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'Criss': a promising new genotype for diversifying avocado production

Abstract

The state of Michoacan, Mexico, possesses rich agroclimatic conditions conducive to avocado cultivation. By 2024, the established cultivation area reached 264,589.06 hectares, producing 2,973,344 t with an average yield of 11.73 t ha^{-1}. This expansion has often involved the conversion of forested land. The 'Hass' cultivar is the preferred choice for commercial production due to its quality traits. However, in the avocado-growing regions of Michoacan, competitive 'Hass'-type variants have been identified, offering greater genetic diversity to enhance crop viability. One such genotype is 'Criss'. This variant was discovered by chance in the 1980s and later formally established in Matanguaran, Uruapan, Michoacan. The 'Criss' genotype is characterized by large fruit size (averaging 342 g), a yield of 240 kg per tree, a medium tree height of 7.5 m, an oil content of 25.1%, and a distinct lipid profile. These traits provide 'Criss' with comparative advantages over 'Hass', making it a promising genotypic alternative to diversify avocado cultivation and enhance the sustainability of this important agricultural system.

Keywords: genotype diversity, morphological description, lipid profile, avocado cultivar

Volume 9 Issue 4 - 2025

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Received: December 05, 2025 | **Published:** December 26, 2025

Abbreviations: CIC, coordination of scientific research; SIAP, agri-food and fisheries information system; ITC, international trade centre; IPGRI, International Plant Genetic Resources Institute; IUPAC, International Union of Pure and Applied Chemistry; MIDI, Microbial Identification Inc.; RAL, reich committee for delivery terms and quality assurance; UMSNH, michoacan university of san nicolas hidalgo

Introduction

Avocado cultivation has expanded significantly in Mexico in recent years, driven by growing consumer preference and increasing global supply and demand. Mexico is the world's leading avocado exporter, accounting for 41.9% of global exports and generating an economic return of USD 4.011 billion.[1] In 2024, the cultivated area reached 264,589.06 ha, with a total production of 2,973,344 t and an average yield of 11.73 t ha^{-1}. The main producing states are Michoacan (2,252,783 t), Jalisco (323,228.37 t), and the State of Mexico (132,478.25 t).[2]

The species is native to Mexico and Central America. Evidence of its consumption dates to between 7000 and 8000 B.C., found in a cave in Coxcatlán, Tehuacán Valley, Puebla, Mexico.[3] Archaeologists have reported avocado fossils corresponding to Persea americana var. drymifolia (Mexican race), P. americana var. americana (West Indian race), and P. americana var. guatemalensis (Guatemalan race), indicating that ancient cultures possessed extensive knowledge of this species.[4,5]

In Michoacan, diverse agroclimatic conditions have enabled the establishment of orchards containing all three botanical races. By 1958, 923 ha of native criollo-type avocados were registered, a genetic resource used as rootstock and interstock to improve fruit quality and yield. The first introduced cultivars were 'Fuerte', 'Bacon', and 'Zutano'.[6] In 1964, the 'Hass' cultivar began to replace both native and introduced cultivars, achieving remarkable global expansion, and becoming the most commercially important cultivar worldwide.[7]

In recent decades, the primary production strategy has been the expansion of cultivated areas, leading to significant environmental impacts from land-use change. Consequently, research efforts over the past twenty years have focused on identifying genotypes with 'Hass'-like traits but with additional desirable characteristics such as compact growth habit, early bearing, and high productivity. To date, approximately twelve genotypes with competitive potential have been identified and evaluated based on morphology, chemical composition, and lipid profile. Among these, the 'Criss' genotype stands out. The ultimate goal of this research is to shift the production strategy towards using distinct genotypes adapted to specific areas, offering comparative advantages over 'Hass'—such as compact growth, larger fruits, and distinctive lipid profiles—to enhance yield per tree rather than expanding into new land, sacrificing the forests.

Materials and methods

Location of the 'Criss' genotype. The trees were evaluated in the orchard "El Estillero 5," owned by Mario Solís Morelos, located in Matanguaran, Uruapan, Michoacan, Mexico (19°20'56.52" N, 102°6'4.16" W), at an altitude of 1595 m above sea level. The trees are established under a square frame planting design, with a spacing of 9 x 9 meters.

