# Tonto Basin Agave

## *Agave delamateri*


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# Tonto Basin Agave

*Agave delamateri*

Tonto Basin Agave, (*Agave delamateri*) is a medium-sized Agave, or Century Plant. It is a plant that looks like a cactus, due to its large spines and thick, succulent-type leaves, but is actually more closely related to the Lily and Amaryllis. This Agave is different from most, though, because it is a hybrid—a plant cultivated by the ancient Sinagua Indians that lived in the area until about 600 years ago. Like most hybrids, this Agave cannot reproduce by flowers and seeds, like other natural plants do. Instead it produces miniature clones, or "pups" to propagate itself. Since each of these clones has the same genetic makeup as the "parent," it can be said that each is actually the same plant as the original one grown by the Sinagua, more than a thousand years ago!

The plants growing in the Peck's Lake area of Clarkdale, Arizona were planted by the Sinagua who inhabited Tuzigoot, a 77-room pueblo that sits on a hill overlooking the area, and other adjacent smaller pueblos. Tuzigoot is now a National Monument.
This Agave typifies sustainable agriculture and sustainable ways. The plant takes little water and demands little care, but gives so much. The ancient Sinaguas derived fiber for tools and clothing from the leaves and a sweet food from the thick body of the plant. Its ruggedness and sustainable nature is evidenced by the fact that it has grown unattended on the site for hundreds of years.

Tonto Basin Agave is listed a species of concern in Arizona, as there are only approximately 90 patches living today. It would rightly be listed as an endangered species if it were not a cultivated hybrid plant.

The plants near Peck's Lake were discovered only a few years ago when a team from the Desert Botanical Garden came to Tuzigoot to ask if there were any "strange" agaves living in the area. I happened to be in the monument museum at the time, and remembered that there was a patch of odd agaves living on the west side of Peck's Lake. I took the team to the plants and they determined through DNA analysis that these were, indeed Tonto Basin Agave. A few years later, when the owner of the land, Phelps Dodge Mining Company, in trying to secure the area, dug a barrier trench and berm around the lake. The largest patch of Agave was directly in their path and were dug up and deposited in the berm. When I realized this was going to happen, I went to the site and was just an hour late! I called Wendy Hodgson and she and a team of botanists came up and we rescued the plants that we could. Some are now at Tuzigoot, at Desert Botanical Garden, and a few other locations. One small patch was unharmed and survives intact today.

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ABSTRACT. Indigenous cultures have long used agave for numerous purposes including food, fiber and beverage. Agaves were traditionally pitbaked by many cultures, allowing the breakdown and digestion of complex types of fructans, a carbohydrate storage product believed to have many health benefits. Many agaves were pre-Columbian cultivars, their distributions and morphology the result of selection and distribution by people. Cultivation of ancient New World cultigens is correlated with clonal reproduction and sterility, which have been documented in Gentry's Americanae, Ditepalae, Rigidae and Sisalanae agave groups. *Agave murpheyi, A. delamateri, A. phillipsiana*, Page Springs and Sacred Mountain agaves are recently recognized plants in the Ditepalae that are a direct link to those once farmed by pre-Columbian agriculturalists centuries ago in Arizona. Vegetative reproduction perpetuated favorable characteristics selected by farmers and allowed agaves to persist for over seven hundred years. Morphological, molecular, taxonomic, cytological, ecological, ethnobotanical and archaeological studies are instrumental in answering a number of questions regarding these plants and their ecological/cultural roles.

Agaves have been of great economic and social importance for the people of Mesoamerica and arid America (Colunga-GarciaMarin and May-Pat (1993). The carbohydrate-rich meristems and fibrous leaves provided important sources of food and fiber. Within the Southwest, plants were also used for making paper, soap, shampoos, medicines, armed fences and fermented beverages, as well as in construction and ceremonial activities, and ornamentals (Castetter et al. 1938; Gentry 1982; Hodgson 2001a). People in the state of Yucatan use every part of wild and cultivated variants of agaves for 40 different purposes, and it is suspected that many more uses were lost or not recorded (Colunga-GarciaMarin and May-Pat 1993). Such multi-purpose plants like agave were, and continue to be, exceptionally important to those who had access to the plants.

