Book 1

Chapter 2

Avocado Botany and Commercial Cultivars Grown in California

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1. The Lauraceae Family

Avocado belongs to the laurel family (plant family: Lauraceae). This family includes camphor, cinnamon, the California laurel and the eastern sassafras. The California laurel (*Umbellularia californica*), also known as the California bay, Oregon myrtle or pepperwood, is the only native laurel to California (Bergh and Ellstrand, 1986).

Most of the laurels are tropical or subtropical in origin, but two American natives, spicebush and sassafras are exceptions. These two are hardy and withstand cold winter temperatures in the eastern United States. The powdered bark of sassafras is still used as an herbal medicine and flavorings in teas and carbonated beverages.

In the laurel family, the most significant genus in agriculture besides the avocado genus *Persea* is the genus *Cinnamomum*. The latter has two species that are adapted to the tropics (origin Southeast Asia) and the ground bark from these trees provides cinnamon spice. A third species (camphor) provides a pungent medicinal extract and lives quite well in southern California.

The *Persea* Genus

There are about 50 described species of *Persea.* Most of the *Persea* species originated in the New World, but *P. indica* apparently originated in the Canary-Madeira-Azores islands. Some species originated in Southeast Asia. *Persea* has been divided further into subgenus *Persea* (includes *P. americana*, the commercial avocado) and subgenus *Eriodaphne* (a group of species of which most are immune to avocado root rot, but unfortunately are not graft compatible to avocado).

In the subgenus *Persea,* three species have been of interest to avocado growers. *Persea shiedeana* is cultivated on a small scale in Mexico and Guatemala for its fruit, but the fruit is inferior to that of *P. americana*. *P. shiedeana* is of interest because it is a parent of the G755 rootstock, a rootstock with improved resistance to avocado root rot. *P. indica* is a small seeded relative that is especially susceptible to avocado root rot. It has been used by laboratories as a sensitive biological indicator for the presence of *Phytophthora cinnamomi* (the fungal cause of avocado root rot) in soil samples submitted by growers. The third species, *P. americana,* is the commercial avocado.

The Avocado – *Persea americana* Miller

Persea is the genus, americana is the species (relating the avocado to its origin in the New World) and Miller is the name of the first scientist to print a description of the avocado (Miller, 1754). The avocado species have generally been divided into three races: Mexican, Guatemalan, and West Indian. Some classifications split off the Mexican race into its own species, *P. drymifolia.* Kopp concluded that they were not separate species, but the Mexican race should be classified as a sub-species (Kopp 1966). Williams separated the Guatemalan into its own species, *P. nubigena*, leaving the other two races in *P. americana* (Williams 1977).

Bergh and Ellstrand, researchers at the University of California, Riverside, used isozyme data, along with morphological, geographical, physiological and biochemical data, to come to the conclusion that the three races were more related than not, and that they should be called "varieties" rather than separated into species (Bergh and Ellstrand 1986). They suggested that the proper separation should be for Mexican *Persea americana var. drymifolia*, for Guatemalan *P. americana var. guatemalensis*, and for West Indian *P. americana var. americana*. Most researchers still use the term "races" to separate the three types. It should be noted that the term "variety" is correct botanically when referring to "sub-species" or "races", but "variety" is commonly used to refer to "cultivars", such as 'Hass' or 'Fuerte'. In this chapter, we will use the commonly used terms "races", and the botanically correct term 'cultivars'. Characteristics of the three races are presented in Table 1.

Table 1. Comparison of three avocado races. (Bergh and Ellstrand, 1986)

TRAIT	MEXICAN	GUATEMALAN	WEST INDIAN
TREE			
Climatic adaptation:	"semitropical"[1]	subtropical	tropical
Cold tolerance:	most	intermediate	least
Salt tolerance:	least	intermediate	most
Hairiness:	most	less	less
Leaf anise:	present	absent	absent
Leaf color:	medium	often redder	paler
FRUIT			
Months to mature:	6	12 or more	5
Size:	small	variable	variable
Pedicel (stem):	small	variable	variable
Skin thickness:	very thin	thick	medium
Skin surface:	waxy bloom	rough	shiny
Seed size:	large	small	variable
Seed cavity:	loose	tight	variable
Seed surface:	smooth	smooth	rough
Oil content:	highest	high	low
Pulp flavor:	spicy	often nutty	mild
Some varieties:	Topa Topa, Mexicola, Duke, Mentone	Reed, Nabal	Waldin, Booth, Trapp

[1] In regions in Central America where all three races are found at the same latitude, the West Indian race will thrive from sea level to an altitude of 1000 meters (tropical), the Guatemalan race from 1000 to 2000 meters (subtropical), and the Mexican from 1500 to 3000 meters (termed "semi-tropical") (Lee 1980).

The Mexican Race

Seeds from the Mexican race of avocado have been used as rootstocks in California since the beginning of the industry. Nurserymen like the big seeds and fast-growing qualities, and growers have found that Mexican rootstocks usually have better and more consistent production than do the Guatemalan and West Indian rootstocks. Of the three races, Mexican seedling rootstocks do best in the colder soils and the calcareous soils that can induce iron chlorosis in leaves. Mexican rootstocks are the least tolerant to soil salinity.

