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Tocopherol content of soybean lines with mid-oleate and 1%-linolenate

by

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A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Plant Breeding

Program of Study Committee:
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Iowa State University

Ames, Iowa

2009

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ABSTRACT

Soybean [*Glycine max* (L.) Merr.] oil is an important commercial source of tocopherol (Vitamin E). Some genetic modifications of the fatty ester composition of soybean oil have resulted in changes in the content of total tocopherol and its components. The objective of this study was to compare the tocopherol content of 20 soybean lines with mid-oleate and 1%-linolenate (MO) content to 20 lines with conventional-oleate and 1%-linolenate (CO) content from each of three segregating populations. The 60 lines were evaluated in three Iowa environments during 2007. The average total tocopherol content in oil across populations was 1789.1 mg kg^{-1} for the MO type and 1781.7 mg kg^{-1} for the CO type. Although the average total tocopherol was similar between the two types, the average proportion of α-tocopherol was 27.6 mg kg^{-1} greater, γ-tocopherol was 76.5 mg kg^{-1} less, and δ-tocopherol was 56.2 mg kg^{-1} greater for the MO than the CO type. There was significant variation among MO lines for total tocopherol and the three components, which indicated that it should be possible to develop cultivars with tocopherol contents that are best suited to the needs of the end-user.

INTRODUCTION

Soybean [*Glycine max* (L.) Merr.] oil is an important source of tocopherols (Vitamin E) (Quek et al., 2007). Tocopherols are an essential nutrient and are used to increase the antioxidant content and shelf-life of food products and in the production of dietary supplements.

Changes in the fatty ester profiles of soybean oil can alter its tocopherol content and composition. Reduced linolenate has been shown to be associated with reduced total tocopherol levels (Mounts et al., 1996; Almonor et al., 1998; Dolde et al., 1999; McCord et al., 2004). The only study that compared normal- and reduced-linolenate lines with similar genetic backgrounds was that of McCord et al. (2004). They reported a decrease of 6.0% in the average total tocopherol content of 1%-linolenate lines compared with normal-linolenate lines derived from each of three segregating populations. The α-, γ-, and δ-tocopherol were proportionately lower for the 1%-linolenate lines than the normal-linolenate lines in their three populations, and the percentages of the three components in the two types of lines were not significantly different. The significant variation they observed among the lines of each type for total tocopherol and the three components indicated that it should be possible to develop 1%-linolenate cultivars with acceptable contents of each of the traits.

Palmitate content had an inverse relationship with total tocopherol content in two studies. Mounts et al. (1996) compared the oil from four soybean lines with elevated palmitate ranging from 144 to 258 g kg^{-1} to the conventional cultivar Hardin 91 with 109 g kg^{-1} palmitate. Their four lines had, on average, lower total tocopherol, lower α-, γ-, and δ-tocopherol, and greater β-tocopherol contents than Hardin 91. Scherder et al. (2006) compared tocopherol contents of reduced- and normal-palmitate lines from each of three

segregating populations. When averaged across the three populations, the reduced-palmitate lines had 15% greater total tocopherol content than the normal-palmitate lines. The average contents of α-, γ-, and δ-tocopherol were greater in the reduced-palmitate lines than in those with normal-palmitate.

The only study that has reported a relationship between oleate and tocopherol content in multiple soybean genotypes was that of Carrão-Panizzi and Erhan (2007). They studied 89 Brazilian cultivars and observed a significant correlation of 0.34 between δ-tocopherol and oleate. The range in oleate contents among their cultivars and its relationship to total tocopherol and other tocopherol components were not reported.

Soybean cultivars with mid-oleate and 1%-linolenate (MO) content and with conventional-oleate and 1%-linolenate (CO) content are in commercial production. Warner and Fehr (2008) indicated that MO oil had frying and shelf-life stability similar to hydrogenated soybean oil and better than CO or conventional soybean oil. Tortilla chips that they fried in the MO oil had better flavor those fried in the other oils, both initially and after four months of storage.

Understanding the tocopherol content of MO lines that can be expected in a soybean breeding program and how it compares with CO lines is important to meet the varied needs of end users. The objective of this study was to compare the tocopherol content of MO and CO soybean lines derived from each of three segregating populations.

LITERATURE REVIEW

Importance of tocopherol

Vitamin E, an important antioxidant, is composed of tocopherols and tocotrienols (Stone and Papas, 2003). Four tocopherols are part of the Vitamin E complex, α-, β-, γ-, and δ-tocopherol, each of which has different properties. α-Tocopherol, the most-studied tocopherol, is necessary for the development of live fetuses in pregnant rats (Stone and Papas, 2003). γ-Tocopherol is thought to be important in the prevention of colon cancer and prostate cancer (Stone and Papas, 1997; Papas, 1999; Giovannucci, 2000).

In soybean oil, γ-tocopherol is present in the greatest concentration and β-tocopherol in the smallest concentration. In a study of 66 soybean cultivars by Rani et al. (2007), mean tocopherol amounts were 269 μg tocopherol per g of oil for α-tocopherol, 40 μg g^{-1} for β-tocopherol, 855 μg g^{-1} for γ-tocopherol, and 241 μg g^{-1} for δ-tocopherol, with a total mean tocopherol amount of 1405 μg g^{-1}. Variations in tocopherol contents have been reported due to genetics, fatty acid composition, growing conditions, storage conditions, and analysis methods (Almonor et al., 1998; Dolde et al., 1999; Papas, 1999; Rani et al., 2007).

Importance of elevated oleate

Soybean oil is composed of five fatty esters: palmitate, stearate, oleate, linoleate, and linolenate. The typical fatty ester profile of soybean oil is 114 g kg^{-1} palmitate, 37 g kg^{-1} stearate, 229 g kg^{-1} oleate, 536 g kg^{-1} linoleate, and 84 g kg^{-1} linolenate (Hammond, 2000). Although soybean oil is widely used, its oxidative stability is low because of the high proportion of polyunsaturated fatty acids (~62% linoleate and linolenate). To increase the oxidative stability of soybean oil, two methods have been widely used: partial hydrogenation of the oil and modification of the fatty ester profile. Partial hydrogenation produces *trans*-

fatty acids, which have been shown to have a negative effect on the serum lipoprotein profile by both lowering high-density lipoprotein cholesterol and raising low-density lipoprotein cholesterol (Mensink et al., 1990). Modification of the fatty ester profile changes the amounts of each fatty ester present in soybean oil, which influences the oxidative stability of the oil (White, 2000).

Soybean oil with elevated oleate content has been shown to have greater oxidative stability than conventional soybean oil and soybean oil with low-linolenate (~20 g kg^{-1}) content (Su and White, 2004a; Warner and Gupta, 2005). Su and White (2004a) tested the frying stability of six oils and oil blends with varying levels of oleate content: 79% oleate (high-oleate oil), 65% oleate (a blend of 75% high-oleate and 25% conventional oil), 51% oleate (a blend of 50% high-oleate and 50% conventional oil), 37 % oleate (a blend of 25% high-oleate and 75% conventional oil), 25% oleate with 1.4% linolenate (low-linolenate oil), and 21.3% oleate (conventional oil). The oil with 79% oleate was the most stable, and stability decreased with decreasing oleate except for the low-linolenate oil, which had frying stability greater than or equal to the oil with 37% oleate. Su and White (2004b) also tested these oils and oil blends for flavor stability and quality by conducting a sensory analysis on bread cubes fried in each oil. They found that the low-linolenate oil (25% oleate and 1.4% linolenate) had greater flavor quality and flavor stability than the oil with 79% oleate, and both had better flavor characteristics than the other four oils. They suggested that an intermediate oleate composition may have a better balance of flavor quality with oxidative stability.

Warner and Gupta (2005) compared the oxidative stability and flavor quality of four oils: cottonseed oil (a standard), low-linolenate oil (20 g kg^{-1} linolenate), high-oleate oil (851

g kg^{-1} oleate) and a 1:1 blend of the high-oleate and low-linolenate oils. They found that the high-oleate oil had the best oxidative and frying stability but poorer flavor quality. The blend of the high-oleate and low-linolenate oils had oxidative and frying stability less than the high-oleate oil but greater than the other two oils, and the flavor quality of the blend was better than the high-oleate oil (Warner and Gupta, 2005).

Warner and Fehr (2008) compared oil from soybean cultivars with mid-oleate and low-linolenate (MO; ~500 g kg^{-1} oleate and 10 g kg^{-1} linolenate) to soybean oil with conventional oleate and low-linolenate (CO; ~270 g kg^{-1} oleate and 11 g kg^{-1}linoleate), conventional soybean oil, and hydrogenated soybean oil for their frying qualities. They found that even after 35 and 55 hrs of frying, the hydrogenated soybean oil and MO oil had the lowest amount of polar compounds of the oils, while conventional soybean oil had the highest. The hexanal levels in hydrogenated soybean oil were lower than the MO oil after 35 hrs of frying and four months of storage and after 55 hrs of frying and two, three, and four months of storage. The MO oil had better fried flavor than the other oils and the least rancid flavor, except for the hydrogenated soybean oil. They suggested that MO oil, because of its good oxidative stability and flavor qualities, is an appropriate substitute for hydrogenated soybean oil.

Inheritance of mid-oleate

Rahman et al. (1994) developed the mid-oleate soybean mutant line M23 by irradiating seeds of the cultivar Bay and evaluating seeds from M2 plants for oleate content. M23 had 461 g kg^{-1} oleate compared with 223 g kg^{-1} oleate for Bay. Takagi and Rahman (1996), using reciprocal crosses between M23 and Bay, determined that the inheritance of mid-oleate content was due to two alleles at a single locus with partial dominance of the wild

type allele. They designated the mutant allele in M23 as *ol*. Kinoshita et al. (1998) determined that the mid-oleate content was caused by a deletion in the *Ol* locus, which encodes *FAD2-1* microsomal ω-6 fatty acid desaturase. Sandhu et al. (2007) determined that the *Fad2-1* modification producing mid-oleate content in M23 was caused by a deletion of the *Fad2-1a* gene and that the *Fad2-1b* gene was not altered. Alt et al. (2005) found that modifying genes influenced oleate content of lines with the *ol* allele. They crossed M23 with the conventional cultivar Archer, screened F_2 plants for the *Fad2-1* deletion by Southern analysis, and evaluated the oleate content of seeds of F_3 progeny from F2 plants of three genotypes: *OlOl*, *Olol*, and *olol*. The mean oleate content of the progeny from the *OlOl* plants was 289 g kg^{-1} with a range of 220 to 357 g kg^{-1}; the mean for *Olol* was 317 g kg^{-1} with a range of 252 to 424 g kg^{-1}, and the mean for *olol* was 394 g kg^{-1} with a range of 350 to 451 g kg^{-1}. The overlapping ranges of oleate content among the three genotypes indicated the presence of modifying genes for oleate content.

Inheritance of 1%-linolenate

Soybeans with 1%-linolenate content were developed at Iowa State University by combining the *fan1(A5)*, *fan2(A23)*, and *fan3* alleles (Fehr and Hammond, 1998). The *fan1(A5)* allele was developed by mutagenizing seed of FA9525 with ethyl methane sulfonate (EMS) (Hammond and Fehr, 1983). The mutant line A5 had a linolenate content of 29 to 41 g kg^{-1} (Fehr and Hammond, 1996). The *fan2(A23)* allele was developed by mutagenizing FA47437 with EMS (Fehr and Hammond, 1996; Walker et al., 1998). Plants with <25 g kg^{-1} linolenate were found in the segregates of a cross between A5 and A23 (Fehr et al., 1992). Two of the segregates with <25 g kg^{-1} were designated A16 and A17. When these lines were crossed with Century 84, segregation ratios of F2:3 lines fit a 1:14:1 ratio

model, indicating that two alleles at independent loci were responsible for the reduced linolenate content (Fehr et al., 1992).

The *fan3* allele was developed by mutagenesis of seed of the soybean line A89-144003 with EMS. The mutant line with the allele, A26, had a linolenate content of 63 g kg^{-1} (Fehr and Hammond, 1998). A26 was crossed to AX5711C04, an experimental line with the genotype *fan1(A5)fan1(A5)fan2(A23)fan2(A23)*. Progeny from this cross were found to have linolenate content of <15 g kg^{-1}. A29, one of the progeny, with the genotype *fan1(A5)fan1(A5)fan2(A23)fan2(A23)fan3fan3* had 11 g kg^{-1} linolenate (Fehr and Hammond, 1998).

Byrum et al. (1997) analyzed the soybean line A5 and found that the low-linolenate content in A5 was due to a partial or full deletion of a microsomal ω-3 desaturase gene. Bilyeu et al. (2003) designated the *fan1(A5)* locus as *GmFAD3A*. Bilyeu et al. (2006) designated *fan3* as *GmFAD3B* after discovering that the mutant allele was caused by a single nucleotide polymorphism (SNP) in *GmFAD3B* that led to a frameshift mutation and early termination of protein product. Bilyeu et al. (2006) designated the *fan2* allele as *GmFAD3C* after finding a SNP that altered a histidine residue required for desaturase activity in the mutation.

Tocopherol content and fatty ester modifications

Palmitate content had an inverse relationship with total tocopherol content in two studies. Mounts et al. (1996) examined the tocopherol content of 12 experimental soybean lines with altered fatty acid compositions from the ARS-USDA/North Carolina State University, Iowa State University, ARS-USDA/Purdue University, and Pioneer Hi-Bred International, Inc., and one conventional cultivar, Hardin 91. Of the 12 experimental lines,

four of them had elevated palmitate of 144 to 258 g kg^{-1} while the conventional cultivar Hardin 91 had 109 g kg^{-1} palmitate. Oils with elevated palmitate had, on average, 945 mg kg^{-1} lower total tocopherol than Hardin 91, and the relative amounts of the four tocopherol components were altered as well. The oils with elevated palmitate averaged 90 mg kg^{-1} lower α-tocopherol, 734 mg kg^{-1} lower γ-tocopherol, and 121 mg kg^{-1} lower δ-tocopherol and 24 mg kg^{-1} greater β-tocopherol contents than Hardin 91. In their study, the seeds tested were produced in different environments, which may have influenced the tocopherol content of the lines (Mounts et al., 1996).

Scherder et al. (2006) examined the effect of low-palmitate on tocopherol content in three segregating populations. Three low-palmitate lines were crossed to three conventional-palmitate lines to develop the populations. From each population, 50 F_3 plants with the highest palmitate and 50 F_3 plants with the lowest palmitate were grown as $F_{3:4}$ lines and the seed was evaluated for palmitate content. The following year, the 27 lines with the lowest palmitate and the 27 lines with the highest palmitate were grown at three locations. Of the 54 $F_{3:5}$ lines tested, the 20 lines with the lowest palmitate and the 20 lines with the highest palmitate in each population were chosen for tocopherol analysis. In all the populations, the low-palmitate lines (~32 to 43 g kg^{-1}) had higher tocopherol content than the conventional-palmitate lines (~91 to 115 g kg^{-1}), with differences ranging from 8.3% to 18.7%. The amounts of individual tocopherols were greater in the reduced-palmitate lines. On average, α-tocopherol was 11.3 mg kg^{-1} greater, γ-tocopherol was 87.3 mg kg^{-1} greater, and δ-tocopherol was 78.3 mg kg^{-1} greater in the reduced-palmitate lines than in those with normal-palmitate (Scherder et al., 2006).

Reduced linolenate has been shown to be associated with reduced total tocopherol levels (Mounts et al., 1996; Almonor et al., 1998; Dolde et al., 1999; McCord et al., 2004). Five of the experimental lines examined by Mounts et al. (1996) had reduced linolenate (17 to 29 g kg^{-1} linolenate) compared to Hardin 91 (65 g kg^{-1} linolenate). The reduced-linolenate lines had on average, 257 mg kg^{-1} lower total tocopherol than Hardin 91. α-Tocopherol of the reduced linolenate lines was 18 mg kg^{-1} lower, and γ-tocopherol was 217 mg kg^{-1} lower than Hardin 91. Average β-tocopherol and δ-tocopherol were not different between the reduced-linolenate lines and Hardin 91 (Mounts et al., 1996).

Almonor et al. (1998) examined three low-linolenate lines and one standard cultivar for fatty acid composition and tocopherol content. The line N78-2245 with homozygous recessive alleles for ω-6 desaturase; PI123440 had recessive alleles for ω-3 desaturase; N85-2176, the product of a cross between N78-2245 and PI123440, had homozygous recessive alleles for both desaturases; and Dare had homozygous dominant alleles for both desaturases. The four lines were grown in the same laboratory at a mean daily temperature of 23.5°C until flowering. After pod initiation, the lines were grown under four temperature regimes: 27.5°C, 23.5°C, 19.5°C, and 15.5°C. Averaged across the temperature treatments, N78-2245 had a linolenate content of 63 g kg^{-1}, PI123440 had a linolenate content of 62 g kg^{-1}, N85-2176 had a linolenate content of 42 g kg^{-1}, and Dare had a linolenate content of 89 g kg^{-1}. They observed that the homozygous recessive alleles for the ω-6 desaturase caused a decrease in total tocopherol content, regardless of the ω-3 desaturase alleles that were present. Reduction in linolenate content was associated with an increase in α-tocopherol content and a decrease in γ-tocopherol. They concluded that low-linolenate cultivars would

have higher α-tocopherol content than conventional-linolenate cultivars (Almonor et al., 1998).

Dolde et al. (1999) examined 11 soybean lines with modified fatty ester composition and 14 lines with conventional composition. Four of the lines with modified fatty ester composition had reduced linolenate ranging from 26 g kg^{-1} to 35 g kg^{-1}. The lines were grown together in the five Midwest environments and a growth chamber. Mean tocopherol content ranged from 1205 μg g^{-1} for one of the reduced-linolenate lines to 2195 μg g^{-1} for one of the conventional lines. They found a positive correlation between linolenate content and total tocopherol, δ-tocopherol and γ-tocopherol content. They suggested that this reduction in tocopherol content could be the result of the narrow genetic background of the low-linolenate phenotype and not a direct effect of low linolenate on the production of tocopherols.

McCord et al. (2004) examined the influence of 1%-linolenate on tocopherol content in three segregating populations. The populations were developed by crossing three 1%-linolenate cultivars with three high-yielding lines with conventional linolenate content. From each population, 25 F_3-derived lines with the lowest linolenate content and 25 lines with the highest linolenate content were grown at three locations. After harvest, fatty ester content of each line was analyzed for each location. The 20 lines with the lowest mean linolenate content and the 20 lines with the highest mean linolenate content were chosen for tocopherol analysis. In all the populations, the low-linolenate lines (~14 g kg^{-1}) had 6.0% lower mean total tocopherol content than the conventional-linolenate lines (~71 g kg^{-1}). However, some overlap of the distributions among lines for the two types indicated that selecting for total tocopherol content similar to that of conventional cultivars should be possible with low-

linolenate lines. The α-, γ-, and δ-tocopherol were proportionately lower for the 1%-linolenate lines than the normal-linolenate lines in their three populations, and the percentages of the three components in the two types of lines were not significantly different.

Rani et al. (2007) evaluated the tocopherol content of 66 conventional soybean cultivars grown under the same environmental conditions. Total tocopherol among cultivars ranged from 422 to 3311 μg g^{-1} , with a mean of 1405 μg g^{-1}. The mean tocopherol amounts were 269 μg g^{-1} for α-tocopherol, 40 μg g^{-1} for β-tocopherol, 855 μg g^{-1} for γ-tocopherol, and 241 μg g^{-1} for δ-tocopherol. They did not observe an association between linolenate (50 to 110 g kg^{-1}) and total tocopherol content. A positive correlation did exist between total tocopherol content and linoleate content (420 to 590 g kg^{-1}) and total polyunsaturated fatty acid content .

Carrão-Panizzi and Erhan (2007) examined 89 Brazilian soybean cultivars grown under similar environmental conditions for tocopherol content. They observed a positive correlation of 0.23 between α-tocopherol and linolenate, a positive correlation between δ-tocopherol and oleate of 0.34, a negative correlation between δ-tocopherol and linoleate of -0.33, and a negative correlation between δ-tocopherol and stearate of -0.24. The fatty ester content of the 89 cultivars in their study was not provided.

