Effect of Controlled Temperature Environments on Oil Content and on Fatty Acid Composition of Corn Oil[1]

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ABSTRACT

Total oil content and fatty acid composition of germ and endosperm oil were determined on grain from three inbred lines and one variety of corn (*Zea mays* L.) grown in four phytotron environments and one standard greenhouse environment during seed maturation. Pronounced differences occurred with reversals for relative percentages of oleic and linoleic acids of germ oil for one inbred line and for the variety. Comparative trends were generally less pronounced for two of the inbred lines. Differences among environments were less evident for palmitic, stearic, and linolenic acids of germ oil and for the fatty acids of the endosperm oil. Total oil was lowest for two inbred lines and the variety grown in the high temperature environment (30 C day/26 C night). The magnitude of temperature effects on oil content and oil composition varied among the four corn genotypes.

INTRODUCTION

Studies of temperature effects on oil content and composition have been restricted largely to the oilseed crops. Low temperatures during seed development generally have been associated with a decreased oil content and an increased unsaturation of the oil.

With soybeans, low temperatures were associated with low oil content and increased unsaturation (linoleic and linolenic acids) of oil under field conditions (1,2) and controlled temperature conditions (3). Date of planting studies with soybeans have shown that delayed planting resulted in low oil content and higher iodine value (4,5). Unsaturation of oil from flax increased with lower temperatures (6-9); but in contrast to that of soybeans, oil content also increased at lower temperatures (6-8). Yermanos et al. (10) studied the temperature response of three wild flax species and found that two of the species responded as the cultivated species responded.

Studies (11,12) have shown that oil content and oil composition of corn kernels are affected by the geographical locations in which the corn is grown. Although several factors probably are involved in the location effects, temperature is undoubtedly a major environmental component. Temperature effects can best be studied in growth chambers that provide accurate temperature controls and that are large enough for growing corn to maturity. The facilities of the phytotron (Southeastern Plant Environment Laboratory, Raleigh, N.C.) were made available for this study.

The objective of this study was to determine the effects of controlled temperatures during seed maturation on oil content of grain and on the fatty acid composition of germ and endosperm oil. Four corn genotypes were included, and these were chosen because of their differences in oil composition.

EXPERIMENTAL PROCEDURES

Corn Genotypes

This study consisted of four corn genotypes (*Zea mays* L.) (three inbreds: Pa36, GE82, and 70-242-5, and one extremely early-maturing, open-pollinated variety, Gaspe Flint) grown in five environments (three phytotron greenhouses, one phytotron growth chamber, and one standard greenhouse). Pa36 is a released inbred line developed at the Pennsylvania Agricultural Experiment Station, University Park, Pa., GE82 and 70-242-5 are unreleased lines developed at the Georgia Experiment Station, Experiment, Ga. The 70-242-5 line is a fourth generation self of an ear-to-row selection from plant introduction 175334 from Nepal. Corn genotypes were chosen because of differences in oil content and composition, as shown in Tables I and II.

Environments

Environment one was a phytotron walk-in growth chamber 2.4 x 3.7 x 2.1 m high, equipped with a combination of cool-white fluorescent and incandescent lamps in an appropriate ratio of 100:30 by wattage. There were 84 T-12, 215 w, 1500 ma fluorescent lamps with 225° reflectors (FR96T12/CW/1500) and 48 incandescent lamps of 130V/100 w each. Illumination was maintained at 400-450 hectolux 1 m below the lamps. All lights were on 9 hr each day (8 a.m.-5 p.m.) and incandescent lights only 3 hr each night (11 p.m.-2 a.m.).

Environment two, three, and four were phytotron

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TABLE I

Oil Content of Grain from Corn Grown in Five Environments

Genotype	Oil content, % dry wt, from environment[a] 1 (18/14)	2 (22/18)	3 (26/22)	4 (30/26)	5	Average 95% confidence interval
Pa36	2.28	2.54	2.38	1.92	2.38	.14
GE82	2.61	2.22	3.66	3.01	4.13	.37
70-242-5	5.05	5.19	5.58	4.00	5.31	.39
Gaspe Flint	5.30	5.36	5.17	4.92	4.01	.20
Mean	3.93	3.83	4.20	3.46	3.96	---

[a]Parenthetical figures are (day/night) temperature C. Temperature for environment five (standard greenhouse) was not controlled.

greenhouses with seasonal light during the day and a 3 hr dark interruption period from incandescent lamps at night (11 p.m.-2 a.m.). Although specific measurements were not made during this experiment, general phytotron data (unpublished) would indicate that the average photosynthetically active radiation for environment one (growth chamber) was ca. equal to that of environment two, three, or four (phytotron greenhouses).

Environment five was a standard greenhouse without supplementary lighting or temperature control, except for ordinary ventilation. Temperatures fluctuated and detailed records were not kept, but maximum day temperatures often exceeded the 30 C temperature of environment four.

