Effect of Planting Date on Sunflower Seed Oil Content, Fatty Acid Composition and Yield in Florida

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ABSTRACT

Plantings of sunflower, *Helianthus annuus* L., were made 5 times between Feb. 2 and Nov. 15 in Florida so that the effect of planting date on the fatty acid composition of sunflower oil might be assessed. Eleven popular hybrids were planted at Gainesville, FL, on Feb. 2 and 28, April 2, and Aug. 14, and 15 hybrids were planted at Lake Worth, FL, on Nov. 15. Sunflower planted on Nov. 15 would be subjected to freezing temperatures if grown in Gainesville. Yields of sunflower achenes for the four planting dates at Gainesville declined with lateness of planting date. Oleic acid content of the oil (17.6–58.4%) was intermediate for the February plantings, highest for the April planting, and lowest for the late plantings. The linoleic acid content (32.5–71.0%) varied inversely with the oleic acid content. Because sunflower oil is needed for different purposes, such as for salad oil, for deep frying and for making margarines, oil low in linoleic acid (high in oleic acid) as well as oil high in linoleic acid (low in oleic acid) are needed. In Florida, adjusting the planting dates should result in the production of oil of the desired fatty acid composition.

INTRODUCTION

The fatty acid composition of sunflower oil is known to vary, depending on the temperature during seed development (1–3). Linoleic acid content of oil from commercial varieties has been found to range from 31.4% for plantings in Texas (2) to 75.9% for plantings in Canada (3). Unger (4) reported that oleic acid decreased and linoleic acid increased rapidly in sunflower oil with lateness of planting date between May 2 and Aug. 1 in northern Texas.

With the long growing season of the deep South, two crops of sunflower can be readily grown. However, studies in Tennessee (5) and Texas (4) have shown that even areas with a long growing season have an optimal planting date for highest potential yield.

The objective of this study was to obtain information on the effect of planting date on the chemical composition and yield of sunflower grown in Florida.

MATERIALS AND METHODS

Sunflower (11 hybrids) was planted on Feb. 2, Feb. 28, April 2, and Aug. 14, 1979, at the University of Florida Experiment Station agronomy farms, Gainesville, FL. Sunflower (15 hybrids) was also planted on Nov. 15 in southeast Florida, near Lake Worth, FL. All four plantings at Gainesville, FL, were on droughty, sandy soil that had been plowed and disked. One liter of Elanco Treflan and 28 kg/ha FMC 10% Furadan were incorporated prior to planting. Experimental designs were randomized, complete blocks replicated 4 times in each test. Rows (four) ran north and south and were 90 cm apart. Soil was fertilized with 672 kg/ha of 4-8-16 (NPK) with ca. 20 kg/ha of $ZnSO_4$ and 7 kg/ha of borax. The sunflower was sidedressed with NH_4NO_3 at ca. 336-420 kg/ha, depending on rainfall. The Nov. 15 planting at Lake Worth was similar to that of the Gainesville planting except that the soil was fertilized with 1,120 kg/ha of 6-6-6 (NPK) at seeding and 1,120 kg/ha of 15-0-15 (NPK) for three sidedress applications. There was very little bird, insect, or disease damage to any test. Sunflower seeds from segments of the center two rows were harvested by hand with a knife. The heads were dried at about 38 C in a forced-air oven to a constant moisture of 6–8% dry basis. Chaff and head pieces were removed by screening over hardware cloth. The seed from each plot were cleaned with a Bates aspirator and then weighed. A Steinlite Electronic Moisture Meter was used to determine moisture content. Weight per unit volume was determined as kg/hl. Yields for the plantings at Gainesville were extrapolated to kg/ha on a 10% moisture basis. The Lake Worth planting was a small sunflower breeding nursery and no yield data were obtained.

Dates of emergence, mid-flower and physiologic maturity as well as the number of days required to reach these growth stages were recorded and calculated. The number of growing degree days (GDD, O C base) between growth stages in all combinations were calculated from meteorological data from a nearby weather station.

