UCCE

Topics in Subtropics Newsletter

University of California Cooperative Extension

Fresno, Kern, Madera, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara,Tulare,&Ventura Counties

News from the Subtropical Tree Crop Farm Advisors in California

Volume 14 No. 1 January – March, 2016

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Topics in Subtropics – January - March, 2016 – Published Quarterly

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Avocado Cultivars, Botanical Races and Genetic Footprints

Vanessa Ashworth and Philippe Rolshausen, Department of Botany and Plant Sciences, University of California Riverside.

Have you ever wondered where your favorite avocado variety came from? Not the nursery where it was purchased but the long, tortuous path that led to its selection. How are different varieties related? Did the expert tell you that your avocado is a "Guatemalan x Mexican" but you were afraid to ask what that means? Has your carefully nurtured seedling raised from a 'Hass' pit morphed into a tree bearing unconvincing fruit? If so, read on.

Avocado breeders refer to the different types of avocado as varieties or, more correctly, as cultivars. The 'Hass' cultivar is by far the best known, but several hundreds of named avocado cultivars have been bred in the USA alone since avocado was first introduced here. None was developed by the big commercial seed companies; Instead, avocados were patiently selected, originally by indigenous cultures of Mesoamerica, much later by growers/enthusiasts, and fairly recently in avocado breeding programs. Almost never do we know the precise pedigree of a cultivar. We are sometimes told the maternal parent, but older cultivars (including 'Hass') typically lack a record of parentage, and any thought of fitting today's cultivars into a concise family tree is hopelessly optimistic. In any case, prior to the mid-19th century very little is known about the plant material that was imported from abroad, with at best an indication of geographic provenance. And yet it would be far more efficient if we could arrange cultivars in a hierarchy or a series of related assemblages, instead of just looking at a random scatter.

In order to understand how today's cultivars are related we need to dig deeper. Going back in time, we know that indigenous civilizations in Mesoamerica recognized the value of the avocado's wild ancestor(s) and were actively selecting superior forms for thousands of years, which eventually led to a semi-domesticated avocado. Evidence of selection by human hand as far back as 8,000 years before present is preserved in archaeological sites in Puebla State, Mexico. At the time of European contact, written records indicate that there already existed three distinct types of avocado, each from a separate geographic center of origin. Today, we refer to them as botanical races, and they represent the "primeval soup" that gave rise to modern avocado cultivars.

Here is what we know about the three botanical races of avocado, respectively called (1) the West Indian (formerly known also as the South American), (2) the Guatemalan, and (3) the Mexican (also known as the "criollo"): Each exhibits a characteristic suite of traits that includes differences in leaf chemistry, peel texture and color, and sources of tolerance (diseases and salinity). The races were domesticated in separate geographic regions, the "West Indian" race in lowland coastal Mesoamerica (possibly Yucatán), the Guatemalan race in upland Guatemala, and the Mexican race in highland Mexico. The Guatemalan and Mexican races remained fairly local, so their names reflect their respective centers of domestication, but the "West Indian" race seems to have been spread far and wide by indigenous cultures in Meso- and South America and was, incorrectly, named for a much later destination. The explorations of the 15th and 16th centuries kicked off the worldwide distribution of (mostly West Indian race) avocados, reaching Spain in the early 17th century, Jamaica in the mid-17th century, and Indonesia by the mid-18th century. It wasn't until the mid- to late 19th century that the three races of avocado found their way to the United States, primarily Florida and California.

After the avocado was introduced to California and elsewhere, there followed countless rounds of selection, generally resulting in hybrids among the botanical races. The selection process consisted of growing out seedlings from the seeds of "good" cultivars and screening them for chance seedlings with promising characteristics. However, in the same way that children are not identical to their parents, seedlings grown from the pit of a fruit are not identical to the tree the fruit came from. Each seedling represents a reshuffled version of its parents' genomes. The only procedure that preserves an identical genome is clonal propagation. Budding and grafting techniques that, today, ensure clonal propagation and keep cultivars "true to type" were not used until the first half of the 20th century.

Contrary to many major crops, most avocado cultivars we have today are bursting with so much genetic diversity that breeding is actually rendered difficult. When we grow out seedlings we get a huge number that look (and taste) nothing like their parents and most are discarded. The poor selection efficiency (an estimated 0.2%) has to do with the large variability caused by multiple domestication centers and a long history of open-pollination. There is no immediate danger of a genetic bottleneck, but breeding is slow and outcomes are unpredictable.

