

ECOLOGICAL ADAPTATION AND THE EVOLUTION OF MODERN AVOCADO CULTIVARS

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SUMMARY

The geographic area in which the avocado originated, stretching from Mexico through Guatemala and probably to Pacific coastal Costa Rica, presents a diverse set of environments. The three races that gave rise to modern avocado cultivars--Antillean (West Indian), Guatemalan and Mexican--accordingly are adapted to quite distinct environmental conditions. The apparent Mexican-Guatemalan hybrids that originated around Atlixco in Puebla State, Mexico, exemplified by 'Fuerte', showed remarkable adaptation when moved to the Mediterranean-type subtropical microclimates common in southern California, permitting a commercial industry to develop and later be transferred to other parts of the world with similar climates, such as South Africa, Israel and Chile. Selection from the material originally brought from Mexico and Central America permitted California to develop commercial cultivars exemplified by 'Hass', 'Fuerte' and 'Reed', among others, that lead the world in the area planted. Guatemalan cultivars are adapted to elevated situations in Central America, yielding well under cool conditions and forming an important dietary staple. The Antillean race, which probably originated along the Pacific coast in Central America, yields well in lowland tropical situations and warm subtropical areas such as southern Florida. Planting Guatemalan and Antillean avocados side-by-side in Florida early in this century produced a new group of hybrid cultivars with quality superior to that of most Antillean cultivars, adaptation to sea level locations, and an extended range of season of maturity that permitted Florida to market fruit into the autumn and winter, well past the season of pure Antillean cultivars. The best of these hybrids, 'Booth 7', 'Booth 8', 'Lula', 'Choquette' and a few others have been exported to warm locations about the tropical world for commercial planting. Thus, selection of avocado germplasm imported from Mexico and Central America into California and Florida produced a group of cultivars that are of significant commercial importance in the world.

KEY WORDS: *Persea americana*, Plant introduction, Varietal improvement, Germplasm

RESUMEN

El área geográfica en donde el aguacate originó, que incluye desde México, Guatemala y probablemente hasta la costa Pacífica de Centroamérica, abarca una gran diversidad de ambientes ecológicos. Por ello, las tres razas que dieron origen a los cultivares

modernos de aguacate, la antillana, la guatemalteca y la mexicana, muestran adaptación a condiciones ambientales muy distintas. Los que parecen híbridos entre las razas mexicana y guatemalteca originados cerca de Atlixco en el estado de Puebla ('Fuerte', por ejemplo) han mostrado una adaptación sobresaliente a los microclimas subtropicales de tipo Mediterráneo en California. Esto permitió el desarrollo de una industria comercial que después fue trasladada a otras partes del mundo de clima semejante, como Sudáfrica, Israel y Chile. La selección del material de México y Guatemala permitió el desarrollo de cultivares comerciales, como por ejemplo 'Hass', 'Fuerte' y 'Reed', que ya constituyen una mayoría de los aguacates sembrados en el mundo. Los aguacates guatemaltecos tienen adaptación a condiciones elevadas, producen bien bajo condiciones frescas y son un componente importante del alimento de la región. La raza antillana produce bien en los trópicos bajos y en regiones cálidas y subtropicales como el sur de Florida. Cuando aguacates de raza guatemalteca y antillana fueron sembrados juntos en Florida a principios de este siglo, se produjo un grupo de cultivares nuevos cuya calidad resultó superior a la de la mayoría de los cultivares de raza antillana. Estos cultivares tienen buena adaptación a localidades cerca del nivel del mar, y un tiempo extendido de producción, lo que permitió a Florida colocar fruta en el mercado durante el otoño e invierno, más tarde que anteriormente. Los mejores de éstos, 'Booth 7', 'Booth 8', 'Lula', 'Choquette' y otros más se han trasladado a regiones cálidas tropicales para su cultivo comercial. Así, la selección del germoplasma traído de México y Centroamérica ha producido un grupo de cultivares que son de gran importancia en el comercio mundial.

