Plant Introductions of Maize as a Source of Oil with Unusual Fatty Acid Composition

Milton D. Jellum

Gas-liquid chromatography was used to determine fatty acid composition of corn (*Zea mays* L.) oil in original sibbed kernels of plant introductions of foreign and U.S. origin, kernels from S_1 ears of plant introductions, and selfed kernels of Australian inbred lines. Extensive variability in oil composition was found among and within various plant introductions and inbred lines. The range in oil composition was 6 to 22% for palmitic acid, 0.6 to 15% for stearic acid, 14 to 64% for oleic acid, and 19 to 71% for linoleic acid. This range in composition of these fatty acids is greater than previously reported in the literature for corn oil. Oil in plant introductions, Australian inbreds, and corn from throughout the U.S. is more highly saturated (higher palmitic and oleic acids and lower linoleic acid) than commercial corn oil. Greater genetic diversity for oil composition is present in corn of foreign origin than in corn of U.S. origin.

Due to advances in analytical instrumentation and techniques, rapid progress has been made in recent years in screening numerous plant genera and species for their potential value as new sources of oil. The quantity and quality (fatty acid composition, color, flavor, odor, and stability) of oil determines its usefulness for either food or industrial uses. Breeding for oil quantity and quality has received greater emphasis in soybeans, safflower, rape, and flax than in corn. However, due to the high quality and demand for corn oil, a great potential exists for development of inbred lines with unique oil content and composition.

Plant introductions have been a valuable source of germ plasm for various traits of agronomic crops. Previous researchers (Cummins *et al.*, 1967; Kinman and Earle, 1964; Knowles, 1965; Yermanos *et al.*, 1966; Zimmerman and Klosterman, 1959) have reported a considerable range in fatty acid composition of oil in plant introductions of flax, safflower, and sunflower. Limited data are available concerning oil composition of plant introductions of corn. Therefore, a survey was made of the oil composition of corn introductions to determine the usefulness of this germ plasm in future breeding and development of corn with specific oil composition. Selected results from a large number of oil analyses and a discussion of the value of plant introductions for future research are presented in this report.

MATERIALS AND METHODS

Kernels of 144 plant introductions from 52 different foreign countries were received from the North Central Regional Plant Introduction Station, Ames, Iowa, in March 1968. In addition, kernels were obtained of 33 open-pollinated varieties and "standard exotics" representing different regions of the U.S. The introductions were taken from approximately 1850 from foreign countries and 260 from the U.S., which are maintained by the Plant Introduction Station. Oil composition was not considered in taking these introductions, since no previous data were available on any of the plant introductions. Introductions were taken to represent different geographic origins and variation in agronomic characters such as ear prolificacy, degree of tillering, maturity, grain type, and grain color. Five germs (scutellum and embryo axis) from each introduction were analyzed individually for oil composition to determine the variability existing in the original sibbed kernels. The introductions were planted at Experiment, Ga., in 1968, and self-pollinated. From 0–11 selfed ears of each introduction were obtained. Oil composition was determined on each ear by one oil sample extracted from three random germs. Additional single germ analyses were made from selfed ears which were either high or low for each of the fatty acids.

Early in 1969, kernels of 140 inbred lines were received from J. M. Colless, Department of Agriculture, New South Wales, Grafton, Australia. Three germs per inbred were analyzed individually for oil composition to determine the variability in composition among kernels within inbreds.

Fatty acid composition was determined on the oil extracted from the germ. Germs were pinched out of the kernel with a long chain-nose pliers and extracted overnight in petroleum ether (Skellysolve F). Methyl esters of the fatty acids were formed by the methanol-sulfuric acid procedure. Preparation of oil samples for analysis by gas-liquid chromatography has been previously described (Jellum and Worthington, 1966).

Analyses were made on a Varian Aerograph Model 1200-2 gas chromatograph (flame ionization detector), Infotronics Model No. CRS-11HSB digital integrator, and Honeywell ElectroniK 18 recorder. Analyses were made on several different columns. Coiled copper columns 1.8 to 2.4-m in length by 6.35 mm outside diameter were packed with 10% stabilized diethylene glycol succinate on Aeropak 30 or Chromosorb W solid supports. Columns and detector response were checked for accuracy with National Heart Institute type fatty acid standards of known composition.