Warner and Fehr (2008) compared oil from soybean cultivars with about 500 g kg^{-1} oleate and 10 g kg^{-1} linolenate to soybean oil with normal-oleate and reduced-linolenate (11 g kg^{-1}) conventional soybean oil, and hydrogenated soybean oil. They evaluated the tocopherol contents of the oils because of their possible influence on the performance characteristics. Before frying, the total tocopherol content of the mid-oleate and reduced-linolenate oil was 952 ppm, which was composed of 151 ppm α-tocopherol, 21 ppm β-

tocopherol, 608 ppm γ-tocopherol, and 172 ppm δ-tocopherol. The oil with conventional-oleate and reduced-linolenate had a total tocopherol content of 903 ppm, with 96 ppm α-tocopherol, 18 ppm β-tocopherol, 597 ppm γ-tocopherol, and 192 ppm δ-tocopherol. The conventional soybean oil had 985 ppm total tocopherol, with 89 ppm α-tocopherol, 26 ppm β-tocopherol, 530 ppm γ-tocopherol, and 340 ppm δ-tocopherol. Each of the oils was processed independently; therefore, it was not possible to attribute differences in tocopherol content among the oils to their differences in fatty ester content.

MATERIALS AND METHODS

The lines used in this study originated from three segregating populations developed at Iowa State University as described by Scherder and Fehr (2008). To develop populations segregating for mid-oleate content, two mid-oleate (MO) lines with ~500 g kg^{-1} oleate and 10 g kg^{-1} linolenate were crossed to three conventional-oleate (CO) cultivars with ~260 g kg^{-1} oleate and 10 g kg^{-1} linolenate. The mid-oleate content of the two MO parents, AX18896-2 and AX18895-6, was derived from M23, a mid-oleate mutant line with the *ol* allele developed at Saga University, Japan (Rahman et al., 1994; Takagi and Rahman, 1996; Alt et al., 2005). In additional to the *ol* allele, the two MO parents had, on the average, 25% of their genetic background from M23 because they were two crossing generations away from the mutant line. The three CO cultivars used were IA2073, IA3024, and IA3025, which have the *fan1(A5)*, *fan2*, and *fan3* alleles for reduced linolenate (Fehr and Hammond, 2000). Population 1 (Pop1) was developed by crossing IA3024 to AX18896-2; population 2 (Pop2) by crossing IA3025 to AX18896-2, and population 3 (Pop3) by crossing IA2073 to AX18895-6.

In 2007, 27 $F_{3:5}$ MO and CO lines from Pop1 and Pop2, 27 $F_{4:6}$ MO and CO lines from Pop3, and two check cultivars, IA3023 and Macon, were grown in a randomized complete-block design at Ames, Carlisle, and Rippey, IA, with two replications at each location (Scherder and Fehr, 2008). The soil type at Ames is a Nicollet loam (fine-loamy, mixed, superactive, mesic Aquic Hapludoll); the soil type at Carlisle is a Tama silty clay loam (fine-silty, mixed, superactive, mesic Typic Agriudoll), and the soil type at Rippey is a Nicollet loam (fine-loamy, mixed, mesic Aquic Hapludoll). The harvested seed was used for tocopherol analysis in this study.

Of the 54 lines of each population evaluated by Scherder and Fehr (2008), the 20 MO lines with the highest mean oleate and less than 15 g kg^{-1} linolenate and the 20 CO lines with the lowest mean oleate and less than 15 g kg^{-1} linolenate averaged across locations were selected for tocopherol analysis. The two checks, IA3023 and Macon, also were analyzed for tocopherol content. The tocopherol analysis was done by high-performance liquid chromatography (HPLC) on 30 random seeds of each line from each replication and location. The 30 seeds were placed in five wells (six seeds per well) of an aluminum plate and crushed with a hydraulic press using 2.76 x 10^5 kPa of pressure. After being crushed, the seeds were soaked in 2 mL hexane for 10 hr. After soaking, a 0.3 mL sample of the hexane-oil mixture from each of the five wells was pooled together in a pre-weighed vial to be used for tocopherol analysis. Another 0.3 mL from each well was pooled in a second vial for fatty ester analysis. The samples for tocopherol analysis were placed under a chemical hood for 10 to 12 hr before being transferred to a vacuum oven (National Appliance Company, Portland, OR) equipped with a model 1300 Welch Duo-Seal vacuum pump (Sargent Welch Scientific Co., Skokie, IL) at ambient temperature to evaporate the hexane. After the hexane evaporated, the vials were re-weighed to determine the weight of the oil extracted. The samples were re-dissolved with HPLC-grade hexane (Fisher Scientific, Fair Lawn, NJ) to a total volume level even with the vial neck, which averaged 1.90 mL.

The 42 samples for each replication of a population were analyzed in field plot-order, and the two replications of a population from a location were analyzed together in an 84-sample HPLC run. External standards of α-, β-, γ-, and δ-tocopherol (Sigma-Aldrich, Inc., St. Louis, MO) were included at the beginning, middle, and end of each run and were used to calculate the amount of each tocopherol in each sample. A 20 μL aliquot of each sample was

injected. Samples were eluted with 1.5% (v/v) isopropanol in HPLC-grade hexane at a 0.7 mL min^{-1} flow rate with a Beckman Coulter System Gold® with UV detector (Beckman Coulter, Inc., Beckman, CA) at a wavelength of 292 nm. The column used was a 250 mm by 4.6 mm Lichrosorb® Si60 (ES Industries, West Berlin, NJ). Due to insufficient separation under our HPLC conditions, the integration of β-tocopherol was included with the γ-tocopherol.

The samples for fatty ester analysis were analyzed by gas chromatography as described by Hammond (1991). The samples for each replication of a population were analyzed in field plot-order. The fatty esters were converted to g kg^{-1} by multiplying the percentages by 10.

Data were analyzed as a randomized complete-block design using the MIXED procedure of SAS version 9.1 (SAS Institute, 2003). Environments and replications were considered random effects, and genotypes were considered fixed. Genotypes were partitioned into MO lines, CO lines, and the orthogonal contrast between the two types. The environment interactions with the three partitioned components were used to test for their significance by an *F*-test. Correlations were calculated on the means across environments for each line of each trait using the correlation (CORR) procedure of SAS version 9.1 (SAS Institute, 2003). The two check cultivars were not included in the statistical analysis. For further detail regarding statistical analysis, see Appendix D.

RESULTS AND DISCUSSION

The mean oleate content of the MO lines in each of the three populations was significantly greater than that of the CO lines, and the ranges among lines for the two types did not overlap in the three populations (Table 1). The average oleate content of MO lines in the three populations of 51.4 g kg^{-1} was ~two-fold greater than the 26.3 g kg^{-1} of the CO lines. The increase in oleate content of the MO lines was associated with a significant decrease in palmitate and linoleate in the three populations. The maximum difference in the mean linolenate content between MO and CO lines in the three populations was only 0.3 g kg^{-1}, and the mean stearate contents of the two types were not significantly different for any of the populations.

The mean total tocopherol content for the MO and the CO lines was similar when averaged across the three populations (Table 1). The average total tocopherol for the MO lines was 1789.1 mg kg^{-1} and for the CO lines was 1781.7 mg kg^{-1}. Although the average total tocopherol for the two types of lines was similar, the relationship between the two traits was not consistent in the three populations. For Pop1, the mean total tocopherol of the MO lines was greater than that of the CO lines, but the difference between the two types was not significant. The positive phenotypic correlation between oleate and total tocopherol was significant for the population (Table 2). For Pop2, the difference between the two types of lines and the phenotypic correlation between the two traits were not significant. For Pop3, the MO lines had significantly lower mean total tocopherol than the CO lines, and the negative phenotypic correlation was significant.

There was significant variation among the MO lines for total tocopherol content, and their ranges in the three populations overlapped with those of the CO lines (Table 1). This indicated that it should be possible to develop MO soybean cultivars that have total tocopherol content similar to that of CO cultivars.

The increase in oleate content of the MO lines altered the relative content of the three tocopherol components (Table 1). Averaged across the populations, the MO lines had an increase of 27.6 mg kg^{-1} in α-tocopherol content, an increase of 56.2 mg kg^{-1} in δ-tocopherol, and a decrease of 76.5 mg kg^{-1} in γ-tocopherol compared with the CO lines. The average percentage of α-tocopherol in the total tocopherol of MO lines increased by 1.5 percentage units and δ-tocopherol by 3.0 units compared with CO lines. These increases for the MO type were accompanied by a 4.5 percentage unit decrease in γ-tocopherol compared with the CO type. These changes in the components generally were reflected in their phenotypic correlations with oleate content for all of the lines in the study (Table 2). All of the populations had significant positive correlations across all lines between oleate and α-tocopherol and δ-tocopherol and two of the populations had significant negative correlations across all lines between oleate and γ-tocopherol. The positive correlations between oleate and δ-tocopherol agreed with the significant correlation of 0.34 between the two traits reported by Carrão-Panizzi and Erhan (2007).

The ranges in the three tocopherol components overlapped for the MO and CO lines; however, the lines with the highest α-tocopherol and δ-tocopherol contents and the lowest γ-tocopherol were of the MO type in each of the populations (Table 1). Total tocopherol across lines was not significantly correlated with α-tocopherol in any of the three populations (Table 2). This result did not agree with those of McCord et al. (2004), Scherder et al.

(2006), and Carrão-Panizzi and Erhan (2007). McCord et al. (2004) reported significant positive correlations between total tocopherol and α-tocopherol that averaged 0.64 across all lines in three populations. Scherder et al. (2006) observed an average correlation coefficient of 0.54 across all lines in their populations, and Carrão-Panizzi and Erhan (2007) reported a correlation coefficient of 0.51 for the 89 cultivars in their study. In the studies of McCord et al. (2004) and Scherder et al. (2006), the tocopherol components responded to the fatty ester modification in a similar manner to each other. In McCord et al. (2004), all of the tocopherol components decreased with reduced-linolenate, and in Scherder et al. (2006), all of the components increased with reduced-palmitate. In this study, α-tocopherol and δ-tocopherol increased with mid-oleate while γ-tocopherol, the component with the highest proportion of total tocopherol, decreased with mid-oleate. This could have contributed to the disagreement between this study and those of McCord et al. (2004) and Scherder et al. (2006).

In the three populations, the correlation coefficients between total tocopherol and γ-tocopherol were significantly positive and averaged 0.89 (Table 2). These results were consistent with the correlation of 0.79 reported by McCord et al. (2004), the 0.96 reported by Scherder et al. (2006), and the 0.96 reported by Carrão-Panizzi and Erhan (2007).

The relationship between total tocopherol and δ-tocopherol was not consistent among our populations. The correlation between the two traits was positive in Pop1 and Pop2 and negative in Pop3. The correlation coefficients reported by McCord et al. (2004), Scherder et al (2006), and Carrão-Panizzi and Erhan (2007) were all positive. McCord et al. (2004) reported a correlation of 0.81 across three populations; Scherder et al. (2006) reported a correlation of 0.93 across populations, and Carrão-Panizzi and Erhan (2007) reported a correlation of 0.84 across 89 cultivars.

The effectiveness of selection for total tocopherol content among MO lines in a breeding program would depend on the influence of genotype x environment interaction. The genotype x environment interaction for total tocopherol content of MO lines was not significant for Pop1 and Pop3, but was significant for Pop2. The impact of these results on selection was evaluated by correlating the total tocopherol content of the MO lines at each location with the other two locations (Table 3). Although there was no significant genotype x environment interaction in Pop1, none of the three locations was significantly correlated to another. For Pop2, which had a significant genotype x environment interaction, the three locations were significantly correlated with each other. In Pop3, Carlisle was significantly correlated with Rippey, but neither location was correlated with Ames. These results indicated that the significance of the genotype x environment interaction in the analysis of variance was not a useful indicator of the relative performance among lines for total tocopherol content. The significance of the interaction was directly associated with the magnitude of the error mean squares. Pop1 and Pop3 had large error mean squares and Pop2 had a much smaller error mean squares.

Another method used to determine the effectiveness of selection among MO lines for total tocopherol was to compare their ranking at the individual locations (Tables 4, 5, and 6). Pop2 had the most consistency across locations when selecting the lines with the highest and lowest total tocopherol (Table 5). The four MO lines with the greatest mean total tocopherol were in the top four lines at each of the locations. For that population, selection of the top four lines for total tocopherol could have been done effectively at any one of the three locations. For Pop1 and Pop3, only one of the four lines with the greatest mean total tocopherol was in the top four lines at all of the locations. For those populations, it would

have been necessary to select about the top half of the lines for total tocopherol at any one location in order to include the four lines with the greatest mean total tocopherol across locations. These results indicated that selection for total tocopherol at one location can be effective for eliminating about half of the lines. Once that selection has been made, multiple locations of testing would be necessary to select the lines with the greatest total tocopherol across the environments that would be encountered in commercial production of a cultivar.

In summary, MO cultivars with reduced linolenate would be expected on the average to have similar total tocopherol, higher α-tocopherol and δ-tocopherol, and lower γ-tocopherol than cultivars with normal oleate and reduced linolenate. There was sufficient genetic variation among MO lines for total tocopherol and its components to select for contents of each that would have the greatest economic value to end users.

Table 1. Mean and range for seed traits of 20 mid-oleate and 20 conventional-oleate soybean lines from three populations grown in three environments in 2007.

		Population											
		1				2				3			
Trait	Type‡	Mean	Range			Mean	Range			Mean	Range		
Oleate	MO	512.7	490.2	–	534.4**	517.6	484.9	–	550.9**	512.5	481.7		542.1**
(g kg^{-1})	CO	271.8**	260.5	–	289.5**	263.7**	244.6	–	276.3**	252.8**	230.0	–	275.8**
Linolenate	MO	12.6	11.9	–	13.5ns	12.1	11.4	–	13.8**	12.0	11.4	–	12.9**
(g kg^{-1})	CO	12.9ns†	12.0	–	14.0**	12.4ns	11.7	–	14.0ns	12.2*	11.2	–	13.5**
Total Tocopherol	MO	1849.3	1469.9	–	2026.3*	1859.4	1652.3	–	2050.3**	1658.7	1480.5	–	1772.1*
(mg kg^{-1})	CO	1667.8ns	1401.4	–	2006.1*	1890.4ns	1741.4	–	2043.5**	1787.0*	1660.8	–	1917.1ns
α-Tocopherol	MO	167.8	125.5	–	218.7**	187.9	129.2	–	290.9**	128.0	90.7	–	153.4**
(mg kg^{-1})	CO	134.1**	114.3	–	163.8**	155.6**	127.1	–	185.6**	111.0ns	88.7	–	141.7**
γ-Tocopherol	MO	1171.0	811.6	–	1328.6*	1235.5	1083.6	–	1405.1**	1139.9	1006.4	–	1241.4**
(mg kg^{-1})	CO	1082.2ns	794.6	–	1371.5*	1375.8*	1261.3	–	1513.6**	1318.0*	1226.9	–	1422.0**
δ-Tocopherol	MO	510.5	413.3	–	603.1**	435.9	358.6	–	502.5**	390.8	317.5	–	467.2ns
(mg kg^{-1})	CO	451.5**	395.4	–	520.2**	359.0**	311.7	–	422.1**	358.0*	269.4	–	437.2ns
Palmitate	MO	91.5	88.7	–	99.0**	95.3	89.0	–	104.5**	90.7	86.1	–	95.4**
(g kg^{-1})	CO	106.6**	102.3	–	111.5**	109.5**	104.9	–	115.3**	106.2**	101.5	–	114.8**
Stearate	MO	43.7	40.6	–	48.1**	45.4	42.4	–	48.8**	43.2	40.5	–	46.5**
(g kg^{-1})	CO	42.7ns	39.6	–	45.3**	45.1ns	41.4	–	50.1**	44.0ns	41.4	–	47.1**
Linoleate	MO	339.6	315.6	–	366.2**	329.6	295.7	–	351.3**	341.8	319.0	–	369.1**
(g kg^{-1})	CO	566.1**	549.5	–	577.9**	569.4**	553.4	–	587.7**	584.8**	562.9	–	608.8**

* Differences between the means of types or among lines within a type were significant at the 0.05 probability level

** Differences between the means of types or among lines within a type were significant at the 0.01 probability level

†ns = differences between the means of types or among lines within a type were not significant at the 0.05 probability level

‡ MO = mid-oleate lines, CO = conventional-oleate lines

Table 2. Phenotypic correlation coefficients among traits for mid-oleate, conventional-oleate, and all soybean lines from three populations.

Trait	Type‡	Tocopherol (mg kg^{-1}) α	γ	δ	Total
			Population 1		
Oleate	M	0.27ns†	-0.16ns	0.13ns	-0.04ns
(g kg^{-1})	C	0.42ns	0.17ns	-0.26ns	0.14ns
	A	0.68**	0.30ns	0.54**	0.50**
α-Tocopherol	M		-0.17ns	-0.57**	-0.21ns
(mg kg^{-1})	C		-0.38ns	-0.45*	-0.37ns
	A		0.03ns	0.02ns	0.17ns
γ-Tocopherol	M			0.25ns	0.94**
(mg kg^{-1})	C			0.49*	0.99**
	A			0.43**	0.95**
δ-Tocopherol	M				0.52*
(mg kg^{-1})	C				0.61**
	A				0.66**
			Population 2		
Oleate	M	-0.08ns	-0.30ns	-0.16ns	-0.31ns
(g kg^{-1})	C	-0.12ns	0.12ns	0.10ns	0.10ns
	A	0.53**	-0.67**	0.66**	-0.17ns
α-Tocopherol	M		-0.46*	-0.45*	-0.27ns
(mg kg^{-1})	C		0.28ns	-0.33ns	0.31ns
	A		-0.49**	0.11ns	-0.15ns
γ-Tocopherol	M			0.69**	0.93**
(mg kg^{-1})	C			0.37ns	0.97**
	A			-0.14ns	0.80**
δ-Tocopherol	M				0.85**
(mg kg^{-1})	C				0.54*
	A				0.44**
			Population 3		
Oleate	M	0.06ns	-0.16ns	-0.09ns	-0.19ns
(g kg^{-1})	C	-0.03ns	-0.09ns	0.30ns	0.05ns
	A	0.45**	-0.82**	0.42**	-0.69**
α-Tocopherol	M		0.24ns	-0.41ns	0.21ns
(mg kg^{-1})	C		0.59**	-0.58**	0.55*
	A		-0.15ns	-0.20ns	-0.06ns
γ-Tocopherol	M			-0.25ns	0.85**
(mg kg^{-1})	C			-0.39ns	0.92**
	A			-0.50**	0.93**
δ-Tocopherol	M				0.26ns
(mg kg^{-1})	C				-0.05ns
	A				-0.20ns

* Significant at the 0.05 probability level

** Significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡M = mid-oleate lines, C = conventional-oleate lines, A = all lines

Table 3. Phenotypic correlation coefficients for total tocopherol content among locations for mid-oleate, conventional-oleate, and all soybean lines from three populations in 2007.

		Location	
Location	Type‡	Carlisle	Rippey
		Population 1	
Ames	M	0.20ns†	0.41ns
	C	0.18ns	0.20ns
	A	0.05ns	0.22ns
Carlisle	M		0.25ns
	C		0.53*
	A		0.55**
		Population 2	
Ames	M	0.86**	0.85**
	C	0.86**	0.84**
	A	0.84**	0.76**
Carlisle	M		0.94**
	C		0.90**
	A		0.91**
		Population 3	
Ames	M	0.11ns	0.43ns
	C	0.00ns	-0.05ns
	A	0.24ns	0.37*
Carlisle	M		0.46*
	C		0.56*
	A		0.71**

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ M = mid-oleate lines, C = conventional-oleate lines, A = all lines

Table 4. Means and ranks for total tocopherol content of 20 mid-oleate and 20 conventional-oleate lines for Population 1, IA3024 x AX18896-2, at all locations in 2007.