Geographic Origin of Avocado

The avocado, *Persea americana* Miller, apparently originated in a broad geographic area stretching from the eastern and central highlands of Mexico through Guatemala to the Pacific coast of Central America (Smith 1966 and 1969, Popenoe 1927). The Antillean (also called West Indian) race of avocado is believed to have come into being on the western coast of Costa Rica (Ben Ya'acov, pers. comm.).

Differentiation of the 3 Horticultural Races

Horticulturists recognized three well-differentiated races, Mexican, Guatemalan and Antillean (=West Indian) based upon morphology and their climatic adaptations some 80 years ago, but the differences had first been noted and recorded in the 17th century by Fray Bernabe Cobo in his *Historia del Nuevo Mundo*, written in 1653 (Popenoe 1934).

Origin of the Atlixco Population and Importation of Fruit to California

Avocados have been utilized and selected in what is now Puebla State of Mexico for some 9,000 years (Smith 1966 & 1969). The first material involved was of the Mexican race native to the area, but in the Valley of Atlixco in Puebla State, seedling avocado trees of the Mexican and Guatemalan race have long been found, as well as apparent inter-racial hybrids such as the original tree of 'Fuerte'. During the years from 1890 until 1911, when the Revolution interrupted commerce, avocado fruit from the Atlixco area

was sent to California to be marketed in Los Angeles. Seeds from this group were planted in considerable quantities about southern California, so genes from Atlixco were well represented in the early cultivars selected for asexual propagation when this became common. (Popenoe, 1926).

Selection of Cultivars from imported Atlixco Material in California and Fuerte's subsequent Importance to California and the world

In 1911, Fred Popenoe, a nurseryman of Altadena, California underwrote a trip to Mexico by Carl Schmidt, whose objective was to collect budwood of superior avocado seedlings growing in the vicinity of Atlixco, in Puebla State. Avocados in Atlixco at that time were grown from seed, but propagation by budding had recently become a standard practice in California, making it possible to select and propagate named cultivars from exceptional seedlings. One of the seedlings Carl Schmidt collected in Atlixco, Number 15, named 'Fuerte' because of its strong growth in the nursery, has subsequently had tremendous impact on the world avocado industry (Popenoe, 1926). By 1947 'Fuerte' was the leading commercial cultivar in present-day Israel (Oppenheimer, 1947), and by 1957, 60 percent of the avocado plantings in South Africa were of 'Fuerte' (Malan, 1957). 'Fuerte' has now been displaced in most areas that have a Mediterranean-type climate by 'Hass', and other adapted cultivars that are more dependably productive than is 'Fuerte', but for many years it led the world in commercial production.

Ecological adaptations of Atlixco Avocados

Atlixco is situated about 1,875 M above sea level and has an average rainfall of about 80 cm during the season from May to October. The average mean annual temperature is about 12.5°C with a maximum of 32° C and a minimum of 2° C. (Shamel, 1936; Mosiño A. and García, 1974) Average mean temperatures available for two California sites are higher than that for Atlixco: 18°C for Los Angeles and 17.2°C for San Diego, but the extreme minimum temperature recorded at both the California cities, -2°C, is considerably lower than the mean minimum for Atlixco (Court, 1974). The fact that a commercial industry was built in southern California with germplasm brought for the most part from Puebla State indicates that this material has the capacity to tolerate occasional freezing weather, if this is of short duration. Additional evidence of its cold tolerance is provided by success of the cultivars from California when they were introduced into Palestine, which is now Israel (Oppenheimer, 1947).