Oil content was determined in duplicate on three composite samples of 40-50 g each of dry seed (130 C for 1 hr) by a Newport MK III wide-line nuclear magnetic resonance analyzer (6). Fatty acid composition of the extracted oil was determined in duplicate on three composite seed samples by gas liquid chromatography with 244 cm x 3 mm stainless steel column packed with 10% EGSS-X on 100/120 mesh Gas Chrom P (7).

RESULTS AND DISCUSSION

The mean oil content for the Feb. 28 planting was significantly lower than the mean oil contents for the other three planting dates (Table I). The differences, however, do not appear to have been related to temperature because the mean average temperature from flowering to maturity was the same for the Feb. 2 and 28 plantings. The mean oil contents for the later plantings (April 2 and Aug. 14) were about the same or higher than those for the earlier planting dates (Feb. 2 and 28). Similarly, an Australian (8) study showed that oil percentage was not consistently related to mean temperature and/or planting date. Florida is more similar to Australia in growing season and environmental temperatures than to other locations in the U.S. where the oil content of sunflower seed has been reported to decrease with lateness of planting date (4,9).

The mean oil contents for the different hybrids were highly varied with the planting date, and the Duncan multiple range analysis showed no significant differences in the oil contents of the hybrids (Table I). Some of the hybrids tended to have lower oil contents than the others under the conditions of the study.

Table II shows the oleic and linoleic acid contents of the oil from the seed of 11 sunflower hybrids from the four planting dates. Analysis of variance showed a highly significant effect between oleic and linoleic acid contents and planting dates (except for Feb. 2 and 28) or temperature ($p<0.0001$). No significant difference, however, was found between the oleic and linoleic acid contents of the different sunflower hybrids at a given planting date ($p>0.1$). The Aug. 14th planting had the lowest mean temperature from flowering

TABLE I

Effect of Planting Date and Hybrid on Oil Content of Sunflower Seed

Brand/hybrid	Oil (% dry basis)[a]				
	Planting date – 1979				Hybrid mean and std. dev.
	Feb. 2	Feb. 28	Apr. 2	Aug. 14	
Sheyenne KG 893	45.1	40.3	42.1	46.9	43.6 ± 3.0
Sunhi S301A (P01)	45.1	39.4	43.8	44.6	43.2 ± 2.6
Interstate IS 3107	44.3	37.1	44.9	45.3	42.9 ± 3.9
Hybrid 903 (Cal/West)	41.5	40.8	43.4	45.4	42.8 ± 2.1
Cargill 204	41.3	40.1	42.5	45.1	42.3 ± 2.1
Northrup King NK 265	40.7	42.8	42.6	42.6	42.2 ± 1.0
Jacques J 701	42.7	36.8	45.2	41.7	41.6 ± 3.5
RBA 300G	39.8	41.3	42.6	42.1	41.5 ± 1.2
Dahlgren DO 844	42.1	42.0	39.9	40.7	41.2 ± 1.1
Sigco 894 A	42.3	38.0	43.1	41.5	41.2 ± 2.2
Golden Harvest GH 20	40.4	39.8	41.5	42.2	40.8 ± 1.1
Planting date mean	42.3	39.9	42.9	43.5	
Std. dev.	±1.8	±1.9	±1.5	±2.0	

[a]In decreasing order of mean.

