# Recent Research on Safflower, Sunflower, and Cotton

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## ABSTRACT

Research on safflower shows the following: a) levels of greater than 80% oleic acid and linoleic acid will be achieved with few effects by management of genes; b) oil content of 50% will be possible in extreme reduced hull types; c) resistance to several diseases has been identified in introductions of domesticated and wild safflower; and d) improvements can be made in ornamental types of safflower used in dried flower arrangements. In sunflower, major improvements are: a) resistance to all important diseases; b) some resistance to larvae of the sunflower moth through use of types with an armored layer in the hull of the seed; and c) development of superior hybrid varieties. In cotton, oil and meal have been improved by the genetic or mechanical removal of gossypol glands.

## INTRODUCTION

This report will deal primarily with recent advances in research on safflower, and secondarily with research advances of sunflower. Thirdly, it shall deal with major accomplishments in cotton seed improvements.

### Safflower (*Carthamus tinctorius* L.)

Countries producing major quantities of safflower are India, with ca. 600,000 ha (G.V. Ramanamurthy, personal communication, 1974), Mexico with 500,000-600,000 ha (F.J. Andrade, personal communication, 1974), and United States with 60,000-100,000 ha (J.R. Smith, personal communication, 1974). In 1974, Spain grew 50,000 ha, Portugal 25,000 ha, and Australia, 22,000 ha (C.E. Claassen, personal communication, 1974). The Middle East, Africa, and a few countries of Europe continue to grow safflower for its flowers, which are dried and used to color foods.

Production in the United States in 1974 was located primarily in the Southwest with 55,000 and 5,000 ha produced in California and Arizona, respectively, and 8,000 ha produced in eastern Montana (J.R. Smith), personal communication, 1974).

Two oil types of safflower continue to be grown commercially, with the original high linoleic type being grown on the largest scale. The high oleic type of safflower oil appears to be used mostly as an edible oil, primarily in the preparation of potato chips and similar products. Some of the oil is being used in cosmetics and some for industrial purposes. A methyl oleate product prepared from high oleic safflower oil in a 1-2% fatty acid ester emulsion shows promise to accelerate drying of grapes (1).

In a former report (2) it was hoped that a safflower variety could be developed with levels of oleic acid $\geqslant 85\%$. This will be achieved by the management of genes with small effects. It will be difficult for plant breeders to develop such a variety, and even moreso if several varieties are needed for different regions, all with very high levels of oleic acid. On the other hand, because the usual high oleic varieties (with 75-78% oleic acid) require the management of a single major gene (3,4), their development presents no problem. Efforts by this author to develop safflower types with levels of linoleic acid $\geqslant 85\%$ have had similar success.

Diseases continue to occupy the attention of all safflower breeders. Of major importance in California are Phytophthora root rot (*P. drechsleri* Tucker), Verticillium wilt (*V. albo-atrum* Reinke & Berth), Fusarium wilt (*F. oxysporum* f. *carthami* Klis. & Hous.), and rust (*Puccinia carthami* Cda).

A major effort was made in 1974 to find germ plasm resistant to Phytophthora root rot. A 3-replicate test was sown on heavy soil of the Rice Facility, recently developed at the University of California at Davis. Seeds were germinated by sprinkle irrigations from May 4-16, 1974, but no additional irrigations were given during early stages of plant development. When most of the entries had either flowered or were in the late bud stage, and were stressed from lack of water, a heavy irrigation was given to the entire nursery (July 22-24), 1974). About 95% of the nursery was killed. The best of the surviving plants were harvested, and will be used to plant a similar nursery in 1975. It is hoped that populations can be developed with high levels of resistance, such that safflower can be safely irrigated under a wide range of agricultural situations.

Resistance to Fusarium wilt is required in almost all locations in the Sacramento Valley of California. Germ plasm from several countries was found to have resistance (5), and resistance has been incorporated into all varieties recommended for areas infested with Fusarium wilt. Bockelman (6) has determined the genetic basis for resistance in some materials.

Safflower is attacked by the same Verticillium wilt that attacks cotton, jeopardizing the acceptance of safflower in cotton producing areas. Fortunately, resistance has been found to Verticillium wilt in safflower (7), which, if incorporated into commercial varieties, should make safflower a safer crop to grow in cotton areas.