Origin of Florida's Antillean Population

The first English-speaking settlers to arrive in the Miami area of south Florida in 1850 found Antillean avocado seedlings naturalized in the hardwood vegetation (**hammocks**) of the area. The origin of these trees is not known but it is reasonable to believe they were introduced from Cuba during the Spanish occupation of Florida, which ended in 1819 with the purchase of Florida from Spain by the United States. (Antillean avocados growing at St. Augustine to the north of Miami, killed by the severe winter weather of 1835, were presumably of the same origin.) (Wolfe *et al.*, 1949)

Development of Asexually Propagated Cultivars in Florida and their Relationship to Development of the Avocado Industry in Florida

Early in the 20th century George Cellon, a nurseryman of Miami, devised the first known method for propagating avocados asexually by budding (Anonymous, 1946). This method was later replaced in Florida by grafting, but it is still employed in California and other areas of commercial production. Superior Antillean seedlings of local origin were selected by Cellon as the first named cultivars and two of these, 'Pollock' and 'Trapp' are still classified as commercial varieties in south Florida (Fla. Avocado Administrative Committee, 1999).

Ecological Adaptations of Cuba's and Florida's Antillean Avocados

The climate of the part of Florida where Antillean Avocados have long been grown is classified as Humid Semi-hot Semi-tropical, 4.45 by Papadakis' (1966) classification. Climates in Cuba, where the Antillean avocado is widely distributed, are classified by Papadakis as Humid Semi-hot Tropical (Habana) or Moist Monsoon with 4-5 dry months (Cienfuegos). The annual mean temperature in Cuba is 25.5° C, with a mean for January of 22.5° C and a mean for August of 27.8°C, and freezing weather never occurring (Inst. Econ., 1974). The main difference between south Florida's climate and the conditions common in Cuba is that freezing weather occasionally occurs in Florida (a minimum of 0°C at Miami in February of some years) but this rarely damages the trees because freezes are usually of short duration. The annual mean temperature at Miami is 23.9°C, with a mean in January of 19.4°C and a mean in August of 27.9°C (Court, 1974). In these conditions trees of the Antillean race grow well, and thus it was possible to establish an industry based on cultivars of this race.

Introduction of Guatemalan Avocados to Florida and their Evaluation

The first Guatemalan avocados 'Colla', 'Collins' and 'Winslow', were introduced into Florida in 1906 (Fairchild, 1939). Their ecological adaptations were quite different from those of the Antillean cultivars that had been selected from Cuban importations. Climates prevailing in the Guatemalan highlands have been classified as "humid tierra templada," suitable for arabica coffee, maize and rice, subdivided into moist monsoon with 4 (or less) dry months, or ever humid (Papadakis, 1966). Genotypes of avocado that thrive under these conditions would be expected to undergo some stress when moved to warm, lowland climates such as those normal in Cuba and southern Florida. The base of the Guatemalan race is made up of a group termed the "Guatemalan Criollos" by Schieber and Zentmyer (1980) which grows in Guatemala and parts of Mexico and El Salvador at elevations from 1500 to 2400 meters (m) and in some cases as high as 2600 m. Plants at the last-named elevation are subject to frost in winter, and all Guatemalan trees grow best at cooler temperatures than those preferred by trees of Antillean race. Guatemalan avocados brought to Florida survived but in most cases did not thrive, apparently because of Florida's year-round warm temperatures. Only one Guatemalan cultivar, 'Taylor', has persisted to the present as a minor commercial variety in Florida.

Origin of Guatemalan-Antillean Hybrid Cultivars

The first Guatemalan-Antillean hybrids to be recorded originated at the U. S. Department of Agriculture (USDA) Plant Introduction Garden at Miami and were seedlings of 'Colla', 'Collins' and 'Winslow' each pollinated by an Antillean parent, and were named 'Collason', 'Collinson' and 'Winslowson' (Fairchild, 1939). They constituted

