

Avocados for Thoughts

I felt like an alien the last few times I visited the produce sections of supermarkets in the US, while on leave from Costa Rica, where I have been residing for some 15 years. What planet is this that produces fruits that look like fabricated Christmas decorations? Transparent containers full of colorful fruits were stacked up neatly on display shelves, in the same manner as all the other dry goods. Each fruit in the boxes is seemingly grown to fit bubble wraps of fixed sizes; each is of a standard shape, identical bright hues and even blush spots. From store to store, the varieties of fruits are amazingly uniform in taste, texture and state of ripeness — a testament to the degree of quality control the US food industry exerts on the consumers' food supply. I cannot deny the convenience of having access to the same familiar food anytime, anywhere. Nonetheless, it is unsettling to realize how far we humans have isolated ourselves from our food supply.

One of my great delights when doing produce shopping in Costa Rica is discovering the great varieties of familiar and unfamiliar fruits available in the many family-run small markets. It is not just different fruits, but the variety within each fruit group. Take the bananas. In addition to the universally available Cavendish cultivar, the local choices range from thumb-sized bananas to the pound-sized plantains, some better eaten as fruits out-of-hand, others cooked. Or take the different species of fragrant passion fruits, ranging from the very tart to the very sweet — egg-shaped, cigar-shaped or spheroid. When ripe, they come in yellow, orange, purple, magenta or shades in between. The infinite variety coming out of local backyards or orchards is startling. Most of all, it is exhilarating to sink one's teeth into totally unexpected combinations of flavors and textures, and to realize that there are still infinite new delights to be discovered.

The prize for the highest local diversity, however, easily goes to the avocados. The Hass avocados imported from Mexico year-round are ubiquitous here, just as in the US. However, between June-August, many different looking avocados often labeled only as "aguacates criollos" or wild avocados appear in the markets. They come in an impressively wide range of sizes (fruit and seed), shapes,

colors (green to deep purple to black), skin texture/thickness, and most of all, fruit flavor and degree of "butteriness". Intrigued, I went searching for information.

The reason for the locally high avocado diversity has a perfectly logical explanation. Costa Rica and the Central America highlands are the ancestral home of the domesticated avocados from the genus *Persea*. The earliest evidence of avocado as food comes from archeological remains in the Puebla state of Mexico, buried in strata from about 10000 years ago. As domestication of *ahuacatl* (Aztecs language meaning testicles) continued, the size of the fruit pits decreased and the thickness of the flesh increased. Domestication and cultivation in the region never ceased, but slowly diffused outward in the intervening millennia, producing varieties and hybrids so numerous and intermixed that scientists had difficulties sorting the ancestry of our modern day avocados. Thanks to recent molecular gene sequencing, the avocado story is finally emerging.

Our present day avocados, *Persea americana*, are the progenies of not one, not two, but three independent domestication centers, yielding the three well separated



Fig.1 Map of three loci of avocado domesticated ecotypes. Mexican (red), Guatemalan (green) and West Indies (yellow).

ecotypes named after their origins: Mexican, Guatemalan and West Indies, respectively *Persea Americana* var. *drymifolia* from Mexico, *Persea Americana* var. *guatemalensis* from Guatemala and *Persea Americana* var. *americana*. The West Indies ecotype, unfortunately, was misnamed because its home is actually the Pacific Coastal region spanning Nicaragua, Costa Rica and Panama (Fig.1). Ethnobotanical and genetic markers investigations indicate that these three variants did not come into contact with each other until after the arrival of conquistadors in the 16th century.

Persea belongs in the Lauraceae family with 50 genera (2500-3000 species) worldwide. It includes the Bay Laurel and cinnamon. It is considered to be the most primitive

dicotyledons, at the basal lineage near the origin of the flowering plant evolution (65 million years ago) from gymnosperm to angiosperm. Today, primitive avocado trees can be still found in $\geq 2000\text{m}$ elevation montane forests in Mexico and Costa Rica, midland forests in Guatemala and humid lowlands in Costa Rica. Imagine the difficulty for the botanists to sort out the coexisting progenies, after thousand of years of cultivation, of selection among wild plants, and later by grafting and hybridization. Primitive, *i.e.*, indigenous fruits have very large pits and thin flesh with rough skin (Fig.3), fruiting in pairs, hence the Aztec testicle attribution.