Department of Agronomy, University of Georgia, College of Agricultural Experiment Stations, Georgia Station, Experiment, Ga. 30212

Table I. Comparison of Oil Composition of Kernels from S_3 Ears with Original Sibbed Kernels of Seven Selected Plant Introductions

PI No.	Origin	No. of S_3 Ears	Range in Fatty Acid Composition of Oil, % Palmitic	Stearic	Oleic	Linoleic
174990	Burma	9	15.3–20.0	2.1–7.5	26.2–43.7	35.3–46.3
		Sib	12.2–17.8	2.3–5.3	29.1–41.8	39.0–53.2
193908	Ethiopia	4	15.7–25.5	2.3–2.5	33.0–34.9	37.2–46.7
		Sib	12.7–16.7	1.8–4.4	29.0–45.4	38.4–53.1
257514	France	2	12.3–12.9	1.7–1.9	32.7–33.4	49.7–51.4
		Sib	9.9–11.8	1.1–1.5	19.0–28.8	57.8–68.2
167962	Turkey	4	16.4–16.9	2.1–6.1	34.1–39.5	37.4–46.4
		Sib	14.5–17.5	1.5–3.2	32.3–44.6	38.6–48.1
185056	Turkey	5	17.7–24.3	1.9–2.8	27.4–31.9	39.7–50.1
		Sib	13.7–16.7	1.2–3.9	29.8–40.6	40.9–51.4
245137	USSR	6	6.9–13.0	1.9–2.4	16.9–25.2	62.8–73.1
		Sib	9.9–12.5	1.8–4.2	19.0–39.4	46.7–67.8
184279	Yugoslavia	4	10.0–21.7	2.8–5.6	19.9–38.1	31.7–63.3
		Sib	9.0–13.9	1.6–3.2	24.4–42.0	45.1–62.9

RESULTS AND DISCUSSION

The results reported herein are from analyses of kernels from different locations and years. Therefore, environmental (location, year, and temperature) effects on oil composition have been included in these results. However, these environmental effects on oil composition were considered to be small as compared to genetic effects. This is based on previous work (Jellum and Marion, 1966) and on extensive analyses of more than 1200 inbred lines grown throughout the U.S., as compared to being grown in Georgia (Jellum, 1968). Jellum and Marion (1966) studied the effect of location, year, planting date, and ear position on the oil content and composition of nine corn hybrids. Hybrid differences were of much greater importance in determining oil composition than the influence of any of the environmental factors studied.

Composition of Oil. Corn oil is composed of saturated and unsaturated fatty acids with carbon chain lengths ranging from 12 to 24. Approximately 95% or more of the total oil is composed of palmitic (16:0), stearic (18:0), oleic (18:1), and linoleic (18:2) acids. Due to space limitations, data will be limited to these major components, except for samples where unusual amounts of other fatty acids were found. Linolenic acid (18:3) is present in all oil samples and may vary from less than 0.5% to more than 2.0%. Other fatty acids in decreasing order of importance and generally less than 0.5% of the total oil are arachidic (20:0), myristic (14:0), and palmitoleic (16:1). In a few oil samples, arachidic acid was present up to 2% of the sample; this will be discussed later.

As a reference for comparison purposes, the fatty acid composition of U.S. commercial corn oil over a 16-month period, as reported by Beadle *et al.* (1965), was 11.5% palmitic, 2.2% stearic, 26.6% oleic, 58.7% linoleic, 0.8% linolenic, and 0.2% arachidic. Linoleic acid is the largest component of corn oil, and it is generally considered undesirable to have less than 56% linoleic acid in corn oil for use in the food industry.