Fruits from the Mexican race have thin, delicate skins that tear easily when shipping or handling. Fruit skin color varies from dark green to deep purple. Crushed leaves from Mexican and most Mexican hybrids have a characteristic anise smell.

There are no pure Mexican varieties grown for fruit commercially in California. However, genes from the Mexican race are important components in the Mexican-Guatemalan hybrid cultivars such as 'Hass' and 'Fuerte'. Two important traits from the Mexican race are imparted into the hybrids. These are the addition of more cold hardiness to the Guatemalan race and advancing the harvest season of the Guatemalans by half a year.

The Guatemalan Race

The Guatemalan race of avocado is native to the highlands of Central America and is less cold tolerant than the Mexican race. The leaves have no anise scent and the young foliage is often reddish. The seed is almost never loose in the cavity.

A characteristic of the Guatemalan race is the much longer time to fruit maturity (compared to the other races). Guatemalan cultivars such as Nabal and Reed may take 15 months or more from bloom to maturity. Historically, this trait was used in California to stretch out the harvest season: hybrids with strong Mexican traits were harvested in the winter; Guatemalan cultivars such as Reed, Nabal, Dickinson, Queen, and Anaheim were harvested six to nine months later in the summer; and Hass (a mostly Guatemalan hybrid) filled in between the two seasons.

A disadvantage to the Guatemalan cultivars is the thicker, woody skins (not all cultivars have this trait). One of the problems with the thick skins was that the consumer could not tell when the fruit had softened enough for eating. The hard-shelled Dickinson cultivar was tested for softening by inserting a toothpick into the stem end of the fruit. The stiffness of the peels did not allow easy peeling; peels were "chipped-off" instead of peeled. The popular Reed cultivar has a thinner skin, but is still very shell-like.

The West Indian Race

The West Indian race is native to the tropical lowlands of Central America. The leaves have no anise scent. Fruit size ranges from small to very large. Seeds are relatively large and are sometimes loose in the cavity. The West Indian fruits have relatively low oil content and are often reported to be "watery" by consumers.

This race is the most cold sensitive of the avocado races and pure cultivars do not grow well in California. Selections of this race appear to have greater salt tolerance and may be useful as rootstocks if selections can be found that can tolerate the colder soils in California. West Indian cultivars and hybrids are well-adapted to southern Florida and provide fruit on the market just ahead of the California winter fruit. Selections have been made in Florida to stretch out their harvest season, but a given cultivar will be on the market for just a few weeks. Thus, the Florida industry relies on early, mid and late season West Indian cultivars.

Mexican-Guatemalan Hybrids

Mexican-Guatemalan hybrids make some of the best avocado cultivars imparting positive traits from both races. The most important cultivar currently in production is 'Hass' which has been described as 85% Guatemalan and 15% Mexican (Bergh and Ellstrand, 1986). The Mexican genes enable Hass to reach maturity earlier than the pure Guatemalan cultivars, and impart more cold tolerance to the tree and fruit, although not as much as a pure Mexican cultivar. The Guatemalan genes impart a thicker skin to the fruit, but still thin enough to peel easily.

Fuerte, which is about half and half Mexican-Guatemalan, has more cold tolerance than Hass. Bacon is mostly Mexican with even more cold tolerance than Fuerte. As a rule of thumb, Hass fruit can stand temperatures as low as 29°F for four hours before showing freeze damage in the fruit, Fuerte fruit can similarly withstand temperatures to 26-27°F before showing damage, and Bacon can withstand temperatures as low as 25°F before showing fruit damage.

Cultivars that are predominantly Mexican include Bacon, Zutano, Shepard, and Rincon. Cultivars that are equally Mexican-Guatemalan include Fuerte and Ryan. Cultivars that are predominantly Guatemalan include Hass, Lamb Hass, Gwen, Pinkerton, Edranol, Hazzard, Sharwill, and Wurtz.

Guatemalan-West Indian Hybrids

Cultivars from these hybrids are generally not important to California, except for the Lula. In years where there may be a shortage of seed, some nurserymen have purchased Lula seed from Florida for propagation. Lula is popular in the nursery because of its fast-growing qualities. Chlorosis symptoms have occasionally been noticed on trees grafted on these rootstocks; more work needs to be done to determine which locations are more acceptable to use Lula as a rootstock in California. Lula (as a rootstock) does best in well-drained soils.

2. Commercial Avocado Cultivars for California

Seedling avocados may take up to 10 years to bear fruit (some seedling trees never bear fruit). Therefore, all commercial avocados are grafted with budwood from a known cultivar to provide consistent fruit quality, trueness of type and precocious production. Most grafted avocado trees begin to bear fruit in the third year after planting, and most groves reach maturity (maximum production) in the eighth to the tenth year.

Every seedling avocado tree has the potential to be a new cultivar due to genetic re-combination during the pollination and fertilization process. The vast majority of these "new cultivars" are inferior to cultivars already known, but every once in a while a new selection may be found among seedling trees that may offer improved fruit set, flavor or any number of other qualities. The Avocado Breeding Project at the University of California, Riverside and at the South Coast Research and Extension Center in Irvine is currently the most active program in the world for breeding and screening new cultivars and rootstocks. This Project is funded by grants from the California Avocado Commission and the California Avocado Society, with substantial volunteer effort from members of the California Rare Fruit Growers and the Cooperative Extension Master Gardener Program. The Breeding Project has been managed by Dr. Mary Lu Arpaia since 1996.