Several introductions of safflower have been identified with resistance to races of rust in the United States (8,9), and plant breeders are incorporating such resistance into commercial varieties. Rust can attack safflower in the seedling stage, and can totally eliminate the stand of a susceptible variety. More often, it appears on well developed plants as dark brown pustules. The history of rust resistance with most crops, including safflower, is that resistance is good for only a few years. The pathogen has a remarkable ability to generate new pathogenic races to overcome resistance of the host plant.

Resistance to leaf spot caused by *Alternaria carthami* Chowd. would make safflower a higher yielding crop not only in the northern Great Plains, but also in northwestern Mexico and Australia. J.W. Bergman, Montana State University (personal communication, 1974), has found one selection with more resistance than commercial varieties. He reports that the wild species of safflower, *C. lanatus*, is immune. Unfortunately, the latter species is distantly related to the cultivated species, though the 2 species will cross to give a sterile hybrid (10).

A major effort was made at one time to develop hybrid varieties of safflower using the thin hull types developed by Rubis (11,12). Such thin hull types have a form of structural male sterility in which the pollen is not readily released. Under isolation they produce seed from selfing or sibling crosses, but in crossing blocks, most of the seed is a result of crosses to a male parent that produces abundant pollen. Unfortunately, the cost of producing seed was high, and enough selfed (or sibbed) seed was produced in crossing blocks to adversely affect yields of the hybrid variety of the next generation (13).

Efforts to raise oil contents of safflower have involved reduction in the hull content. The Rubis thin hull type has up to 46% oil, but is weak stemmed and low in yield. A brown striped type developed by Rubis was equally high in oil but phytomelanin pigment of that type adversely affected oil quality (14). Urie and Zimmer (15) have developed a reduced hull type with oil contents up to 44%. More recently, Urie (personal communication, 1974) has developed an extreme reduced hull type that has oil content ≥ 50%. The reduced hull types have normal pollen production, and their oil is of good quality.

Oilseed companies are developing most of the varieties that are used in California and Arizona. Researchers with universities and the USDA are developing germ plasm, and are advancing knowledge about genetics, cytogenetics, and production practices.

There is good evidence that safflower was domesticated for its flowers, which were used to color cloth and foods (16). After drying, red flowers remain red for ca. 6 months if not exposed to the sun. A small though widely scattered market has developed for dried flowers of safflower, much of it being satisfied by UC-26, a release of the University of California. Improved versions should be available in a year or so. Some will have the normal type of open floret, and others will have closed florets.

### Sunflower (*Helianthus annuus* L.)

Sunflower is grown both as an oilseed and a confectionary crop in the U.S. All of the oilseed production in 1974 (180,000 ha) was in the Great Plains area, including North Dakota, Minnesota, and adjacent states, and 1600 hectares in Texas (17). There were 95,000 hectares of confectionary types grown in the U.S. in 1974, all but 1700 hectares in the Northern Great Plains. California has grown 1000-2000 hectares of the confectionary type for many years. Oilseed types have small seeds with 45-50% oil content, and confectionary types have large seeds with 25-35% oil content.

A major effort has been made in the U.S. and in other countries to develop germ plasm and varieties with resistance to disease. Important diseases are rust caused by *Puccinia helianthi* Schw., downy mildew caused by *Plasmopara halstedii* (Farl.) Berl & de T., and Verticillium wilt caused by *Verticillium albo-atrum* Reinke & Berth. Resistance to all of these diseases has been found.

Plant breeders are working hard to develop superior hybrid varieties that utilize cytoplasmically male sterile types as female parents. Therefore, it is likely that all varieties grown in the United States 5 years hence will be hybrids. Plant breeders with commercial companies are developing most of the varieties that will be used in the U.S. Besides their superior performance, hybrid varieties are more uniform than open pollinated varieties, an important consideration when using insecticides at particular stages of development, or when harvesting.

