer in North Dakota, USA, devoted about 10% of their acreage to sunflower production for fuel, the total on-farm fuel requirement could be met (Hofman and Hauck, 1982).

Oil concentration and fatty acid composition, especially oleic and linoleic fatty acids, of oil from wild and cultivated sunflower varies greatly mainly as a response to temperature during seed development (Harris et al., 1978; Seiler, 1986). A high temperature during seed maturation results in oil with high oleic acid concentration, and a low linoleic acid concentration.

The genus *Helianthus* consists of 51 species and 19 subspecies with 14 annual and 37 perennial species (Schilling and Heiser, 1981). The narrow genetic base of cultivated sunflower has been broadened by the infusion of genes from wild species. This has resulted in continuous improvement of agronomic and economic traits in cultivated sunflower (Thompson et al., 1981; Seiler, 1992; Seiler and Rieseberg, 1997). Recent emphasis on the concentration and fatty acid composition of sunflower oil has increased interest in using wild species in breeding programs, but the introgression of low oil concentration and quality from the wild species into cultivated sunflower is of concern.

H. 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). Sand sunflower is a diploid annual species of hybrid origin that is endemic to active sand dunes, an extreme environment from its parents, *H. annuus* and *H. petiolaris* (Ludwig et al., 2004). Based on sand 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).

H. deserticola (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 (Heiser et al., 1969). This species is also a diploid hybrid that inhabits the desert floor, an extreme environment relative to its parental species, *H. annuus* and *H. petiolaris* (Gross et al., 2004).

Both species are excellent candidates for oil concentration and quality improvement, as well as drought tolerance. The objective of the study was to undertake an expedition to the desert southwest USA to collect achenes of the two desert species, *H. anomalus* and *H. deserticola*, and assess their potential for improving oil concentration and quality in cultivated sunflower.

2. Materials and methods

2.1. Plant material

Populations of wild sunflowers were collected between 16 and 23 September 2000. The expedition covered a distance of 4100 km in three states: Utah, Arizona, and Nevada. Wild sunflower heads were collected from 200 to 250 plants within each population and bulked into a single sample. Herbarium specimens were deposited at the USDA-ARS wild *Helianthus* herbarium at Fargo, North Dakota. Achene samples were sent to the USDA-ARS North Central Regional Plant Introduction Station, Ames, Iowa, where they will be maintained and distributed.

All populations were collected throughout the broad distributional range of the species. Prior collection sites and generalized distribution maps were used to locate populations. Population size (number and extent), habi-