TABLE II

Effect of Planting Dates on Oleic and Linoleic Acid Contents of Oil from Selected Sunflower Hybrids

Brand/hybrid	Planting dates – 1979							
	Feb. 2		Feb. 28		Apr. 2		Aug. 14	
	18:1[a]	18:2[b]	18:1[a]	18:2[b]	18:1[a]	18:2[b]	18:1[a]	18:2[b]
Cargill 204	35.6	54.3	32.7	56.1	56.4	35.2	19.2	68.9
Sunhi S 301A (PO 1)	37.4	52.5	39.4	48.4	57.2	34.4	19.3	69.7
Hybrid 903 (Cal/West)	40.9	47.9	37.7	50.4	52.1	38.5	17.6	71.0
Sheyenne KG893	35.3	53.0	37.3	51.5	55.1	36.6	19.5	66.8
Sigco 894A	40.5	49.1	34.7	54.2	58.4	33.2	20.0	67.4
Golden Harvest GH 20	34.1	54.4	41.1	47.2	53.0	38.7	20.5	67.5
Dahlgren DO 844	34.5	55.4	34.5	54.2	50.7	41.1	20.5	68.1
Jacques J 701	32.5	57.3	38.5	49.8	56.8	33.2	19.9	68.2
RBA 300 G	37.4	52.6	35.5	52.6	49.5	40.9	18.7	68.9
Northrup King NK 265	40.6	48.7	30.7	57.7	54.2	35.2	21.6	65.9
Interstate IS 3107	42.8	46.9	38.9	49.2	57.6	32.5	16.6	70.4
Mean	37.4	52.0	36.5	51.9	54.6	36.3	19.4	68.4
Std. dev.	3.3	3.5	3.1	3.3	3.0	3.1	1.4	1.5

[a]Oleic acid, area %.
[b]Linoleic acid, area %.

to maturity (18 C) and the highest average linoleic acid content (68.4%). The April 2nd planting had the highest mean temperature (27 C) and the lowest average linoleic acid content (36.3%). The results substantiate the findings reported by Robertson et al. (2,3).

The saturated fatty acid contents were significantly lower in the seed of the April 2nd planting (highest mean temperature and lowest linoleic acid content) than in the seed from the other plantings. The combined palmitic and stearic acid contents averaged 8.1% for the April 2nd planting and 9.5–9.9% for the other three planting dates.

Meteorological and cultural characteristics of the four sunflower plantings at Gainesville, FL, are shown in Table III. The Growing Degree Days (GDD, O C base) from emergence to maturity for all four planting dates in Gainesville was ca. 2,000. The GDD from mid-flowering to maturity for the February planting dates was different from that of the April and August plantings. GDD per day from mid-flowering to maturity was almost linearly related to oleic and linoleic acid contents (Fig. 1) with $r_2 = 0.94$ for both acids.

The average GDD for the four planting dates from planting to maturity was 2,200 (Table III). This compared with 2,038 reported by Anderson et al. (10) and 2,075 reported by Robinson (11) when his data are converted to an O C base. Keefer et al. (8) reported that a GDD summation from a base of O C was the most reliable index of commencement of flowering. In general, accuracy of predictions are no better when based on the temperature concept than on the simple heat sum (10).

For the Nov. 15, 1979 (harvested March 10, 1980), Lake Worth planting, the mean daily temperature during maturation was 17.5 C, or slightly lower than that for the Aug. 14th planting. The mean linoleic acid content of the seed of 15 hybrids was 70.2% (Table IV). This high linoleic acid content would be expected because of the low average maturation temperature.

In parts of the U.S., earlier planting dates result in higher mean temperature during sunflower seed development than later plantings (4). However, this is not the case in Florida where sunflower can be grown year-round in different parts of the state. Our data indicate that, in Florida, sunflower planted in April mature during periods of high temperature and will produce oil low in linoleic acid (<40%), and that those planted from Aug. to Nov. mature during periods of cool temperature and produce oil high in linoleic acid content (65–70%).