Preliminary Work with Plant Introductions. Selfing was begun in a group of 82 plant introductions at the Georgia Station in 1960. Three generations of selfing were made before work with this material was terminated. However, kernels (which had lost their viability) from S_3 ears were available for analyses of oil composition in 1968. Oil composition of 260 ears was determined by analyzing one oil sample (germs from six kernels) from each ear. New kernels of seven introductions, which had unusual oil composition, were obtained from the North Central Plant Introduction Station in 1969. Oil composition was determined individually on 10 kernels of these seven introductions. Oil composition data for comparison of S_3 kernels with the original sibbed kernels are summarized in Table I. In general, the range in oil composition of the S_3 ears exceeded the range found among kernels in the original sibbed kernels. Analyses of the sibbed kernels indicated PI 257514 (France), PI 245137 (USSR), and PI 184279 (Yugoslavia) to be good sources of high linoleic acid. High linoleic acid composition was present among S_3 ears of PI 245137 and PI 184279, but not of PI 257514.

Oil Composition of Foreign and U.S. Introductions. The range in variability of oil composition is shown in Table II for kernels from S_1 ears and for single kernels of the original sibbed kernels of 40 selected introductions from a total of 177 studied. These were selected to include different countries of origin and for variability in oil composition of greatest interest for future research. The major use of corn oil is in food products and, since linoleic acid is of prime importance for this use, most of the introductions which showed a potential development of inbreds with oil of 56% or more of linoleic acid were included in Table II. The range in oil composition of the sibbed kernels was not indicative of the range which was obtained among S_1 ears for certain introductions. For example, S_1 ears from PI 185618 (Egypt), PI 221703 (Indonesia), and PI 303889 (Japan) were obtained which had linoleic acid composition lower and higher than the range exhibited by the original sibbed kernels. Many examples are shown in Table II, where the fatty acid composition of the S_1 ears: fell within the range of the sibbed kernels; exceeded the sibbed kernels on the low side; exceeded the sibbed kernels on the high side; or exceeded the sibbed kernels both on the low and high sides. Analyses on the original kernels of PI 172332 (Australia), PI 193425 (Hungary), PI 195242 (Israel), PI 303889 (Japan), PI 171895 (Turkey), PI 245138 (USSR), and PI 181989 (Yugoslavia) indicated these as potential sources for low palmitic acid composition. Low palmitic acid (less than 9.5%) was recovered among S_1 ears in all these introductions, except PI 172332 and PI 171895. A source of high stearic acid was found in original kernels of PI 197503 (Ethiopia), PI 175335 (India), and PI 175334 (Nepal), and the stearic acid recovered among S_1 ears exceeded

Table II. Variability in Fatty Acid Composition of Oil of Kernels from S_1 Ears and of Original Sibbed Kernels of 40 Selected Plant Introductions