Entry	Type†	Location						Overall Mean	Rank
		Ames		Carlisle		Rippey			
		Mean	Rank	Mean	Rank	Mean	Rank		
		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})	
418001	MO	1646.7	20	1799.9	14	1820.2	12	1755.6	17
418002	MO	1786.2	16	1924.0	8	1648.0	17	1786.1	16
418003	MO	1824.2	13	1474.2	20	1111.2	20	1469.9	20
418004	MO	2078.6	1	2010.8	3	1737.2	14	1942.2	8
418005	MO	1677.1	19	1945.5	6	2019.6	4	1880.8	9
418007	MO	2041.1	4	1952.6	4	1993.1	8	1995.6	3
418008	MO	1843.3	12	1877.4	10	1789.2	13	1836.7	12
418010	MO	1925.4	11	1805.1	12	1633.2	18	1787.9	15
418011	MO	1949.4	9	1950.4	5	1980.6	9	1960.1	6
418012	MO	1798.1	14	1788.6	15	1927.1	10	1837.9	11
418014	MO	1948.2	10	1926.5	7	1652.4	16	1842.4	10
418016	MO	1681.3	18	1640.2	17	1702.3	15	1674.6	18
418017	MO	1949.7	8	2012.6	2	2044.2	2	2002.2	2
418018	MO	2035.4	5	1820.8	11	2008.1	6	1954.7	7
418019	MO	1978.7	7	1485.5	19	1993.3	7	1819.2	14
418020	MO	1727.3	17	1726.5	16	1489.3	19	1647.7	19
418022	MO	2046.5	3	1533.3	18	2324.2	1	1968.0	5
418024	MO	1995.9	6	1909.2	9	2032.8	3	1979.3	4
418026	MO	1788.0	15	1803.9	13	1865.7	11	1819.2	13
418027	MO	2053.3	2	2017.4	1	2008.1	5	2026.3	1
418028	CO	2014.4	4	1520.7	7	1606.2	8	1713.8	8
418029	CO	1873.4	15	1048.3	18	1480.8	14	1467.5	18
418030	CO	2008.7	6	1405.1	14	1220.5	19	1544.8	15
418031	CO	1923.3	11	1475.4	10	1917.3	6	1772.0	7
418032	CO	1699.0	20	1310.0	16	1461.0	16	1490.0	17
418034	CO	2092.3	1	1408.8	13	1510.4	13	1670.5	10
418035	CO	1978.2	7	1081.7	17	1769.8	7	1609.9	11
418036	CO	2011.6	5	1636.2	5	2006.4	2	1884.8	3
418037	CO	1778.1	19	1420.5	12	1528.6	12	1575.7	13
418039	CO	1877.3	14	1967.4	2	1936.7	4	1927.1	2
418040	CO	1928.8	10	1559.2	6	1583.8	9	1690.6	9
418041	CO	1886.7	13	1900.5	3	1571.3	10	1786.2	6
418042	CO	1850.9	17	1872.6	4	1917.9	5	1880.4	4
418043	CO	2041.6	3	1984.8	1	1991.8	3	2006.1	1
418046	CO	1952.6	9	1450.1	11	1170.1	20	1524.3	16
418048	CO	2042.3	2	1498.8	8	2020.7	1	1853.9	5
418049	CO	1892.2	12	1486.8	9	1266.8	17	1548.6	14
418050	CO	1964.0	8	1012.8	19	1227.4	18	1401.4	20
418051	CO	1778.5	18	959.4	20	1473.4	15	1403.8	19
418054	CO	1866.0	16	1392.0	15	1553.1	11	1603.7	12
	SEM‡	76.5		268.4		242.6		142.3	
	LSD 0.05	220.5		777.4		642.2		340.8	
	LSD 0.01	295.2		1040.8		859.7		451.9	

† MO = mid-oleate lines, CO = conventional-oleate lines
‡ SEM = standard error of the mean

Table 5. Means and ranks for total tocopherol content of 20 mid-oleate and 20 conventional-oleate lines for Population 2, IA3025 x AX18896-2, at all locations in 2007.

Entry	Type†	Location						Overall Mean	Rank
		Ames		Carlisle		Rippey			
		Mean	Rank	Mean	Rank	Mean	Rank		
		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})	
419002	MO	1885.3	10	1800.2	10	1992.8	7	1892.8	9
419006	MO	1730.0	19	1621.4	18	1734.9	17	1695.4	19
419007	MO	1917.9	8	1816.2	9	2002.1	6	1912.1	8
419008	MO	1809.7	16	1631.6	17	1689.8	19	1710.4	18
419009	MO	1987.9	4	1898.9	3	2108.5	1	1998.5	3
419010	MO	2006.1	3	1886.8	5	2071.9	4	1988.3	4
419011	MO	2030.1	2	1957.6	1	2075.6	3	2021.1	2
419012	MO	1953.2	7	1865.1	7	2017.0	5	1945.1	5
419013	MO	1862.7	13	1597.2	19	1729.1	18	1729.7	17
419014	MO	1844.9	14	1737.6	13	1857.7	13	1813.4	13
419015	MO	1711.6	20	1580.1	20	1665.0	20	1652.2	20
419017	MO	1954.0	6	1891.0	4	1972.6	9	1939.2	7
419018	MO	1875.4	11	1671.2	16	1795.7	16	1780.8	15
419020	MO	2135.0	1	1924.0	2	2091.9	2	2050.3	1
419021	MO	1785.7	18	1701.7	14	1842.2	15	1776.5	16
419022	MO	1901.3	9	1745.6	11	1943.2	10	1863.4	10
419023	MO	1798.0	17	1686.3	15	1896.3	12	1793.5	14
419025	MO	1979.8	5	1876.4	6	1977.3	8	1944.5	6
419026	MO	1838.3	15	1841.6	8	1908.0	11	1862.6	11
419027	MO	1863.9	12	1738.5	12	1851.1	14	1817.8	12
419028	CO	1834.5	18	1681.5	19	1789.3	19	1768.5	19
419029	CO	1896.6	15	1689.5	18	1751.9	20	1779.4	18
419030	CO	1962.2	9	1826.8	8	1955.4	7	1914.8	8
419031	CO	1935.2	13	1732.5	14	1882.9	9	1850.2	12
419032	CO	2089.7	4	1917.4	5	2021.8	2	2009.6	5
419033	CO	2051.1	7	1845.8	6	1970.9	6	1955.9	6
419034	CO	1955.7	10	1833.9	7	1818.4	16	1869.3	10
419036	CO	2176.6	1	1936.1	3	2017.7	4	2043.5	1
419037	CO	1764.4	20	1664.0	20	1795.7	18	1741.4	20
419038	CO	1964.7	8	1723.5	15	1858.0	15	1848.7	13
419039	CO	1866.4	16	1753.1	13	1871.5	13	1830.3	15
419040	CO	1940.0	12	1780.0	12	1866.8	14	1862.2	11
419041	CO	1922.4	14	1819.9	9	1875.4	12	1872.6	9
419043	CO	1944.1	11	1708.1	17	1877.2	11	1843.1	14
419045	CO	2123.6	2	1951.5	1	2012.2	5	2029.1	2
419046	CO	2068.5	5	1933.6	4	2059.5	1	2020.5	4
419048	CO	1825.2	19	1780.7	11	1878.9	10	1828.2	16
419051	CO	2109.6	3	1946.0	2	2020.5	3	2025.4	3
419052	CO	2068.3	6	1796.5	10	1896.7	8	1920.5	7
419054	CO	1847.1	17	1722.5	16	1813.9	17	1794.5	17
	SEM‡	47.1		30.6		25.7		51.1	
	LSD 0.05	116.4		88.5		69.9		73.9	
	LSD 0.01	155.8		118.5		93.6		98.0	

† MO = mid-oleate lines, CO = conventional-oleate lines
‡ SEM = standard error of the mean

Table 6. Means and ranks for total tocopherol content of 20 mid-oleate and 20 conventional-oleate lines for Population 3, IA2073 x AX18895-6, at all locations in 2007.

Entry	Type†	Location						Overall Mean	Rank
		Ames		Carlisle		Rippey			
		Mean	Rank	Mean	Rank	Mean	Rank		
		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})		(mg kg^{-1})	
420001	MO	1994.0	1	1521.0	17	1558.0	11	1691.0	8
420002	MO	1783.4	13	1675.0	6	1610.2	4	1689.6	9
420004	MO	1911.3	2	1719.3	3	1513.2	16	1714.6	5
420006	MO	1797.6	12	1649.8	11	1409.0	19	1618.8	15
420008	MO	1907.7	3	1791.9	1	1616.7	3	1772.1	1
420009	MO	1897.0	4	1550.2	15	1668.5	1	1705.2	6
420011	MO	1832.0	10	1390.0	20	1483.2	17	1568.4	18
420012	MO	1886.7	6	1654.7	10	1666.4	2	1735.9	2
420013	MO	1615.4	20	1463.8	18	1362.3	20	1480.5	20
420014	MO	1698.2	17	1658.4	8	1588.7	8	1648.4	12
420015	MO	1657.2	19	1698.4	4	1559.0	10	1638.2	13
420016	MO	1749.3	14	1656.4	9	1608.8	5	1671.5	11
420017	MO	1895.9	5	1675.1	5	1592.2	7	1721.0	4
420019	MO	1871.3	7	1460.6	19	1546.5	14	1626.1	14
420020	MO	1688.6	18	1616.5	13	1540.4	15	1615.2	17
420021	MO	1855.2	8	1620.3	12	1556.2	12	1677.2	10
420022	MO	1698.5	16	1604.1	14	1546.9	13	1616.5	16
420025	MO	1850.3	9	1745.4	2	1581.1	9	1725.6	3
420026	MO	1723.5	15	1526.8	16	1438.9	18	1563.1	19
420027	MO	1821.3	11	1659.1	7	1605.3	6	1695.2	7
420029	CO	1814.6	15	1652.4	17	1609.1	17	1692.0	19
420030	CO	2042.1	2	1786.8	11	1815.1	2	1881.3	3
420031	CO	1754.6	19	1859.1	8	1766.6	5	1793.4	9
420032	CO	1943.8	6	1719.4	15	1607.0	18	1756.7	13
420033	CO	1965.2	4	1825.6	10	1654.4	14	1815.0	7
420034	CO	1925.6	7	1898.4	4	1733.7	10	1852.5	5
420035	CO	2075.3	1	1866.9	6	1705.6	11	1882.6	2
420037	CO	1951.8	5	1644.6	18	1560.1	19	1718.8	18
420038	CO	1905.9	8	1526.9	20	1750.9	8	1727.9	16
420039	CO	1839.8	13	1596.4	19	1546.1	20	1660.7	20
420040	CO	1782.6	16	1724.6	14	1752.8	7	1753.4	14
420041	CO	1873.3	11	1727.1	13	1636.8	15	1745.8	15
420044	CO	1768.6	18	1877.9	5	1757.6	6	1801.4	8
420045	CO	1848.5	12	1656.4	16	1676.4	12	1727.1	17
420047	CO	1818.0	14	1866.8	7	1636.7	16	1773.8	11
420048	CO	1981.9	3	1999.4	1	1770.0	3	1917.1	1
420049	CO	1709.4	20	1855.4	9	1766.9	4	1777.3	10
420051	CO	1882.6	10	1727.3	12	1672.5	13	1760.8	12
420052	CO	1780.4	17	1956.5	2	1745.7	9	1827.5	6
420053	CO	1889.1	9	1908.6	3	1825.2	1	1874.3	4
	SEM‡	145.5		120.9		39.0		81.6	
	LSD 0.05	260.6		254.6		100.1		146.4	
	LSD 0.01	348.9		340.8		134.0		194.2	

† MO = mid-oleate lines, CO = conventional-oleate lines

‡ SEM = standard error of the mean

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APPENDIX A

ANALYSES OF VARIANCE AND ENTRY MEANS FOR SEED TRAITS ACROSS LOCATIONS

Table A1. Analysis of variance for Population 1, IA3024 x AX18896-2, across three Iowa environments in 2007.

		Mean Squares						
Sources of variation‡	df	Oleate (g kg-1)	Linolenate (g kg-1)	Total Tocopherol (mg kg-1)	α-Tocopherol (mg kg-1)	α-Tocopherol (% of total)	γ-Tocopherol (mg kg-1)	γ-Tocopherol (% of total)
E	2	22945.0*	11.6ns†	1430107.0ns	23667.0**	239.3*	1330030.0ns	1266.3ns
R/E	3	1071.2**	8.7**	262003.0*	207.4ns	14.1*	381902.0**	412.9**
G	39	89932.0**	1.5**	202772.0**	3991.7**	17.1**	135509.0*	84.7*
M	19	934.2**	1.2ns	118081.0*	3599.1**	19.0**	89913.0*	68.0*
C	19	346.0**	1.6**	194035.0*	990.1**	15.0**	163349.0*	105.8*
M vs C	1	3483014.2**	5.5ns	1977934.6ns	68480.2**	19.6ns	472876.9ns	0.2ns
G x E	78	277.6ns	0.6ns	87885.0ns	355.3**	4.9ns	77320.0ns	52.8ns
M x E	38	329.0ns	0.8*	56932.0ns	509.1**	4.5ns	44248.0ns	32.8ns
C x E	38	132.3ns	0.4ns	82743.0ns	207.2ns	3.7ns	77783.0ns	53.8ns
M vs C x E	2	2061.7**	0.3ns	773667.6**	246.9ns	34.6**	696872.1**	414.2**
Error	117	265.5	0.5	86803.0	213.0	4.6	75419.0	53.3
CV (%)		4.3	6.1	16.9	12.5	24.6	24.7	11.6

		Mean Squares				
Sources of variation	df	δ-Tocopherol (mg kg-1)	δ-Tocopherol (% of total)	Palmitate (g kg-1)	Stearate (g kg-1)	Linoleate (g kg-1)
E	2	276795.0*	1183.5ns	294.1**	1372.0**	16476.0*
R/E	3	15466.0**	281.5**	11.6**	0.8ns	805.8*
G	39	18483.0**	54.4*	391.5**	21.8**	79635.0**
M	19	19405.0**	55.5**	40.8**	23.0**	1035.8**
C	19	7539.9**	54.9ns	43.2**	18.5**	369.6**
M vs C	1	208887.7**	23.6ns	13672.1**	61.1ns	3079052.4**
G x E	78	2799.2ns	32.5ns	4.3**	3.5*	227.5ns
M x E	38	3571.2ns	19.3ns	3.6ns	2.5ns	285.6ns
C x E	38	2128.2ns	35.6ns	4.1*	2.1ns	115.8ns
M vs C x E	2	881.3ns	223.8**	20.2**	47.7**	1246.6**
Error	117	2939.7	30.8	2.6	2.2	237.9
CV (%)		11.0	20.2	2.1	4.3	3.3

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ E = environments, R/E = replications within environment, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table A2. Analysis of variance for Population 2, IA3025 x AX18896-2, across three Iowa environments in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate (g kg-1)	Linolenate (g kg-1)	Total Tocopherol (mg kg-1)	α-Tocopherol (mg kg-1)	α-Tocopherol (% of total)	γ-Tocopherol (mg kg-1)	γ-Tocopherol (% of total)
E	2	40661.0**	17.3ns†	466492.0**	27268.0**	112.9**	318733.0**	145.8**
R/E	3	817.3*	7.2**	18180.0**	361.8ns	0.5**	12520.0**	1.9*
G	39	100254.0**	2.0*	66786.0**	5424.5**	19.7ns	68124.0**	72.5**
M	19	1665.3**	2.0**	80038.0**	5977.5**	23.5**	43117.0**	17.0**
C	19	554.9**	1.8ns	54014.0**	1851.2**	4.9**	34565.0**	6.3**
M vs C	1	3867734.9**	6.4ns	57692.6ns	62810.1**	227.5**	1180885.5*	2385.3**
G x E	78	350.0ns	1.2ns	4134.2**	317.3*	1.0**	2404.8*	1.2**
M x E	38	414.9ns	0.8ns	3707.0*	506.2**	1.6**	2233.3ns	1.5**
C x E	38	114.1ns	1.3ns	2954.5ns	136.7ns	0.3ns	1757.4ns	1.0ns
M vs C x E	2	3030.0**	4.2*	34667.2**	156.1ns	0.7ns	17961.9**	0.0ns
Error	117	277.6	1.1	2410.7	209.4	0.5	1509.5	0.7
CV (%)		4.8	9.0	3.4	10.4	10.8	3.8	1.6

Sources of variation	df	Mean Squares				
		δ-Tocopherol (mg kg-1)	δ-Tocopherol (% of total)	Palmitate (g kg-1)	Stearate (g kg-1)	Linoleate (g kg-1)
E	2	205772.0**	433.6**	303.0**	881.8*	29327.0**
R/E	3	422.4ns	1.3ns	9.5*	82.9**	582.0ns
G	39	20028.0**	43.6**	377.0**	21.4**	89478.0**
M	19	17202.0**	19.7**	98.1**	19.5**	1469.9**
C	19	5220.7**	9.8**	45.2**	24.0**	686.4**
M vs C	1	355060.4**	1139.2**	11982.2**	6.5ns	3448659.9**
G x E	78	549.7**	0.9ns	4.4**	4.8**	297.7ns
M x E	38	637.0**	1.3ns	4.9**	3.2*	362.6ns
C x E	38	347.0ns	0.5ns	3.1ns	3.0*	143.8ns
M vs C x E	2	2741.3**	0.8ns	21.9**	69.6**	1989.3**
Error	117	314.0	0.9	2.6	1.8	246.4
CV (%)		5.9	4.5	2.1	4.8	3.8

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ E = environments, R/E = replications within environment, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table A3. Analysis of variance for Population 3, IA2073 x AX18895-6, across three Iowa environments in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate (g kg-1)	Linolenate (g kg-1)	Total Tocopherol (mg kg-1)	α-Tocopherol (mg kg-1)	α-Tocopherol (% of total)	γ-Tocopherol (mg kg-1)	γ-Tocopherol (% of total)
E	2	19705.0**	4.9ns†	964976.0ns	65009.0ns	115.8*	2638153.0**	3136.9ns
R/E	3	211.2ns	1.2ns	541501.0**	7027.2**	5.9**	81189.0**	459.9**
G	39	104936.0**	1.3**	53494.0**	2172.3**	8.7**	73976.0**	61.8**
M	19	1550.9**	0.9**	29124.0*	1546.2**	5.7**	25730.0**	27.4*
C	19	828.0**	1.7**	28725.0ns	1992.9**	5.0**	25941.0**	13.8ns
M vs C	1	4047320.6**	4.1*	987136.4*	17476.6ns	135.0**	1903304.8*	1629.0*
G x E	78	508.8**	0.5ns	16224.0ns	221.9ns	0.5ns	6607.4**	11.6**
M x E	38	410.0**	0.3ns	12543.0ns	235.9ns	0.6ns	5353.9ns	13.4**
C x E	38	204.6ns	0.7ns	18057.0*	161.2ns	0.4ns	6248.2*	8.8ns
M vs C x E	2	8164.8**	0.1ns	51326.8*	1107.2**	0.8ns	37247.6**	28.8*
Error	117	230.0	0.6	11630.0	210.5	0.6	3628.0	6.7
CV (%)		5.9	5.9	7.4	12.5	10.2	6.6	4.8

Sources of variation	df	Mean Squares				
		δ-Tocopherol (mg kg-1)	δ-Tocopherol (% of total)	Palmitate (g kg-1)	Stearate (g kg-1)	Linoleate (g kg-1)
E	2	838277.0ns	4405.0*	235.9**	167.0**	15223.0**
R/E	3	237091.0**	436.3**	8.4**	1.4ns	279.4ns
G	39	9625.0*	50.4**	435.1**	19.2**	92041.0**
M	19	10091.0ns	35.3*	51.3**	18.3**	1376.6**
C	19	6274.2ns	24.6**	76.3**	19.1**	942.8**
M vs C	1	64442.5*	826.1*	14545.5**	38.0ns	3545540.6**
G x E	78	5986.0*	13.1**	4.0**	2.7**	409.8**
M x E	38	6436.3ns	14.9**	4.8**	2.8**	327.1*
C x E	38	5782.8ns	9.9ns	1.5ns	1.2ns	179.8ns
M vs C x E	2	1290.3ns	39.2**	37.5**	28.1**	6349.0**
Error	117	4274.3	8.1	1.9	1.4	198.1
CV (%)		20.7	16.5	2.0	3.8	4.4