Descriptors used. The morphological description included five randomly selected trees. The evaluation of vegetative and reproductive organs was based on the avocado descriptor manual proposed by IPGRI.[8] A total of 88 descriptors were used: 13 for the tree, 14 for the leaf, 15 for the flower, 34 for the fruit, and 12 for the seed.

Lipid profile determination. A homogeneous sample of freeze-dried pulp was used for fatty acid derivation. Fatty acids were detected using an Agilent GC 7890 chromatograph equipped with a 25 m fused silica capillary column, using hydrogen as the carrier gas, and analyzed with Sherlock software version 3.1 (MIDI Inc., Delaware, USA). Methyl esters were extracted according to standard procedures.[9] Quantification was achieved using the internal standard methyl nonadecanoate (19:0) of known concentration and by comparing peak areas. A combination of fatty acid methyl esters (10-20 carbons in length) provided by MIDI Inc. (Newark, USA) was used for standard calibration.

Results

Description of morphological characteristics

Overall tree. The tree exhibits a semicircular shape and medium vigor, with a crown diameter of 6.6 to 8m, a height of 7 to 9.5 m, and an average trunk circumference of 57.5 to 120 cm (Figure 1). The trunk surface is rough, and branches are irregularly distributed. The branching pattern is intensive, with several branches arising below the apex of the twig with each growth flush. The crotch angle of the main branches is acute. Young twigs are green with a pubescent surface and green lenticels.

Figure 1 Morphological traits of the 'Criss' avocado tree: (A) vigor and shape, (B) trunk surface, (C) branch distribution and pattern, (D) crotch angle of main branches, (E) color and pubescence of a young twig.

The leaf. Leaf morphology is oblong-lanceolate with an acute base and apex. The petiole's crotch angle is acute, and the margin is undulate. Venation on the upper surface has an intermediate relief, with primary veins diverging at a 90° angle from the main vein. The leaf texture is semi-hard, and both surfaces exhibit sparse pubescence. The mature leaf color is chrome green (RAL 6020). Defoliation is partial. The leaf has a slight anise smell, the blade measures 8.2 to 24.7 cm with 7 to 18 primary veins.

Flower. The flower is type A and fern green (RAL 6025). Petals and sepals exhibit dense pubescence, and the style is straight. Pollen and nectaries are present. The inflorescence has 43 to 508 flowers and 3 to 29 branches, with a length of the main axis ranging from 4.48 to 59.66 cm, the pedicel measures from 2.75 to 10.26 mm, the petals measure from 2.93 to 6.08 mm and finally, the sepals measure from 1.97 to 5.97 mm.

Fruit. The fruit is a high spheroid with medium gloss and a flattened base. The apex is centrally positioned and rounded. The skin surface is intermediate, and its color is leaf green (RAL 6002). Lenticels on the fruit are small with intermediate density. The fruit is 7.9 to 12.2 cm long, 7.1 to 9 cm in diameter, and weighs an average of 342.28 g (ranging from 233 to 504 g). The pedicel is asymmetrical, cylindrical, with a nailhead apex, and green in color. Its junction with the peduncle is conspicuous. The peduncle is 5.7 to 21.2 cm long and 2.7 to 9.3 mm in diameter, while the pedicel is 1.1 to 2.1 cm long. The skin is pliable and has slight adherence to the flesh. The flesh next to the skin is yellow-green (RAL 6018), and the flesh next to the seed is ivory (RAL 1014). The flesh texture is buttery, with low sweetness, low bitterness, an intermediate nutty taste, and low fiber content; however, the overall taste was rated as poor. Discoloration of the open fruit after four hours is low and brown in color. Skin thickness is 1.29 to 2.2 mm, and the fruit has a post-harvest shelf-life of approximately 14 days.

Seed. The seed is spheroid and centrally positioned. The cotyledons have an intermediate surface texture, are attached, and are beige (RAL 1001) in color. The seed coat is not free and is not attached to the flesh. There is no free space in the seed cavity. The seed weighs 25 to 89 g and measures 3.1 to 5 cm in length and 3.2 to 5.2 cm in diameter. The seed cavity is 3.4 to 5.4 cm long and 3.2 to 5.2 cm in diameter . Figure 2 shows the characteristics of the inflorescence, leaves, fruit, and seed.