Hundreds of cultivars were described during the 20th Century, most by individual growers and nurserymen, but a few were purposely bred and described by University researchers in the 1990's. The predominant commercial cultivars have been reduced from many to just a few; the 'Hass' cultivar in the 2011-2012 crop year was estimated to account for 96.9% of the commercial production (in pounds) in California. Other cultivars have been reduced in acreage due to poor market demand and low prices. 'Lamb Hass', a U. C. patented cultivar released in 1998, was estimated to account for 2.25% of California avocados in 2011-2012, and was the only minor variety increasing in acreage (Tables 2 and 3).

The following tables show the trend in avocado production in California in the last ten years. Note the decline in the minor varieties for demand in the markets.

Table 2. Estimated acreage and yield for avocado cultivars in California in 2001-2002 (California Avocado Commission).

Cultivar	Bearing Acreage	Estimated yield (lbs/A) in 2001-2002	Estimated yield in California (million lbs) in 2001-2002
Hass	51, 575	7,044	363.3
Fuerte	1,452	4,125	6.0
Bacon	1,961	6,645	13.0
Zutano	706	3,144	2.2
Pinkerton	1,035	4,715	4.9
Reed	430	7,163	3.1

Gwen	260	5,633	1.5
Lamb Hass	420	5,143	2.2
Other	388	3,058	1.2
Total	**58,227**	**6,825**	**397.4**

Table 3. Estimated acreage and yield for avocado cultivars in California in 2011-2012 (California Avocado Commission).

Cultivar	Acreage (includes 7,800 acres of topped/stumped groves)	Yield in lbs/A in 2011-2012	Yield in California (million lbs) in 2011-2012
Hass	56,548	7,924	448.1
Lamb Hass	1,964	5,295	10.4
Other	1,117	3,312	3.7
Total	**59,629**	**7,753**	**462.3**

Table 4. Decline in production from various avocado cultivars 2002-2012. Acreage from most of the minor cultivars is no longer determined, but AMRIC keeps track of yield (in pounds). Data is supplied by13 of the major packers in the industry to AMRIC.

Season	Fuerte	Bacon	Zutano	Pinkerton	Gwen	Reed	Other greens
2002	3,476,645	9,734,690	888,980	3,230,570	1,746,815	3,185,455	465,340
2003	1,645,350	7,885,025	410,230	3,060,065	1,397,065	3,143,605	470,870
2004	2,743,590	7,399,135	346,795	5,226,390	1,603,630	1,715,270	668,140
2005	1,504,250	5,130,725	223,475	715,500	727,950	1,948,350	333,900
2006	2,321,050	3,747,775	160,425	4,186,900	908,475	2,331,925	486,150
2007	805,450	1,262,550	27,000	135,000	204,300	1,229,525	263,700
2008	619,825	1,823,700	58,500	1,288,400	470,250	1,334,750	190,800
2009	130,550	1,473,650	233,475	515,900	268,125	673,700	162,900
2010	708,650	1,372,700	229,925	638,200	267,300	583,800	519,300
2011	430,000	1,364,900	262,200	553,500	162,000	1,444,900	144,900
2012	655,900	1,068,700	133,200	399,100	184,500	817,900	132,300

Descriptions of the California Avocado Cultivars

Characteristics of the main cultivars were summarized in 1996 by Gray Martin (a former staff research associate with the University of California's Avocado Breeding Program) and Bob Gleinn (a farmer/volunteer with the breeding program). The summary was published as part of a Cooperative Extension county publication in San Diego in 1996 (Martin and Gleinn 1996). This chart is presented as Table 4. It should be noted that this chart will be updated in the near future, but at this time it is the best information available.

The Major Cultivar

Hass. (Flower type: A). Hass originated as a chance seedling variety in La Habra Heights, California. The cultivar was selected by Rudolph Hass in the 1920's and patented in 1935 (see Chapter 1 – History of the Avocado Industry in California).

Hass is recognized as the best overall quality avocado available, has the longest harvest season (January - August in San Diego county, as late as June - October in Santa Barbara and San Luis Obispo counties), and is currently the recommended cultivar for new plantings. Hass is grown in most of the southern California coastal counties and the western end of Riverside County, especially in locations that have mild summer temperatures and little frost (if any) in the winter. Hass acreage by county is presented in Table 4.

Table 4. Hass avocado acreage and production (estimated) by county in California in 2001-2002 (California Avocado Commission).

County:	Estimated acres	Lbs/acre	Total lbs (millions)
San Diego	22,862	7,410	169.9
Riverside	5,980	8,459	50.6
Orange	1,653	3,705	6.1
Los Angeles	220	6,486	1.5
Ventura	11,608	7,383	85.7
Santa Barbara	7,660	5,237	40.1
San Luis Obispo	1,303	6,687	8.7
San Joaquin Valley	57	3,837	0.2
Other	232	4,248	1.0

Hass is also recognized to have several shortcomings, including poor fruit set in some locations, sensitivity to saline irrigation water, intolerance to cold temperature below 30°F (Bergh 1984), and susceptibility to persea mites and avocado thrips. These problems (discussed in further detail at the end of this section) have fueled the interest in new cultivars, and funding for the breeding program has remained a top priority in the California avocado industry.