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ E = environments, R/E = replications within environment, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table A4. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 1, IA3024 x AX18896-2, across three Iowa environments in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418001	MO	490.2	12.8	1755.6	185.7	10.6	1146.6	65.4	423.3	24.0	90.2	40.6	366.2
418002	MO	494.0	12.9	1786.1	163.7	9.3	1148.7	63.5	473.6	27.2	90.9	45.2	357.0
418003	MO	519.8	12.2	1469.9	195.5	14.1	811.6	52.8	462.7	33.1	88.7	41.8	337.6
418004	MO	516.6	12.9	1942.2	173.7	9.2	1213.1	61.4	555.4	29.4	89.1	42.8	338.6
418005	MO	530.4	13.0	1880.8	176.7	9.4	1229.8	65.3	474.3	25.3	90.0	44.1	322.5
418007	MO	512.1	13.5	1995.6	175.5	8.8	1300.9	65.2	519.2	26.0	89.7	44.7	340.0
418008	MO	496.3	12.1	1836.7	173.6	9.4	1239.8	67.5	423.3	23.1	92.2	43.9	355.7
418010	MO	506.0	13.4	1787.9	143.3	8.2	1056.7	58.3	587.9	33.5	90.7	48.1	341.9
418011	MO	512.4	12.8	1960.1	153.4	7.8	1287.9	65.8	518.8	26.4	92.1	43.9	338.9
418012	MO	531.7	12.3	1837.9	173.6	9.5	1136.8	61.9	527.6	28.7	96.9	43.5	315.6
418014	MO	500.6	12.1	1842.4	125.5	6.9	1187.1	63.4	529.7	29.7	92.4	41.9	353.1
418016	MO	507.6	11.9	1674.6	169.6	10.3	1029.0	61.4	474.2	28.3	99.0	45.6	335.9
418017	MO	521.4	12.7	2002.2	152.1	7.6	1254.0	62.7	596.0	29.7	90.0	47.5	328.3
418018	MO	512.1	12.4	1954.7	142.9	7.3	1269.2	65.0	542.7	27.6	90.3	43.3	341.9
418019	MO	512.7	12.2	1819.2	128.6	7.6	1087.4	58.4	603.1	34.0	89.6	43.6	341.9
418020	MO	528.4	12.3	1647.7	171.4	10.7	1063.1	63.1	413.3	26.2	91.6	40.8	326.9
418022	MO	514.9	12.7	1968.0	161.6	8.8	1243.1	61.9	563.3	29.3	89.9	41.8	340.7
418024	MO	506.7	12.4	1979.3	215.1	10.9	1274.4	64.4	489.8	24.6	90.0	44.6	346.4
418026	MO	534.4	11.9	1819.2	218.7	12.0	1112.3	61.2	488.2	26.7	94.4	43.0	316.4
418027	MO	506.5	12.5	2026.3	154.9	7.6	1328.6	65.7	542.9	26.7	91.9	42.6	346.5
418028	CO	260.5	12.4	1713.8	122.6	7.6	1100.8	62.3	490.4	30.1	105.2	44.0	577.9
418029	CO	271.4	13.6	1467.5	143.6	10.8	915.2	59.8	408.7	29.5	104.4	44.3	566.4
418030	CO	261.6	12.6	1544.8	135.7	9.5	945.9	58.8	463.2	31.7	111.1	42.3	572.4
418031	CO	269.8	13.0	1772.0	118.1	7.2	1174.7	64.9	479.2	27.9	102.3	44.6	570.4

Table A4. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418032	CO	274.0	12.7	1490.0	132.4	9.4	962.2	62.3	395.4	28.3	109.9	45.3	558.1
418034	CO	275.4	12.0	1670.5	132.7	8.5	1107.3	64.0	430.5	27.6	111.5	41.0	560.1
418035	CO	266.9	12.7	1609.9	127.5	8.9	1051.6	62.1	430.8	28.9	106.8	41.0	572.7
418036	CO	274.7	14.0	1884.8	127.9	7.3	1301.3	67.9	455.5	24.8	105.7	43.4	562.2
418037	CO	279.9	12.8	1575.7	137.5	9.2	1017.2	62.3	421.1	28.4	106.8	41.9	558.6
418039	CO	285.7	13.9	1927.1	134.4	7.0	1328.4	69.0	464.3	24.1	107.5	43.5	549.5
418040	CO	270.0	12.5	1690.6	163.8	10.6	1082.8	61.2	444.0	28.1	103.6	39.6	574.5
418041	CO	289.5	12.6	1786.2	151.7	8.6	1188.9	65.4	445.6	26.0	105.4	39.6	552.9
418042	CO	262.3	12.8	1880.4	119.2	6.3	1290.3	68.7	470.9	25.0	110.1	44.4	570.3
418043	CO	262.6	13.7	2006.1	114.3	5.7	1371.5	68.4	520.2	25.9	106.9	43.4	573.5
418046	CO	269.4	12.8	1524.3	125.4	8.9	921.3	57.3	477.6	33.9	106.9	42.1	569.5
418048	CO	277.9	12.6	1853.9	127.4	7.4	1220.7	64.9	505.9	27.7	106.9	44.6	557.2
418049	CO	273.2	12.8	1548.6	158.9	10.9	936.1	57.6	453.6	31.6	106.9	40.4	570.2
418050	CO	269.3	12.4	1401.4	135.0	10.6	794.6	53.6	471.8	35.8	106.9	41.2	571.0
418051	CO	269.2	12.6	1403.8	135.6	10.7	869.6	58.9	398.6	30.4	106.9	44.1	571.6
418054	CO	272.6	12.8	1603.7	137.4	9.5	1064.4	63.9	401.9	26.5	106.9	42.6	563.8
SEM		11.9	0.4	142.3	12.5	1.3	134.6	3.7	40.1	3.2	106.9	2.5	10.3
LSD 0.05		19.2	0.9	340.8	21.7	2.5	319.6	8.4	60.8	6.5	106.9	2.1	17.3
LSD 0.01		25.4	1.2	451.9	28.7	3.4	423.9	11.1	80.7	8.7	106.9	2.8	23.0
IA3023		243.1	63.2	1912.2	125.2	6.6	1250.2	65.4	536.8	28.0	104.8	37.6	551.4
Macon		241.5	68.6	1750.8	129.9	8.0	1157.2	64.1	463.7	27.9	106.3	40.3	543.4

† MO = mid-oleate lines, CO = conventional-oleate lines

Table A5. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 2, IA3025 x AX18896-2, across three Iowa environments in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419002	MO	510.8	11.5	1892.8	177.3	9.4	1256.0	66.4	459.5	24.2	93.9	45.2	338.7
419006	MO	497.6	13.8	1695.4	197.3	11.7	1132.3	66.8	365.8	21.6	102.6	46.6	339.5
419007	MO	508.9	12.1	1912.1	225.4	11.8	1207.8	63.2	478.9	25.0	91.5	44.3	343.2
419008	MO	544.5	12.3	1710.4	195.4	11.4	1132.4	66.1	382.6	22.4	98.4	43.9	300.9
419009	MO	498.1	12.2	1998.5	198.1	10.0	1312.1	65.7	488.3	24.4	94.3	46.2	349.3
419010	MO	511.7	12.3	1988.3	156.5	7.9	1334.9	67.2	496.9	24.9	91.1	44.6	340.5
419011	MO	506.6	11.4	2021.1	184.3	9.1	1334.3	66.0	502.5	24.8	93.3	44.2	344.5
419012	MO	517.9	11.5	1945.1	179.2	9.2	1297.9	66.8	468.0	24.0	96.4	43.5	330.6
419013	MO	550.9	12.2	1729.7	201.1	11.6	1148.2	66.3	380.4	22.0	98.3	43.0	295.7
419014	MO	508.8	12.5	1813.4	290.9	16.1	1163.9	64.2	358.6	19.7	90.3	45.4	343.0
419015	MO	534.0	12.9	1652.2	192.2	11.7	1083.6	65.6	376.4	22.8	92.8	42.4	317.8
419017	MO	514.3	11.7	1939.2	169.6	8.8	1273.2	65.7	496.4	25.6	95.4	48.6	329.9
419018	MO	509.9	11.4	1780.8	170.7	9.6	1244.9	69.9	365.1	20.5	98.7	44.8	335.2
419020	MO	524.9	12.2	2050.3	178.6	8.7	1405.1	68.5	466.6	22.8	94.4	46.2	322.3
419021	MO	534.5	12.0	1776.5	194.4	11.0	1160.4	65.3	421.7	23.7	91.8	44.4	317.4
419022	MO	484.9	12.3	1863.4	162.9	8.8	1271.4	68.2	429.1	23.0	104.5	47.0	351.3
419023	MO	513.1	12.4	1793.5	168.3	9.4	1188.9	66.3	436.3	24.2	93.9	47.8	332.8
419025	MO	540.3	11.6	1944.5	129.2	6.7	1320.1	67.9	495.2	25.4	96.9	44.6	306.7
419026	MO	522.4	11.5	1862.6	191.7	10.3	1190.2	63.9	480.7	25.8	89.0	48.8	328.3
419027	MO	517.5	11.9	1817.8	195.6	10.8	1252.6	68.9	369.6	20.3	99.1	47.0	324.5
419028	CO	244.6	12.9	1768.5	180.1	10.2	1267.7	71.7	320.7	18.1	107.5	47.4	587.7
419029	CO	274.7	12.6	1779.4	148.7	8.4	1272.3	71.5	358.4	20.2	109.0	46.5	557.3
419030	CO	258.0	12.2	1914.8	136.1	7.1	1386.1	72.4	392.5	20.5	111.7	42.8	575.3
419031	CO	253.8	12.6	1850.2	168.5	9.1	1341.7	72.5	339.9	18.4	112.0	41.4	580.1

Table A5. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419032	CO	252.4	11.9	2009.6	146.7	7.3	1466.9	73.0	396.1	19.7	108.0	45.2	582.7
419033	CO	276.3	12.1	1955.9	152.1	7.8	1444.7	73.8	359.1	18.4	107.8	43.7	560.1
419034	CO	270.4	12.5	1869.3	146.7	7.8	1397.8	74.7	324.9	17.4	108.0	44.2	565.0
419036	CO	267.6	11.9	2043.5	175.1	8.6	1513.6	74.0	354.7	17.4	110.8	47.0	562.8
419037	CO	265.5	11.7	1741.4	150.4	8.7	1261.3	72.4	329.6	18.9	107.6	45.3	569.8
419038	CO	261.8	12.2	1848.7	131.7	7.2	1341.4	72.5	375.6	20.3	109.3	44.7	572.0
419039	CO	270.8	14.0	1830.3	170.2	9.3	1311.3	71.6	348.9	19.0	106.0	45.4	563.8
419040	CO	256.5	12.0	1862.2	127.1	6.8	1358.8	73.0	376.3	20.2	115.1	44.7	571.6
419041	CO	251.6	12.3	1872.6	169.9	9.1	1390.9	74.3	311.7	16.7	109.3	44.4	582.4
419043	CO	274.2	12.0	1843.1	157.0	8.6	1342.2	72.8	343.9	18.6	111.7	45.0	557.1
419045	CO	273.1	12.3	2029.1	169.2	8.3	1437.8	70.8	422.1	20.8	111.7	50.1	553.4
419046	CO	251.0	13.2	2020.5	174.0	8.6	1452.2	71.9	394.4	19.5	111.7	42.0	586.8
419048	CO	262.3	12.9	1828.2	152.7	8.4	1333.2	72.9	342.4	18.7	111.7	43.3	572.4
419051	CO	272.0	12.6	2025.4	185.6	9.2	1500.9	74.1	338.8	16.7	111.7	46.7	553.4
419052	CO	274.0	11.8	1920.5	133.8	7.0	1394.7	72.6	392.0	20.4	111.7	45.3	564.0
419054	CO	263.2	12.5	1794.5	136.1	7.6	1300.5	72.5	357.9	19.9	111.7	46.9	569.4
SEM		15.0	0.5	51.1	12.9	0.8	41.5	0.9	30.8	1.4	111.7	2.1	13.1
LSD 0.05		21.5	1.2	73.9	20.5	1.1	319.6	1.3	26.9	1.1	111.7	2.5	19.8
LSD 0.01		28.5	1.6	98.0	27.2	1.5	74.8	1.7	35.7	1.4	111.7	3.3	26.3
IA3023		251.3	64.4	1859.4	135.9	7.3	1291.0	69.4	432.6	23.2	103.6	38.8	541.8
Macon		236.0	74.6	1967.8	120.9	6.2	1454.4	73.9	392.5	19.9	107.5	40.0	542.0

† MO = mid-oleate lines, CO = conventional-oleate lines

Table A6. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 3, IA2073 x AX18895-6, across three Iowa environments in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420001	MO	500.0	11.6	1691.0	109.3	6.4	1147.8	67.6	434.0	26.0	93.8	43.3	351.3
420002	MO	542.1	11.8	1689.6	146.8	8.6	1168.4	68.8	374.3	22.5	86.7	40.5	319.0
420004	MO	505.2	12.1	1714.6	148.9	8.6	1193.9	69.3	371.8	22.1	92.7	41.6	348.4
420006	MO	504.8	12.2	1618.8	120.3	7.3	1031.4	63.6	467.2	29.1	90.2	46.5	346.3
420008	MO	524.8	11.6	1772.1	136.1	7.6	1220.6	68.8	415.3	23.6	88.3	44.7	330.7
420009	MO	487.5	12.9	1705.2	126.2	7.3	1168.3	68.4	410.8	24.3	90.8	40.8	368.1
420011	MO	528.6	12.1	1568.4	122.5	7.6	1052.2	66.7	393.7	25.7	89.9	46.3	323.2
420012	MO	507.2	12.3	1735.9	127.8	7.3	1165.7	67.3	442.4	25.5	94.1	44.2	342.3
420013	MO	533.8	11.7	1480.5	142.3	9.5	1006.4	67.9	331.8	22.6	90.2	42.8	321.5
420014	MO	511.1	12.6	1648.4	153.4	9.2	1161.6	70.3	333.4	20.5	86.1	42.5	347.7
420015	MO	499.6	11.7	1638.2	130.8	8.0	1190.0	72.6	317.5	19.5	95.1	44.6	349.2
420016	MO	527.0	12.5	1671.5	169.6	7.0	1197.3	71.4	356.9	21.6	88.0	43.7	328.9
420017	MO	481.7	12.0	1721.0	144.5	8.4	1241.4	72.0	335.2	19.6	95.4	42.3	368.6
420019	MO	512.8	11.9	1626.1	110.3	6.7	1143.9	70.1	372.0	23.3	88.2	45.5	341.7
420020	MO	517.5	11.4	1615.2	90.7	5.5	1119.1	69.0	405.4	25.5	91.0	43.6	336.5
420021	MO	527.2	11.9	1677.2	132.7	7.8	1136.8	67.6	407.7	24.6	93.2	41.1	326.6
420022	MO	519.8	11.4	1616.5	123.4	7.6	1108.2	68.3	384.9	24.1	94.1	43.0	331.7
420025	MO	514.0	11.7	1725.6	144.8	8.4	1154.2	67.0	426.6	24.7	87.2	41.1	346.0
420026	MO	487.9	11.9	1563.1	121.1	7.7	1024.1	65.4	417.9	26.9	87.8	43.2	369.1
420027	MO	517.0	12.1	1695.2	111.6	6.5	1167.2	68.7	416.4	24.7	90.2	42.3	338.5
420029	CO	253.2	11.2	1692.0	96.7	5.7	1238.5	73.1	356.8	21.2	108.7	47.1	579.9
420030	CO	255.7	12.2	1881.3	117.9	6.2	1403.5	74.5	360.0	19.3	104.5	43.0	584.6
420031	CO	240.6	12.0	1793.4	90.9	5.1	1344.4	75.1	358.2	19.8	101.5	45.2	600.8
420032	CO	263.6	13.5	1756.7	88.8	5.0	1296.9	73.7	371.0	21.3	108.4	45.8	568.7

Table A6. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420033	CO	257.1	12.4	1815.0	141.7	7.7	1353.1	74.6	320.3	17.7	106.4	41.9	582.3
420034	CO	265.8	12.2	1852.5	132.5	7.1	1389.9	75.1	330.2	17.8	108.3	43.6	570.1
420035	CO	255.6	11.4	1882.6	101.4	5.3	1344.0	71.3	437.2	23.4	111.1	42.5	579.4
420037	CO	252.7	12.0	1718.8	95.9	5.5	1263.0	73.3	359.9	21.2	107.3	45.4	582.6
420038	CO	250.1	12.8	1727.9	102.9	5.8	1255.9	72.8	369.1	21.4	114.8	44.9	577.5
420039	CO	234.4	12.6	1660.7	88.7	5.3	1226.9	73.7	345.1	21.0	103.8	44.4	604.7
420040	CO	245.2	12.3	1753.4	121.2	6.9	1264.9	72.1	367.3	21.1	103.1	41.8	597.5
420041	CO	266.0	12.8	1745.8	96.4	5.4	1269.8	72.8	379.6	21.8	105.4	42.5	573.5
420044	CO	241.4	12.2	1801.4	91.2	5.1	1336.4	74.3	373.7	20.7	102.0	46.7	597.7
420045	CO	245.4	12.4	1727.1	116.0	6.7	1231.3	71.3	379.8	22.0	108.5	43.9	589.9
420047	CO	269.3	12.8	1773.8	119.1	6.7	1297.5	73.4	357.2	19.9	108.5	43.4	572.6
420048	CO	244.8	11.9	1917.1	123.3	6.4	1421.9	74.1	371.9	19.5	108.5	43.8	590.7
420049	CO	254.9	12.0	1777.3	124.7	7.0	1297.4	73.2	355.1	19.7	108.5	41.8	589.0
420051	CO	275.8	12.4	1760.8	94.2	5.3	1290.8	73.3	375.8	21.4	108.5	47.0	562.9
420052	CO	230.0	12.0	1827.5	136.1	7.5	1422.0	77.9	269.4	14.6	108.5	41.4	608.8
420053	CO	253.5	11.7	1874.3	139.8	7.4	1412.5	75.3	322.0	17.2	108.5	43.5	583.8
SEM		12.8	0.3	81.6	17.5	0.8	109.9	3.9	66.8	4.5	108.5	1.1	11.4
LSD 0.05		25.9	0.8	146.4	17.1	0.8	319.6	3.9	88.9	4.2	108.5	1.9	23.3
LSD 0.01		34.4	1.1	194.2	22.7	1.1	123.9	5.2	117.9	5.5	108.5	2.5	30.9
IA3023		242.0	61.7	1588.3	115.3	7.3	1153.1	72.8	319.9	19.9	105.6	38.9	551.8
Macon		237.1	71.5	1767.1	119.3	6.7	1327.0	75.2	320.8	18.1	106.9	40.8	543.8

† MO = mid-oleate lines, CO = conventional-oleate lines

APPENDIX B

ANALYSES OF VARIANCE FOR SEED TRAITS AT INDIVIDUAL LOCATIONS

Table B1. Analysis of variance for Population 1, IA3024 x AX18896-2, at Ames, IA, in 2007.