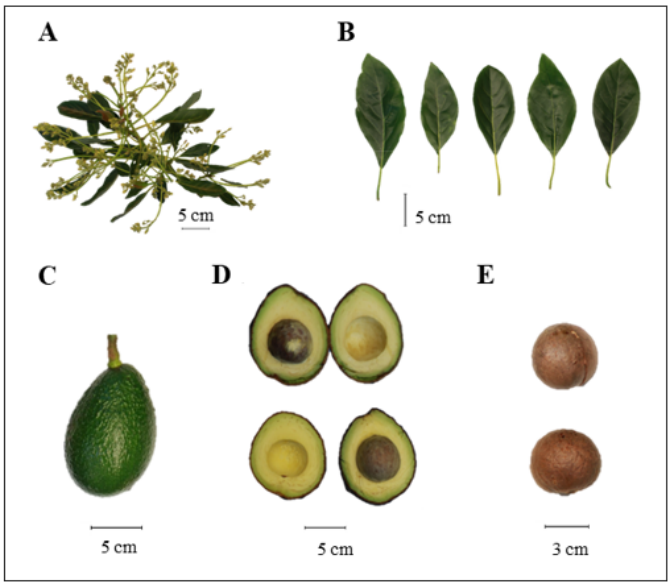

Figure 2 Morphology of the 'Criss' avocado genotype: (A) inflorescences, (B) leaves, (C, D) fruit, (E) seed.

Lipid profile of the 'Criss' avocado genotype

Lipid analysis identified 14 fatty acids: six saturated and eight unsaturated. Oleic acid was the most abundant (40.49%), followed by linoleic acid (25.23%), palmitic acid (17.30%), and palmitoleic acid (10.58%). Petroselinic acid and gondoic acid were also identified, which have not been previously reported in avocados (Table 1).

Figure 3 shows the comparative analysis of fatty acid classes between the 'Criss' and 'Hass' cultivars. The total saturated fatty acid content was similar between both genotypes. In contrast, the 'Criss' genotype exhibited a markedly distinct profile in its unsaturated fractions. It displayed a significantly lower monounsaturated fatty acid (MUFA) content (56.80%), which was primarily driven by a reduced proportion of oleic acid. Conversely, 'Criss' showed a substantially higher polyunsaturated fatty acid (PUFA) content (25.23%), largely attributable to an elevated concentration of linoleic acid, resulting in a uniquely differentiated lipid profile for the 'Criss' genotype compared to the 'Hass' reference.

Citation: Guillén-Andrade H, Escalera-Ordaz AK, Flores RA, et al. 'Criss': a promising new genotype for diversifying avocado production. *Horticult Int J.* 2025;9(4):202–205. DOI: 10.15406/hij.2025.09.00346

Table 1 Fatty acid composition (%) in mesocarp samples from the 'Criss' genotype compared to reference values for the 'Hass' cultivar[10-12]

Fatty Acid			Concentration (%)	
			'Criss'	'Hass'[10-12]
Saturated	14:00	Myristic acid	0.18	0.31-1.28
	16:00	Palmitic acid	17.3	13.4 - 25.63
	16:0 anteiso	Anteiso-hexadecanoic acid	0.06	-
	18:00	Stearic acid	0.32	0.24 - 0.93
	19:0 10-methyl	10-methylnonadecanoic acid	0.07	-
	20:00	Arachidic acid	0.05	0.7 - 0.17
Unsaturated	16:1 w5c	(11Z)-hexadec-11-enoic acid	0.21	-
	16:1 w7c	Palmitoleic acid	10.58	3.4 - 13.14
	17:1 w6c	(11Z)-heptadec-11-enoic acid	0.06	-
	17:1 w8c	Margaroleic acid	0.14	-
	18:1 w6c	Petroselinic acid	5.26	-
	18:1 w9c	Oleic acid	40.49	42.59 - 67.4
	18:2 w6,9c	Linoleic acid	25.23	10.64 - 20.87
	18:03	Linolenic acid	-	0.59 - 3.19
	20:01	Eicosenoic acid	-	0.37 - 0.484
	20:1 w9c	Gondoic acid	0.05	-