For environments one-four, plants were grown initially in environment three from planting (May 26, 1971) to pollination. After self-pollination, plants were placed in the four appropriate phytotron environments at the temperatures (day/night) indicated in Figure 1. These plants were grown in 4 liter pots. Seeds for environment 5 were planted on the same date (May 26) in the soil ground bed of the standard greenhouse.

Samples and Analytical Procedures

Ears were harvested after physiological maturity. The number of ears for each genotype in each environment ranged from two-five with an average of four. Oil content was determined on each ear by standard methods of the Association of Official Analytical Chemists. Fatty acid composition of oil was determined by gas liquid chromatography (GLC) for four germ oil samples and one endosperm oil sample from each ear. Samples one and two were each a bulk of germs from seven kernels for each ear. Samples three and four, which were used to determine genetic variability, were germs from single kernels from each ear. Because variability among samples was minimal, data for samples one-four were combined for germ oil means. Sample five was a bulk of the endosperms of 16 kernels of samples one-four. A description of GLC equipment and procedures has been published (13). Germ and endosperm lipids were extracted overnight in a 2:1 mixture (4-5 ml) of petroleum ether (Skellysolve F) and absolute methanol. Further extraction was obtained by adding 10 ml of 3% sulfuric acid in anhydrous methanol and heating in a hot water bath at 63 C for 5 hr (procedure used for obtaining fatty acid methyl esters). Methyl esters of fatty acids were separated on a 2.3 m x 3.17 mm stainless steel column packed with 10% preconditioned EGSS-X on 100/120 mesh Gas Chrom Q.

Statistical Analysis of Data

In combined analyses of variances, environments and genotypes were consideref fixed effects, and the pooled sums of squares for ears in genotypes x environments were used to determine error. Separate analyses were calculated for each genotype, and the error mean square for ears in environments was used to calculate confidence intervals.

RESULTS AND DISCUSSION

The average oil content of the grain on dry wt basis for each of the genotypes in five environments is given in Table I. In the controlled environments (environments one-four) oil content of three of the four genotypes was lowest for the high temperature (environment four); GE82 was the exception. Lower oil content has been reported for higher temperatures for flax (6-8) but higher oil content for higher temperatures for soybeans (1-5). Pa36 had the lowest oil content of the four genotypes (except in environment two) (Table I) and had the greatest unsaturation (highest linoleic) (Table II). However, GE82, which was chosen for its general low linoleic acid, was also quite low in oil content. Trends for oil content generally were associated

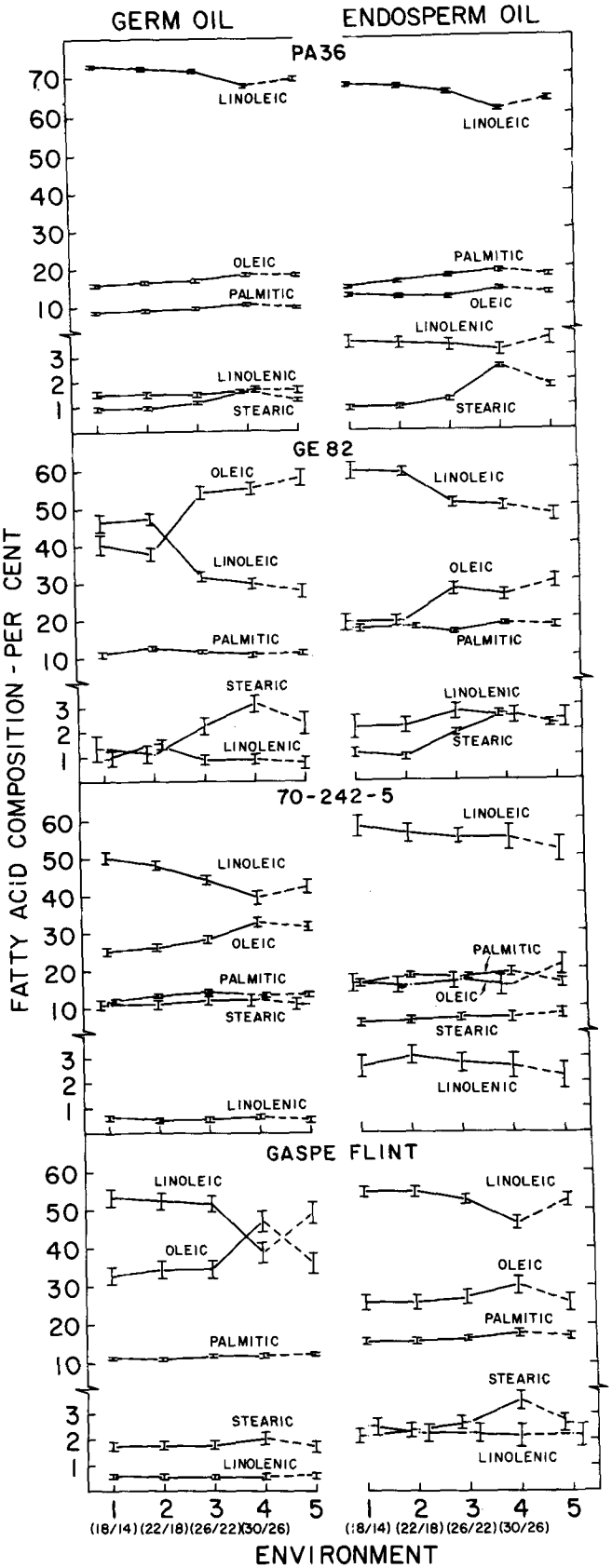

FIG. 1. Fatty acid composition of germ and endosperm oil for four corn genotypes in five environments. Parenthetical figures for environments one-four are (day/night) temperatures C. Detailed records were not kept for environment five. Vertical ranges for each point are 95% confidence intervals.