Other qualities of Hass include a relatively heavy yield in some areas to light yields in others, somewhat alternating production, small seed and a nutty flavor. The industry has tried to stretch Hass into an almost year-round cultivar, but early season Hass fruits are not as palatable as mid-season fruits, and late season fruits often turn rancid rapidly upon softening. Since the strong entry from Chile in the winter market, the California industry is now focusing on harvesting most of the crop between February to August, with some later harvesting from the northern counties in September and October.

Hass is a Mexican-Guatemalan hybrid (mostly Guatemalan) tree that has a moderately spreading canopy. If left un-pruned, the tree may grow to 50-60 feet in height. The fruit varies from 6 to 14 ounces, turns black at ripening. The black color is useful for consumers to know when the fruit is ready to eat, and the dark color hides some defects in the peel, such as bruising and fingernail marks from pickers. The fruit is often “size-picked”, which means that 7.5-9 oz. fruits (size 48) and larger are usually picked as early in the season as possible to get the best price. This is followed by a least one more size

1) Table 5. AVOCADO CULTIVARS THAT ARE COMMERCIALLY AVAILABLE

	HASS	FUERTE	GWEN	PINKERTON	REED	BACON	LAMB/HASS	SIR PRIZE
(b) MARKET ACCEPTANCE (Compared to Hass)	Excellent	Good/Fair	a) Good	Good	Good	Fair	Very Good	Good
(c) FRUIT Skin Color	Black	Green	Green	Gram	Green	Green	Black	Black
Overall Quality	Excellent	Excellent	Very Good	Very Good	Very Good	Average	Very Good	Excellent
Taste	Excellent	Excellent	Very Good	Very Good	Very Good	Good	Very Good	Excellent
Appearance	Hass	Smooth Green	Green Hass	Necky Hass	Round	Smooth Green	Large Hass	Black Fuerte
Early Pick	January	November	April	January	May	October	May	November
Late Pick	August	March	September	May	November	February	November	March
Dominant Size	48	48	40	40	32	40	36	36
Size Range	40-60	40-60	32-48	32-48	32-40	40-48	32-48	32-48
Peel Thickness	Medium	Med. Thin	Med. Thick	Medium	Thick	Thin	Thick	Med. Thin
Peel Pliability	Very Good	Very Good	Good	Very Good	Good	Fair	Good	Good
Seed Size	Medium	Medium	Medium	Small	Medium	Large	Medium	Small
(d) TREE Productivity	100**	75	125	125	150	100	150	100
Bearing Habit	Somewhat Alternating	Alternating	Consistent	Consistent	Highly Alternating	Somewhat Alternating	Somewhat Alternating	Somewhat Alternating
Wind Tolerance	Low	High	Low	High	Moderate	Moderate	High	Moderate
Persea Mite Tolerance	Low	Moderate	Very Low	Low	Moderate	High	High	Moderate
Cold Tolerance	Fair	Good	Fair	Fair	Fair	Good	Fair	Good*
Precociousness	2-3 Years	2-3 Years	1 Year	1-2 Years	2 Year	1 Year	1-2 Years	2-3 Years
Shape	Spreading	Spreading	Upright	Medium	Upright	Upright	Upright	Upright
Tree Per Acre	50-100	50-100	100-160	100-140	100-140	80-120	100-140	100-140
Flower Type	A	B	A	A	A	B	A	B
Bloom Months	Mar-May	Feb-Apr	Mar-May	Jan-Mar	Apr-June	Feb-Apr	Mar-May	Feb-Apr
(e) POST HARVEST								
Storage Shelf life	Good+	Fair	Good-	Excellent	Good	Fair	Good-	Excellent
Shipping Quality	Good	Fair	Good-	Good	Good	Fair	Good-	Good
Response to Ethylene	Excellent	Poor	Unknown	Excellent	Poor	Poor	Unknown	Unknown
Ripeness Detection	Good	Good	Fair	Good	Fair	Good	Fair	Good
Peelability	Good	Good	Shell-Like	Good	Shell-Like	Fair	Shell-Like	Fair
FOOTNOTES	*University of California, Riverside Avocado Breeding Program ** Productivity estimates all relative to Hass						All weather related data based upon South Coast Field Station location in Irvine, CA	

pick and concluded with a strip-pick. Some growers will strip pick early in the season; smaller fruit at this time will usually (but not always) bring less dollars per pound, but the average price for all fruit may be higher than the average price for all fruit later in the season. It is recommended that at least 1/3 of the crop be picked before April in order for the tree to have a good return bloom in the following spring.

Growers in the Ventura/Santa Barbara area have noted increased fruit set in Hass (an A flower type) when trees are near a B flower type cultivar such as Bacon or Zutano. This effect is occasionally noted in San Diego-Riverside counties. Recently, in a comparison of B flower type trees, it was noted that Hass yield was considerably higher when located one tree away from Zutano (M. L. Arpaia and B.A. Faber, personal communication). The effect progressively diminished when the Zutano tree was located two, three and four trees away.