a new type of avocado on the face of the earth, and were of immediate interest because they combined enhanced fruit quality from the Guatemalan parent with adaptation to warm lowland conditions derived from the Antillean parent. Furthermore, their fruit matured at a later season than did Antillean cultivars, opening the autumn and winter markets to Florida fruit. 'Collinson' bears an attractive fruit that unfortunately has some marketing defects, namely shy bearing under some conditions, sensitivity to low storage temperatures and a tendency for the seed to germinate while still in the fruit nevertheless it continues to be a minor commercial cultivar in Florida. The Guatemalan-Antillean hybrid cultivars that have achieved greatest commercial success, however, resulted from the collaboration of a resident of Homestead named Will Booth with W. J. and Isabelle Krome, proprietors of a nursery in southern Dade County, Florida. The Kromes had an experimental planting of mixed cultivars and selections of both races. In 1920, Will Booth planted seeds of Guatemalan cultivars from the Krome planting and grew them to fruiting age, at which time their hybrid origin became evident (W. H. Krome, pers. comm.). The tree designated 'Booth 2' first fruited in 1927, as did others in the numbered series of Booth cultivars. Booth seedlings 1, 3, 5, 7 and 8 were propagated commercially in 1935 (Wolfe *et al.*, 1949). They appeared on the scene when Florida was experiencing severe competition from Cuba in marketing its Antillean cultivars, which matured in summer and early autumn (Brooks, 1929). The Guatemalan-Antillean hybrids growing in Florida matured fruit in autumn and winter, at a time when Cuba did not have fruit available to market, and thus Florida's avocado industry survived through growing these new cultivars. When trade between Cuba and the U.S.A. was interrupted in the early 1960s, production of Antillean cultivars again became important in Florida, as production of hybrid cultivars continues to be.

Effect of the Success of 'Fuerte' in California on Avocado Culture Elsewhere; Establishment of 'Fuerte' Orchards in Israel, South Africa, Chile, Australia

Avocados were introduced to what is now Israel in 1908, but the named cultivars 'Fuerte' and 'Dickinson' were not brought in for trial before 1924. In 1934, 'Benik', 'Nabal' and 'Queen' were imported from California. By 1947, 'Fuerte' was the leading commercial cultivar, but because of irregular bearing a more dependable cultivar was sought. Other cultivars under trial at that time were 'Duke', 'Northrup', 'Mexicola', 'Ganter', 'Puebla', 'Caliente' and 'Anaheim'. 'Hass' was introduced into Israel in the late 1940s and was added to the list of recommended varieties by the mid-sixties (Ohad, 1965; Ticho and Gefen, 1965). 'Fuerte' continued to be the most commonly planted cultivar into the late 1970s (Gustafson, 1967), and remains important. In recent years, cultivars which developed within the country as well as some of California's newer cultivars have been planted in Israel. The subtropical Mediterranean climate in that part of the world is characterized by winter weather (November to mid-March) which is generally cool but may be as warm as 30°C on cloudless days. (Occasional temperatures of 40°C or above may occur during extremely hot "khamsin days" in springtime.) Freezing temperatures may rarely occur on the coastal plain, with temperatures in some pockets lacking air drainage having descended as low as -4.5°C (Oppenheimer, 1947). The success of Israel's avocado industry, based on germplasm from California, most of which came originally from Mexico, is exemplified by production figures over a 35-year period, rising from 800 metric tons (mt) in 1961 to 75,900 mt in 1996 (FAOSTAT database, 1999). Avocados are widely grown in South Africa,

principally in the eastern and northern Transvaal and also in frost-free coastal belts of the Cape Province and Natal, as well as Swaziland (Malan, 1957). The climate for Nelspruit in the Transvaal is classified as Low Tierra Fria with a dry monsoon, suitable for wheat, maize, rice and cotton (Papadakis, 1966). Nelspruit is also a center of citrus production. In the 35 years from 1961 to 1996, South African avocado production increased by more than 10-fold, from 4,700 mt to 49,100 mt (FAOSTAT Database, 1999).