In Gainesville, yields were highest for the February plantings, intermediate for the April planting and lowest for the August plantings (Table V). Our data and those of Unger (4) indicate that yield is highest when sunflower is planted

TABLE III

Meteorological Data for and Cultural Characteristics of Sunflower Hybrids Planted at Four Dates at Gainesville, Florida, 1979

Characteristics	Planting dates – 1979			
	Feb. 2	Feb. 28	Apr. 2	Aug. 14
Emergence date	Feb. 17	Mar. 11	Apr. 12	Aug. 21
Mid-flower date	May 2	May 15	June 10	Oct. 7
Physiological maturity date	June 2	June 12	July 10	Nov. 22
Planting to emergence, days	15	11	10	7
Emergence to mid-flower, days	74	63	59	47
Mid-flower to maturity, days	31	30	30	46
Emergence to maturity, days	105	93	89	93
Planting to maturity, days	120	104	99	100
Growing deg. days (GDD, OC base)				
Planting to emergence	163	172	215	187
Emergence to mid-flower	1282	1219	1387	1223
Mid-flower to maturity	699	697	803	836
Emergence to maturity	1981	1916	2190	2059
Planting to maturity	2144	2088	2405	2245

as soon as the mean air temperature reaches ca. 15-17 C in the spring, and that it decreases with each subsequent planting. A similar trend was reported by Graves et al. (5) for sunflower grown in Tennessee. They obtained significantly higher yields from varieties planted in April and progressively lower yields from varieties planted in May, June and July. Robinson (9) also reported decreasing yields with later plantings after May 3rd. Although Unger (4) reported no significant relationship between plant height and yield, we found that both plant height and yield were higher for the February plantings than for the later plantings (April and August). Robinson (9) also reported that, in general, the taller plants had the highest yields.

Because neither plant nutrients nor water was a limiting factor in most of these studies, the main factors affecting yields were the closely related environmental ones of temperature, radiation and day length (8). High temperatures during the vegetative stage prior to flowering seem to be associated with high yields. Three consecutive days of temperatures above 38 C during the flowering and early seed filling phases appear to be detrimental (8).

When hybrids that carry resistance to *Alternaria* leaf and stem spot (diseases very severe in Florida) become available in Florida, it should be possible to grow sunflower with compositions that are similar to those of peanut oil and/or safflower oil. Sunflower oil is used in diverse ways–as high

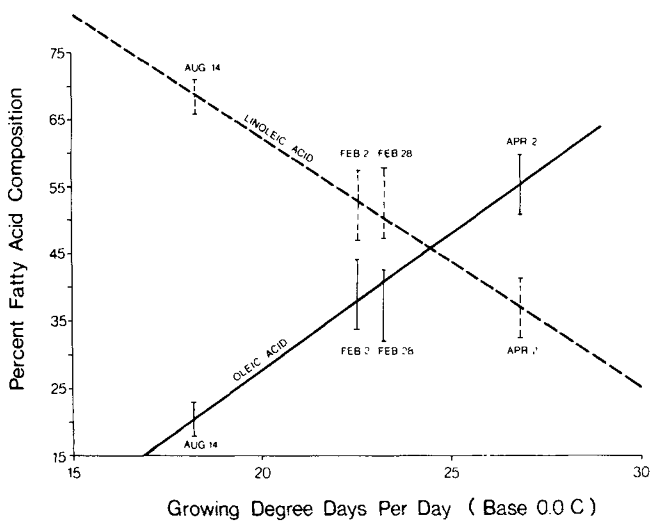

FIG. 1. Effect of growing degree days per day from mid-flowering to maturity on the percentage fatty acid composition of sunflower seed.

TABLE IV

Oil and Fatty Acid Composition of Sunflower Cultivars Planted November 15, 1979, at Lake Worth, Florida[a]