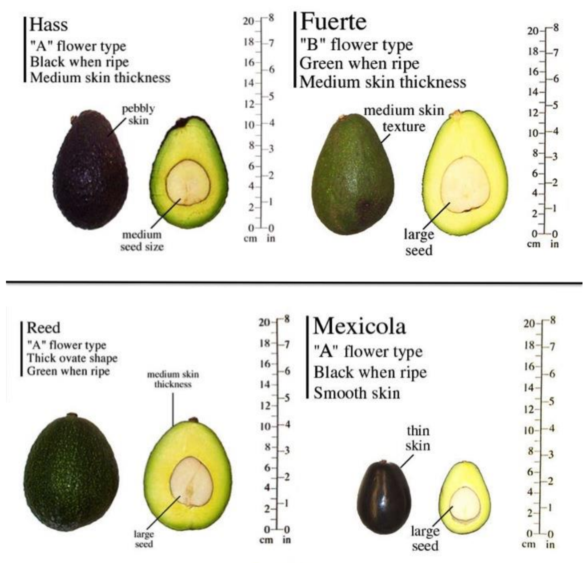
In the absence of accurate breeding pedigrees, we have come to describe avocado cultivars in terms of their resemblance to one or several botanical races, based on their combination of traits. For example, 'Hass' is considered to be a Guatemalan x Mexican (G x M) hybrid because it has the thick, rough skin of the Guatemalan race but the high oil content of the Mexican race. Cultivar 'Gwen' is also called a G x M hybrid, but is possibly a little more Guatemalan than Mexican and certainly more Guatemalan than 'Hass'. Cultivar 'Fuerte' is often called a G x M hybrid or sometimes Mexican which makes it more Mexican than 'Hass' and a lot more Mexican than 'Gwen' but not as Mexican as 'Mexicola'... What these examples show is that description of avocado cultivars in terms of botanical race composition has its limitations and we are most likely dealing with a continuum of blending among the three botanical races. Can we improve on this? ¡Sí, se puede!

Enter the modern tools of genomics: molecular markers and new analytical approaches are emerging that can peek inside ancestral genomes and discover hidden patterns within genetic information. The new approaches track the progress of tiny nuggets of genetic information (markers) by comparing their distribution across a large numbers of cultivars. Several studies have revealed that today's cultivars continue to harbor the genetic footprints of the three botanical races and a lot more besides. In this instance, having cultivars bursting with genetic diversity is a good thing. Eventually, given a large enough dataset (markers and cultivars), we will be able to place cultivars into assemblages that go beyond first-pass assignments to one or more botanical races.

A working framework of cultivar assemblages confers predictive information that helps guide cultivar choice and breeding decisions. In a slow-growing tree crop such as avocado where years elapse before many traits are available, a marker-guided, predictive framework represents huge savings in time and resources. A simple example illustrates this point: In the event of an epidemic there is no time to start breeding new cultivars from scratch. Instead, the first line of defense is to explore tolerance present in existing cultivars, and having access to a framework helps prioritize among hundreds of cultivars. Avocados of Mexican ancestry are known to exhibit better disease tolerance than Guatemalan and West Indian stock, so material that contains a Mexican-race footprint would be a good choice for early screenings for tolerance. Epidemics such as grape phylloxera or potato blight are well known examples where the mainstream cultivars shared too uniform a genetic base and where a cultivar monoculture permitted disease pressure to attain dangerous proportions. Consequently, today's dominance of 'Hass' should be viewed with some trepidation.

In fact, it is possible that we are facing a new epidemic right now: Fusarium dieback (FD) has impacted many tree species, especially the avocado, in southern California since its introduction in 2013. The Fusarium fungus is transmitted by a beetle, the polyphagous shot hole borer (PSHB), and fungus and beetle act in partnership to breach the defenses of their plant host, leading to wilting, branch dieback, and fruit losses. Moreover, we know that 'Hass' is highly susceptible to the disease. It is time to look for sources of tolerance and to revisit the cultivars that have lost ground to 'Hass', such as 'Bacon', 'Fuerte', and 'Reed', and to take advantage of germplasm collections that contain material of older vintage, often dating back to the start of the 20th century, if not before. A major germplasm collection is maintained at the University of California South Coast Research & Extension Center in Irvine, and additional material is grown at UC Riverside's Agricultural Operations. A good digital resource to study the diversity of cultivars available in California is the UC Riverside Avocado Information website *http://ucavo.ucr.edu/avocadovarieties/VarietyFrame.html*.