Although Hass has become the cultivar of choice (due to market demand and return prices to the grower), many growers are unhappy with the performance of the trees. Bergh (1984) summarized the problems:

1. "*Cold tender*". As mentioned, this is a characteristic of the Guatemalan race. When avocados were planted during acreage expansion in the 1970's, this feature was carefully considered and almost all Hass trees were planted on the upper slopes of hills. Warm air rising during cold nights usually kept the Hass trees from freezing. More cold tolerant cultivars were planted on the lower slopes. With the decline in prices in the 1980's for cold tolerant cultivars such as Bacon, Zutano and Fuerte, many of these trees were topworked to Hass and many eventually froze outright, or suffered enough chronic frost damage to make the grove unprofitable.
2. "*Productivity is inferior*". Good yield data is difficult to obtain, and is conflicting because of the differences in irrigation (both amount of water and water quality), fertilization, location, presence of root rot etc. Despite this, a UC Cooperative Extension study in 1984 indicated that, for 19 years through 1982, Hass yields in California averaged 7,249 lbs/acre compared to Fuerte yields that averaged 4,842 lbs/acre (Takele 1984). Due to a variety of reasons, many Hass groves produce considerably less, but a few groves consistently produce more. Despite the differences in yield among the Hass groves, it has been consistently noted among growers that certain cultivars such as Zutano and Reed produce more fruit per acre than Hass. It is believed by many growers and researchers that avocado has the physiological potential to produce more fruit per acre, and they would like an improved cultivar with qualities like Hass.
3. *"Tree production alternates"*. In the "on" year, a tree can be so heavily laden with fruit that branches start to break, fruit will be small and competition for resources may lead to leaf drop and sun-burned branches.
4. *"Grove production varies from year to year"*. Fuerte yields have always been known to be severely alternating, often causing serious cash flow problems for growers. Unfortunately, in some areas, Hass yields from the grove can also be severely alternating. Bergh cites data from a ten acre Hass grove which averaged 8,752 lbs/A over a five year period, but individual year averages were 20,995, 4,057, 14,260, 1,813 and 2,635 lbs/A during this period.
5. *"Industry production varies from year to year"*. In Takele's economic study, the Hass industry in California (in the last four reported years) averaged 6,777, 3,396, 10,829 and

4,960 lbs/A respectively. This variation is probably a weather-related problem in the spring during flowering and fruit set, but it causes problems with marketing during the "on" years (resulting in low prices to growers) and servicing the market during the "off" years (resulting in abnormally high prices to consumers, with the resulting interest in Hass exports to the U.S. from foreign competitors).

6. *"Black color of the fruit is not universally preferred".* Over the years, the black color has gradually replaced the preferred green color of Fuerte and other greenskins, but consumers on the East Coast who were used to green fruit from Florida, were slow to accept the black fruit.
7. *"The tree is too large".* Large trees add to picking costs and picking can be hazardous. Spraying is also difficult with large trees. Pruning appears to be a necessary production practice, but this also adds considerably to production costs.
8. *"Hass requires more fertilizer".* This was an observation by former farm advisor Don Gustafson in San Diego County.
9. *"Hass is more subject to stresses".* Hass is thought to be more subject to drought, salinity, insect damage, and blackstreak disease, although there is little scientific evidence to substantiate these claims.
10. *"Fruit size averages too small".* Fruit is small in "on" crop years, and as the tree matures.

In spite of all these problems, Hass has done so well at the market that it has displaced the winter greenskin cultivars. The consequence of the popularity of this fruit is that produce buyers started purchasing Hass from Chile in the winter months to fill the displays at the supermarkets. This demand for Hass fruit in the market year-round eventually led to pressure on the USDA to allow importation of Hass from Mexico, Dominican Republic, New Zealand and Peru (in 2011). The California farmer that filled the fall-winter niche with greenskins had to topwork to Hass to stay in business. If the climate were too cold where the newly-topworked trees were located, these trees suffered chronic frost damage or were killed outright by a prolonged frost.

The Minor Cultivars

During the twentieth century, there were many cultivars selected from chance seedlings found in groves and dooryards in California. Many were named and registered with the California Avocado Society, but only a few had the qualities that made them a lasting success at the market place. Fuerte was a leading cultivar in the first half of the century, but is slowly disappearing due to the overwhelming popularity of Hass. Some of the newer cultivars were selected by researchers at U. C. Riverside in a continuing search for a more productive cultivar than Hass; these include Gwen, Lamb Hass, GEM and SirPrize.

Fuerte. (Flower type: B). Fuerte was found by Carl Schmidt as a dooryard seedling in Atlixco, Mexico in 1911 (see Chapter 1). It survived a freeze in Los Angeles in 1913 and eventually became the cultivar of choice in California prior to the emergence of Hass. The fruit is a greenskin when ripe, pear-shaped with a flat area on the bottom corner, 8 to 14 ounces in size and very high quality. The Fuerte is still thought by many in the avocado industry to be the best tasting avocado.
The Fuerte tree is large and spreading. The leaves have a strong anise smell when crushed, and there is red flecking on wood of new shoots. The tree is intermediate in cold resistance to about 27° F. The

tree performs best away from the coastal influence, but not into the hot interior zones.