PI No.	Origin	No. of S_1 Ears	Range in Fatty Acid Composition of Oil, %			
			Palmitic	Stearic	Oleic	Linoleic
			Introductions of foreign origin			
267214	Albania	3	14.3–17.7	1.3–2.2	26.3–36.0	44.9–55.7
		Sib	15.3–22.9	1.4–2.1	13.7–31.1	48.7–64.9
162575	Argentina	7	11.1–15.0	1.9–3.2	28.9–45.5	38.3–55.2
		Sib	10.9–12.9	1.4–2.4	32.5–40.4	45.2–51.4
172332	Australia	4	10.5–12.2	1.8–2.1	21.6–33.0	53.1–64.1
		Sib	7.8–13.4	1.6–2.3	24.7–33.1	52.0–64.5
180165	Austria	5	10.7–12.2	1.8–2.3	18.1–33.0	51.1–66.6
		Sib	10.7–12.1	1.2–2.0	28.0–38.6	46.8–58.7
240328	Bolivia	4	10.4–17.4	1.5–2.4	26.4–37.1	45.2–52.9
		Sib	11.9–13.7	1.5–2.1	23.2–37.9	47.0–62.1
267206	Bulgaria	4	14.2–18.9	1.5–2.8	25.5–50.2	31.3–60.5
		Sib	12.9–21.3	1.7–2.5	26.1–35.1	43.2–56.6
185618	Egypt	4	10.6–13.5	2.1–4.0	19.1–44.8	34.6–64.4
		Sib	11.0–12.2	2.0–2.9	26.9–36.4	49.0–58.8
185619	Egypt	7	13.8–19.5	1.3–9.3	22.8–38.5	40.6–55.2
		Sib	12.5–16.4	1.0–2.6	25.5–36.8	44.0–56.1
180231	England	7	11.1–13.0	1.7–2.4	19.0–34.4	50.0–65.9
		Sib	11.9–12.8	1.3–2.2	20.9–35.1	51.0–65.1
197503	Ethiopia	5	15.8–19.9	1.7–11.2	24.4–37.7	39.1–54.1
		Sib	14.0–16.7	1.3– 8.4	30.3–39.7	42.8–46.6
257514	France	6	10.3–11.6	1.4–1.6	24.4–29.6	56.1–61.3
		Sib	9.9–10.8	1.1–1.4	23.3–31.5	55.6–63.6
193425	Hungary	4	7.9–11.6	1.8–3.2	20.9–31.8	53.5–66.6
		Sib	9.1–11.4	1.2–2.9	20.7–37.3	48.5–66.7
175335	India	7	14.5–16.3	1.9–7.4	25.3–38.0	36.7–51.6
		Sib	14.2–16.9	2.2–5.5	23.5–39.1	40.5–56.3
221703	Indonesia	5	10.4–13.6	1.5–2.4	22.8–36.5	46.1–61.8
		Sib	10.2–11.1	1.3–2.2	31.4–35.0	51.6–54.9
195242	Israel	9	7.8–15.7	1.2–2.4	27.3–38.8	46.0–59.3
		Sib	6.4–12.0	1.1–1.8	25.7–46.0	40.2–63.3
200202	Italy	6	13.4–18.2	1.5–5.2	25.9–43.3	38.4–49.3
		Sib	14.6–17.1	1.3–1.8	34.8–41.9	41.7–46.0
303889	Japan	4	6.8– 8.3	2.2–3.0	31.8–57.1	31.1–55.5
		Sib	6.9– 7.9	1.8–2.5	39.8–49.3	40.0–49.3
181837	Lebanon	5	13.9–16.2	1.8–3.4	20.2–38.2	40.6–58.9
		Sib	12.8–17.9	2.2–3.2	21.0–28.7	55.0–59.9
175334	Nepal	5	14.1–17.3	2.8–11.5	28.8–35.1	36.7–50.6
		Sib	14.7–15.7	1.5– 6.3	27.4–30.8	49.8–54.3
186204	Palestine	6	10.9–13.6	1.2–3.5	21.3–28.8	51.8–64.1
		Sib	10.6–13.9	1.6–2.5	22.1–28.2	55.9–61.1
267208	Poland	4	11.7–15.3	1.6–2.1	28.9–40.5	43.6–53.8
		Sib	10.1–12.9	1.2–2.2	23.1–41.1	45.8–62.8
267205	Rumania	8	10.8–14.7	1.2–2.4	20.0–42.4	42.3–65.5
		Sib	10.2–13.2	1.2–2.1	24.9–44.5	43.1–61.7
247070	Spain	6	14.4–17.0	1.7–2.9	32.8–38.5	40.8–47.9
		Sib	12.2–15.6	1.8–2.2	24.0–31.2	50.2–60.5
177651	Syria	4	13.8–15.2	2.1–8.6	33.6–41.7	39.6–41.3
		Sib	13.9–15.1	1.7–2.9	32.7–41.2	39.8–49.0
303943	Taiwan	6	13.2–14.2	3.2–3.8	40.2–46.8	34.3–40.3
		Sib	13.8–14.3	2.7–3.1	38.1–40.3	42.1–44.2
171895	Turkey	8	12.5–18.2	1.4–2.8	24.0–38.7	43.0–59.8
		Sib	9.0–15.6	1.4–2.0	28.9–44.7	39.9–58.3
245133	USSR	5	11.5–13.4	1.7–3.1	18.4–32.5	51.4–66.7
		Sib	11.8–14.9	1.9–2.6	19.2–24.6	58.6–65.0
245138	USSR	5	8.9–13.9	1.4–2.7	24.7–31.5	51.2–60.9
		Sib	9.1–14.7	1.2–2.6	22.2–34.1	53.1–62.9

