Dynamics of Oil and Fatty Acid in Historical Sorghum Varieties

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Summary

One of the important characteristics of cereal crops is their diverse pool of fatty acids. This study aims to determine the changes in sorghum oil content and fatty acid profile across many years of the market's variety releases. Six sorghum varieties, all released between 1960 and 2019, were evaluated and grain traits were analyzed using linear models. Ten different fatty acids were characterized, but only three out of the total represented more than 90% of the total oil concentration: linoleic, oleic, and palmitic acid. Total oil and linoleic acid concentration (g of oil/kg) slightly decreased across years of release. In contrast, palmitic and oleic acid concentrations (g of oil/kg) increased over time. These results indicate past breeding efforts have not substantially modified sorghum's profile of fatty acids.

Introduction

Sorghum [*Sorghum bicolor (L.) Moench*] is a versatile crop that can be grown as a grain or forage. Sorghum has a remarkable ability to maintain yields under adverse conditions, especially drought, compared with other grain crops. This makes sorghum an important source of food, feed, fiber, and fuel in the global agro-ecosystem (Kresovich et al., 2005). The sorghum grains contain 8 to 12% protein, 3 to 4% oil, approximately 76% starch, and approximately 2% fiber. The oil in sorghum grain provides high quality food. Although cereal crops with low oil concentration may not confer much as domestic oil sources, their importance is driven by advantages of their fatty acid (FA) constituents (Mehmood et al., 2008). Therefore, considering the importance of biochemical analysis of sorghum, it is relevant to explore from a historical perspective the effects of breeding and variety development on FA profile, which to our knowledge, is currently lacking in the scientific literature. The present study was conducted to quantify potential changes in sorghum oil concentration and fatty acid profile across the different years of market release for commercial hybrids.

Procedures

Field Experiments

This research project was conducted in Wamego, KS, United States, during the 2021 growing season. Sorghum was planted on June 7, 2021, and standard agronomic practices were followed to maintain the field free of weeds, pests, and diseases during the

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season. Six sorghum varieties from Corteva Agriscience (Johnston, Iowa, US) released between 1960 and 2019 were evaluated, herein termed as hybrid 1 (1960), hybrid 2 (1982), hybrid 3 (1997), hybrid 4 (2006), hybrid 5 (2010), and hybrid 6 (2019). Genotypes are representative of each year of release and were widely grown in the Midwest region of the US. All sorghum grains were sampled at physiological maturity to determine their fatty acid composition.

Total Oil and Fatty Acid Content Determination

Seed oil content and fatty acid composition were quantified using a well-established method (Miquel and Browse, 1992) with minor modifications. Briefly, dry seeds were powdered, and 1.5 mL of toluene was added, to which 100 µg of triheptadecanoin was added as an internal standard. Total lipids were transmethylated by adding 1 mL of 2.5% (v/v) H_2SO_4/methanol and heating at 90°C (194°F) for 1 h. The fatty acid methyl esters were extracted from the organic phase after the addition of 1.5 mL of potassium chloride and 2 mL hexane, and quantified by gas chromatography using a DB-23 column on a Shimadzu GC2100+ gas chromatograph. The oven temperature was initially 200°C (392°F) for 2 min; then ramped to 240°C (464°F) at 10°C/min (50°F/min) and held at that temperature for 4 min. Chromatogram peak areas were corrected for flame ionization detector response, and oil content was determined as described previously (Li et al., 2006). After obtaining FA concentration in grains, total oil concentration was quantified as the sum of each individual FA. Fatty acids content and total oil for each sample were estimated as the product between seed dry weight and component concentration.

Statistical Analysis

Traits were analyzed using linear models in R software (lm and emmeans package, lm function) (Bates et al., 2015). The year of release was used as a continuous numerical variable. Differences between varieties were analyzed using analysis of variance for variety, year of release, and their interaction as fixed effects. When significant effects were found ($P \leq 0.05$), comparisons were performed using Tukey's test.

Results

Ten fatty acids in sorghum grain oil were detected and quantified in all the years of release (Fig 1). Linoleic acid (18:2), oleic acid (18:1), and palmitic acid (16:0) were the three predominant fatty acids. Low amounts of alpha-linolenic acid (18:3), arachidic acid (20:0), behenic acid (22:0), erucic acid (22:1), palmitoleic acid (16:1), stearic acid (18:0), and gondoic acid (20:1) were also present.