Is the consumer ready to embrace new cultivars? Preliminary evidence is promising. There are few opportunities today to come face-to-fruit with the more unusual cultivars because they have largely been banished to back yards or live sheltered lives in today's germplasm collections. A notable exception is the UC Riverside avocado breeding program. Headed by Dr. Mary Lu Arpaia, the program runs a monthly avocado tasting session where participants record their views on visual (external) fruit characteristics and on fruit sensory qualities (flavor). These tasting sessions have shown that participants are drawn to novel fruit shapes/sizes and value the taste of many cultivars, not just of 'Hass'. There is also considerable interest in learning more about existing cultivars and about the history of avocado breeding and domestication.



Some of the avocado cultivars featured on the UC Riverside Avocado Information website

Clearly, to place avocado cultivars into a workable framework that reflects their interconnections as well as the footprint of the three botanical races will be a valuable addition to the tools available to breeders and will benefit our knowledge of avocado diversity. For now, however, we are unable to give concise answers to the questions of the introductory paragraph, but it is safe to say that your favorite cultivar is probably a hybrid between at least two botanical races of avocado, contains genetic footprints left by ancient Mesoamerican breeders, capriciously gives rise to highly promising seedlings, and has a murky pedigree yet to be laid bare.

Drought Induced Problems in Our Orchards

Ben Faber, UCCE Advisor Ventura County

Abiotic disorders are plant problems that are non-infective. They are not caused by an organism, but through their impacts, allow damage by organisms. Damage to a tree hit by lightning or a tractor breaches the protective bark which allows fungi to start working on the damaged area, eventually leading to a decayed trunk. It was the mechanical damage, though, that set the process in motion

Too much or too little water can also predispose a plant to disease, e.g. Phytophthora root rot or asphyxiation from waterlogging or irrigations.

Curling leaves from lack of water

Asphyxiation from too much water

Phytophthora root rot on left from too much water

<u>Salinity Effects from Lack of Water</u>

Lack of water and especially sufficient rainfall can lead to salinity and specific salts like boron, sodium and chloride accumulating in the root zone. This happens from a lack of leaching that removes native soil salts from the root zone or the salts from the previous salt-laden irrigation from the root zone. These salts cause their own kind of damage, but they can also predispose a tree to disorders, disease and invertebrate (insect and mite) damage.

Lack of water and salt accumulation act in a similar fashion. Soil salt acts in competition with roots for water. The more soil salt, the harder a tree needs to pull on water to get what it needs. The first symptom of lack of water or salt accumulation may be an initial dropping of the leaves. If this condition is more persistent, though we start to see what is called “tip burn” or “salt damage”. Southern California is tremendously dependent on rainfall to clean up irrigation salts, and when rain is lacking, irrigation must be relied on to do the leaching.

Tip Burn

More advanced salt damage. Loss of canopy leaves can lead to fruit sunburn (bottom right hand corner).

As the lack of leaching advances (lack of both rainfall and sufficient irrigation leaching) the canopy thins from leaf drop, exposing fruit to sunburn and fruit shriveling.

Leaf drop and fruit shriveling in avocado.

In the case of sensitive citrus varieties like mandarins, water stress can lead to a pithy core with darker colored seeds, almost as if the fruit had matured too long on the tree.

Endoxerosis with the dry outed core.

Total salinity plays an important factor in this disorder, but specific salts may also cause injury. These salts accumulate in the older leaves, and cause symptoms that are characteristic in most trees.   Boron will appear on older leaves, causing an initial terminal yellowing in the leaf that gradually turns to a tip burn.

Boron toxicity

Often times it is hard to distinguish between chloride, sodium and total salinity damage. It is somewhat a moot point, since the method to control all of them is the same – increased leaching. There is no amendment or fertilizer that can be applied that will correct this problem. The damage symptoms do not go away until the leaf drops and a new one replaces it. By that time hopefully rain and/or a more efficient irrigation program has been put in place.

Sodium toxicity tends to be marginal and at the tip, as well.