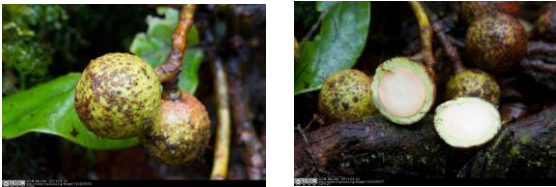


Fig.2 Wild avocado growing in Nicaraguan cloud forest. (Photo: reading.ac.uk/tropical-biodiversity)

Mature *Persea* trees in the wild can reach 20 m, with inconspicuous greenish small flowers pollinated by small insects. Curiously, each flower under favorable conditions opens twice daily, the first time as functional female and the second as male. This maximizes cross-pollination, with a back-up mechanism of self-pollination if all fails. The fruits are highly variable in size, shape, rind texture, and flesh thickness or seed size even within the same ecotype. Avocado fruits do not ripen on the trees, but start several days after it is picked. Unlike most fruits, avocado accumulates oil and not sugar as it ripens. By weight, 20-30% of the mature fruit is mono-saturated fatty acids.

The Mexican avocado is the oldest variety used as food, traditionally a staple in Mexico since 500 B.C. In spite of the global spread of avocados by the Spanish conquistadors and European explorers, including to Florida and California in the 1800's, it remained a semi-domesticated fruit crop with low demand until the 1920's. Commercialization of avocados did not begin until Rudolph Hass, a Whittier CA postman, succeeded in growing a strong seedling from three nursery seeds. The lone tree was spared from the axe because his children liked the taste of the odd bumpy fruit. Hass was able to sell his bumper crops to a local grocery store catering to the chefs of wealthy families for \$1 a piece (\$14 in 2016), prompting him to patent (the first patented tree ever) his tree. Hass made about \$5000 profit from the sale of cuttings while he continued to work as a postman. Today, Mexico grows 45% of the world's four billion avocados annually, worth \$1 billion. The US per capita annual avocado consumption increased from 1.1 lbs. (1989) to 7 lbs. in 2014 (compared to 20 lbs. in Mexico). The current drought in California and weather-related growing problems elsewhere drove the production down and the

price up. The insatiable demand for the fruit resulted in the US relaxing its import restriction and now supplementing its avocado with imports from Mexico, Chile, Peru and the Dominican Republic.

While the Hass variety dominates (80%) the trade, the development and interest on other promising cultivars continues. Currently there are 200-300 *Persea* varieties listed, with various combinations of traits from all three ecotypes. In parallel, botanists and geneticists are busily collecting both indigenous and semi-domesticated avocado trees in Central America, hoping to tease out the complex genotypes and to understand the biochemistry of each gene's contribution to the various traits manifested in the polymorphic fruits. Enthusiastic collectors, or "wild fruit hunters", are still combing Central American, the avocado hotspot, for esoteric and unusual avocados to expand the existing germplasm collections and to save wild or domesticated avocado breeds before they disappear.

I particularly like the stories of two such hunters, Richard Campbell and his co-collector Noris Ledesma. They explored in Costa Rica between 2002-2008. Their favorite specimen, a large smooth-skinned avocado named Blas, came from a giant 100 year old tree, whose famous fruits attracted harvesters in oxcarts from 100 miles away. Campbell and Ledesma would find esoteric specimens in the local markets, along roadsides, in backyards, behind carwashes and in truck stops. They would scour villages with a bullhorn, shouting out invitations to bring homegrown avocados to a weekend competition, awarding bicycles as prizes. Once they have selected their fruit of interest, the challenge was to trace its source tree, then to convince/negotiate with the tree's owners for budwood, often over several rounds of beer. Hundreds of their living specimens, including the mother tree of the Pura Vida gourd-shaped fruit, or the seedless Juan Jose avocado, or the previously mentioned large Blass, are now grown as



Fig 3 (Left) Samples from the Fairchild Botanical Garden avocado collection, the Bamboo (middle) and Juan Jose cultivars of the West Indies ecotype (right).

part of the living collection at the Farm Genetic Resource Center of the Fairchild Tropical Botanical Garden in Florida (Fig.3). Campbell collected 200 specimens, but he believes there are still thousands out there with desirable traits. For his trees, the collecting came none too soon. In the few short years since their last safari, many of the mother trees of the accessioned specimens are now gone, cut to clear the land or for wood.