Total seed oil concentration varied significantly across years of release ($P < 0.001$; Figure 2), presenting a negative trend over time. Similarly, the polyunsaturated FA linolenic acid was also affected by the year of release ($P < 0.001$; Figure 3A) with an overall decrease in its concentration. On the other hand, the saturated FA palmitic acid showed a small trend to increase its amount in the total oil concentration (Figure 3B). No clear relationship was found for oleic acid ($r^2 = 0.1$).

Conclusion

Total oil and linoleic acid concentrations were negatively associated with year of release. Contrastingly, palmitic acid increased with the year of release. The identified changes in the oil profile were relatively low, indicating that past breeding efforts have not substantially modified sorghum fatty acids profile.

Acknowledgments
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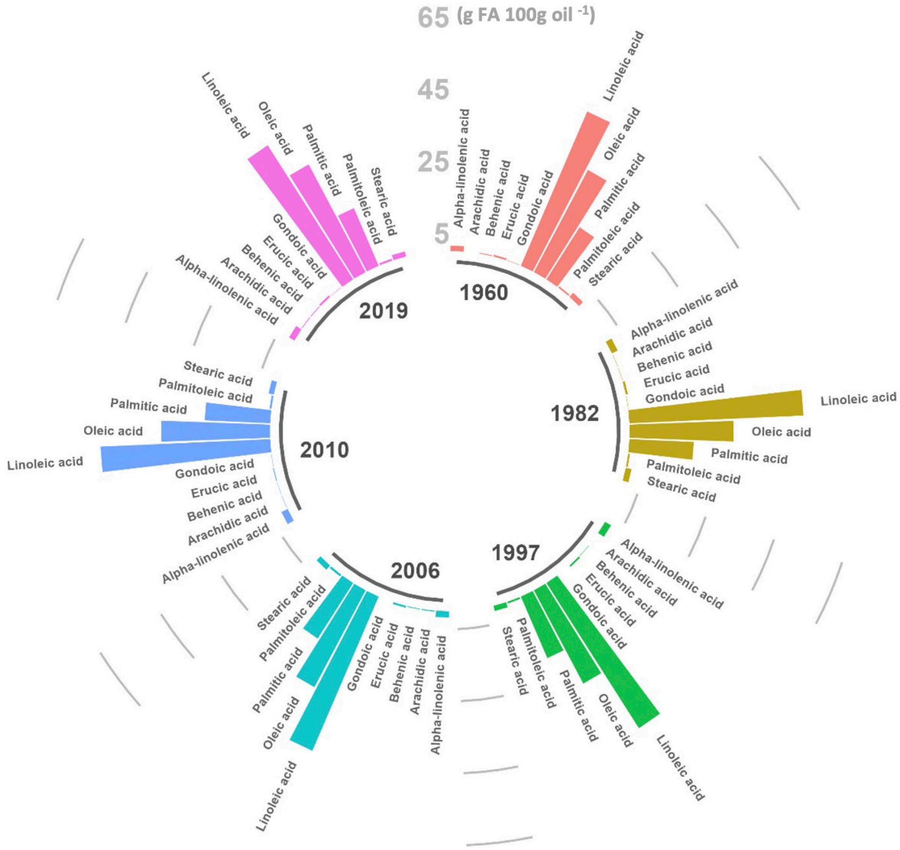

Figure 1. Fatty acids profile in sorghum grains in different years of release.

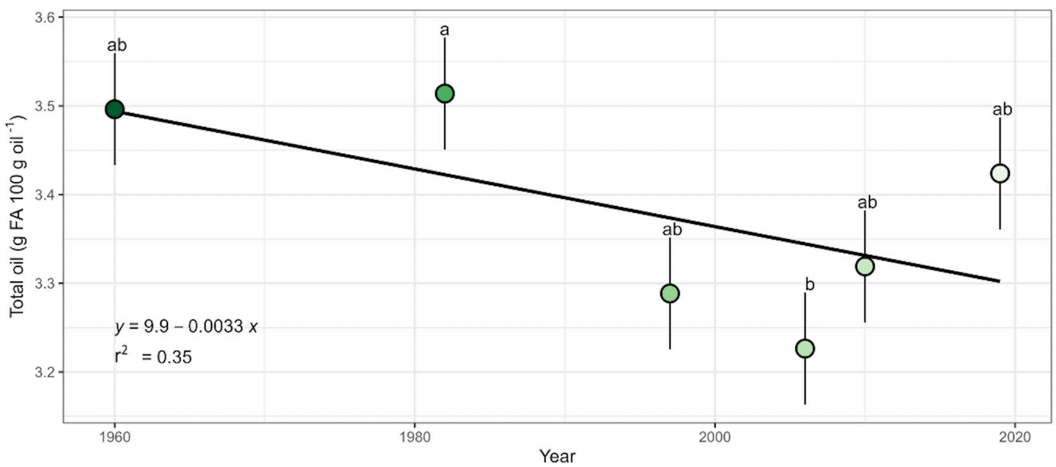

Figure 2. Relationship between year of release and total oil concentration. The error bar represents the standard deviations of the mean. Different lowercase letters indicate significant differences among years of release according to Tukey's test ($P \leq 0.05$).