Fruit set is erratic; some trees never seem to have very much fruit. Groves are alternate bearing, usually more so than Hass groves. Fruit set in Fuerte often improves dramatically when the trees are interset with varieties that have "A" type flowers; in past years these varieties were usually Covacado, Jalna, or Topa Topa.

Some Fuerte groves have a long flowering periods, lasting sometimes from October to July. Some of the early flowers may set "off-bloom" fruit that mature in early fall, these often have the flat bottom on the corner. Early bloom fruit may be harvested just after the off-bloom fruit. When temperatures are less than ideal for fruit set, "cukes" may be formed (cukes are fruits that have been stimulated to grow by the pollen tube, but the fertilization event was never completed, leading to a small, narrow seedless fruit). Cukes are harvested and sold as "cocktail" avocados.

Zutano. (Flower type: B). This cultivar is believed to have originated as a seedling tree on the Truitt Ranch on Alvarado Street in Fallbrook, California (Koch 1983). Zutano is a vigorous upright tree that produces heavily. The fruit are green at ripening, thin skinned, glossy green skin, pear shaped and vary from 8 to 14 oz. The quality of the fruit is relatively poor; consumers comment that the flavor is poor and "watery". This a result of low accumulation of oil (or dry matter) in the flesh. Zutanos that are harvested late in their season have a more acceptable flavor, but surface corking, end spots and internal breakdown reduce or eliminate marketability. Most Zutanos have been removed or top-worked to a better cultivar. The remaining Zutano fruit is often used as "nurse" seeds for clonal propagation of avocados. Zutano by itself as a rootstock is very susceptible to avocado root rot caused by *Phytophthora cinnamomi.*
Zutanos may be useful in acting as a pollinizer tree for Hass, since Hass is an A flower type and Zutano is a B flower. Farm advisors have often noted that Hass trees near a Zutano usually have substantially larger crops than Hass trees farther away from the Zutano. Several trials were established in Ventura County in the late 1990's to determine the best pollinizer tree for Hass. Preliminary data indicate that Zutano appears to be the best of the B flower type trees, and the effect is best when the Hass tree is one tree away from the Zutano. Great variation may occur from year to year; however, some years there seems to be no effect (M.L. Arpaia and B. Faber, personal communication).

Prices have been so low for Zutano fruit that the sale of fruit seldom pays for the water. The dilemma for the grower remains, does the effect of the pollinizer tree on the surrounding Hass trees increase the yield enough to make up for the loss of a Hass tree in the space now occupied by a Zutano tree? This question has not been answered yet, but some growers are planting Zutanos around the edge of the Hass grove, or along the grove roads, and pruning them like a pole, not to produce fruit, but to provide some flowers for the bees to visit.

Zutanos are still grown in the San Joaquin Valley where it is too cold for Hass in the winter, but even this acreage is declining due to poor prices for fruit.

Bacon. (Flower type: B). Bacon originated as a seedling tree on the ranch of James E. Bacon in Buena Park, California in 1928. Mr. Bacon was screening large numbers of seedlings for cold hardiness, and settled on one that produced fruit early in the season (November-January) and is now probably the most cold-hardy of the commercial varieties. The Bacon variety was introduced to the avocado industry in the late 1920's.

It has been reported that trees will survive temperatures as low as 24° F, but the fruit stem will be damaged during the cold temperatures and the fruit must be harvested immediately after the cold snap. During warmer winters, if fruit is left on the tree past January, dark cracked areas will often develop on the bottom of each fruit.

The fruit is dark green, oval in shape of medium quality and 7 to 14 ounces in weight. The fruit is better quality than Zutano, but overall yields are not as good as Zutano. Bacon fruit are lumped with the "greenskins" at the market and consequently command a poor price. The tree is an upright growing tree and is commonly grown on a 15' x 15' spacing. The leaves, when crushed, have an anise smell. Like the Zutano, Bacon (a B flower) may be useful as a pollinizer for Hass.

Reed. (Flower type: A). Reed was found as a seedling at the James S. Reed Ranch in Carlsbad, California in 1948. The Reed is thought to be a cross between Anaheim and Nabal, two Guatemalan-type varieties. The fruit is almost round and relatively large, averaging 8 – 12 ounces near the coast and 12 – 18 ounces inland. The skin is green in color and "shell-like". The Reed is harvested from July through September, but will last on the trees in some groves until the middle of November. The fruit has a rich, nutty flavor and the cut surface does not darken. The fruit has good shipping and shelf-life qualities. In the early 1980's the Reed was thought to fill a niche late in the season when the Hass harvest was declining. Unfortunately, this niche has been filled by importations of Hass from Chile.

The tree has an upright shape and is a heavy producer. Some growers plant the Reed on a close spacing (8 to 10 feet), keep it pruned to 10-12 feet in height, and produce excellent yields per acre. Although the dollar return for Reed in less than Hass, increased yield per acre may be suitably profitable for the grower.

The Reed has some resistance to *Persea* mite. The Reed always seems to produce well (without a pollinizer tree nearby) in the backyard.

Pinkerton (Flower type: A). Pinkerton originated as a seedling about 1959 on the John Pinkerton Ranch in Saticoy, Ventura County, California. The cultivar is thought to be a hybrid of Hass x Rincon. The cultivar was patented in 1975.