		Mean Squares						
Sources of variation‡	df	Oleate (g kg^{-1})	Linolenate (g kg^{-1})	Total Tocopherol (mg kg^{-1})	α-Tocopherol (mg kg^{-1})	α-Tocopherol (% of total)	γ-Tocopherol (mg kg^{-1})	γ-Tocopherol (% of total)
R	1	3074.7**	3.6**	4746.4ns†	360.8ns	0.5ns	3462.3ns	29.3*
G	39	28194.0**	0.7ns	29609.0**	1559.1**	5.7**	20579.0**	20.0**
M	19	375.1ns	0.6ns	39170.0**	1677.8**	6.4**	18843.0**	11.0*
C	19	141.8ns	0.7ns	20369.0ns	589.3*	2.2**	9359.0*	5.1ns
M vs C	1	1089754.0**	3.1*	23493.8ns	17732.5**	60.0**	266746.1**	475.0**
Error	39	322.1	0.4	11886.0	294.9	0.8	4925.5	5.0
CV (%)		4.8	4.9	5.7	11.7	11.5	5.5	3.3

		Mean Squares				
Sources of variation	df	δ-Tocopherol (mg kg^{-1})	δ-Tocopherol (% of total)	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Linoleate (g kg^{-1})
R	1	11824.0ns	22.2ns	21.2**	0.0ns	2383.3**
G	39	10707.0**	18.9**	119.1**	9.3**	25275.0**
M	19	12558.0**	19.2**	19.8**	8.7**	402.2ns
C	19	6635.3ns	9.2ns	17.7**	7.1**	168.0ns
M vs C	1	52911.7**	197.5**	3931.8**	65.4**	974909.3**
Error	39	4227.5	6.7	2.5	2.1	290.1
CV (%)		13.4	10.2	1.6	3.3	3.6

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B2. Analysis of variance for Population 1, IA3024 x AX18896-2, at Carlisle, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	119.8ns†	19.8**	2343.3ns	42.9ns	1.6ns	304.3ns	13.6ns
G	39	33130.0**	1.1**	180638.0ns	1834.5**	12.6ns	133056.0ns	73.0ns
M	19	736.7**	1.1*	58188.0ns	1832.1**	10.6ns	53434.0ns	44.2ns
C	19	161.8ns	1.1*	183154.0ns	543.6**	14.4ns	153630.0ns	88.0ns
M vs C	1	1274998.8**	0.6ns	2459392.5**	26407.9**	14.7ns	1254977.4**	335.8ns
Error	39	273.7	0.5	147725.0	189.1	9.8	133645.0	93.4
CV (%)		4.1	5.8	23.4	8.1	28.5	34.7	15.6

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	4241.8ns	24.7ns	0.1ns	1.4ns	30.3ns
G	39	5462.0**	37.0ns	148.6**	6.0**	28876.0**
M	19	4707.8**	27.8ns	12.9**	3.5*	728.2**
C	19	2213.9ns	37.1ns	22.2**	8.2**	147.2ns
M vs C	1	81503.9**	210.1*	5128.0**	11.9*	1109534.7**
Error	39	1364.3	46.1	3.5	1.8	236.8
CV (%)		8.8	25.2	1.9	3.5	3.5

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B3. Analysis of variance for Population 1, IA3024 x AX18896-2, at Rippey, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate (g kg^{-1})	Linolenate (g kg^{-1})	Total Tocopherol (mg kg^{-1})	α-Tocopherol (mg kg^{-1})	α-Tocopherol (% of total)	γ-Tocopherol (mg kg^{-1})	γ-Tocopherol (% of total)
R	1	0ns†	2.7*	778919.0**	218.5ns	40.2**	1141940.0**	1195.8**
G	39	29163.0**	0.9*	168295.0ns	1308.6**	8.5**	136513.0ns	97.2ns
M	19	480.4*	1.1*	134587.0ns	1107.4**	11.0**	106132.0ns	78.3ns
C	19	307.1ns	0.7ns	155997.0ns	271.7ns	5.7ns	155926.0ns	120.3*
M vs C	1	1122384.8**	2.3*	1042383.6**	24833.6**	14.0*	344897.5ns	17.8ns
Error	39	200.8	0.5	100799.0	155.1	3.2	87687.0	61.5
CV (%)		3.6	5.5	18.4	9.1	21.6	28.2	13.3

Sources of variation	df	Mean Squares				
		δ-Tocopherol (mg kg^{-1})	δ-Tocopherol (% of total)	Palmitate (g kg^{-1})	Stearate (g kg^{-1})	Linoleate (g kg^{-1})
R	1	29334.0**	797.5**	13.5*	0.9ns	3.7ns
G	39	7912.3**	63.4ns	132.4**	13.4**	25938.0**
M	19	9281.5**	47.1ns	15.3**	15.8**	476.7**
C	19	2947.1ns	79.8*	11.5**	7.6**	285.9ns
M vs C	1	76234.7**	63.6ns	4652.8**	79.2**	997101.5**
Error	39	3227.4	39.6	2.0	2.8	186.9
CV (%)		10.6	19.3	1.5	3.6	3.1

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B4. Analysis of variance for Population 2, IA3025 x AX18896-2, at Ames, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	92.5ns†	4.7ns	48293.0**	761.2ns	0.1ns	33126.0**	1.8ns
G	39	30044.0**	1.5ns	26028.0**	2086.9**	7.6**	31159.0**	24.9**
M	19	968.0**	2.5*	22012.0**	2596.1**	9.8**	15633.0**	7.1**
C	19	163.0ns	0.5ns	25688.0**	794.4**	2.0**	16698.0**	2.3**
M vs C	1	1150224.7**	0.7ns	108785.7**	16972.0**	74.4**	600929.9**	789.5**
Error	39	280.5	1.3	3312.0	289.1	0.7	2198.5	0.6
CV (%)		4.6	8.9	3.0	9.3	8.8	3.4	1.1

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	103.3ns	2.8ns	12.4*	2.6ns	30.1ns
G	39	6170.6**	15.5**	117.3**	8.4**	27208.0**
M	19	5327.8**	8.3**	40.4**	7.6**	805.4**
C	19	2112.7**	3.6**	18.6**	7.5**	194.1ns
M vs C	1	99282.4**	378.9**	3454.5**	41.2**	1042121.0**
Error	39	446.9	1.2	2.2	1.9	243.4
CV (%)		1.8	5.6	1.4	3.0	3.3

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B5. Analysis of variance for Population 2, IA3025 x AX18896-2, at Carlisle, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	1708.5*	10.5**	82.1ns†	262.3ns	0.9ns	830.4ns	3.7*
G	39	35994.0**	1.1ns	22708.0**	2544.1**	9.6**	22432.0**	25.3**
M	19	879.5**	0.8ns	27714.0**	3087.2**	12.5**	16228.0**	7.9**
C	19	405.8ns	1.1ns	18029.0**	912.9**	2.5**	11294.0**	2.3**
M vs C	1	1379359.0**	4.2*	16466.9**	23218.0**	91.4**	351921.8**	793.2**
Error	39	310.3	0.6	1914.6	225.0	0.5	1274.1	0.7
CV (%)		4.3	6.5	2.4	8.2	6.9	2.9	1.2

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	469.7ns	1.0ns	0.2ns	240.8**	529.4ns
G	39	5530.7**	12.9**	125.1**	8.2**	31715.0**
M	19	4912.4**	5.6**	30.8**	7.2**	790.6**
C	19	1299.6**	2.7**	18.8**	6.1**	451.6ns
M vs C	1	97669.2**	346.1**	3934.0**	66.6**	1213273.8**
Error	39	231.8	0.7	3.6	0.9	277.5
CV (%)		4.2	4.1	1.9	2.3	3.8

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B6. Analysis of variance for Population 2, IA3025 x AX18896-2, at Rippey, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	650.9ns†	6.5*	6164.4*	61.9ns	0.5ns	3604.3ns	0.1ns
G	39	34916.0**	1.8ns	26320.0**	1428.0**	4.4**	19342.0**	24.7**
M	19	647.5**	0.4ns	37726.0**	1306.7**	4.5**	15722.0**	4.9**
C	19	274.3ns	2.8*	16205.0**	417.4**	1.2**	10088.0**	3.7**
M vs C	1	1344211.3**	9.8**	1774.4ns	22932.4**	63.0**	263957.5**	802.6**
Error	39	241.9	1.2	1195.5	114.0	0.3	1055.8	0.7
CV (%)		39.2	9.0	1.8	7.1	6.9	2.5	1.2

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	694.3ns	0.2ns	15.9**	5.4ns	1186.6*
G	39	9425.9**	17.0**	143.5**	14.4**	31150.0**
M	19	8235.4**	8.4**	36.7**	11.1**	599.1**
C	19	2502.4**	4.5**	13.9**	16.5**	328.4ns
M vs C	1	163591.5**	415.7**	4637.5**	37.8**	1197243.7**
Error	39	263.4	0.9	2.1	2.5	218.3
CV (%)		3.6	3.9	1.4	3.3	3.3

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B7. Analysis of variance for Population 3, IA2073 x AX18895-6, at Ames, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	236.3ns†	3.7ns	1047222.0**	11904.0**	2.0ns	10399.0*	1366.5**
G	39	29400.0**	1.0ns	21895.0ns	1141.6**	4.1**	19189.0**	34.0*
M	19	461.8ns	0.5ns	20549.0ns	881.6**	3.0**	15154.0**	35.3*
C	19	295.8ns	1.6ns	19098.0ns	769.0**	2.2**	6903.6**	18.2ns
M vs C	1	1132189.9**	1.9ns	100631.2*	13159.5**	59.8**	329301.2**	311.3**
Error	39	293.3	1.1	16601.0	225.7	0.8	2237.8	18.0
CV (%)		4.7	8.5	7.0	10.0	10.9	3.3	5.4

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	659762.0**	1264.4**	10.0*	2.1ns	358.7ns
G	39	13379.0ns	32.6ns	123.8**	6.1**	26074.0**
M	19	14651.0ns	37.2ns	17.8**	5.7**	454.6ns
C	19	11750.0ns	24.4ns	30.2**	6.6**	299.3ns
M vs C	1	20138.1ns	98.2*	3915.8**	1.2ns	1002579.4**
Error	39	11138.0	21.7	2.1	1.7	250.1
CV (%)		41.2	34.6	1.5	2.9	3.3

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B8. Analysis of variance for Population 3, IA2073 x AX18895-6, at Carlisle, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	327.2ns†	0.0ns	551261.0**	4030.1**	0.8ns	211283.0**	6.7*
G	39	40254.0**	0.3**	40361.0**	956.9**	3.2**	38065.0**	21.4**
M	19	795.9**	0.2**	21044.0ns	720.5*	2.2**	11970.0ns	7.9**
C	19	578.8**	0.4**	32450.0*	1080.0**	2.2**	22027.0**	5.9**
M vs C	1	1543790.2**	0.6**	557678.1**	3110.0**	41.0**	838582.3**	573.4**
Error	39	228.3	0.1	15840.0	319.7	0.6	7086.9	1.0
CV (%)		3.8	2.2	7.4	15.7	11.6	7.3	1.5

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	48102.0**	2.8ns	1.4ns	0.4ns	303.4ns
G	39	3731.8**	18.5**	165.3**	10.0**	35023.0**
M	19	4407.1**	12.5**	24.7**	8.3**	665.6**
C	19	2578.6*	9.2**	29.7**	7.6**	558.1**
M vs C	1	12813.4**	307.8**	5410.4**	86.9**	1342656.2**
Error	39	1202.9	1.2	1.5	1.4	194.3
CV (%)		8.1	4.3	1.2	2.8	3.1

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

Table B9. Analysis of variance for Population 3, IA2073 x AX18895-6, at Rippey, IA, in 2007.

Sources of variation‡	df	Mean Squares						
		Oleate ($g\ kg^{-1}$)	Linolenate ($g\ kg^{-1}$)	Total Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol ($mg\ kg^{-1}$)	α-Tocopherol (% of total)	γ-Tocopherol ($mg\ kg^{-1}$)	γ-Tocopherol (% of total)
R	1	70.1ns†	0.0ns	26020.0**	5147.1**	15.0**	21885.0**	6.5*
G	39	36300.0**	0.9*	23685.0**	517.5**	2.4**	29937.0**	29.5**
M	19	1113.2**	0.8ns	12617.0**	415.9**	1.7**	9314.3**	11.1**
C	19	362.5**	1.1*	13290.0**	466.3**	1.3**	9507.3**	7.2**
M vs C	1	1387670.2**	1.8ns	431480.6**	3421.1**	35.9**	809916.5**	801.9**
Error	39	168.5	0.5	2448.8	86.0	0.3	1559.2	1.2
CV (%)		3.3	5.8	3.0	9.8	9.4	3.6	1.6

Sources of variation	df	Mean Squares				
		δ-Tocopherol ($mg\ kg^{-1}$)	δ-Tocopherol (% of total)	Palmitate ($g\ kg^{-1}$)	Stearate ($g\ kg^{-1}$)	Linoleate ($g\ kg^{-1}$)
R	1	3407.9*	41.5**	13.8*	1.7ns	176.1ns
G	39	4486.3**	25.5**	154.2**	8.5**	31763.0**
M	19	3904.8**	15.3**	18.4**	9.9**	910.6**
C	19	3510.8**	10.8**	19.4**	7.3**	445.1**
M vs C	1	34071.7**	498.7**	5294.3**	6.1*	1213002.9**
Error	39	482.4	1.4	2.1	1.1	149.9
CV (%)		5	4.4	1.5	2.4	2.7

* significant at the 0.05 probability level

** significant at the 0.01 probability level

† ns = not significant at the 0.05 probability level

‡ R = replications, G = genotypes, M = mid-oleate lines, C = conventional-oleate lines

APPENDIX C

TYPE AND ENTRY MEANS FOR SEED TRAITS AT INDIVIDUAL LOCATIONS

Table C1. Means for seed traits of 20 mid-oleate and 20 conventional-oleate soybean lines from Pop1, IA3024 x AX18896-2, grown in three Iowa environments in 2007.

		Location			
Trait	Type‡	Ames	Carlisle	Rippey	Overall
Oleate	MO	490.1	532.2	515.9	512.7
(g kg^{-1})	CO	256.6**	279.8**	279.0**	271.8**
	$\bar{x}$	373.3	406.0	397.4	392.3*
Linolenate	MO	12.7	12.2	12.8	12.6
(g kg^{-1})	CO	13.1**	12.4ns†	13.1*	12.9ns
	$\bar{x}$	12.9	12.3	12.9	12.7ns
Total Tocopherol	MO	1888.7	1820.2	1839.0	1849.3
(mg kg^{-1})	CO	1923.0ns	1469.6**	1610.7**	1667.8ns
	$\bar{x}$	1905.9	1644.9	1724.9	1758.5ns
α-Tocopherol	MO	161.6	188.0	153.9	167.8
(mg kg^{-1})	CO	131.8**	151.7**	118.7**	134.1**
	$\bar{x}$	146.7	169.9	136.3	151.0**
α-Tocopherol	MO	8.6	10.6	8.7	9.3
(% of total)	CO	6.9**	11.4ns	7.9*	8.7ns
	$\bar{x}$	7.8	11.0	8.3	9.0*
γ-Tocopherol	MO	1217.7	1179.4	1115.9	1171.0
(mg kg^{-1})	CO	1333.2**	928.9**	984.5ns	1082.2ns
	$\bar{x}$	1275.5	1054.2	1050.2	1126.6ns
γ-Tocopherol	MO	64.5	64.1	59.5	62.7
(% of total)	CO	69.4**	60.0ns	58.6ns	62.7ns
	$\bar{x}$	66.9	62.1	59.1	62.7ns
δ-Tocopherol	MO	509.4	452.8	569.3	510.5
(mg kg^{-1})	CO	457.9**	388.9**	507.5**	451.5**
	$\bar{x}$	483.7	420.8	538.4	481.0*
δ-Tocopherol	MO	26.9	25.3	31.7	28.0
(% of total)	CO	23.7**	28.6*	33.5ns	28.6ns
	$\bar{x}$	25.3	27.0	32.6	28.3ns
Palmitate	MO	93.6	91.6	89.3	91.5
(g kg^{-1})	CO	107.6**	107.6**	104.5**	106.6**
	$\bar{x}$	100.6	99.6	96.9	99.0**
Stearate	MO	44.7	38.3	47.9	43.7
(g kg^{-1})	CO	42.9**	39.1*	45.9**	42.7ns
	$\bar{x}$	43.8	38.7	46.9	43.2**
Linoleate	MO	359.0	325.6	334.2	339.6
(g kg^{-1})	CO	579.8**	561.2**	557.5**	566.1**
	$\bar{x}$	469.4	443.4	445.8	452.9*

* differences between the means of types or of environments were significant at the 0.05 probability level.

** differences between the means of types or of environments were significant at the 0.01 probability level.

†ns = differences between the means of types or of environments were not significant at the 0.05 probability level.

‡ MO = mid-oleate lines, CO = conventional-oleate lines

Table C2. Means for seed traits of 20 mid-oleate and 20 conventional-oleate soybean lines from Pop2, IA3025 x AX18896-2, grown in three Iowa environments in 2007.

		Location			
Trait	Type‡	Ames	Carlisle	Rippey	Overall
Oleate	MO	485.8	541.3	525.6	517.6
(g kg^{-1})	CO	246.0**	278.7**	266.4**	263.7**
	$\bar{x}$	365.9	410.0	396.0	390.6**
Linolenate	MO	12.9	11.6	11.8	12.1
(g kg^{-1})	CO	12.7ns†	12.1*	12.5**	12.4ns
	$\bar{x}$	12.8	11.9	12.1	12.2ns
Total Tocopherol	MO	1893.5	1773.5	1911.2	1859.4
(mg kg^{-1})	CO	1967.3**	1802.2**	1901.7ns	1890.4ns
	$\bar{x}$	1930.4	1787.8	1906.4	1874.9**
α-Tocopherol	MO	197.3	199.1	167.4	187.9
(mg kg^{-1})	CO	168.2**	165.1**	133.5**	155.6**
	$\bar{x}$	182.7	182.1	150.4	171.8**
α-Tocopherol	MO	10.5	11.3	8.8	10.2
(% of total)	CO	8.6**	9.2**	7.0**	8.3**
	$\bar{x}$	9.5	10.2	7.9	9.2**
γ-Tocopherol	MO	1284.4	1178.8	1243.3	1235.5
(mg kg^{-1})	CO	1457.8**	1311.5**	1358.1**	1375.8*
	$\bar{x}$	1371.1	1245.2	1300.7	1305.7**
γ-Tocopherol	MO	67.8	66.5	65.1	66.4
(% of total)	CO	74.1**	72.8**	71.4**	72.8**
	$\bar{x}$	70.9	69.6	68.2	69.6**
δ-Tocopherol	MO	411.8	395.5	500.5	435.9
(mg kg^{-1})	CO	341.3**	325.6**	410.1**	359.0**
	$\bar{x}$	376.6	360.5	455.3	397.5**
δ-Tocopherol	MO	21.7	22.2	26.1	23.4
(% of total)	CO	17.4**	18.1**	21.6**	19.0**
	$\bar{x}$	19.5	20.2	23.8	21.2**
Palmitate	MO	97.8	95.4	92.9	95.3
(g kg^{-1})	CO	110.9**	109.4**	108.1**	109.5**
	$\bar{x}$	104.4	102.4	100.5	102.4**
Stearate	MO	46.8	40.7	48.8	45.4
(g kg^{-1})	CO	45.4**	42.5**	47.4**	45.1ns
	$\bar{x}$	46.1	41.6	48.1	45.3*
Linoleate	MO	356.8	311.0	321.0	329.6
(g kg^{-1})	CO	585.1**	557.3**	565.7**	569.4**
	$\bar{x}$	470.9	434.1	443.4	449.5**

* differences between the means of types or of environments were significant at the 0.05 probability level.

** differences between the means of types or of environments were significant at the 0.01 probability level.

†ns = differences between the means of types or of environments were not significant at the 0.05 probability level.

‡ MO = mid-oleate lines, CO = conventional-oleate lines

Table C3. Means for seed traits of 20 mid-oleate and 20 conventional-oleate soybean lines from Pop3, IA2073 x AX18895-6, grown in three Iowa environments in 2007.

		Location			
Trait	Type‡	Ames	Carlisle	Rippey	Overall
Oleate	MO	483.72	533.11	520.59	512.47
(g kg^{-1})	CO	245.79**	255.28**	257.19**	252.75**
	$\bar{x}$	364.8	394.2	388.9	382.6**
Linolenate	MO	12.2	11.7	12.0	12.0
(g kg^{-1})	CO	12.5ns†	11.9**	12.3ns	12.2*
	$\bar{x}$	12.3	11.8	12.2	12.1ns
Total Tocopherol	MO	1806.7	1616.8	1552.6	1658.7
(mg kg^{-1})	CO	1877.7*	1783.8**	1699.5**	1787.0*
	$\bar{x}$	1842.2	1700.3	1626.0	1722.8ns
α-Tocopherol	MO	163.3	120.0	100.9	128.0
(mg kg^{-1})	CO	137.6**	107.5**	87.8**	111.0ns
	$\bar{x}$	150.5	113.7	94.3	119.5ns
α-Tocopherol	MO	9.1	7.4	6.5	7.7
(% of total)	CO	7.3**	6.0**	5.2**	6.2**
	$\bar{x}$	8.2	6.7	5.8	6.9*
γ-Tocopherol	MO	1371.3	1055.0	993.5	1139.9
(mg kg^{-1})	CO	1499.6**	1259.8**	1194.7**	1318.0*
	$\bar{x}$	1435.5	1157.4	1094.1	1229.0**
γ-Tocopherol	MO	76.4	65.3	64.0	68.5
(% of total)	CO	80.3**	70.6**	70.3**	73.7*
	$\bar{x}$	78.4	67.9	67.1	71.1ns
δ-Tocopherol	MO	272.1	441.9	458.2	390.8
(mg kg^{-1})	CO	240.4ns	416.6**	417.0**	358.0*
	$\bar{x}$	256.3	429.2	437.6	374.4ns
δ-Tocopherol	MO	14.6	27.3	29.6	23.8
(% of total)	CO	12.3*	23.4**	24.6**	20.1*
	$\bar{x}$	13.5	25.4	27.1	22.0*
Palmitate	MO	92.7	90.9	88.3	90.7
(g kg^{-1})	CO	106.7**	107.3**	104.6**	106.2**
	$\bar{x}$	99.7	99.1	96.5	98.4**
Stearate	MO	44.4	40.9	44.3	43.2
(g kg^{-1})	CO	44.2ns	43.0**	44.8*	44.0ns
	$\bar{x}$	44.3	41.9	44.5	43.6**
Linoleate	MO	367.0	323.4	334.8	341.8
(g kg^{-1})	CO	590.9**	582.5**	581.1**	584.8**
	$\bar{x}$	479.0	453.0	458.0	463.3**

* differences between the means of types or of environments were significant at the 0.05 probability level.