Hybrid	Total oil (% dry basis)	Fatty acid composition (area %)			
		16:0	18:0	18:1	18:2
DO 843	39.6	4.8	6.1	19.3	68.6
DO 704	42.6	5.2	5.2	17.5	69.7
DO 714	38.2	5.0	4.7	17.1	71.1
DO 713	41.2	4.6	6.5	18.9	67.9
Sigco 894A	41.5	5.4	5.2	21.3	66.1
RBA 300G	41.1	5.2	4.9	18.6	69.5
Cargill 204	40.4	4.9	4.9	21.3	67.1
Cenex 897	43.9	5.2	4.3	19.6	69.3
18-18508	43.4	5.2	5.2	19.0	68.9
16-18502	44.7	4.8	5.0	17.4	71.1
16-18518	40.4	5.0	5.1	15.6	73.2
16-18535	44.0	4.7	4.8	16.5	72.6
186-82715	46.4	5.2	4.8	17.7	70.9
186-82736	45.5	5.5	4.5	16.0	72.7
186-82756	44.2	5.3	4.2	15.1	73.7
Mean	42.5	5.1	5.0	18.1	70.2
Std. dev.	±2.4	±0.3	±0.6	±1.9	±2.3

[a]Duplicate analyses.
[b]Seed used in these analyses were furnished to the authors by the Dahlgren Company, a Division of Beatrice Foods, 1220 Sunflower Street, Crookston, MN 56716.

TABLE V

Effect of Planting Date on the Seed Yield of 11 Sunflower Hybrids at Gainesville, Florida, 1979

Brand/hybrid	Yields (kg/ha at 10% moisture)					
	Planting date				Hybrid mean and std. dev.	
	Feb. 2	Feb. 28	Apr. 2	Aug. 14		
Dahlgren DO-844	1960	2790	1970	1550	2070	520
Sheyenne KG 893	2830	1770	1720	1500	1960	600
Jacques J 701	3020	1780	1870	1050	1930	810
RBA 300-G	1420	2790	2170	1330	1930	690
Hybrid 903 (Cal/West)	1410	2580	1960	1670	1900	500
Sunhi S301A (P01)	2530	2120	1770	1150	1900	590
Cargill 204	2000	2640	1460	1370	1870	590
Northrup King NK 265	2350	1790	1990	1060	1800	540
Interstate IS 3107	1840	1600	1690	1340	1620	210
Sigco 894-A	2220	1870	1330	1050	1610	520
Golden Harvest GH-20	750	2380	1520	1220	1470	690
Hybrid mean	2030	2200	1770	1300		
Standard deviation	670	460	260	210		

quality salad oils, deep or French frying oils, and in highly polyunsaturated margarines. Although the yields will be lower for the sunflower planted later in the year, oil for the different uses can be obtained by merely selecting the season of the year that results in its having the desired fatty acid composition.

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REFERENCES

1. Canvin, D.T., Can. J. Bot. 43:63 (1965).
2. Robertson, J.A., J.K. Thomas and D. Burdick, J. Food Sci. 36: 873 (1971).
3. Robertson, J.A., W.H. Morrison, III, and R.L. Wilson, "Effects of Planting Location and Temperatures on the Oil Content and Fatty Acid Composition of Sunflower Seeds," USDA, SEA, Agricultural Research Results, ARR-S-3/, October 1979.
4. Unger, P.W., Agron. J. (in press).
5. Graves, C.R., J.R. Overton, T. McCutchen, B.N. Duck and J. Connell, "Production of Sunflowers in Tennessee," Bulletin 494, University of Tennessee Agric. Expt. Sta., Knoxville, TN, April 1972.
6. Robertson, J.A., and W.H. Morrison, III, JAOCS 56:961 (1979).
7. Robertson, J.A., G.W. Chapman and R.L. Wilson, Ibid. 55:266 (1978).
8. Keefer, G.D., J.E. McAllister, E.S. Uridge and B.W. Simpson, Aust. J. Exp. Agric. Anim. Husb. 16:417 (1976).
9. Robinson, R.G., Agron. J. 62:665 (1970).
10. Anderson, W.K., R.C.G. Smith and J.R.M. William, Field Crops Res. 1:141 (1978).
11. Robinson, R.G., Crop Sci. 11:635 (1971).