John's son, Allan Pinkerton, was quoted as saying that "sloppy farm management produced the seedling" (Koch, 1984). Sloppy management means that a seedling was allowed to grow without timely removal, or a graft on a top-worked tree did not take, and it was not re-grafted in a timely fashion. This is certainly one instance where the avocado industry benefited from poor management.

The Pinkerton fruit has a green peel at ripening, with a small seed and very good fruit quality and flavor. Pinkerton is mostly of the Guatemalan race. The peel is pebbly like Hass, but the fruit has a longer neck than Hass. Under cooler conditions the neck can be especially long to the point that they are difficult to pack into standard cartons. The harvest season is from January through May.

Pinkerton blooms over a long time period. Fruit that set early in the bloom cycle are nearly round and can mature a month or two before the glossier and slimmer late set fruit.

The tree has a moderately spreading canopy, has the same tolerance to cold as Hass and is a more consistent and heavier producer than Hass. The tree has been noted to have stronger limbs than Hass and can withstand strong winds better. The leaves do not have an anise smell when crushed.

In the 1980's, it was thought by several industry analysts that Pinkerton could play a strong role in the California avocado industry. Koch suggested that growers should grow a mixture of Hass, Reed, and Pinkerton; this would allow growers in San Diego County to produce good quality fruit year round (Koch 1983). Warren Currier and Hank Brokaw spearheaded a special marketing effort that was fairly successful; prices in 1984 were almost equal to prices of Hass and about twice that of Fuerte (Bergh 1984). Unfortunately, importations of Hass from Chile starting in the mid 90's replaced most of the market for winter Pinkertons.

3. The New Generation of Varieties

The following varieties were developed and released from the Avocado Breeding Project at UC Riverside under the direction of Dr. Bob Bergh. The Breeding Project is now under the direction of Dr. Mary Lu Arpaia and she is investigating and developing many new potential cultivars such as Nobel and Marvel. GEM and Harvest were released to the nurseries in 2003. Holiday was released but not patented because it was thought that it would not become popular in the commercial industry but might become popular as a backyard tree with fruit being harvest around the holidays at the end of the year.

Lamb Hass. (Flower type: A). Lamb Hass originated as a cross between Gwen and Thille. Lamb Hass was selected because of its good flavor, superior production (side by side with Hass, Lamb Hass almost always has more fruit, often an increase of 50%), and a skin that turns black at ripening. Lamb Hass has increased in popularity in California, acreage increased from 420 bearing acres in 2002 to 1,964 acres in 2012.

Lamb Hass was originally named BL122. The 'Lamb' part of the name was chosen to honor Bob, Bert, and John Lamb whose ranch in Camarillo was the site of a large planting of seedlings from crosses made by Dr. Bergh. 'Hass' was kept in the name to indicate the close relationship to our main variety (Lamb Hass is a grandchild of Hass). The Lamb Hass variety was patented by the University of California in 1996.

The Lamb Hass fruit is usually larger than Hass, typical weight of a fruit is between 10 to 18 ounces. The fruit is distinguished from Hass by its broad shoulders. Consumer taste tests rate the flavor highly, but not quite as high as Hass or Gwen (M. L. Arpaia, personal communication). However, proper taste tests are difficult because the season is later than Hass; fruit should not be harvested before May-June. Thus, a Lamb Hass tested at the beginning of its season will likely not rate as well as the Hass fruit in the middle of its season. It remains to be seen how long the fruit will hold on the tree; some growers report that fruit will hold into November, but holding fruit late may contribute to alternate bearing. In 2011, the entry of Hass from Peru into the US in the late summer (the main harvest season for Lamb Hass) likely caused the depressed prices for Lamb Hass in California.

Further testing for qualities such as post harvest handling, shipping, alternate bearing, taste, etc. are currently being conducted by Dr. Mary Lu Arpaia, coordinator of the Avocado Breeding Project.

Lamb Hass seems to be more tolerant of wind, heat, and Persea mites (compared to Hass). Lamb Hass is not expected to have good cold tolerance, probably showing frost injury at 29-30° F.

Gwen. (Flower type: A). Gwen is a selection from seedlings of the little-known variety 'Thille'. (Thille is a seedling from Hass). Thille seedlings were planted at the University of California's South Coast Field Station in Irvine, California in 1963; one of those seedlings (at the time called T225) was selected as a promising cultivar because of excellent fruit quality and heavy set. T225 (later named 'Gwen') had the Guatemalan traits of thick, rough skin, a small, tight seed and a "nutty" flavor. The fruit at the station would hang on the tree for 1½ years after set and had a sensitivity to cold, further evidence of a strong Guatemalan influence. However, the skin color remained green at ripening, unlike the black Hass color. The cultivar was thought to be an important contribution from the UC Avocado Breeding Program, and Gwen was patented by the University of California (with Dr. Bob Bergh as the inventor) in October, 1984.

From 1985 to 1990 almost 600 acres were top-worked to Gwen (Currier, 1991), but several problems developed that stalled its introduction as an important new cultivar.