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Table II. Variability in Fatty Acid Composition of Oil of Kernels from S_1 Ears and of Original Sibbed Kernels of 40 Selected Plant Introductions

PI No.	Origin	No. of S_1 Ears	Range in Fatty Acid Composition of Oil, % Palmitic	Stearic	Oleic	Linoleic
				Introductions of foreign origin		
270091	W. Pakistan	6	13.6–16.3	2.8–6.6	27.0–36.0	38.7–53.7
		Sib	12.0–15.1	3.5–4.6	26.8–38.4	42.2–54.0
181989	Yugoslavia	3	9.4–12.4	1.9–2.0	21.2–37.7	48.7–65.4
		Sib	9.0–12.3	1.2–2.0	23.8–34.6	52.7–61.7
				Introductions of U.S. origin		
317678	Arizona	3	13.7–16.0	3.2–4.1	29.9–36.4	44.4–48.9
		Sib	11.9–13.7	3.1–3.9	32.7–39.5	42.8–48.8
214291	Iowa	5	8.4–12.2	1.6–2.3	21.4–37.2	50.5–62.9
		Sib	8.8–11.4	1.3–1.7	21.5–40.7	47.9–64.7
286382	Missouri	5	16.6–18.4	1.5–1.8	40.8–44.3	35.8–39.8
		Sib	15.0–16.1	1.6–1.8	38.0–41.1	41.4–43.5
218140	New Mexico	6	11.8–16.1	1.5–3.0	22.2–35.6	46.3–60.3
		Sib	10.5–16.7	1.5–2.5	31.5–44.5	39.4–52.2
213775	North Dakota	4	11.1–12.4	1.7–2.8	24.0–41.3	43.8–55.2
		Sib	10.2–12.5	1.7–2.5	24.9–39.0	47.0–59.8
198641	Ohio	6	11.5–13.6	2.0–3.8	33.9–46.2	37.9–49.7
		Sib	12.0–13.7	1.9–2.8	30.2–33.2	51.3–54.3
245130	Rhode Island	5	12.1–18.1	2.8–7.7	30.6–43.4	37.0–45.9
		Sib	11.0–14.7	2.4–4.1	40.3–44.9	37.8–43.5
311229	Utah	4	11.2–16.0	2.9–4.5	33.5–49.6	33.8–47.1
		Sib	12.7–13.8	2.2–3.2	32.1–44.1	38.1–51.6
311243	Virginia	8	13.9–15.9	1.4–3.8	36.7–49.0	33.6–46.1
		Sib	12.2–15.5	1.5–2.1	31.9–44.0	40.5–51.1
217487	Washington	5	14.0–15.2	1.7–2.0	35.3–47.0	36.1–47.1
		Sib	12.1–12.8	1.1–2.2	22.2–40.8	43.9–62.6

Table III. Comparison of the Range in Oil Composition of Kernels from Selected S_1 Ears with Extremes in Fatty Acid Composition with the Oil Composition of Original Sibbed Kernels

PI No.	Origin	Source	Range in Fatty Acid Composition of Oil, % Palmitic	Stearic	Oleic	Linoleic
303889	Japan	S_1 ear	6.8–9.3	1.4–4.2	39.8–56.1	33.3–47.6
		Sib	6.2–8.0	1.7–2.8	32.0–42.3	46.8–57.7
244067	Yemen	S_1 ear	19.1–22.2	1.3–1.8	23.3–29.7	47.7–51.5
		Sib	13.3–17.4	1.2–5.7	26.9–34.7	46.5–55.1
267205	Rumania	S_1 ear	9.6–15.2	0.6–1.3	19.2–31.4	52.7–69.4
		Sib	9.2–15.3	1.1–2.0	25.3–42.4	44.4–61.3
175334	Nepal	S_1 ear	10.8–13.4	9.1–13.1	34.4–38.6	35.7–39.4
		Sib	14.9–21.1	1.5– 6.2	27.2–34.3	43.4–51.9
180165	Austria	S_1 ear	11.0–14.3	1.3–2.1	15.1–27.1	58.2–68.8
		Sib	10.2–14.0	1.3–2.2	23.4–35.0	50.4–62.9
303851	Chile	S_1 ear	12.8–16.4	1.7–2.4	45.5–64.3	19.8–35.4
		Sib	13.6–15.3	1.3–2.3	36.4–46.6	37.7–48.2
245133	USSR	S_1 ear	11.1–13.9	1.4–2.0	14.9–21.4	65.5–71.0
		Sib	11.9–14.1	1.5–2.7	19.0–26.1	59.0–65.8