** differences between the means of types or of environments were significant at the 0.01 probability level.

†ns = differences between the means of types or of environments were not significant at the 0.05 probability level.

‡ MO = mid-oleate lines, CO = conventional-oleate lines

Table C4. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 1, IA3024 x AX18896-2, at Ames, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418001	MO	468.7	12.8	1646.7	183.0	11.1	1103.1	67.0	360.7	21.9	91.8	42.0	384.8
418002	MO	459.8	13.1	1786.2	152.6	8.5	1204.5	67.4	429.0	24.1	93.7	45.7	387.8
418003	MO	506.6	12.9	1824.2	165.5	9.1	1148.3	63.0	510.4	27.9	89.0	42.5	349.1
418004	MO	503.9	13.5	2078.6	163.0	7.8	1338.5	64.4	577.1	27.8	90.4	44.9	347.4
418005	MO	505.2	12.5	1677.1	164.4	9.7	1098.4	65.2	414.3	25.1	92.0	43.6	346.7
418007	MO	479.7	13.5	2041.1	174.3	8.5	1326.1	65.0	540.7	26.5	92.7	45.8	368.4
418008	MO	477.3	12.2	1843.3	209.0	11.3	1242.0	67.4	392.3	21.3	93.1	46.5	371.5
418010	MO	502.6	12.4	1925.4	138.0	7.2	1167.3	60.7	620.1	32.1	91.5	49.1	344.5
418011	MO	485.5	13.1	1949.4	135.3	6.9	1282.5	66.0	531.6	27.1	94.1	44.0	363.5
418012	MO	505.4	12.5	1798.1	169.0	9.4	1093.9	60.8	535.2	29.7	100.8	44.4	337.1
418014	MO	489.8	11.8	1948.2	129.4	6.6	1301.9	66.8	516.9	26.5	94.2	43.2	361.2
418016	MO	487.2	12.1	1681.3	150.9	9.0	1008.7	60.0	521.7	31.0	100.9	46.9	353.0
418017	MO	511.6	12.6	1949.7	144.0	7.4	1221.7	62.7	584.0	30.0	91.1	48.9	335.8
418018	MO	488.7	12.9	2035.4	160.6	7.9	1296.6	63.8	578.2	28.4	92.2	44.8	361.6
418019	MO	487.0	12.7	1978.7	114.1	5.8	1247.0	63.0	617.7	31.2	92.9	45.1	362.5
418020	MO	499.1	14.1	1727.3	152.9	8.9	1176.2	68.1	398.3	23.0	94.8	41.5	350.6
418022	MO	491.0	12.7	2046.5	138.2	6.8	1344.7	65.7	563.6	27.5	91.2	43.4	361.9
418024	MO	484.5	12.4	1995.9	222.7	11.2	1268.9	63.6	504.3	25.2	92.3	45.7	365.2
418026	MO	492.4	12.2	1788.0	219.3	12.3	1147.2	64.2	421.4	23.5	98.2	44.3	353.0
418027	MO	475.5	12.9	2053.3	145.6	7.1	1337.3	65.5	570.3	27.4	94.8	42.3	374.5
418028	CO	253.1	12.8	2014.4	124.2	6.2	1383.3	68.7	507.0	25.2	105.9	45.9	582.4
418029	CO	264.0	13.6	1873.4	136.2	7.3	1296.2	69.2	441.0	23.5	105.9	44.9	571.7
418030	CO	247.0	13.0	2008.7	138.5	6.9	1349.2	67.2	521.0	25.9	112.3	43.1	584.6
418031	CO	266.5	13.6	1923.3	121.6	6.3	1307.5	68.0	494.3	25.6	101.7	45.2	573.2
418032	CO	254.7	12.9	1699.0	140.2	8.3	1192.0	70.2	366.8	21.6	112.3	44.9	575.2

Table C4. Continued

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418034	CO	258.9	12.4	2092.3	149.3	7.2	1466.9	70.0	476.0	22.8	112.9	41.0	575.1
418035	CO	240.8	12.8	1978.2	116.6	5.9	1449.9	73.3	411.7	20.8	108.0	40.8	597.6
418036	CO	260.8	13.6	2011.6	120.5	6.0	1430.7	71.1	460.4	22.9	106.4	42.2	577.0
418037	CO	262.3	12.7	1778.1	137.7	7.8	1260.7	70.9	379.7	21.3	107.7	42.3	575.1
418039	CO	273.8	14.6	1877.3	125.3	6.7	1326.2	70.7	425.8	22.7	107.0	44.7	560.1
418040	CO	249.6	13.2	1928.8	152.5	7.9	1335.7	69.4	440.5	22.8	104.2	39.2	593.9
418041	CO	263.5	12.5	1886.7	167.2	8.9	1307.1	69.4	412.5	21.7	107.1	40.1	577.0
418042	CO	250.3	12.9	1850.9	111.3	6.0	1257.5	68.1	482.1	25.9	111.4	44.4	581.1
418043	CO	247.7	14.6	2041.6	97.9	4.8	1351.7	66.3	592.0	28.9	106.7	43.8	587.4
418046	CO	253.7	13.1	1952.6	123.3	6.3	1335.1	68.4	494.2	25.2	107.2	42.7	583.5
418048	CO	266.1	13.0	2042.3	116.7	5.7	1379.8	67.6	545.8	26.7	108.9	44.4	567.7
418049	CO	261.6	12.4	1892.2	163.0	8.6	1307.7	69.1	421.6	22.3	104.7	41.1	580.4
418050	CO	252.4	12.8	1964.0	126.7	6.4	1363.2	69.4	474.2	24.1	107.5	41.7	585.8
418051	CO	245.9	13.0	1778.5	133.2	7.5	1249.4	70.3	395.9	22.2	104.4	43.5	593.3
418054	CO	260.2	13.3	1866.0	134.6	7.2	1314.8	70.5	416.6	22.3	110.0	42.7	574.0
SEM		14.0	0.5	76.5	12.2	0.6	49.4	1.7	47.0	1.9	91.8	1.0	13.1
LSD 0.05		36.3	1.3	220.5	34.7	1.8	142.0	4.5	131.5	5.2	3.2	2.9	34.5
LSD 0.01		48.6	1.8	295.2	46.5	2.4	190.1	6.0	176.1	7.0	4.3	3.9	46.1
IA3023		245.4	61.7	1965.0	117.6	6.0	1250.7	63.7	596.7	30.4	105.5	38.5	549.1
Macon		229.9	73.2	2021.2	120.9	6.0	1451.5	71.9	448.8	22.1	107.5	41.6	547.8

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C5. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 1, IA3024 x AX18896-2, at Carlisle, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418001	MO	512.8	13.5	1799.9	224.5	12.5	1176.2	65.4	399.2	22.1	89.4	36.7	347.7
418002	MO	518.1	12.6	1924.0	182.9	9.5	1281.4	66.6	459.7	23.9	91.0	39.4	339.0
418003	MO	539.8	11.7	1474.2	242.5	17.2	821.7	53.5	410.0	29.3	89.1	37.2	322.4
418004	MO	530.2	12.5	2010.8	191.1	9.5	1334.4	66.4	485.4	24.1	90.2	37.5	329.8
418005	MO	540.7	14.0	1945.5	189.0	9.7	1303.6	67.0	453.0	23.3	92.0	38.1	315.4
418007	MO	537.7	12.5	1952.6	200.3	10.2	1306.1	66.9	446.2	22.9	89.4	38.2	322.2
418008	MO	496.9	12.1	1877.4	178.3	9.5	1300.7	69.3	398.4	21.2	93.0	38.2	359.9
418010	MO	516.4	13.1	1805.1	156.9	8.7	1174.8	65.1	473.3	26.2	91.8	41.8	336.9
418011	MO	542.4	12.3	1950.4	171.9	8.8	1304.5	66.9	474.0	24.3	91.1	38.4	315.9
418012	MO	559.0	11.8	1788.6	183.2	10.3	1123.6	62.8	481.9	26.9	95.3	37.9	296.0
418014	MO	507.1	12.2	1926.5	140.5	7.3	1330.6	69.1	455.4	23.6	93.4	37.5	350.0
418016	MO	530.7	11.2	1640.2	190.8	11.6	1042.4	63.6	407.0	24.8	99.4	39.2	319.5
418017	MO	531.7	12.5	2012.6	161.2	8.0	1260.1	62.6	591.3	29.4	90.3	41.4	324.2
418018	MO	533.1	11.9	1820.8	156.5	8.6	1220.6	67.0	443.6	24.4	91.0	38.1	326.0
418019	MO	512.5	11.9	1485.5	150.5	11.0	842.0	53.3	493.0	35.8	90.4	37.9	347.5
418020	MO	557.2	11.1	1726.5	197.5	11.4	1142.4	66.2	386.7	22.4	90.9	36.7	304.3
418022	MO	541.3	12.1	1533.3	180.0	12.3	901.3	56.0	452.1	31.7	90.2	38.3	318.2
418024	MO	514.1	11.9	1909.2	243.2	12.8	1276.8	66.9	389.2	20.4	91.1	38.8	344.2
418026	MO	570.0	11.1	1803.9	241.7	13.4	1111.6	61.6	450.6	24.9	94.9	37.5	286.5
418027	MO	553.5	12.0	2017.4	178.2	8.8	1333.8	66.1	505.4	25.0	89.2	38.3	307.2
418028	CO	264.9	11.8	1520.7	138.0	9.6	982.2	61.9	400.5	28.5	106.5	39.8	577.2
418029	CO	272.1	13.8	1048.3	160.1	15.3	555.3	53.0	332.9	31.8	104.0	41.2	569.1
418030	CO	273.2	12.2	1405.1	153.1	12.1	893.6	60.4	358.5	27.4	112.0	40.7	562.1
418031	CO	280.9	12.3	1475.4	128.3	9.7	932.2	59.6	414.9	30.7	103.3	40.4	563.3
418032	CO	282.0	12.4	1310.0	146.3	12.2	796.8	57.7	366.9	30.1	110.4	42.9	552.5

Table C5. Continued

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418034	CO	280.7	11.6	1408.8	139.2	10.4	910.8	61.9	358.8	27.7	113.7	38.0	556.1
418035	CO	276.8	12.1	1081.7	143.3	13.2	567.2	52.4	371.3	34.4	108.0	37.2	566.0
418036	CO	285.7	14.3	1636.2	157.1	10.7	1064.2	62.2	415.0	27.1	105.6	41.9	552.7
418037	CO	304.7	12.0	1420.5	154.6	11.7	883.4	59.3	382.5	29.1	106.4	38.4	538.7
418039	CO	278.6	13.5	1967.4	142.1	7.2	1398.5	71.1	426.8	21.6	113.0	39.0	555.9
418040	CO	284.5	12.0	1559.2	199.2	14.5	957.9	57.1	402.1	28.3	103.8	36.3	563.5
418041	CO	294.5	12.2	1900.5	171.6	9.0	1318.0	69.4	410.8	21.6	106.2	36.0	551.2
418042	CO	268.2	12.7	1872.6	140.6	7.5	1299.2	69.4	432.8	23.1	111.5	40.9	566.8
418043	CO	271.7	12.9	1984.8	139.9	7.0	1408.2	71.0	436.7	22.0	107.1	39.6	568.9
418046	CO	272.8	12.2	1450.1	141.6	10.7	892.6	57.6	415.9	31.7	107.2	38.4	569.6
418048	CO	279.5	12.1	1498.8	137.5	10.0	952.0	61.2	409.4	28.7	110.5	40.2	557.9
418049	CO	278.5	11.7	1486.8	176.8	13.2	906.7	56.7	403.3	30.1	104.0	37.1	568.8
418050	CO	282.8	11.5	1012.8	159.0	15.7	486.4	47.8	367.4	36.5	108.4	35.9	561.5
418051	CO	285.9	11.8	959.4	147.3	15.3	472.5	49.3	339.6	35.4	102.8	40.9	558.7
418054	CO	277.6	12.3	1392.0	158.5	13.1	901.1	61.1	332.4	25.8	109.0	38.1	563.2
SEM		11.6	0.7	268.4	9.6	2.2	255.3	6.8	27.0	4.8	1.3	1.0	10.8
LSD 0.05		33.5	1.4	777.4	27.8	6.3	739.4	19.5	2.0	13.7	3.8	2.7	31.1
LSD 0.01		44.8	1.9	1040.8	37.2	8.5	989.9	26.2	100.0	18.4	5.1	3.6	41.7
IA3023		245.3	62.9	1855.7	143.3	7.7	1246.4	67.2	466.1	25.1	104.8	36.0	551.2
Macon		244.5	64.2	1557.7	146.7	10.3	999.6	61.0	411.4	28.7	107.6	37.2	546.6

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C6. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 1, IA3024 x AX18896-2, at Rippey, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418001	MO	489.1	12.1	1820.2	149.6	8.2	1160.6	63.9	510.0	27.9	89.4	43.3	366.2
418002	MO	504.1	13.2	1648.0	155.6	9.9	960.3	56.3	532.1	33.8	88.1	50.4	344.4
418003	MO	513.0	12.2	1111.2	178.5	16.1	464.9	41.8	467.9	42.1	88.2	45.6	341.2
418004	MO	515.8	12.9	1737.2	167.0	10.3	966.4	53.6	603.8	36.2	86.8	46.1	338.5
418005	MO	545.4	12.6	2019.6	176.7	8.7	1287.3	63.7	555.7	27.5	86.1	50.6	305.4
418007	MO	519.0	14.5	1993.1	152.0	7.6	1270.5	63.7	570.7	28.7	87.1	50.0	329.4
418008	MO	514.7	11.9	1789.2	133.5	7.4	1176.5	65.9	479.2	26.7	90.6	47.0	335.9
418010	MO	499.0	14.6	1633.2	134.9	8.6	828.0	49.1	670.3	42.3	88.8	53.5	344.3
418011	MO	509.4	12.9	1980.6	152.9	7.7	1276.8	64.5	550.9	27.8	91.2	49.3	337.2
418012	MO	530.8	12.6	1927.1	168.5	8.7	1192.9	61.9	565.7	29.4	94.6	48.4	313.8
418014	MO	504.9	12.3	1652.4	106.6	6.8	928.9	54.2	616.9	39.0	89.7	45.1	348.1
418016	MO	504.9	12.5	1702.3	172.8	10.2	1035.7	60.7	493.8	29.1	96.7	50.7	335.3
418017	MO	521.0	13.0	2044.2	151.1	7.4	1280.3	62.8	612.8	29.9	88.8	52.3	325.0
418018	MO	514.4	12.6	2008.1	111.7	5.6	1290.3	64.3	606.1	30.1	87.8	47.1	338.2
418019	MO	538.7	12.2	1993.3	121.3	6.1	1173.3	58.9	698.7	35.0	85.5	48.0	315.7
418020	MO	528.8	11.8	1489.3	163.7	11.7	870.8	55.2	454.8	33.1	89.2	44.3	326.0
418022	MO	512.3	13.4	2324.2	166.7	7.2	1483.3	64.1	674.2	28.7	88.5	43.8	342.1
418024	MO	521.4	13.0	2032.8	179.3	8.8	1277.5	62.8	576.0	28.3	86.5	49.3	329.9
418026	MO	540.7	12.4	1865.7	194.9	10.5	1078.2	57.8	592.6	31.7	90.3	47.1	309.7
418027	MO	490.5	12.7	2008.1	140.7	7.0	1314.5	65.5	552.9	27.5	91.8	47.1	358.0
418028	CO	263.5	12.5	1606.2	105.5	7.0	937.0	56.2	563.7	36.8	103.3	46.5	574.3
418029	CO	278.2	13.4	1480.8	134.5	9.8	894.0	57.1	452.3	33.1	103.3	46.9	558.4
418030	CO	264.7	12.5	1220.5	115.5	9.5	594.8	48.7	510.2	41.8	109.1	43.3	570.5
418031	CO	262.1	13.1	1917.3	104.4	5.4	1284.5	67.1	528.4	27.5	102.0	48.2	574.7
418032	CO	285.3	12.9	1461.0	110.7	7.9	897.9	58.9	452.4	33.2	107.1	48.2	546.7

Table C6. Continued

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
418034	CO	286.8	12.1	1510.4	109.5	7.8	944.2	60.0	456.7	32.3	108.0	44.1	549.1
418035	CO	283.0	13.1	1769.8	122.4	7.7	1137.8	60.7	509.6	31.6	104.4	44.9	554.6
418036	CO	277.7	14.1	2006.4	106.3	5.3	1408.9	70.3	491.3	24.4	105.2	46.0	557.0
418037	CO	272.8	13.9	1528.6	120.3	8.3	907.3	56.7	501.0	34.9	106.4	44.9	562.2
418039	CO	304.7	13.6	1936.7	135.8	7.0	1260.5	65.1	540.4	27.9	102.5	46.7	532.5
418040	CO	275.8	12.3	1583.8	139.8	9.4	954.6	57.2	489.4	33.3	102.7	43.3	566.0
418041	CO	310.5	13.1	1571.3	116.2	7.9	941.5	57.5	513.6	34.6	103.1	42.8	530.6
418042	CO	268.5	13.0	1917.9	105.8	5.5	1314.3	68.5	497.8	25.9	107.6	48.1	562.9
418043	CO	268.5	13.7	1991.8	105.2	5.3	1354.7	68.0	531.9	26.7	107.0	46.8	564.2
418046	CO	281.7	13.0	1170.1	111.2	9.5	536.1	45.9	522.8	44.6	104.6	45.2	555.6
418048	CO	288.1	12.9	2020.7	128.0	6.3	1330.3	65.9	562.4	27.8	103.8	49.3	546.1
418049	CO	279.6	14.4	1266.8	136.8	10.8	593.9	46.9	536.1	42.3	101.9	43.0	561.4
418050	CO	272.6	12.9	1227.4	119.5	9.7	534.2	43.5	573.8	46.8	102.6	46.1	565.9
418051	CO	276.0	13.1	1473.4	126.3	9.2	886.9	57.2	460.2	33.6	100.3	47.9	562.9
418054	CO	280.1	12.8	1553.1	119.2	8.3	977.2	60.3	456.7	31.4	105.8	47.1	554.4
SEM		9.9	0.5	242.6	8.9	1.4	238.8	6.7	44.0	5.4	1.1	1.2	9.5
LSD 0.05		28.7	1.4	642.2	25.2	3.6	599.0	15.9	114.9	12.7	2.8	3.4	27.7
LSD 0.01		38.4	1.9	859.7	33.7	4.9	801.9	21.2	153.8	17.0	3.8	4.5	37.0
IA3023		238.7	65.0	1916.0	114.8	6.0	1253.5	65.4	547.7	28.6	104.1	38.2	553.9
Macon		250.0	68.3	1673.5	122.3	7.7	1020.6	59.3	530.7	33.0	103.8	42.1	535.9