Chile has a variety of climates, among them subtropical semiarid Mediterranean and marine Mediterranean (Papadakis, 1966), which are well suited to avocado culture. Seedlings of Mexican race were known in the country from colonial times, but California commercial cultivars were first imported by the Ministry of Agriculture in 1928. Because of climatic problems where they were planted, in Santiago, they attracted little attention. In 1932, however, a shipment of 14 cultivars of Mexican, Guatemalan and hybrid origin was received and planted at La Cruz, Chile, followed by additional cultivars in a couple of other shipments. These formed the nucleus of a developing avocado industry. 'Hass' was imported in 1944. In 1958, all production was marketed within Chile, and prices were occasionally depressed when fruit supplies exceeded demand (Magdahl, 1958). By 1965, however, demand was good and the industry was growing (Schmidt, 1965). This trend continued and accelerated as Chile entered the export market; its avocado production rose from 8,000 t in 1961 to 55,000 t by 1996 (FAOSTAT Database, 1999).

Avocados are grown in a variety of locations in Australia along the eastern coast of the country (Schulz 1961), with climatic classifications ranging from humid subtropical through semi-hot semitropical, semi-Mediterranean subtropical, cool winter hot tropical and humid semi-hot tropical (Papadakis, 1966). Some of the earliest cultivar importations came from California to Queensland in 1933, and very few introductions from Florida are grown there (Zentmyer, 1965). The fruit was not well known within Australia for some years after the first introductions, but the arrival of American servicemen in 1942 established a demand for it, and demand within the country grew slowly in the years after World War II (Sharpe, 1950; Storey, 1960). By 1961 four main cultivars were grown: 'Hass', 'Fuerte' and 'Rincon', all imported from California, and a cultivar that originated in Australia, 'Sharwil' (Schulz, 1961). The increased popularity of the avocado in recent years is demonstrated by the fact that only 400 mt of fruit were produced in 1961, but production by 1996 had risen to 16,400 mt (FAOSTAT Database, 1999).

Effect of Success of Antillean and Guatemalan-Antillean Hybrid Cultivars on Production Elsewhere, as Reflected in Exports of Germplasm

In the 65 years from 1933 to 1998, 179 distributions (one or more cultivars or seeds) of avocado germplasm were sent from USDA's clonal repository at Miami to much of the world including equatorial Africa, the Caribbean and tropical America, and various parts of Asia and Oceania (USDA 1933-98). Some distributions were in response to individual requests, and others were made in cooperation with various aid-oriented organizations. These distributions have without question been instrumental in the three-fold increase in world avocado production that came about in the 35 years from 1961 to 1996. There is no record of germplasm distributions from Miami to Cameroon, but that

country's record is impressive; its avocado production increased from 12,000 t in 1961 to 45,000 t in 1996. The increase was less in Ghana, which produced 4,000 t in 1961 and 6,300 t in 1996. Production figures for Senegal are not available before 1991, when production was 16,000 t, and increased to 20,000 t by 1996. Obviously figures varied from one country to another, but the change in avocado production for Africa as a whole rose from 44,000 t in 1961 to 204,000 t in 1996. One Asian country that received germplasm from the USDA in Florida was the Philippines, where production rose from 13,300 t in 1961 to 26,000 t in 1996. The upward change for Asia as a whole during this period was from 44,200 t in 1961 to 273,900 t in 1996. (FAOSTAT Database, 1999) Looking at the total world, a dramatic increase in avocado production is apparent in the immediate past, from 696,900 t in 1961 to 2,231,500 t in 1996. This 3.2-fold increase was reached in large part by the transfer of germplasm from Mexico through California to parts of the world where Mediterranean-type climates predominate, and from the Caribbean and Guatemala through Florida to those areas which have warm lowland-type climates.