the amount found in the original kernels. On the other hand, high stearic acid (9.3 and 8.6%) was found in S_1 ears of PI 185619 (Egypt) and PI 177651 (Syria), which was not expected from analyses of the original kernels. Of the 40 introductions listed in Table II, S_1 ears with oil of 60% or more linoleic acid were obtained from 15 different introductions. Some of these could be predicted from the analyses of original kernels, while others could not. However, analysis of the original sibbed kernels was valuable in screening introductions for their potential use in selection and breeding of a corn with a particular fatty acid composition.

S_1 Ears with Extremes in Oil Composition. S_1 ears with low and high amounts of the major fatty acids were selected for additional analyses from 553 S_1 ears from introductions of foreign origin. Ten kernels from each selected S_1 ear and from the original sibbed kernels were analyzed individually for oil composition. Results of these analyses are summarized in Table III. For PI 175334, the range in oil composition of kernels from the S_1 ear did not fall within the range of the composition of the sibbed kernels for any of the four fatty acids. In almost all comparisons for each fatty acid, the range in variability of the S_1 ears exceeded the variability

Table IV. Oil Composition of 10 Selected Inbred Lines from a Total of 140 Inbreds Received from Australia

Inbreds	Fatty Acid Composition of Oil, %				
	Palmitic	Stearic	Oleic	Linoleic	Linolenic
CB-1	10.5	2.30	29.0	56.2	0.95
CG	13.0	1.95	27.7	56.7	0.81
CI-7B	12.2	1.73	63.5	21.7	0.89
CI-21	10.8	1.76	20.3	66.3	0.79
CM101	13.8	4.94	16.7	62.8	1.74
CM102	14.3	8.87	32.5	42.9	1.42
HB	13.4	1.82	25.5	58.3	0.61
H21	12.5	0.79	30.7	55.3	0.88
LC	15.2	2.18	39.4	41.7	1.08
67A	19.6	1.80	32.3	45.1	1.19

of the original sibbed kernels either on the low or high side, or both. The average oil composition of the S_1 ears was radically different from the average of the sibbed kernels except for PI 244067.

Inbred Lines from Australia. Three kernels from each of 140 Australian inbred lines were analyzed individually for oil composition. Variability among kernels within inbreds was small compared with variability among inbred lines. Results from 10 inbreds exhibiting differences in oil composition are given in Table IV. The oil of most inbred lines has less than 0.1% palmitoleic acid, but inbred HB had approximately 0.3% palmitoleic acid. While all corn oil may have a trace of 17-carbon chain fatty acids, inbred LC was unusually high in these components. Inbred CI-7B had 21.7% linoleic acid and inbred CM102 had 8.8% stearic acid. These extremes for linoleic and stearic acids are greater than found from the analyses of over 1500 released and unreleased inbreds from 27 states throughout the U.S. (Jellum, 1968). Oil composition of CI-7B and HB grown in Georgia in 1969 was 14.4, 1.4, 54.4, 28.6, and 0.8% (CI-7B) and 14.5, 1.3, 26.5, 56.8, and 0.4% (HB) palmitic, stearic, oleic, linoleic, and linolenic, respectively. The effects of environmental factors on oil composition appear to be greater on certain inbred lines and, also, that differences (due to environmental factors) in oil composition are larger between inbreds grown in Australia and U.S. than of inbreds grown in different regions of the U.S.