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C7. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 2, IA3025 x AX18896-2, at Ames, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419002	MO	478.9	12.0	1885.3	185.2	9.8	1292.4	68.6	407.7	21.6	97.5	46.7	365.1
419006	MO	477.7	15.8	1730.0	231.5	13.4	1167.0	67.5	331.4	19.1	101.9	49.1	355.6
419007	MO	499.2	12.4	1917.9	239.9	12.5	1239.6	64.6	438.4	22.9	93.2	44.7	350.7
419008	MO	501.9	13.0	1809.7	206.8	11.4	1242.4	68.6	360.5	19.9	102.2	44.9	338.0
419009	MO	470.7	12.4	1987.9	188.5	9.5	1328.9	66.9	470.4	23.7	98.2	47.1	371.8
419010	MO	460.7	13.5	2006.1	157.2	7.8	1374.7	68.5	474.2	23.7	93.9	44.9	387.3
419011	MO	489.3	11.9	2030.1	181.3	8.9	1366.9	67.3	481.9	23.7	95.8	45.8	357.3
419012	MO	497.6	11.9	1953.2	190.0	9.7	1330.1	68.1	433.1	22.2	99.1	45.0	346.5
419013	MO	524.8	12.6	1862.7	222.6	11.9	1269.1	68.1	371.1	19.9	100.5	46.6	315.7
419014	MO	488.5	13.2	1844.9	310.9	16.9	1197.2	64.9	336.8	18.2	91.7	47.6	359.1
419015	MO	502.6	15.5	1711.6	201.0	11.7	1139.5	66.6	371.0	21.7	94.2	43.4	344.4
419017	MO	506.8	12.0	1954.0	171.8	8.8	1299.7	66.5	482.5	24.7	95.0	49.2	337.1
419018	MO	454.0	12.3	1875.4	195.6	10.4	1339.6	71.4	340.3	18.1	102.9	46.7	384.2
419020	MO	484.0	12.5	2135.0	187.0	8.7	1498.1	70.2	449.9	21.1	97.1	46.1	360.5
419021	MO	494.3	13.5	1785.7	203.1	11.4	1189.7	66.6	392.9	22.0	94.3	45.5	352.6
419022	MO	424.9	13.5	1901.3	164.8	8.7	1330.9	70.0	405.6	21.4	109.0	47.8	404.9
419023	MO	484.3	13.1	1798.0	176.4	9.8	1215.9	67.6	405.7	22.6	96.6	49.7	356.3
419025	MO	506.3	12.6	1979.8	137.2	6.9	1376.1	69.5	466.5	23.6	100.2	47.2	333.8
419026	MO	494.1	11.7	1838.3	197.9	10.8	1186.9	64.6	453.5	24.7	90.8	51.4	352.2
419027	MO	475.8	12.0	1863.9	197.3	10.6	1304.1	70.0	362.5	19.5	102.0	46.8	363.5
419028	CO	237.4	13.7	1834.5	191.2	10.4	1338.5	73.0	304.8	16.6	108.2	48.3	592.5
419029	CO	253.1	13.7	1896.6	166.1	8.8	1376.5	72.6	354.1	18.7	108.1	46.3	579.0
419030	CO	233.8	11.9	1962.2	141.9	7.2	1450.2	73.9	370.0	18.9	114.2	42.3	598.0
419031	CO	235.9	13.1	1935.2	183.4	9.5	1427.0	73.7	324.8	16.8	114.3	42.3	594.6
419032	CO	241.1	12.7	2089.7	163.6	7.8	1564.6	74.9	361.5	17.3	108.5	46.8	591.1

Table C7. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419033	CO	252.8	12.9	2051.1	164.5	8.0	1552.6	75.7	333.9	16.3	111.0	44.9	578.5
419034	CO	248.2	13.0	1955.7	165.6	8.5	1482.8	75.8	307.3	15.7	110.2	45.5	583.3
419036	CO	246.3	12.6	2176.6	195.4	9.0	1638.8	75.3	342.3	15.7	113.2	46.6	581.5
419037	CO	242.9	12.2	1764.4	157.2	8.9	1307.7	74.1	299.5	17.0	109.7	44.8	590.5
419038	CO	235.3	12.1	1964.7	135.6	6.9	1469.0	74.8	360.0	18.3	110.6	43.0	599.0
419039	CO	258.7	12.8	1866.4	187.2	10.0	1354.4	72.6	324.8	17.4	107.3	45.3	576.0
419040	CO	238.1	12.2	1940.0	137.2	7.1	1432.5	73.8	370.2	19.1	116.9	45.0	587.9
419041	CO	235.9	12.8	1922.4	186.1	9.7	1449.4	75.4	286.9	14.9	111.0	45.2	595.2
419043	CO	252.4	12.0	1944.1	166.2	8.6	1438.2	73.9	339.7	17.5	113.9	45.6	576.1
419045	CO	254.9	12.6	2123.6	179.9	8.5	1538.5	72.5	405.1	19.1	110.3	49.2	573.1
419046	CO	234.6	13.0	2068.5	188.1	9.1	1512.2	73.1	368.2	17.8	109.5	42.4	600.6
419048	CO	250.8	13.3	1825.2	152.6	8.4	1363.2	74.7	309.3	17.0	109.7	43.7	582.6
419051	CO	258.3	12.8	2109.6	200.7	9.5	1586.3	75.2	322.6	15.3	116.9	47.3	564.8
419052	CO	260.6	12.1	2068.3	151.5	7.3	1516.3	73.3	400.6	19.4	105.7	46.1	575.6
419054	CO	248.9	12.4	1847.1	149.2	8.1	1356.8	73.5	341.0	18.5	109.9	46.8	582.0
SEM		11.7	0.8	47.1	12.3	0.6	38.5	0.6	14.8	0.8	1.1	1.0	10.9
LSD 0.05		33.9	2.3	116.4	34.4	1.7	94.8	1.6	42.8	2.2	3.0	2.8	31.6
LSD 0.01		45.4	3.1	155.8	46.0	2.3	127.0	2.1	57.2	2.9	4.0	3.7	42.2
IA3023		253.9	63.3	1843.8	139.8	7.6	1298.6	70.4	405.5	22.0	104.8	39.9	538.2
Macon		224.8	74.2	2015.5	124.3	6.2	1503.5	74.6	387.7	19.2	108.4	40.1	552.6

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C8. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 2, IA3025 x AX18896-2, at Carlisle, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419002	MO	532.1	10.9	1800.2	188.4	10.5	1191.1	66.2	420.7	23.4	94.2	41.2	321.7
419006	MO	520.2	13.4	1621.4	202.3	12.5	1075.5	66.3	343.6	21.2	103.0	42.6	321.0
419007	MO	521.6	11.8	1816.2	246.3	13.5	1151.0	63.5	418.8	23.1	92.1	40.6	333.9
419008	MO	582.7	11.9	1631.6	219.1	13.4	1050.2	64.4	362.3	22.2	97.7	39.7	268.1
419009	MO	508.6	12.3	1898.9	218.4	11.5	1239.4	65.3	441.1	23.2	95.0	41.3	343.0
419010	MO	550.4	11.3	1886.8	165.5	8.8	1280.4	67.9	440.9	23.4	90.0	39.8	308.7
419011	MO	509.7	11.1	1957.6	203.4	10.4	1301.8	66.5	452.3	23.1	94.0	39.4	345.9
419012	MO	543.5	11.0	1865.1	165.6	8.9	1260.8	67.6	438.7	23.5	95.8	37.1	312.8
419013	MO	562.3	11.9	1597.2	194.2	12.1	1053.5	66.0	349.5	21.9	100.1	37.8	288.0
419014	MO	535.2	12.3	1737.6	329.0	18.9	1093.4	62.9	315.2	18.1	91.2	40.8	320.7
419015	MO	563.6	11.6	1580.1	221.4	14.0	1020.2	64.6	338.5	21.4	91.8	38.4	294.6
419017	MO	514.2	11.8	1891.0	176.1	9.3	1263.6	66.8	451.3	23.9	98.5	43.2	332.3
419018	MO	547.5	11.0	1671.2	176.4	10.6	1178.0	70.5	316.8	19.0	97.8	41.5	302.3
419020	MO	553.5	12.0	1924.0	183.6	9.5	1302.0	67.7	438.3	22.8	94.5	43.7	296.4
419021	MO	558.4	11.2	1701.7	211.0	12.4	1117.2	65.7	373.6	21.9	92.1	39.1	299.4
419022	MO	522.2	11.2	1745.6	175.1	10.0	1193.6	68.4	376.9	21.6	102.3	41.7	322.6
419023	MO	542.3	11.4	1686.3	180.0	10.7	1127.1	66.8	379.2	22.5	93.2	42.7	310.5
419025	MO	572.1	10.9	1876.4	136.6	7.3	1289.5	68.7	450.3	24.0	94.8	38.8	283.6
419026	MO	548.6	11.5	1841.6	206.0	11.2	1183.1	64.2	452.5	24.6	89.8	42.8	307.4
419027	MO	538.2	12.6	1738.5	184.2	10.6	1205.2	69.3	349.1	20.1	100.1	42.2	307.0
419028	CO	251.5	12.2	1681.5	186.1	11.1	1189.0	70.7	306.4	18.2	107.7	44.0	584.7
419029	CO	309.4	12.1	1689.5	154.9	9.2	1205.2	71.3	329.4	19.5	110.5	42.9	525.3
419030	CO	281.4	13.2	1826.8	152.8	8.4	1316.7	72.1	357.2	19.6	110.9	41.8	552.9
419031	CO	273.1	12.3	1732.5	180.4	10.4	1252.3	72.3	299.7	17.3	110.8	39.3	564.5
419032	CO	260.1	11.2	1917.4	148.3	7.7	1407.1	73.4	362.0	18.9	108.0	41.3	579.4

Table C8. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419033	CO	296.2	11.5	1845.8	164.4	8.9	1351.7	73.2	329.7	17.9	107.5	40.0	545.0
419034	CO	302.2	12.3	1833.9	166.2	9.1	1358.8	74.1	308.9	16.9	105.7	42.7	537.4
419036	CO	278.8	11.3	1936.1	182.9	9.4	1426.9	73.7	326.2	16.9	110.9	44.8	554.3
419037	CO	282.5	11.4	1664.0	158.7	9.5	1202.3	72.2	303.1	18.2	107.5	44.5	554.2
419038	CO	283.5	11.6	1723.5	142.7	8.3	1250.3	72.5	330.5	19.2	109.3	41.7	554.1
419039	CO	289.6	12.2	1753.1	179.9	10.3	1257.1	71.7	316.0	18.0	105.6	43.4	549.4
419040	CO	272.0	12.0	1780.0	127.6	7.2	1314.0	73.8	338.3	19.0	114.9	42.8	558.6
419041	CO	265.4	12.2	1819.9	182.2	10.0	1345.3	73.9	292.4	16.1	108.7	40.9	573.0
419043	CO	288.0	11.9	1708.1	166.1	9.7	1253.4	73.4	288.6	16.9	112.8	42.5	544.9
419045	CO	281.0	12.2	1951.5	178.8	9.2	1394.1	71.4	378.7	19.4	113.8	46.1	547.0
419046	CO	259.5	14.4	1933.6	187.7	9.7	1379.4	71.3	366.5	19.0	105.9	40.1	580.3
419048	CO	274.8	12.9	1780.7	168.7	9.5	1295.1	72.7	316.9	17.8	108.5	42.0	561.9
419051	CO	280.3	12.3	1946.0	207.9	10.7	1433.5	73.7	304.6	15.7	115.7	44.4	547.4
419052	CO	274.6	11.3	1796.5	132.1	7.4	1321.8	73.6	342.6	19.1	105.5	42.2	566.5
419054	CO	270.8	11.7	1722.5	132.7	7.7	1275.6	74.0	314.2	18.3	108.3	43.5	565.7
SEM		13.1	0.7	30.6	10.6	0.5	25.1	0.6	10.9	0.6	1.3	1.9	11.9
LSD 0.05		35.6	1.6	88.5	30.3	1.5	72.2	1.7	2.0	1.7	3.8	2.0	33.7
LSD 0.01		47.7	2.1	118.5	40.6	2.0	96.7	2.2	41.2	2.2	5.1	2.6	45.1
IA3023		258.1	65.8	1799.4	143.4	8.0	1246.1	69.3	409.9	22.8	102.5	37.0	536.8
Macon		244.2	74.9	1885.5	127.0	6.7	1407.9	74.7	350.6	18.6	107.3	37.5	536.3

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C9. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 2, IA3025 x AX18896-2, at Rippey, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419002	MO	521.4	11.6	1992.8	158.1	7.9	1284.7	64.5	550.0	27.6	90.2	47.8	329.2
419006	MO	494.9	12.2	1734.9	158.0	9.1	1154.5	66.5	422.4	24.3	102.8	48.1	342.1
419007	MO	505.9	12.2	2002.1	189.9	9.5	1232.8	61.6	579.4	28.9	89.3	47.6	345.0
419008	MO	548.8	12.0	1689.8	160.1	9.5	1104.7	65.4	425.0	25.1	95.4	47.2	296.7
419009	MO	515.1	11.9	2108.5	187.4	8.9	1367.9	64.9	553.2	26.2	89.6	50.3	333.3
419010	MO	523.9	12.1	2071.9	146.7	7.1	1349.5	65.1	575.7	27.8	89.4	49.0	325.7
419011	MO	520.9	11.3	2075.6	168.1	8.1	1334.3	64.3	573.2	27.6	90.3	47.4	330.4
419012	MO	512.8	11.6	2017.0	181.9	9.0	1302.8	64.6	532.3	26.4	94.5	48.6	332.7
419013	MO	565.7	12.0	1729.1	186.5	10.8	1122.0	64.9	420.6	24.3	94.4	44.6	283.5
419014	MO	502.8	12.2	1857.7	232.9	12.5	1201.1	64.6	423.7	22.8	88.1	47.9	349.1
419015	MO	535.8	11.7	1665.0	154.3	9.3	1091.1	65.5	419.7	25.2	92.6	45.5	314.5
419017	MO	522.0	11.4	1972.6	161.0	8.2	1256.2	63.7	555.5	28.2	92.8	53.5	320.4
419018	MO	528.2	11.1	1795.7	140.2	7.8	1217.2	67.8	438.4	24.4	95.5	46.1	319.2
419020	MO	537.3	12.1	2091.9	165.2	7.9	1415.2	67.6	511.5	24.5	91.7	49.0	310.0
419021	MO	550.9	11.5	1842.2	169.3	9.2	1174.2	63.7	498.7	27.1	88.9	48.6	300.2
419022	MO	507.6	12.3	1943.2	148.8	7.7	1289.6	66.4	504.7	26.0	102.2	51.7	326.5
419023	MO	512.8	12.6	1896.3	148.5	7.8	1223.8	64.5	524.0	27.6	92.1	51.1	331.5
419025	MO	542.4	11.4	1977.3	113.9	5.8	1294.6	65.5	568.9	28.8	95.7	47.9	302.8
419026	MO	524.6	11.3	1908.0	171.2	9.0	1200.6	62.9	536.1	28.1	86.5	52.3	325.4
419027	MO	538.5	11.3	1851.1	205.4	11.1	1248.5	67.4	397.2	21.5	95.4	52.0	302.9
419028	CO	244.8	12.7	1789.3	163.0	9.1	1275.5	71.3	350.8	19.6	106.8	49.9	585.9
419029	CO	261.6	11.9	1751.9	125.0	7.1	1235.3	70.5	391.6	22.4	108.3	50.5	567.7
419030	CO	258.8	11.7	1955.4	113.6	5.8	1391.4	71.2	450.4	23.0	110.1	44.4	575.0
419031	CO	252.5	12.5	1882.9	141.8	7.5	1345.9	71.5	395.3	21.0	111.1	42.8	581.3
419032	CO	255.9	11.8	2021.8	128.1	6.3	1429.0	70.7	464.8	23.0	107.5	47.4	577.5

Table C9. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
419033	CO	280.0	12.0	1970.9	127.4	6.5	1429.7	72.5	413.7	21.0	105.1	46.1	556.9
419034	CO	260.8	12.3	1818.4	108.2	5.9	1351.7	74.3	358.5	19.7	108.3	44.4	574.3
419036	CO	277.7	11.8	2017.7	146.9	7.3	1475.1	73.1	395.7	19.6	108.3	49.5	552.7
419037	CO	271.2	11.6	1795.7	135.5	7.5	1274.0	71.0	386.2	21.5	105.6	46.8	564.8
419038	CO	266.6	13.0	1858.0	116.8	6.3	1304.8	70.2	436.3	23.5	108.0	49.4	563.0
419039	CO	264.2	17.1	1871.5	143.4	7.7	1322.4	70.6	405.8	21.7	105.2	47.5	566.1
419040	CO	259.4	12.0	1866.8	116.5	6.2	1330.0	71.2	420.3	22.5	113.7	46.5	568.5
419041	CO	253.5	11.9	1875.4	141.4	7.5	1378.0	73.5	355.9	19.0	108.4	47.1	579.1
419043	CO	282.1	12.2	1877.2	138.6	7.4	1335.2	71.1	403.4	21.5	108.4	47.1	550.4
419045	CO	283.4	12.2	2012.2	148.8	7.4	1380.8	68.6	482.6	24.0	109.5	54.9	540.1
419046	CO	258.9	12.3	2059.5	146.1	7.1	1464.9	71.1	448.5	21.8	105.6	43.6	579.7
419048	CO	261.4	12.5	1878.9	136.7	7.3	1341.2	71.4	401.0	21.4	109.0	44.4	572.7
419051	CO	277.5	12.7	2020.5	148.2	7.3	1483.0	73.4	389.3	19.3	113.4	48.3	548.2
419052	CO	286.9	11.9	1896.7	117.8	6.2	1346.0	71.0	432.9	22.8	103.6	47.7	549.9
419054	CO	270.0	13.5	1813.9	126.4	7.0	1269.0	70.0	418.6	23.1	105.9	50.3	560.5
SEM		11.2	0.8	25.7	7.5	0.4	23.6	0.6	11.7	0.6	1.1	1.1	11.0
LSD 0.05		31.5	2.2	69.9	21.6	1.1	65.7	1.7	32.8	1.9	2.9	3.2	29.9
LSD 0.01		42.1	3.0	93.6	28.9	1.4	88.0	2.2	43.9	2.5	3.9	4.3	40.0
IA3023		242.1	64.2	1935.1	124.5	6.4	1328.2	68.6	482.4	24.9	103.6	39.6	550.6
Macon		239.2	74.7	2002.3	111.4	5.6	1451.8	72.5	439.2	22.0	106.7	42.5	537.0

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C10. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 3, IA2073 x AX18895-6, at Ames, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420001	MO	484.6	11.8	1994.0	144.9	7.2	1414.0	70.9	435.1	21.8	94.6	44.6	364.5
420002	MO	494.6	12.1	1783.4	191.6	10.7	1419.5	79.6	172.3	9.6	91.1	41.0	361.3
420004	MO	456.1	11.9	1911.3	181.3	9.4	1433.1	75.2	296.9	15.3	97.2	43.7	391.2
420006	MO	485.6	12.3	1797.6	159.4	8.9	1276.4	72.3	361.8	18.8	91.4	47.3	363.4
420008	MO	513.6	11.9	1907.7	171.5	9.0	1433.0	75.8	303.2	15.2	89.3	45.3	340.1
420009	MO	461.3	13.1	1897.0	175.6	9.3	1403.3	74.5	318.1	16.3	91.6	42.1	392.1
420011	MO	490.2	12.1	1832.0	174.2	9.6	1351.9	74.4	306.0	16.1	93.1	48.1	356.7
420012	MO	481.9	12.3	1886.7	169.1	8.9	1390.4	74.8	327.1	16.3	96.2	45.1	364.5
420013	MO	496.7	12.0	1615.4	181.0	11.1	1132.4	70.2	302.0	18.7	92.5	44.3	354.5
420014	MO	476.7	13.0	1698.2	192.5	11.3	1353.7	79.7	152.0	8.9	87.9	45.3	377.3
420015	MO	488.8	11.6	1657.2	162.4	9.8	1385.0	83.6	109.8	6.6	96.8	45.1	357.8
420016	MO	483.8	13.3	1749.3	136.2	7.8	1445.1	82.6	168.0	9.6	91.5	44.4	367.1
420017	MO	456.4	12.2	1895.9	176.4	9.4	1473.6	78.2	245.9	12.4	97.0	43.0	391.5
420019	MO	471.4	12.5	1871.3	150.8	8.0	1460.7	79.0	259.8	13.0	90.4	46.6	379.1
420020	MO	489.1	11.5	1688.6	117.6	7.0	1378.8	81.7	192.2	11.4	92.4	45.0	362.2
420021	MO	495.0	12.1	1855.2	174.7	9.4	1392.6	75.7	288.0	14.9	96.6	43.2	353.2
420022	MO	504.8	11.6	1698.5	146.8	8.6	1360.4	80.1	191.3	11.3	94.3	44.8	344.6
420025	MO	493.8	11.8	1850.3	184.7	10.1	1351.8	74.0	313.8	15.9	88.8	43.1	362.6
420026	MO	469.1	12.2	1723.5	141.5	8.2	1175.4	68.2	406.6	23.6	88.7	43.8	386.5
420027	MO	481.3	12.1	1821.3	133.7	7.4	1394.8	77.1	292.8	15.5	93.3	43.0	370.5
420029	CO	234.2	11.4	1814.6	125.9	7.0	1425.0	78.9	263.6	14.1	109.5	45.8	599.2
420030	CO	235.5	12.3	2042.1	148.3	7.2	1626.6	80.1	267.3	12.7	106.2	43.0	603.1
420031	CO	242.3	12.1	1754.6	104.4	5.9	1496.6	85.4	153.5	8.7	101.3	45.6	598.8
420032	CO	244.4	13.1	1943.8	126.7	6.6	1559.5	80.9	257.6	12.5	109.9	46.6	586.1
420033	CO	262.6	12.5	1965.2	179.4	9.1	1533.4	78.6	252.3	12.3	105.9	42.8	576.4