LITERATURE CITED

- ANONYMOUS. 1946. George Beauregard Cellon 1862--1945. In Memoriam. California Avocado Society Yearbook 1946:127.
- BROOKS, C. I. 1929. Avocados. Proceedings Florida State Horticulture Society 42: 123-129.
- COURT, A. 1974. The climate of the conterminous United States. *In: Climates of North America*. R. A. Bryson and F. K. Hare, Eds. World Survey of Climatology, Vol. II. Elsevier, Amsterdam-London-New York. 420 p.
- FAIRCHILD, D. 1939. Reminiscences of early avocado introductions. California Avocado Society Yearbook 1939: 44-46.
- FAOSTAT Database, Food & Agricultural Organization. 1999. United Nations, Rome. (Accessible on Internet at <<http://apps.fao.org/lim500/nph-wrap.pl?Production.Crops.Primary&Domain=SUA>>)
- FLORIDA AVOCADO ADMINISTRATIVE COMMITTEE, 1999. Shipping Schedule, 1999-2000 Season. Fla. Avocado Administrative Committee, Homestead, Florida, USA.
- GUSTAFSON, C. D. 1967. The avocado industry in Israel. California Avocado Society Yearbook 51: 85-88.
- INSTITUTE OF ECONOMICS, UNIVERSITY OF HABANA, CUBA. 1974. *In Encyclopaedia Britannica Macropedia* 5: 349.
- MAGDAHL, R. A. 1958. Report from Chile. California Avocado Society Yearbook 42:44-52.
- MALAN, E. F. 1957. Avocados. *In Handbook for Farmers in South Africa, Vol. 2, Agronomy and Horticulture*. The Government Printer, Pretoria. 880 p.
- MOSIÑO ALEMÁN, P. A.; GARCÍA, E. 1974. The climate of Mexico. *In Climates of North America*. R. A. Bryson and F. K. Hare, Eds. World Survey of Climatology, Vol. II. Elsevier, Amsterdam-London-New York 420 p.
- OHAD, R. 1965. More on avocados in Israel. California Avocado Society Yearbook 49: 61-66.
- OPPENHEIMER, C. 1947. The avocado industry in Palestine. California Avocado Society Yearbook 1947:112-119.

- PAPADAKIS, J. 1966. Climates of the world and their agricultural potentialities. DAPCO, Rome. 174 p.
- POPENOE, W. 1926. The parent Fuerte tree. Annual Report California Avocado Association 1925-26: 23-24.
- POPENOE, W. 1927. Manual of Tropical and Subtropical Fruits. Macmillan, New York and London.
- POPENOE, W. 1934. Early history of the avocado. California Avocado Association Yearbook 1934: 106-110.
- SCHIEBER, E.; ZENTMYER, G. 1980. The "Guatemalan Criollos." California Avocado Society Yearbook 64: 85-90.
- SCHMIDT, M. 1965. Avocado growing in Chile. California Avocado Society Yearbook 49: 45-46.
- SCHULZ, G. H. 1961. The avocado in Queensland, Australia. California Avocado Society Yearbook 45: 37-38.
- SHAMEL, A. D. 1936. The parent Fuerte avocado tree. California Avocado Association Yearbook 1936: 86-92.
- SHARPE, F. V. 1950. The avocado in Australia. California Avocado Society Yearbook 1950: 124-125.
- SMITH, C. E., JR. 1966. Archaeological evidence for selection in avocado. Economic Botany 20:169-175.
- SMITH, C. E. 1969. Additional notes on pre-conquest avocados in Mexico. Economic Botany 23: 135-140.
- STOREY, W. B. 1960. The avocado in Australia. California Avocado Society Yearbook 44: 66-71.
- TICHO, R. J.; GEFEN, B. 1965. The avocado in Israel. California Avocado Society Yearbook 49: 55-60.
- WOLFE, H. S.; TOY, L. R.; STAHL, A. L. (G. D. RUEHLE, revised). 1949. Avocado production in Florida. Bulletin 141, Agricultural Extension Service. Gainesville, Florida, USA.
- UNITED STATES DEPARTMENT OF AGRICULTURE 1933-98. Distribution records, National Clonal Germplasm Repository, USDA/Agricultural Research Service, Miami, Florida, USA.
- ZENTMYER, G. A. 1965. Avocado culture and avocado diseases in Australia and the South Pacific. California Avocado Society Yearbook 49: 19-25.