- Although Gwen trees set fruit in abundance at the South Coast Field Station, large solid blocks of Gwen in San Diego County often had poor fruit set. A grower from Escondido, Tom Markle, inadvertently discovered that Gwen trees set much better when they were close to his Zutano trees that had grown back from failed Gwen grafts. Gwen apparently had a strong requirement for cross-pollination to a B flower type variety.
- Gwen maturity was later than Hass. Misinformation to the industry caused fruit to be picked as early as January 15th, but it was eventually shown that fruit picked before April 15th often shriveled. Fruit that were held later on the tree to reduce the shriveling had a high drop rate. Eventually it was determined that the dry weight of Gwen should be 25.9% before the fruit is harvested, but many growers reported that an excessive amount of fruit was on the ground before that dry weight could be achieved.
- Freezes in 1987, 1988, and 1990 severely damaged many of the Gwen groves, usually because the Gwens were topworked onto Bacon and Zutanos that were originally planted on the lower slopes. Gwen also seemed to be particularly sensitive to soil dryness and wind, resulting in fruit drop and leaf drop. In order for the trees to carry extra heavy crops, the environmental stresses had to be eliminated.
- Buyers for the chain stores still preferred the black Hass fruit. Gwen growers organized to form the Gwen Growers Association, assessed themselves ¾ cents per pound and developed a marketing plan. Despite this effort, returns for Gwen fruit were seldom more than half the returns for Hass fruit. The bumper crop for Hass in 1993 further reduced prices for all avocado growers and resulted in discouragement for the Gwen growers.

Despite the problems with the new Gwen cultivar, an important step had been taken in the UC breeding program. It was thought that a new cultivar could be successful if it was closer to Hass in color and provided the grower with more fruit set. This optimism led the way for the discovery and development of Lamb Hass. In 2012 in can be seen that Gwen is disappearing as a cultivar in California.

Sir Prize. (Flower type B). In the search for black fruit that could be a good winter variety, a selection was chosen from the Lamb Ranch that had promised to replace Bacon and Zutano. The fruit of Sir

Prize looks like a black, rough Fuerte, has a small seed and has an excellent, nutty rich flavor. The maturity season appears to be November – March. It was hoped that it would have good cold tolerance and could be a good cultivar for the San Joaquin Valley, but most of the early plantings froze in the winters of 1999 and 2000. There is speculation that it could be a good cross-pollinizer for Hass, but this remains to be proven. Peak bloom period is earlier than 'Hass' by several weeks. Yield may be rather light, but it hasn't been properly tested in many areas.

GEM (Flower type A). GEM is also a black-skinned fruit that was selected from the Lamb Ranch. The average fruit weight is 7-11 oz and the harvest season is roughly that of Hass. The tree has an open and spreading growth. Perhaps the best character of GEM is that the fruit, when cut in half, has a much slower oxidation rate (the flesh stays greener longer) than does Hass. The tree has less alternate bearing than does Hass. GEM was patented under the experimental name 3-29-5 in 2003.

Holiday (also known as the XX3) (Flower type A). A very large, attractive fruit with a green skin at ripeness. Average fruit wt is 18-24 oz. The tree is a semi-dwarf and smaller than a Wertz tree. The harvest season starts around the holidays in December-January. This cultivar shows promise as a fruit to be sold at farmer's markets. This tree was not patented, but was released from the breeding program for propagation by nurseries in 2001.

4. Miscellaneous Cultivars.

Miscellaneous cultivars that are still seen in some groves and dooryards are summarized in Table 6. The cold tolerance listed for each cultivar assumes that the tree is at least 3 years old. The cold tolerance depends on many factors, including length of time at the given temperature, hardening of the tree, and irrigation status. Other minor cultivars can be found on Dr. Arpaia's UC Riverside website: http://www.ucavo.ucr.edu/AvocadoVarieties/AvocadoVarieties.html

Table 6. Descriptions of Miscellaneous Avocado Cultivars (after Silva et al. 2002)

Cultivar	Parentage	Fruit peel color	Fruit peel texture	Fruit peel thickness	Fruit quality	Fruit flavor	Seed size	Bearing habit	Flower type	Cold limit	Mature season
Duke	Mexican	green	smooth	Very thin	Good	spicy	large	consistent	A	20 F	Sep-Oct
Not commercial due to its thin skin and short season. Valuable to the backyard grower for its good flavor and cold tolerance.											
Jim	Mostly Mexican	green	smooth	thin	Very good	Mild spicy	medium	Fairly consistent	B	24 F	Nov-Feb
Jim has a longer season and better fruit quality than Zutano, better fruit set than Bacon and shorter trees than both cultivars											
Mexicola	Mexican	purple	Very smooth	Very thin	good	Anise-like	large	consistent	A	20 F	Aug-Oct
Extremely cold hardy, but not commercial due to thin skin and too small a fruit. Flavor is very good.											
Stewart	Mostly Mexican	purple	leathery	thin	excellent	flavorful	medium	variable	A	25 F	Oct-Dec
Stewart is rated as one of the best cultivars for cold regions. Production good in some areas and inferior in others.											
Wurtz	Guatemalan	green	pebbly	medium	good	mild	large	alternating	A	31 F	May-Aug
Small tree ideal for gardens. May be sold as Littlecado, "Dwarf" or Minicado											

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