Table C10. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420034	CO	268.5	12.3	1925.6	167.5	8.7	1518.5	79.3	239.6	12.0	109.0	44.7	565.7
420035	CO	245.9	11.4	2075.3	126.7	6.1	1526.4	73.6	422.1	20.3	112.4	42.2	588.2
420037	CO	242.5	12.1	1951.8	128.1	6.6	1526.5	78.6	297.2	14.9	108.1	45.7	591.9
420038	CO	241.4	12.8	1905.9	123.8	6.5	1490.4	78.9	291.8	14.6	116.3	45.2	584.4
420039	CO	225.5	13.7	1839.8	116.9	6.4	1447.0	79.1	275.9	14.5	104.1	45.1	611.7
420040	CO	247.5	12.6	1782.6	157.1	8.8	1474.9	82.7	150.6	8.4	104.1	41.5	594.5
420041	CO	242.7	15.3	1873.3	129.6	6.8	1469.0	79.1	274.8	14.1	107.5	43.8	590.8
420044	CO	245.1	12.0	1768.6	117.7	6.7	1489.0	84.2	161.9	9.2	101.8	46.6	594.7
420045	CO	250.2	12.5	1848.5	138.7	7.5	1399.1	76.2	310.7	16.3	108.2	43.7	585.5
420047	CO	263.7	13.3	1818.0	134.7	7.4	1424.8	79.4	258.6	13.2	102.3	43.2	577.6
420048	CO	237.7	12.0	1981.9	143.4	7.3	1570.6	79.4	268.0	13.4	108.9	44.1	597.5
420049	CO	256.4	12.0	1709.4	147.5	8.6	1432.4	83.9	129.6	7.5	102.3	42.1	587.3
420051	CO	260.0	12.4	1882.6	117.3	6.2	1484.3	79.3	280.9	14.5	102.0	47.3	578.3
420052	CO	221.8	12.1	1780.4	159.3	8.9	1514.0	85.0	107.1	6.0	107.2	40.7	618.4
420053	CO	248.5	11.6	1889.1	159.9	8.5	1584.2	83.9	145.0	7.7	107.5	44.0	588.6
SEM		12.1	0.8	145.5	16.1	0.7	34.9	5.1	117.0	5.1	1.1	0.9	11.2
LSD 0.05		34.6	2.1	260.6	30.4	1.8	95.7	8.6	213.5	9.4	2.9	2.6	32.0
LSD 0.01		46.4	2.8	348.9	40.7	2.5	128.1	11.5	285.8	12.6	3.9	3.5	42.8
IA3023		234.9	61.1	1531.7	130.8	8.6	1265.9	82.7	135.0	8.7	106.8	40.1	557.2
Macon		224.0	76.3	1841.9	145.5	7.9	1469.8	80.4	226.6	11.7	106.8	41.4	551.7

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C11. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 3, IA2073 x AX18895-6, at Carlisle, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420001	MO	518.8	11.5	1521.0	90.3	5.9	1016.3	67.0	414.4	27.1	94.6	41.4	333.9
420002	MO	562.3	12.0	1675.0	139.2	8.3	1074.4	64.1	461.4	27.6	86.7	38.6	300.6
420004	MO	536.9	11.6	1719.3	141.8	8.2	1164.5	67.7	413.0	24.1	92.9	38.3	320.4
420006	MO	531.2	11.7	1649.8	117.8	7.1	1006.5	61.0	525.5	31.8	90.1	44.0	323.2
420008	MO	533.3	11.2	1791.9	125.4	7.0	1196.8	66.8	469.7	26.2	90.0	39.6	326.0
420009	MO	517.1	11.6	1550.2	107.0	6.9	1012.5	65.3	430.6	27.8	90.9	38.7	341.9
420011	MO	551.2	12.3	1390.0	97.2	6.9	894.0	64.4	398.7	28.7	90.4	44.4	301.8
420012	MO	532.6	12.2	1654.7	96.5	5.8	1065.4	64.5	492.8	29.7	94.2	41.6	319.6
420013	MO	549.0	11.6	1463.8	138.8	9.5	980.0	66.9	345.0	23.6	90.2	40.5	308.8
420014	MO	543.4	12.2	1658.4	153.3	9.2	1100.6	66.3	404.4	24.5	85.3	39.1	320.2
420015	MO	492.6	11.8	1698.4	128.9	7.6	1145.6	67.4	423.9	25.0	97.0	43.2	355.6
420016	MO	549.0	11.9	1656.4	115.3	7.0	1092.6	66.0	448.6	27.1	87.2	43.6	308.5
420017	MO	498.4	12.0	1675.1	138.5	8.3	1159.8	69.2	376.7	22.5	97.0	39.8	352.9
420019	MO	559.1	11.4	1460.6	95.4	6.6	965.4	66.2	399.8	27.3	87.3	42.9	299.3
420020	MO	550.7	11.4	1616.5	92.1	5.6	1011.6	62.6	512.7	31.8	89.8	40.8	307.5
420021	MO	531.3	11.9	1620.3	129.9	8.0	1044.8	64.5	445.6	27.5	95.5	38.2	323.3
420022	MO	532.3	11.4	1604.1	120.3	7.5	1014.1	63.2	469.7	29.3	94.1	42.5	319.8
420025	MO	529.7	11.5	1745.4	139.0	8.0	1111.1	63.7	495.4	28.4	87.8	38.6	332.5
420026	MO	497.5	11.9	1526.8	122.0	8.0	976.0	63.9	428.8	28.1	87.7	41.6	361.3
420027	MO	546.4	12.0	1659.1	110.2	6.6	1067.7	64.4	481.2	29.0	89.4	40.5	311.8
420029	CO	264.4	10.7	1652.4	83.9	5.1	1171.9	70.9	396.7	24.0	110.1	47.4	567.6
420030	CO	280.7	11.8	1786.8	112.4	6.3	1285.5	71.9	388.8	21.8	104.3	42.5	560.9
420031	CO	244.3	11.8	1859.1	98.5	5.3	1294.5	69.7	466.1	25.0	102.5	44.3	597.2
420032	CO	275.4	12.6	1719.4	78.3	4.5	1209.3	70.3	431.8	25.1	109.7	44.3	558.1
420033	CO	242.6	12.5	1825.6	137.0	7.5	1330.3	72.9	358.2	19.6	109.2	39.9	596.0

Table C11. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420034	CO	258.7	12.1	1898.4	132.5	7.0	1382.7	72.8	383.1	20.2	109.5	41.8	577.9
420035	CO	263.6	11.4	1866.9	100.3	5.4	1328.0	71.1	438.6	23.5	111.9	42.4	570.9
420037	CO	252.4	11.9	1644.6	84.7	5.1	1167.9	71.2	392.1	23.8	108.2	43.8	583.7
420038	CO	242.5	12.4	1526.9	94.3	5.9	1056.5	69.6	376.1	24.5	116.5	44.5	584.1
420039	CO	239.3	11.9	1596.4	69.2	4.3	1155.4	72.4	371.7	23.3	104.8	42.8	601.3
420040	CO	246.4	12.0	1724.6	107.9	6.2	1155.4	67.0	461.3	26.8	103.8	42.2	595.7
420041	CO	282.8	11.5	1727.1	89.9	5.2	1193.0	69.1	444.2	25.7	105.3	40.7	559.9
420044	CO	236.4	12.2	1877.9	86.2	4.6	1318.6	70.2	473.1	25.2	103.4	46.2	601.9
420045	CO	242.3	12.2	1656.4	115.3	6.9	1128.5	68.1	412.6	25.0	110.3	42.6	592.8
420047	CO	273.4	12.5	1866.8	134.1	7.2	1322.6	70.8	410.0	22.0	103.0	42.5	568.7
420048	CO	242.3	11.7	1999.4	129.3	6.5	1423.1	71.2	447.1	22.4	110.3	42.9	592.9
420049	CO	254.0	11.9	1855.4	126.2	6.8	1262.9	68.1	466.2	25.1	103.0	39.9	591.3
420051	CO	286.9	12.4	1727.3	87.4	5.0	1209.4	70.0	430.6	24.9	102.8	45.1	553.0
420052	CO	229.4	11.8	1956.5	140.2	7.2	1440.8	73.6	375.5	19.2	109.9	40.9	608.1
420053	CO	248.2	11.5	1908.6	142.2	7.5	1358.7	71.2	407.8	21.3	108.5	42.9	589.0
SEM		10.7	0.2	120.9	14.4	0.5	78.1	0.8	34.5	0.8	0.9	0.8	9.9
LSD 0.05		30.6	0.5	254.6	36.2	1.5	170.3	2.1	70.2	2.2	2.5	2.4	28.2
LSD 0.01		40.9	0.7	340.8	48.4	2.0	228.0	2.8	93.9	2.9	3.3	3.2	37.7
IA3023		254.4	60.1	1645.6	118.0	7.2	1124.8	68.4	402.8	24.5	105.3	38.4	541.8
Macon		242.5	67.7	1770.1	111.1	6.2	1290.4	72.9	368.6	20.8	108.1	39.6	542.1

† MO = mid-oleate lines, CO = conventional-oleate lines

Table C12. Mean performance of 20 mid-oleate and 20 conventional-oleate entries for Population 3, IA2073 x AX18895-6, at Rippey, IA, in 2007.

Entry	Type†	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420001	MO	496.8	11.7	1558.0	92.6	5.9	1013.0	65.0	452.5	29.0	92.2	43.9	355.4
420002	MO	569.4	11.5	1610.2	109.7	6.8	1011.2	62.8	489.2	30.4	82.3	41.8	295.1
420004	MO	522.6	13.0	1513.2	123.6	8.2	984.0	65.0	405.6	26.8	88.1	42.8	333.7
420006	MO	497.7	12.6	1409.0	83.6	5.9	811.2	57.5	514.2	36.5	89.1	48.3	352.4
420008	MO	527.7	11.8	1616.7	111.5	6.9	1032.1	63.8	473.2	29.3	85.5	49.2	325.9
420009	MO	484.1	14.0	1668.5	95.9	5.7	1089.0	65.3	483.7	29.0	90.1	41.7	370.2
420011	MO	544.3	11.9	1483.2	96.1	6.4	910.8	61.3	476.3	32.2	86.3	46.6	311.0
420012	MO	507.0	12.4	1666.4	117.7	7.1	1041.4	62.5	507.3	30.4	92.0	45.9	342.8
420013	MO	555.8	11.6	1362.3	107.1	7.8	906.7	66.5	348.5	25.6	87.8	43.7	301.2
420014	MO	513.3	12.6	1588.7	114.3	7.2	1030.6	64.9	443.9	27.9	85.3	43.2	345.6
420015	MO	517.4	11.6	1559.0	101.0	6.5	1039.2	66.7	418.7	26.9	91.4	45.5	334.2
420016	MO	548.2	12.2	1608.8	100.6	6.3	1054.3	65.5	454.0	28.2	85.4	43.2	311.1
420017	MO	490.2	11.9	1592.2	118.6	7.5	1090.7	68.5	382.8	24.1	92.3	44.2	361.5
420019	MO	508.0	11.7	1546.5	84.6	5.5	1005.5	65.0	456.3	29.5	86.9	47.0	346.6
420020	MO	512.8	11.5	1540.4	62.2	4.0	966.9	62.8	511.3	33.2	90.9	45.0	340.0
420021	MO	555.4	11.8	1556.2	93.7	6.0	972.9	62.5	489.6	31.5	87.6	42.0	303.4
420022	MO	522.5	11.3	1546.9	103.0	6.7	950.3	61.5	493.6	31.9	93.8	41.7	330.8
420025	MO	518.6	11.7	1581.1	110.8	7.0	999.8	63.2	470.5	29.8	85.2	41.7	342.9
420026	MO	497.3	11.8	1438.9	99.9	6.9	920.8	64.0	418.3	29.1	87.1	44.3	359.6
420027	MO	523.4	12.1	1605.3	90.8	5.7	1039.2	64.7	475.2	29.6	87.9	43.6	333.1
420029	CO	261.0	11.5	1609.1	80.3	5.0	1118.7	69.5	410.1	25.5	106.5	48.2	573.0
420030	CO	250.9	12.4	1815.1	92.9	5.1	1298.4	71.5	423.9	23.4	103.1	43.6	590.0
420031	CO	235.1	12.0	1766.6	69.7	3.9	1242.0	70.3	454.8	25.7	100.7	45.8	606.5
420032	CO	271.2	14.9	1607.0	61.5	3.8	1122.0	69.8	423.6	26.3	105.7	46.4	561.8
420033	CO	266.2	12.2	1654.4	108.5	6.6	1195.6	72.3	350.3	21.1	104.2	42.9	574.7

Table C12. Continued.

Entry	Type	Oleate	Linolenate	Tocopherol							Palmitate	Stearate	Linoleate
				Total	α	α	γ	γ	δ	δ			
		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	% of total	mg kg^{-1}	% of total	mg kg^{-1}	% of total	g kg^{-1}	g kg^{-1}	g kg^{-1}
420034	CO	270.2	12.3	1733.7	97.4	5.6	1268.4	73.2	367.9	21.2	106.6	44.3	566.8
420035	CO	257.3	11.6	1705.6	77.3	4.5	1177.7	69.0	450.7	26.4	109.1	43.0	579.0
420037	CO	263.3	12.1	1560.1	75.0	4.8	1094.7	70.2	390.4	25.0	105.5	46.9	572.3
420038	CO	266.3	13.2	1750.9	90.5	5.2	1220.8	69.7	439.6	25.2	111.6	44.9	564.0
420039	CO	238.6	12.3	1546.1	80.0	5.2	1078.3	69.7	387.8	25.1	102.6	45.3	601.2
420040	CO	241.8	12.5	1752.8	98.6	5.6	1164.2	66.4	490.0	27.9	101.5	41.8	602.5
420041	CO	272.5	11.6	1636.8	69.7	4.3	1147.4	70.1	419.7	25.6	103.5	42.9	569.7
420044	CO	242.8	12.4	1757.6	69.9	4.0	1201.5	68.4	486.2	27.7	100.9	47.5	596.6
420045	CO	243.9	12.6	1676.4	93.9	5.6	1166.4	69.6	416.1	24.8	106.9	45.4	591.3
420047	CO	270.8	12.6	1636.7	88.7	5.4	1145.0	70.0	403.1	24.6	100.6	44.5	571.6
420048	CO	254.4	11.9	1770.0	97.3	5.5	1272.0	71.8	400.6	22.7	107.7	44.5	581.6
420049	CO	254.3	12.2	1766.9	100.5	5.7	1196.8	67.7	469.6	26.6	101.6	43.5	588.4
420051	CO	280.6	12.3	1672.5	78.0	4.7	1178.7	70.5	415.8	24.9	101.1	48.5	557.5
420052	CO	238.8	12.1	1745.7	108.9	6.2	1311.2	75.1	325.6	18.6	106.5	42.7	599.9
420053	CO	263.9	12.0	1825.2	117.4	6.4	1294.8	70.9	413.1	22.6	106.8	43.7	573.7
SEM		9.1	0.5	39.0	10.3	0.6	32.2	0.8	16.7	1.1	1.1	0.8	8.7
LSD 0.05		26.3	1.5	100.1	18.8	1.1	79.9	2.2	44.4	2.4	2.9	2.2	24.8
LSD 0.01		35.2	2.0	134.0	25.1	1.4	106.9	2.9	59.5	3.2	3.9	2.9	33.2
IA3023		236.7	63.9	1587.7	97.1	6.1	1068.7	67.3	421.9	26.6	104.8	38.3	556.4
Macon		244.8	70.4	1689.3	101.2	6.0	1220.8	72.3	367.2	21.8	105.9	41.3	537.7

† MO = mid-oleate lines, CO = conventional-oleate lines

APPENDIX D

STATISTICAL ANALYSIS

Analyses of variance were conducted for each line used in tocopherol analysis. Environments and replications were considered random effects, and genotypes were considered a fixed effect.

The linear additive model for the analysis of variance for tocopherol content across environments was:

$$Y_{ijk} = \mu + E_i + R/E_{j/i} + G_k + EG_{ik} + e_{ijk}$$

where,

Y_{ijk} = the observed value of the kth genotype within the jth replication at the ith environment,

μ = the overall mean,

E_i = the effect of the ith environment,

$R/E_{j/I}$ = the effect of the jth replication within the ith environment,

G_k = the effect of the kth genotype,

EG_{ik} = the effect of the interaction between the ith environment and the kth genotype, and

e_{ijk} = the error of the effect of the ijk^{th} observation.

Table D1. Analysis of variance and expected mean squares for each population across three environments.

Sources of variation	Degrees of freedom	df	Expected mean squares
Environments (E)	e-1	2	$\sigma^2_e + g\sigma^2_{R/E} + gr\sigma^2_E$
Replications/E	(r-1)e	3	$\sigma^2_e + g\sigma^2_{R/E}$
Genotypes(G)	(g-1)	39	$\sigma^2_e + r\sigma^2_{GE} + re\Phi_G$
Mid-Oleate (M)	(m-1)	19	$\sigma^2_e + r\sigma^2_{ME} + re\Phi_M$
Conventional (C)	(c-1)	19	$\sigma^2_e + r\sigma^2_{CE} + re\Phi_C$
M vs C	1	1	$\sigma^2_e + r\sigma^2_{(MvsC)E} + re\Phi_{MvsC}$
G x E	(e-1)(g-1)	78	$\sigma^2_e + r\sigma^2_{GE}$
M x E	(e-1)(m-1)	38	$\sigma^2_e + r\sigma^2_{ME}$
C x E	(e-1)(c-1)	38	$\sigma^2_e + r\sigma^2_{CE}$
M vs C x E	1(e-1)	2	$\sigma^2_e + r\sigma^2_{(MvsC)E}$
Error	e(r-1)(g-1)	117	σ^2_e
Total	erg-1	239	

The linear additive model for the analysis of variance for tocopherol content at an individual environment was:

$$Y_{ij} = \mu + R_i + G_j + e_{ij}$$

where,

Y_{ij} = the observed value of the jth genotype within the ith replication,

μ = the overall mean,

R_i = the effect of the ith replication,

G_j = the effect of the jth genotype, and

e_{ijk} = the error of the effect of the ijk^{th} observation.

Table 2. Analysis of variance and expected mean squares for each population at an individual environment.

Sources of variation	Degrees of freedom	df	Expected mean squares
Replications	(r-1)	1	$\sigma^2_e + g\sigma^2_R$
Genotypes	(g-1)	39	$\sigma^2_e + r\Phi_G$
Mid-Oleate (M)	(m-1)	19	$\sigma^2_e + r\Phi_M$
Conventional (C)	(c-1)	19	$\sigma^2_e + r\Phi_C$
M vs C	1	1	$\sigma^2_e + r\Phi_{MvsC}$
Error	(r-1)(g-1)	39	σ^2_e
Total	rg-1	79	

The coefficient of variation (CV) and least significant difference (LSD) at the 0.05 and 0.01 probability levels were calculated as:

$$\text{CV (\%)} = \frac{\sqrt{MSE}}{\bar{x}} \times 100$$

$$\text{LSD} = t_{\alpha}\sqrt{\frac{2MSE}{n}}$$

where,

MSE = the error mean square for an individual location or genotype x environment interaction for combined environments,

$\bar{x}$ = the mean of all entries for a trait,

n = the number of observations in each entry mean, and

t = the critical t value at either the 0.05 or 0.01 probability level.