Throughout its growing region, wild or semi-domesticated avocados thrive traditionally in backyards and in public places with little attention. The global avocado mania and high prices have driven the development of larger scale avocado orchards, especially Hass fruits, in Michoacán, Mexico. This crop expansion is the leading cause of deforestation in that country. With the loss of forest comes the loss of clean water. But the list of negative consequences is much longer. For example, the montane Michoacán forest is the very same natural habitat of the monarch butterflies for their overwintering. Although there is currently no direct evidence that the specific overwintering sites are affected, their proximity to the avocado-driven deforestation cannot be good news for the butterflies. Deforestation, for certain, is destroying the natural habitat of countless species of unknown flora and fauna in Michoacán.

Let's not forget the importance of avocados for wild life, especially the frugivorous birds. As previously mentioned, the tropical Lauraceae family includes several large genera of avocados including not only *Persea*, but also *Nectandra*, *Ocotea* and *Beilshmiedia*, all bearing oily and nutritious fruits of varying sizes. Only a handful of the *Persea* species are of interest to us humans, but there are about 400 species of wild avocados in the remaining three genera in Costa Rica alone that are absolutely vital to the birds. The majority of tropical birds are frugivores and a subset are specialized frugivores, meaning birds that feed mainly on fruits rich in fats — wild avocados — and protein from insects. For these specialized frugivores, wild avocados mean the difference between life and death. In the Neotropics, there are about 60 bird species of specialized frugivores, of which the Resplendent Quetzal (Fig. 4) and the Three-wattled Bellbird are the most famous. Typically the specialized frugivores ingest the fruits whole, digest the soft flesh and void the seeds intact, either by regurgitation or by defecation. Their annual migration from the highlands to the lowlands require access to wild avocados along their route. Shrinkage of habitats and food supply along their migration path is reducing the population of both the quetzals and bellbirds, two among many that are not receiving attention.



Fig 4 A resplendent quetzal in the cusp of ingesting a wild avocado on the left and perched next to a tree loaded with fruits on the right.

As is often the case, these specialized frugivorous birds may depend on the fruits but the trees are, in turn, dependent on the birds for seed dispersal. The large avocado seed size requires large birds with wide mouths to swallow the seed whole and to act as long distance seed dispersal agents. Such interdependent relationship often favors speciation and diversification over long evolutionary history. Loss of bird species will mean loss of tree diversity, loss of tree diversity means fewer birds... the unavoidable and eternal vicious cycle.



Finally, a note for the interested: in our own cloud forest reserve there is a scarce and uncommon endemic species of Lauraceae, *Povedadaphne quadriporata*, a large tree with kiwi-size fruits with magenta colored seeds, the only species in the genus. (I admired its magenta-tinged flesh and imagined it on a plate of salad). It is named after Luis J. Poveda Alvarez, a professor of ethnobotany at the National University of Costa Rica. Shortly after we inaugurated our reserve, professor Poveda visited us with a heavy knapsack. As he hiked along the trail, he spotted "his" tree, he looked up at the large tree, smiled happily, then pulled out a bottle of guaro (distilled sugarcane, 40% alcohol) from his pack. He tipped the bottle, filled his cheeks with the elixir, and sprayed the tree as a good send-off. For extra luck, he took a small sip, blessed the tree and walked on.

Two thoughts for the next time you buy an avocado. Know your avocado(s) and think of *Nectandra*.