Plant Introductions with Unusual Amounts of Minor Component Fatty Acids. All corn oil has a measurable amount of myristic acid and trace amounts of several other short chain fatty acids which elute from the chromatographic column before palmitic acid. Palmitoleic acid is present in amounts usually less than 0.1%. Trace amounts of the 17-carbon (saturated and unsaturated), behenic (22:0), and lignoceric (24:0) fatty acids are present in all corn oil samples. Generally, arachidic acid is less than 0.5% of total oil composition. However, arachidic acid may quite often be present in amounts greater than 0.5% and be equal to or greater than linolenic acid. High amounts of arachidic acid were consistently present in oil samples which were high (over 5%) in stearic acid. Arachidic acid in amounts over 2% were found in oil samples which were extremely high (over 10%) in stearic acid.

Unusually high amounts of the minor component fatty acids may be valuable in genetic studies and in studies of the biosynthesis of fatty acids. Analyses of sibbed kernels indicated PI 180163 and PI 180164 from Austria as sources of oil high in myristic acid composition. PI 192946 (China) had more than 0.5% palmitoleic acid, which was also observed in oil from most of the S_1 ears. Other introductions high in palmitoleic acid were PI 180165 (Austria), PI 257514 (France), and PI 236995 (Siberia). High amounts of the 17-carbon fatty acids were found in PI 162931 (Paraguay), PI 247071 (Spain), and PI 204802 (Turkey). As noted above, high amounts of arachidic acid were associated with high stearic acid and were found in PI 185619 (Egypt), PI 195117 and PI 197503 (Ethiopia), PI 175335 (India), PI 175334 (Nepal), PI 177651 (Syria), and PI 270091 (West Pakistan).

Additional research with these minor component fatty acids is required to determine their mode of inheritance and

Table V. Correlation Coefficients among Fatty Acids of Corn Oil

PI[a]	No. of Obs.		Fatty Acid			
			Stearic	Oleic	Linoleic	Linolenic
1	553	Palmitic	0.12**	−0.22**	−0.13**	0.01
2	163	Palmitic	0.12	0.04	−0.35**	−0.22**
3	718	Palmitic	0.08	−0.21**	−0.15**	0.14**
4	165	Palmitic	0.17*	0.09	−0.41**	0.08
5	260	Palmitic	0.11	0.06	−0.46**	0.04
1	553	Stearic		0.10*	−0.32**	−0.09
2	163	Stearic		0.06	−0.23**	−0.12
3	718	Stearic		0.07	−0.23**	0.27**
4	165	Stearic		0.31**	−0.45**	0.29**
5	260	Stearic		0.08	−0.26**	0.04
1	553	Oleic			−0.92**	−0.32**
2	163	Oleic			−0.93**	−0.39**
3	718	Oleic			−0.93**	−0.34**
4	165	Oleic			−0.94**	−0.17*
5	260	Oleic			−0.90**	−0.21**
1	553	Linoleic				0.28**
2	163	Linoleic				0.42**
3	718	Linoleic				0.22**
4	165	Linoleic				0.06
5	260	Linoleic				0.12

*, ** Significant at the 5 and 1% levels, respectively.
[a] Source of introductions as follows: 1 = S_1 ears of foreign origin, 2 = S_1 ears of U.S. origin, 3 = sibbed kernels of foreign origin, 4 = sibbed kernels of U.S. origin, and 5 = S_3 ears of 1962 seed.