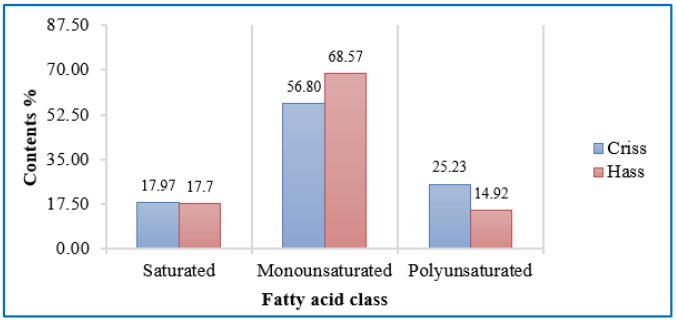

Figure 3 Saturated, monounsaturated and polyunsaturated fatty acid profile in the 'Criss' avocado genotype and the 'Hass' cultivar.

Discussion

The avocado-growing region of Michoacan features diverse agroecological conditions, including 10 climate types, altitudes ranging from 1100 to 2900 m asl, seven soil types (predominantly andosols, 89.81%), and temperatures between 10 and 28 °C.[13,14] These factors significantly influence crop development. Within this region, nine homogeneous production zones have been identified based on eight agroecological factors.[14] This diversity has facilitated the emergence of 'Hass' variants like 'Criss'.

The 'Criss' genotype offers several advantages over 'Hass'. Its medium tree size (7.5 m) allows for higher planting densities and more efficient harvesting. Another advantage is its earliness; flowering occurs from July to October, and it reaches physiological maturity in early May, approximately one month earlier than 'Hass'. Furthermore, the average fruit size of 342 g is substantially larger than the 200 g average for 'Hass'.[15,16] In terms of oil content—a key commercial parameter—'Criss' presented a value of 25%, which is considered excellent and is comparable to the upper range reported for 'Hass' (12.9% to 26.7%).[17]

The lipid profile of 'Criss' shows relevant differences from that of 'Hass'. While oleic acid is the predominant fatty acid in 'Hass' (42.59-67.4%),[10] its proportion is lower in 'Criss'. Conversely, linoleic acid is present in higher concentrations in 'Criss', and the absence of linolenic and eicosenoic acids was noted, suggesting a differentiated lipid composition. The identification of petroselinic and gondoic acids, not previously reported in avocado, is a significant finding. The remaining fatty acids fell within the ranges reported for 'Hass'.[10,11] Additionally, five compounds associated with microbial marker lipids were detected in 'Criss', a relevant finding as such biomarkers can indicate the presence and activity of specific microbial communities.[18,19]

From a functional perspective, these differences in fatty acid composition could impact oil properties. The lower oleic acid content in 'Criss' suggests lower oxidative stability and shelf-life, as oleic acid is associated with greater resistance to lipid peroxidation in vegetable oils.[20,21] In contrast, the higher linoleic acid content could enhance the nutritional value by providing more essential ω-6 fatty acids, albeit at the cost of reduced oxidative stability.[10,17]

Conclusion

The avocado genotype 'Criss' possesses several comparative advantages over the 'Hass' cultivar, including high oil content, a higher proportion of nutritionally valuable linoleic acid, larger fruit size, earlier bearing, and a medium tree size conducive to high-density planting. These characteristics make 'Criss' a commercially viable and valuable alternative to 'Hass', offering means to diversify avocado cultivation genetically and enhance productivity.

Acknowledgments

The authors thank the Coordination of Scientific Research (CIC) of the Universidad Michoacana de San Nicolás de Hidalgo (UMSNH) for the partial funding of this research project.

Conflicts of Interest

The authors declare no conflict of interest. All authors have read and agreed to the published version of the manuscript. This document

presents original research and has not been submitted for publication elsewhere.

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Citation: Guillén-Andrade H, Escalera-Ordaz AK, Flores RA, et al. 'Criss': a promising new genotype for diversifying avocado production. *Horticult Int J.* 2025;9(4):202–205. DOI: 10.15406/hij.2025.09.00346