The Plant Geneticist's Contribution Toward Changing Lipid and Amino Acid Composition of Safflower[1]

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ABSTRACT

Current research on the fatty acid composition of the seed oil of safflower (*Carthamus tinctorius* L.) has shown the following: (1) there is a possibility that the oleic acid content can be increased above 80%, though probably not above 85%, by use of modifying genes and the major gene *ol*; (2) wild species do not look very promising as a source of genes for modifying fatty acid composition; (3) commercially grown high linoleic and high oleic types are temperature stable; (4) an experimental type with about equal amounts of oleic and linoleic acids is responsive to temperature, with high temperature increasing oleic acid and low temperature increasing linoleic acid; and (5) stearic acid in another experimental type with higher levels of stearic acid (5-10%) is reduced by low temperatures.

[1]One of seven papers presented at the Symposium, "The Plant Geneticist's Contribution Toward Changing Lipid and Amino Acid Composition of Oilseeds," AOCS Meeting, Houston, May 1971.

Safflower (*Carthamus tinctorius* L.) is grown on 200,000-300,000 acres in California, with an average yield of about 2,000 lb./acre. Two oil types are grown commercially: one with high levels of linoleic acid, long known to the vegetable oil industry; and one with high levels of oleic acid, developed and evaluated only in recent years.

The University of California has released two varieties with high levels of oleic acid: UC-1, in 1966 (3,4); and UC-84, in 1970. Companies that contract acreages of safflower have developed and are developing additional varieties with similar oil. A type with about equal amounts of oleic and linoleic acids in the oil is still experimental (4,5). Also experimental is a type with levels of stearic acid from 5-10% (7).

TABLE I

Fatty Acid Composition of Some Introductions and Selections of Safflower

UC designation or variety name	Fatty acid composition			
	Palmitic	Stearic	Oleic	Linoleic
India 65-204	6.5	2.7	31.6	59.2
India 65-246	6.7	1.9	24.6	66.8
India 65-465	6.4	1.7	25.3	66.6
Australian introduction	7.6	1.0	28.3	63.1
US-10 selection	7.5	2.1	25.8	64.6
US-10, high linoleic	7.9	2.4	17.9	71.8
UC-1, high oleic	5.9	1.6	78.8	13.7

TABLE II

Fatty Acid Composition of Wild Species of Safflower

Species	Where grown	Fatty acid composition, range, %			
		Palmitic	Stearic	Oleic	Linoleic
Species with 12 pairs of chromosomes					
C. oxyacantha	Field	5.3-13.4	1.4-6.7	6.8-30.6	54.5-83.3
	Greenhouse	9.9-10.6	2.3-2.9	12.4-15.3	72.0-74.3
C. flavescens	Field	4.9- 8.9	2.1-4.9	12.6-24.2	64.5-76.8
C. palaestinus	Field	5.1-11.1	1.7-3.7	15.2-28.6	58.8-71.6
	Greenhouse	9.9-10.6	2.3-2.9	12.4-15.3	72.0-74.3
C. nitidus	Field	9.3-10.5	2.1-5.1	7.2-19.9	65.5-81.0
Species with 10 pairs of chromosomes					
C. tenuis	Field	10.3-11.4	4.9-5.0	14.3-15.3	69.0-69.4
C. glaucus	Field	6.4-13.6	2.9-8.4	14.9-28.9	55.9-74.8
	Greenhouse	6.7- 7.8	1.9-3.1	11.7-13.3	76.9-78.6
C. alexandrinus	Field	9.8-12.2	3.0-7.1	10.0-16.6	67.5-74.8
	Greenhouse	8.5	3.4	12.1	76.0
C. leucocaulos	Field	7.3-12.6	5.3-7.0	8.5-13.7	69.4-74.3
C. dentatus	Field	7.5-14.5	3.5-6.1	14.4-20.5	58.9-71.3
	Greenhouse	6.1-10.0	2.0-3.3	8.5-18.3	71.2-80.7
Species with 22 pairs of chromosomes					
C. lanatus	Field	8.8-12.6	5.3-8.0	12.3-19.3	63.8-74.5
	Greenhouse	9.6-11.4	3.9-5.6	9.0-12.2	70.8-77.5
Species with 32 pairs of chromosomes					
C. turkestanicus	Field	7.1-10.7	2.7-4.9	10.7-21.3	68.3-77.0
C. baeticus	Field	8.6-11.2	2.1-6.2	10.4-22.1	63.1-77.7
	Greenhouse	9.2-11.3	4.2-5.8	11.5-20.0	69.5-76.2

TABLE III

Fatty Acid Composition of Safflower Types Grown Under Different Temperatures in 1970

Type	Temperature[a]	Fatty acid, %			
		Palmitic	Stearic	Oleic	Linoleic
High linoleic	Low	6.5	1.9	9.1	82.4
	Intermediate	6.4	1.4	14.0	78.2
	High	7.3	2.0	15.2	75.5
High oleic	Low	5.4	0.9	69.7	24.0
	Intermediate	5.2	1.8	71.6	21.4
	High	6.0	2.3	77.4	14.3
Intermediate linoleic	Low	6.5	1.9	16.5	75.1
	Intermediate	6.7	0.8	29.0	63.5
	High	6.5	1.8	53.1	38.6
High stearic	Low	6.1	4.3	9.0	80.6
	Intermediate	6.7	5.5	10.9	76.9
	High	6.5	10.6	14.2	68.7

[a]Day and night temperatures were respectively as follows: low = 18.4 and 15.6 C; intermediate = 26.7 and 23.9 C; and high = 29.4 and 21.1 C.