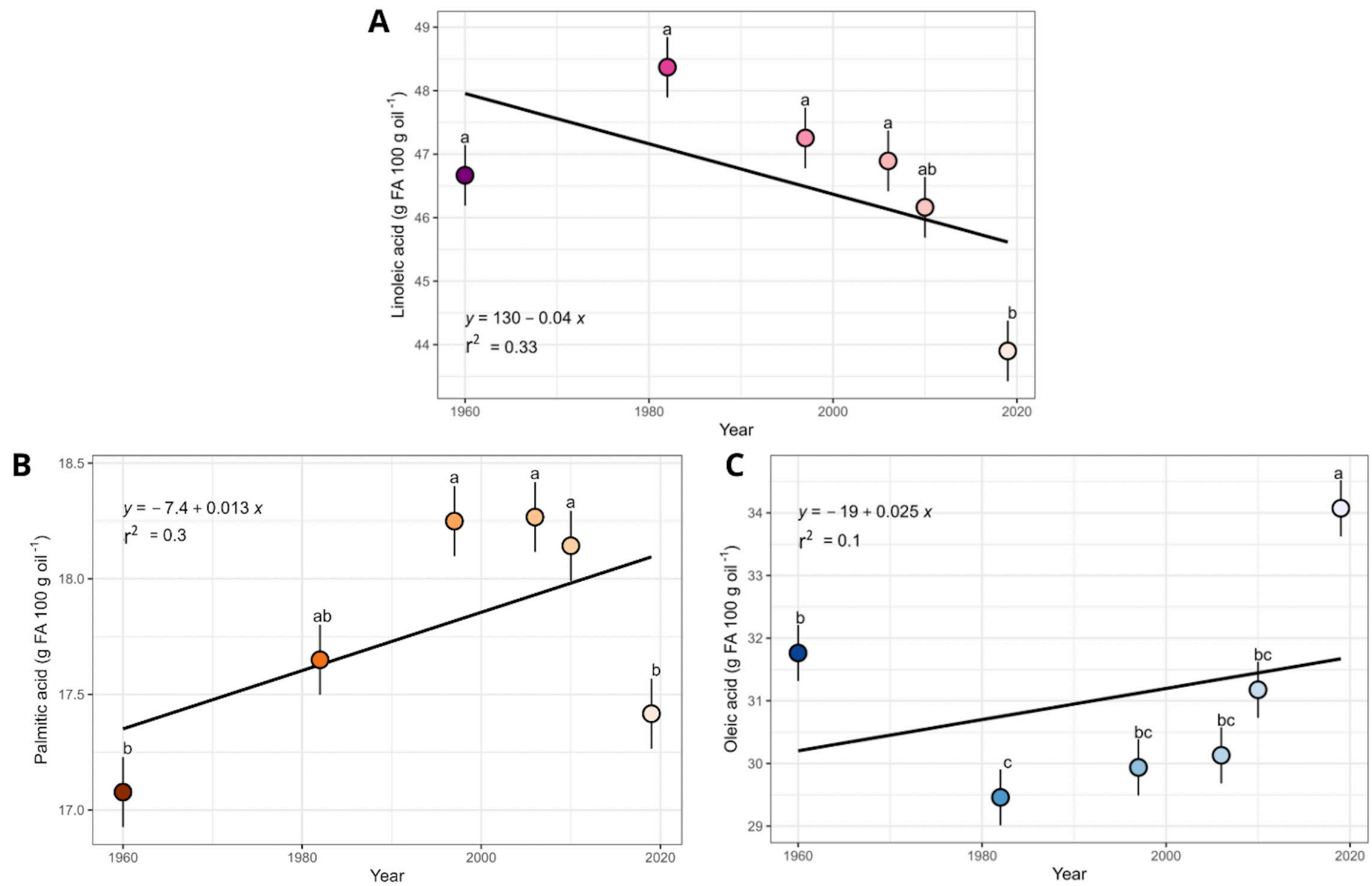

Figure 3. Relationship between year of release and linoleic acid (A), palmitic acid (B) and oleic acid (C). The error bar represents the standard deviations of the mean. Different lowercase letters indicate significant differences among years of release according to Tukey's test (*P* ≤ 0.05).