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Selective Hydrogenation of Soybean Oil: XI. Trialkyl Silane-Activated Copper Catalysts

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ABSTRACT

Addition of triethyl silane to copper stearate resulted in an active heterogenous catalyst for the hydrogenation of soybean oil. The linolenate selectivity of this catalyst (K_{Le}/K_{Lo} = 2.4 to 3.9) was much lower than that obtained with copper chromite (8.4). Unlike copper-chromite catalyst, triethyl silane-activated copper formed stearate during hydrogenation. Both silica and alumina increased catalyst activity. Linolenate selectivity improved slightly in the presence of alumina.

Previous investigators have shown that copper catalysts are, by far, the most selective for the hydrogenation of linolenate in soybean oil (1,2). However, the activity of these catalysts is much lower than that of commercial nickel catalyst (3). Copper catalysts of improved activity are obtained when copper is supported on high surface silica (4-6).

Tulupov reported that copper stearate catalyzes the homogeneous hydrogenation of cyclohexene in ethanol at room temperature (7). Later, Larsen and Chang (8) were unable to repeat the work. Copper oleate in admixture with cadmium oleate catalyzed the hydrogenolysis of oleic acid to oleyl alcohol (9). The active catalyst was reported to be heterogeneous with an average particle size of 4.8 nm.

In this laboratory, copper stearate by itself was found to hydrogenate soybean oil slowly. Addition of triethyl silane (TES) resulted in a heterogeneous catalyst with improved activity. In this report, the results of hydrogenation of soybean oil with the new catalyst system is described.

The preparation of the catalyst and hydrogenation procedure is briefly as follows. About 75 g commercially refined and bleached soybean oil, 0.37 g copper stearate (ICN Pharmaceuticals, Inc., Plainview, NY) and, when necessary, 0.37 g each of either Cab-O-Sil or Alon C (fumed silica or alumina from Cabot Corporation, Boston, MA) were heated in an Erlenmeyer flask equipped with a side arm, which was sealed with a serum cap, to 70 C under vacuum to remove any traces of moisture. The mixture was then magnetically stirred and kept under a blanket of nitrogen while 1 ml TES (Petrarch Systems, Inc., Levittown, PA) was injected through the serum cap. No visible reaction occurred at this temperature. The active catalyst is apparently formed at the temperature of the reaction. The whole mixture was then transferred under nitrogen pressure as quickly as possible into a 150-ml magnetically stirred, Magna-Dash autoclave which was electrically heated to 200 C under 10 psi nitrogen. Hydrogen (150 psi) was admitted from an external reservoir through a pressure regulator valve. Samples were removed at intervals for analyses by methods described previously (10).

The plot of log IV vs time (Fig. 1) showed that copper

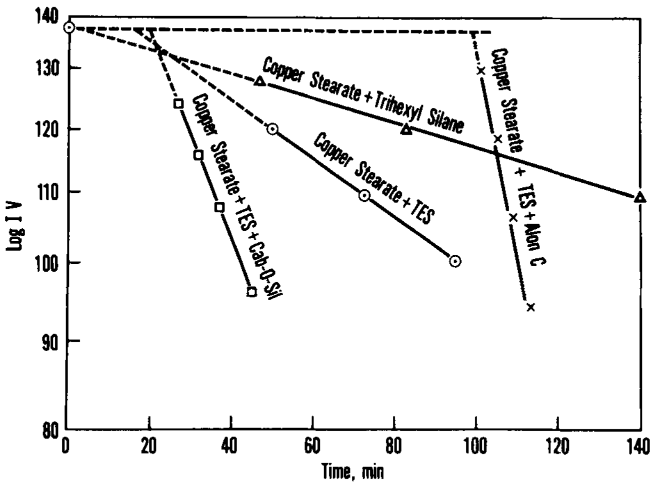

FIG. 1. Hydrogenation of soybean oil with trialkyl silane-activated copper catalysts (0.05% copper at 200 C and 150 psi).