with trends of linoleic acid for two genotypes Pa36 and Gaspe Flint but not for GE82 and 70-242-5 (Table I and Fig. 1).

Mean fatty acid composition of the oil extracted from

TABLE II

Average Fatty Acid Composition of Oil from the Germ and Endosperm of Corn Grown in Five Environments

Genotype	Fatty acid composition of oil, % by wt				
	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Germ oil					
Pa36	9.4	1.2	17.0	70.8	1.5
GE82	11.4	2.0	49.1	36.4	1.0
70-242-5	13.3	11.5	28.8	44.9	.6
Gaspe Flint	11.6	1.8	37.0	49.0	.6
Endosperm oil					
Pa36	17.2	1.5	12.8	65.1	3.5
GE82	17.7	1.8	24.4	53.4	2.4
70-242-5	17.6	6.9	17.0	55.1	2.7
Gaspe Flint	16.4	2.7	26.7	51.9	2.3

the germ and endosperm for each genotype in each environment is portrayed in Figure 1 with the 95% confidence intervals for each point. Environments one-four are of primary interest; environment five, which was not controlled and not directly comparable, is of only supplementary interest.

Differences in fatty acid composition of the genotypes are evident in Table II where each mean is an average percentage for the five environments. Also evident are the differential responses to the environments (Fig. 1). These responses are most evident for oleic and linoleic acids. These two fatty acids constitute the major part of the oil. The correlation coefficients between oleic and linoleic acids were -0.91 for germ oil and -0.88 for endosperm oil (significant at the 1% level) as calculated for the 20 means (four genotypes in five environments).

Environmental threshold effects were pronounced for GE82 and Gaspe Flint for oleic and linoleic acids, with reversals of relative percentages for germ oil. The threshold for GE82 was within the range of environments two and three, and for Gaspe Flint it occurred in the range of environments three and four. The threshold for Gaspe Flint coincided with poorer general growth. Previous experiences, and observation in this study, have shown that growth of Gaspe Flint was good in environments one, two, and three but relatively poor in environment four. Thresholds for endosperm oil were generally the same as the thresholds for germ oil, but percentage differences were less pronounced and there were no extreme reversals.

Pa36 and 70-242-5 exhibited significant differences among environments for some of the fatty acids as indicated by the confidence intervals in Figure 1. Trends for oleic and linoleic were more of a linear nature with less pronounced thresholds and no extreme reversals.

Plant growth was satisfactory. Pa36 and Gaspe Flint plants were normal, except as noted above for Gaspe Flint in environment four. GE82 and 70-242-5 plants were excessively tall, and a few were slow to develop ears. At maturity some ears were not developed fully and were discarded on the basis of below normal mean kernel wt. Influence of kernel wt was considered minimal, however, because none of the correlation coefficients between kernel wt and fatty acid percentages were significant at the 5% level or less. Pa36, GE82, and 70-242-5 were inbred lines with mainly sampling variation, whereas Gaspe Flint had additional plant-to-plant genetic variation.

Meyer and Bloch (14) showed that increased unsaturation of oil in yeast grown at low temperatures was due to an increased activity of the desaturating enzymes. In higher plants, Harris and James (15) found increased unsaturation of seed lipids from castor, sunflower, and flax grown at low temperatures. They increased unsaturation of the seed lipids by supplemental O_2 at higher temperatures; therefore, they concluded that increased unsaturation of seed lipids at low temperatures was due to an increase in available O_2, which is a rate-limiting factor for desaturation.

Harris and James (15) found that crops differed in their magnitude of response in changes of fatty acids with temperatures. Knowles (16) recently reviewed the safflower research in California in which varietal differences in response of oil composition to temperature during seed maturation was established. Our study with corn showed an increased unsaturation of seed oil with decreased temperatures during seed maturation. However, considerable differences in response to temperature were found among the four corn genotypes (Fig. 1). The inbred line Pa36, which was high in linoleic acid, was quite stable for most of its fatty acids when grown at all temperatures. GE82, which was low in linoleic acid, was highly responsive to temperature differences for the fatty acids, except palmitic acid which changed little. In safflower, the high and low linoleic acid types tended to be stable when grown at different temperatures (16).

Our data show that the environment during grain maturation (primarily temperature differences in this study) can markedly influence fatty acid composition of germ and endosperm oil of corn and that the type and degree of influence vary among genotypes.

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