<u>The Impact of Drought on Nutrient Deficiencies</u>

Salinity and drought stress can also lead to mineral deficiencies. This is either due to the lack of water movement carrying nutrients or to direct completion for nutrients. A common deficiency for drought stressed plants is nitrogen deficiency from lack of water entraining that nutrient into the plant.

Nitrogen deficiency

Nitrogen deficiency usually starts out in the older tissue and gradually spreads to the younger tissue in more advanced cases.

The salts in the root zone can also lead to competition for uptake of other nutrients like calcium and potassium. Apples and tomatoes are famous for displaying blossom end rot when calcium uptake is low, but we have also seen it in citrus. Low calcium in avocado, and many other fruits, leads to lower shelf life. Sodium and boron accumulation in the root zone can lead to induced calcium deficiencies and increased sodium can also further lead to potassium deficiencies. Leaching can help remove these competitive elements.

Bitter Pit of apple from low calcium

Blossom end rot in citrus

Incipient potassium deficiency from drought

<u>Drought Effects on Tree Disease</u>

Drought and salt stress can also lead to increased incidence of some diseases. Some of these diseases are secondary pathogens and unless it is a young tree (under three years of age) or one blighted with a more aggressive disease, the disease condition is not fatal. Often times, in the best of years, on hilly ground these diseases might be seen where water pressure is lowest or there are broken or clogged emitters. The symptoms are many – leaf blights, cankers, dieback, gummosis – but they are all caused by decomposing fungi that are found in the decaying material found in orchards, especially in the naturally occurring avocado mulch or artificially mulched orchards. Many of these fungi are related *Botryosphaerias*, but we once lumped then all under the fungus *Dothiorella*. These decay fungi will go to all manner of plant species, from citrus to roses to Brazilian pepper. The good news is that, in many cases, once the drought and salt stress has been dealt with the disease symptoms slowly disappear.

Black Streak in avocado

Leaf Blight in avocado. Notice the uneven marginal burn to distinguish it from "tip burn". The necrosis can occur anywhere on the leaf without a pattern

Salt and Pepper syndrome where large parts of the leaf stems dieback and the rest stays green

Citrus dieback. In young trees this can grow down to the graft and kill the tree

Botryosphaeria that has gone from leaves to fruit

Bot gummosis in Citrus

Another secondary pathogen that clears up as soon as the stress is relieved is bacterial canker in avocado. These ugly cankers form white crusted circles that ooze sap, but when the tree is healthy again, the cankers dry up with a little bark flap where the canker had been.

Bacterial canker in avocado

<u>Drought Effect on Pests</u>

Water/salt stress also makes trees more susceptible to insect and mite attack. Mites are often predated by predacious mites, and when there are dusty situations, they can’t do their jobs efficiently and mites can get out of hand. Mite damage on leaves is often noted in well irrigated orchards along dusty picking rows

Citrus red mite leaf damage.

Many borers are attracted to water stressed trees and it is possible that the Polyphagous and Kuroshio Shot Hole Borers are more attracted to those trees.

Shot Hole Borer in avocado

And then we have conditions like Valencia rind stain that also appears in other citrus varieties. We know it will show up in water stressed trees, but we aren't sure what the mechanism that causes this rind breakdown just at color break. Could it be from thrips attracted to the stressed tree or a nutrient imbalance, it's not clear?

Rind Stain

Water and salt stress can have all manner of effects on tree growth. It should lead to smaller trees, smaller crops and smaller fruit. The only way to manage this condition is through irrigation management. Using all the tools available, such as CIMIS, soil probes, soil sensors, your eyes, etc. and good quality available water are the way to improve management of the orchard to avoid these problems.

Upcoming Meetings and Programs:

Avocado Grower Seminar Series

Walk About: 6 Stations in a Local Avocado Grove

Tuesday, June 7, 2016, 1:00 p.m. to 3:00 p.m., San Luis Obispo - Location To Be Announced
Wednesday, June 8, 2016, 9:00 a.m. to 11:00 a.m., Ventura – Location To Be Announced
Thursday, June 9, 2016, 1:00 p.m. to 3:00 p.m., Fallbrook – Location To Be Announced

> This newsletter is published three to four times a year with educational subjects in subtropical horticulture. Please let us know topics you would like to be addressed in this Newsletter!

Topics in Subtropics

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