— The editor —

Recent News Highlights

July Local young volunteers worked with Nectandra Institute (NI) staff to [collect aquatic macroinvertebrates](#) along streams and rivers in the upper [Balsa River Watershed](#). We have been monitoring these organisms semiannually since 2009 in over 20 stream locations. The volunteers were rewarded for their hard work with an [outing to Juan Castro Blanco National Park for Water](#) — the source of potable water for several dozens of communities all around it.

July There is no better time than Costa Rica's rainy season (May to November) for planting trees. [FEDAPRO](#), our most recent NI [eco-loan](#) recipient, held a [tree-planting event for local school children](#) on its 7.8 ha (21 A) piece of restoration land. After planting trees, the children hiked its trails, which are managed by FEDAPRO as part of its educational, ecological and hydrological objectives.

August [Annual tree measuring work](#) continued this month on several restoration properties purchased by Nectandra Institute's eco-loan partners. The measurements over the years show variable intra-species growth rate within the same property. A quick analysis suggests that ≥ 50 centimeters tall seedlings have a higher success rate, as well as those that were germinated and grown in immediately local nurseries. We are analyzing the influence of specific site related environmental variables, e.g. wind exposure, soil conditions, and competing surrounding vegetation, on subsequent rooting and growth.

Each year at the end of August, students from local, vocational high schools select organizations to work as interns. This year, NI's interns spent a week with our staff biologist to [collect tree growth data and do restoration work](#). Over the last three years, some two dozen high school and university volunteers from Costa Rica, the United States, Mexico, and Australia have provided NI with their invaluable support.

September The annual New Culture of Water Month is a multi-event celebration created by NI to raise awareness for forest conservation and water protection. This is achieved through [a series of educational, artistic, recreational, and cultural activities](#). This year's 9th inauguration ceremony featured a presentation by a well-known local organic farmer. The New Culture of Water Queen Pageant candidates showed off dresses made from recycled materials and answered questions on environmental or conservation-related topics. Competing grade school student teams were tested on their ecological knowledge in the CRECER (acronym for to grow in Spanish) competition in an academic decathlon-type format.

Madeline Gilbert and Logan Taylor, our latest student volunteers from University Studies Abroad Consortium worked for three months on [classifying the macroinvertebrate specimens](#) collected during July from various points along streams and rivers in the upper Balsa River Watershed. They sorted the specimens by family and calculated the water quality water scores using a formula that rates the differential level of contaminant sensitive to contamination tolerant organisms.

October Several of NI's community partners carried out [tree planting activities](#) at their respective restoration lands, recruiting school children, company employees from a state-run bank and workers from a private sector company based in the capital city of San Jose. They helped plant over 300 trees on four different eco-loan properties.

November [Nectandra Cloud Forest Reserve](#) was added to NI's macroinvertebrates water quality monitoring program. University student interns assisted NI staff to [evaluate two streams in the Reserve](#). Preliminary results indicated the water sampled to be of fair to excellent quality, depending on the time of year. One of the Reserve's streams is recovering from pesticide-laced runoff from the upslope neighbor, a former *Dracaena* (native African decorative plants used mostly in public places) plantation. On our wish list is the purchase of this 140 ha (378A) neighboring property with the headwaters of the Reserve's streams for forest restoration and conservation.

December We took [time-lapse photos](#) at several properties to capture the changes that occurred over nine years' worth of restoration. Twice yearly from fixed points within each eco-loan financed property, we make photographic documentation to record the progression of the ecological restoration.

Nectandra Institute helped organize the seventh annual "Conteo Navideño del Bosque Nuboso de Occidente" (An Audubon-sanctioned Christmas bird count in the San Ramón area of Costa Rica). Nectandra Institute founded this yearly event together with the [Fundación Bosque Nuboso de Occidente](#). This year, approximately 45 birdwatchers covered 18 different routes, one of which passed through Nectandra Cloud Forest Preserve and another traversed an eco-loan financed restoration property. This year's official results are still being tabulated, but last year's edition resulted in 347 species totaling 6019 birds seen by participants along the various routes. This represents over a third of the almost 900 avian species found in all of Costa Rica. It's worth mentioning that birds play a very important role in seed dispersion in [forest restoration projects](#).

— Reported by Luis Villa —