Insects are a major problem with sunflowers, moreso in the U.S. than in the Old World. The apparent reason for the difference is that sunflowers are indigenous to North America, where insect pests have evolved with wild and domesticated sunflower. Many pests of the crop have been left behind when sunflower has been transported abroad. Control in most cases has been achieved by using insecticides. Some resistance to sunflower moth (*Homoeosoma electellum* Hulst) has been provided by the armored layer present in the hull of some varieties (18). The armored layer is a form of phytomelanin pigment.

Birds are a major problem in sunflower nurseries and in small increase fields grown under isolation. They are less of a problem in large commercial plantings because the damage is spread over a large area. Chemical control, either by using poisons that kill the birds or chemicals that repel them, has not been consistently successful. Unfortunately, the birds begin feeding long before the heads are mature. Studies at the University of California indicate that sunflower seed can be harvested when the seed contains 25-30% moisture, some 2 weeks before the seed would be dry enough to harvest directly. Obviously, seed harvested commercially with high levels of moisture would have to be dried artificially.

Sunflower oil has been accepted readily in the marketplace. The criticisms come both from those who would like to have an oil with higher levels of linoleic acid and those who want an oil with more oleic acid present. Levels of these fatty acids are sensitive to temperature, low temperatures raising levels of linoleic acid, and high temperatures raising levels of oleic acid (19). As a consequence, southern grown sunflower seed that develops during the heat of the summer has oil with oleic acid levels ca. 40%. Northern grown seed, or seed from late sown sunflower of southern states, has oil with oleic acid content 20% or less. Varieties are needed that are either high linoleic or high oleic types over a wide range of environments. Such types may be found in wild populations (20). If so, it should require only a few generations to transfer the responsible genes to the domesticated type. Fernandez (21) found a genotype in a collection made in southwestern Idaho that has high levels of oleic acid.

A sunflower oil with higher levels of linoleic acid, i.e., highly polyunsaturated, is desired for the soft margarine and coatings industries. With the development of protected lipids for the diet of ruminants, there is developing an increased interest in high linoleic sunflower oil and seeds (22). The protected lipids are not metabolized by the organisms of the rumen. As a result of the protection, the linoleic acid is not broken down in the rumen, and later becomes incorporated in the butterfat and in meat fat. Thus, meat and milk with higher levels of polyunsaturated fat can be produced. The hulls of sunflower seeds are less fibrous than those of safflower, making sunflower more attractive to processors interested in grinding whole seeds for use in protected feeds.

Chlorogenic acid present in seed of all sunflower varieties adversely affects meal quality because it darkens upon oxidation to a green or brown color that impairs acceptability of products made from the meal (23). B.H. Beard (USDA) is searching among wild populations for types with reduced levels of chlorogenic acid.

### Cottonseed (*Gossypium* spp.)

The major accomplishments in cottonseed improvement involve the removal of gossypol glands from the seed, on one hand by mechanical means, and on the other by genetic means. A commercial plant using the liquid cyclone process (LCP) developed by the Southern Regional Research Center to remove gossypol glands from cottonseed has been built by the Plains Cooperative Oil Mill at Lubbock, Texas (24). Capacity is 25 tons of 65% protein flour per 24 hr day. The cottonseed flour can substitute directly for soy flour in the preparation of several foods (25).

The use of varieties that have glandless seed will provide large volumes of seed that can be processed cheaply to produce gossypol free meal and flour. The protein products derived from glandless seed are lighter in color than those derived from glanded seed by LCP, thus providing a better ingredient for some foods. As in sunflower, the kernel of glandless seed when removed from the hull and roasted should provide a palatable product for consumption directly as a salted nut, or as an ingredient of candy and ice cream. Recently developed glandless varieties appear to be equal in lint yield to those with glands.

There appears to be no serious effort being made to improve cottonseed in terms of oil content and fatty acid composition, as has been done with safflower and sunflower. With glandless varieties becoming available in larger amounts, and the seed thereby being increased in value, it is likely that such improvements will be made. The development of varieties with thinner hulls would be an obvious first step to increased oil content.

Oils from different varieties and species apparently are not greatly different in fatty acid composition under the same environment. However, both variety and location were responsible for the ranges in linoleic acid from 34.0-56.7% reported by Stansbury and Hoffpauir (26). As linoleic acid increased, saturated acids decreased from ca. 29% to ca. 21%, and oleic acid from 36% to 22%.

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