Our current research on fatty acids of safflower oil is proceeding along three lines: (1) a search of introductions of cultivated safflower for additional genes that modify fatty acid composition; (2) a search of related wild species for variability in fatty acid composition; and (3) a study of the effect of temperature on fatty acid composition. This is a progress report on these studies.

SEARCH FOR ADDITIONAL GENES IN CULTIVATED SAFFLOWER

The major genetic locus, *ol*, governs the proportions of oleic and linoleic acid, with the genotype *olol* having 72-80% oleic acid in the seed oil, and the genotype *OlOl* 72-80% linoleic acid (4,6). The genotype ol^1ol^1 has about equal amounts (45%) of each (4,5).

Another locus, *st*, largely determines the levels of stearic acid (7). The genotype *stst* has oil with 5-10% stearic acid, and *StSt* has 1-3%.

In a few introductions, most of them from India, we have found levels of oleic acid that are slightly higher (20-30%), and levels of linoleic acid that are slightly lower (60-70%), than in high linoleic oil (Table I). If alleles at a locus or loci other than *ol* were involved, it should permit the combination of such alleles with the genotype *olol* of high oleic oil, perhaps to raise the level of oleic acid above 80%.

Data from F_2 populations of crosses of UC-1 (genotype *olol*) to the deviating types of Table I suggest, with one exception, that another allele at the *ol* locus is involved. This means that all true breeding derivatives of these crosses will have fatty acid compositions like those of UC-1 or the deviating type; they should not yield types with a higher oleic acid content than that of UC-1.

In the cross, India 65-246 x UC-1, some F_2 segregates extended beyond the range of both parents. Those with higher linoleic acid levels, and lower oleic, than India 65-246 are assumed to have the genotype of commercial high linoleic types. Those with higher oleic acid contents than UC-1 are assumed to have the genotype *olol* of UC-1 plus one or more modifying genes from India 65-246. No segregates have been obtained with oleic acid contents above 85%. Populations from this and other crosses are being carried forward to F_3 and F_4 for verification of the above hypotheses and for more intensive study.

WILD SAFFLOWER SPECIES

Wild species of safflower have been collected from Asia, Europe, Africa, and the U.S. Oil from several plants of these grown in both greenhouse and field have been examined for fatty acid composition (Table II). Data from greenhouse and field are presented separately because temperatures were usually somewhat higher in the field.

Except for *C. nitidus*, all species with 12 pairs of chromosomes are closely related to cultivated safflower. All have fatty acid compositions similar to those of commercially grown high linoleic types. Some collections, however, do appear to be a source of genes that could be used to raise levels of palmitic acid.

Species with 10 pairs of chromosomes are similar to one another in several respects, and all will intercross rather readily. They are, however, distinctly different from species with 12 pairs. Unfortunately they do not offer variability that is not present in cultivated safflower or closely related wild species with 12 pairs of chromosomes. Most species with 10 pairs will cross with most species with 12 pairs, though with difficulty.

Species with 22 and 32 pairs of chromosomes are assumed to be polyploids resulting from combinations of species with 10 and 12 pairs of chromosomes. So it is not surprising that they express the limited variability in fatty acid composition of the species with lower chromosome numbers.

In summary, therefore, the wild species do not appear to offer variability of much interest to the plant breeder. True, we have not examined a vast amount of material, as has been done for the domestic species. We shall continue to measure the fatty acid composition of wild species as new collections become available, particularly those closely related to cultivated safflower.

EFFECTS OF TEMPERATURE

Bartholomew (1), examined the fatty acid compositions of three genotypes with oils differing in levels of oleic and linoleic acids. They were as follows:

Type	Genotype	Variety or number
High linoleic	*OlOlStSt*	US-10
High oleic	*ololStSt*	1968 Sel. 996-3
Intermediate linoleic	ol^1ol^1StSt	1968 Sel. 1038-1
High stearic	*OlOlstst*	1968 Sel. 3465

Three temperatures were used in two experiments, one conducted in 1969, and the other in 1970. Since the results were similar, only data from 1970 are presented (Table III).

The fatty acid composition of the high linoleic type was remarkably uniform at the different temperatures. At the highest temperature linoleic acid was down slightly, and oleic acid was up a corresponding amount.

Likewise, the fatty acid composition of a high oleic type was relatively stable at different temperatures. Again at the highest temperature linoleic acid went down, and oleic acid up, a slight amount.

The type having about equal amounts of oleic and linoleic acid in the seed oil showed a strong response to temperature. At low temperatures it approached the fatty acid composition of high linoleic safflower oil, i.e., linoleic acid content was high at the expense of oleic acid. At high temperatures an opposite situation prevailed, with oleic acid increasing and linoleic acid decreasing. In this respect it resembles sunflower oil in its response to temperature (2). Because of the fluctuation in fatty acid composition of this intermediate type, I am not optimistic about its commercial future. At present there are no commercially grown varieties of this type.

The fourth type, with higher levels of stearic acid, was also responsive to temperature changes. Low temperatures reduced the levels of stearic acid.

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[Received August 18, 1971]