Table VI. Average Fatty Acid Composition of Corn Oil of Various Plant Introductions and U.S. Inbred Lines

		Fatty Acid Composition of Oil, %				
Source	No.	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Foreign—1962 S_3 ears	82	15.0	2.56	32.4	48.3	1.21
Foreign—S_1 ears	144	14.2	2.56	34.7	46.7	1.05
U.S.—S_1 ears	33	14.5	2.51	36.0	45.7	1.03
Foreign—Sibbed	144	13.8	2.03	33.9	49.2	1.02
U.S.—Sibbed	33	13.1	2.33	36.8	46.9	0.98
Australia—Inbreds	140	14.2	2.17	35.3	47.0	1.15
Georgia—Inbreds	81	15.6	2.40	37.5	43.4	1.20
Illinois—Inbreds	72	12.4	1.68	29.3	55.4	0.96
Indiana—Inbreds	41	12.9	1.64	28.1	56.3	0.99
North Dakota—Inbreds	18	12.1	1.53	25.7	59.5	1.18
Com. Oil—Beadle *et al.*, 1965		11.5	2.20	26.6	58.7	0.80

to isolate them into homozygous inbred lines. High amounts of minor component fatty acids are also present in various inbred lines of U.S. origin (Jellum, 1968).

Correlation Coefficients. It is generally recognized that oleic acid has a high negative correlation coefficient with linoleic acid in corn oil. However, few data have been published concerning the correlation among the fatty acids in corn oil. Correlation coefficients among fatty acids are given in Table V. A high negative correlation coefficient of 0.90 to 0.94 was obtained between oleic and linoleic acids. Although many other correlation coefficients were highly significant, most of these were generally quite low and concurrent selection of any two fatty acids (except oleic and linoleic) in either direction should be possible.

Summary and Comparisons of Oil Composition. Averages are given in Table VI for fatty acid composition of oil for various groups of plant introductions, inbred lines from four states, and commercial corn oil. The analyses of introductions of foreign and U.S. origin and of 140 inbred lines from Australia showed that they were quite uniform in oil composition with a range in linoleic acid composition of from 45.7 to 49.2%. The average linoleic acid composition (43.4%) of 81 inbred lines selfed at the Georgia Station was lower than that of any introduction group. The average oil composition of Illinois and Indiana inbred lines was quite different than introductions and similar to commercial corn oil. Average linoleic acid composition of 18 North Dakota inbred lines was higher than the Illinois and Indiana inbreds and also higher than commercial oil. It is of interest that linoleic acid composition of introductions of U.S. origin was about 46% as compared to 56% for Illinois and Indiana inbred lines. Beadle *et al.* (1965) concluded that oil from corn of foreign origin was more highly saturated and lower in linoleic acid than U.S. corn. This is true when foreign corn is compared with corn of Illinois and Indiana. However, the results of this study show that the average oil composition of U.S. corn is similar to that of corn from other countries. Analyses of oil composition of numerous inbred lines from throughout the U.S. (Jellum, 1968) show that inbreds from the northern states average 56% or higher linoleic acid and that inbreds from southern states compare with the composition of the Georgia inbreds as given in Table VI. Jellum and Marion (1966) concluded that genetic factors had a much greater influence than environmental factors on oil content and quality of corn. Northern inbreds grown in Georgia or in their original environment have similar oil composition. Therefore, differences between northern and southern inbred lines in oil composition is due to genetic differences rather than environmental differences. Since the average linoleic acid composition of oil of U.S. corn is about 46% (results of introductions, Table VI), there appears to have been natural selection for higher levels of linoleic acid in the development of inbreds and hybrids in the northern areas of the U.S. In other crops, higher levels of linoleic acid are generally found in northern areas or are associated with lower temperatures (Canvin, 1964; Ford and Zimmerman, 1964; Kinman and Earle, 1964).

CONCLUSIONS

Variability in the fatty acid composition of corn has been recognized and reported in previous studies. However, most of these studies have been with commercial corn oil rather than oil from genetically diverse corn germ plasm. Results of the present study have shown the extensive variability in oil composition of plant introductions. The extreme range in composition of most fatty acids in corn oil has been considerably extended by germ plasm of plant introductions as compared to available germ plasm in inbreds and open-pollinated varieties of U.S. origin. For example, the highest stearic acid composition was about 6 to 7% for one inbred line of U.S. origin from the analyses of more than 1500 inbred lines. A number of oil samples from various kernels and ears of several different introductions have been found which contain from 10 to 16% stearic acid. Therefore, plant introductions appear to be a valuable source of genetic diversity for oil composition and should receive greater attention in future studies.

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