## Agaves for Use as Food.

Pre-Columbian, historic and even present-day peoples highly valued agaves for their source of sweet, flavorful food and often used the plants (cooked or uncooked) as an article of trade. Harvesting and processing agaves was a complex process requiring time and energy. Not all agaves are edible as many have high sapogenin content and other toxic compounds (Gentry 1982). The tender young flower stalk or base of the stalk was roasted or baked (Hodgson 2001a). However, it was the meristem (heart, *cabeza*) of a soon to flower agave that was the preferred food once roasted or baked. Large heads were usually preferred over smaller species because of their size (Gentry 1982; Hodgson 2001a). The ability to distinguish flowering agaves from non-flowering ones and bitter species from non-bitter ones was (and still is) difficult and requires great skill on the part of the harvester. Preparing agave evolved from roasting the stalks or hearts atop a fire to baking many hearts in rock-lined pits, which facilitated social interactions and exchange. The sweeter and less fibrous baked agave heart and the remaining leaf bases were eaten

on the spot or stored indefinitely after the cooked material was cut and pounded into thin sheets, cakes or loaves and quickly dried to minimize spoilage.

In arid regions, pit baking using rock-lined pits is a superb method to render the stored carbohydrates within the agave meristem, in the form of fructans, edible. Fructan (found in approximately 36,000, or 15% of known plants) is a major storage carbohydrate that is polymers of fructose linked by B2-1 bonds. Long-chain fructan polymers are generally termed inulin while short-chained polymers are called oligofructans, a subgroup of inulin. Oligofructans are more soluble than inulin or sucrose and are very sweet, providing 30 to 50 percent of the sweetness of table sugar (Niness 1999). Fructans are generally classified as a dietary fiber and are not digested by enzymes in the mammalian small intestine but are digested by microflora in the colon. Fructans help develop and support beneficial bacteria that break down the compounds in the colon (providing limited amounts of calories) as well as eliminate pathogenic bacteria and yeast. Fructans may have other numerous benefits but test results are inconsistent (Schneeman 1999).

Fructans' differences in structures, particularly chain length, will elicit different effects. Agave fructans are far more complex (Lopez et al. 2003; Wang and Nobel 1998) than the single, long chained inulin from chicory (*Intybus chicoria* L.), which supplies most of the commercially used fructan. Theoretically, such complexity of fructans will elicit more different effects. For pre-Columbian farmers, although the caloric yield of agaves was little, other health benefits were probably derived from eating baked agave.

Long term, moist heating, such as boiling in water or pit-baking, will hydrolyze more complex carbohydrate fructan into oligofructose and the even more easily digested and exceedingly sweet fructose. Such cooking also softens structural cellulose, thereby slowing the movement of these high fiber foods through the intestine (O'Connell et al. 1999). Where obtaining water is a concern, pitbaking of fructan containing tuber-like roots or other carbohydrate storing organs (such as the agave meristem, or heart) was commonly employed.

## Cultivation of Agaves.

When attempting to better understand how important cultivated and wild plants were to people, it is important to understand them in their cultural context. The genetic diversity maintained by cultigens within a certain area reflects how long and continuously the crop has been cultivated, the ecological diversity of the habitat, cultural diversity and cultivation practices, and the level of introgression between crops and their wild relatives (Parker et al. 2007). In addition, a multidisciplinary approach using ecological, archaeological, taxonomic, ethnobotanical (historic and present), molecular, cytological and hybridization studies is required to understand plant-human interactions. Too often researchers within and among different disciplines operate independently of each other, including botanists and archaeologists.

Agaves are excellent candidates for cultivation in arid areas. Plants do well in soils too thin or mineral-deficient for other more water- or nutrient-loving crops such as maize, beans or squash. Many agave species can reproduce via vegetative means through the production of pups and bulbils from the rhizomes and inflorescence shoots, respectively. Vegetational reproduction allows for the selection and "fixing" of plants' favorable attributes, with successive generations often expressing these same characteristics. Clonality and sterility are often mutually inclusive in plant cultivars that

reproduce by vegetative means. Although advantageous for harvesters and processors, these phenomena are the cause of considerable confusion for taxonomic clarity of different taxa whose origins may be complexly interrelated. Such confusion is experienced in deciphering the taxonomy and systematics of Gentry's groups Sisalane, Americanae, Rigidae and Ditepalae. Certain characteristics that would be advantageous for selection by harvesters and farmers could be selection for taste, fiber strength and rot-resistance, cloning (by rhizomes or stalk shoots), size of plants at maturity, reduced maturation time, ease of leaf cutting, smaller, more decurrent or porrect spines, absence of spines, time of flower stalk initiation, pest resistance and drought (and cold?) resistance. Most are vegetative characteristics that are more easily changed than characteristics associated with sexual reproduction, and respond positively under cultivation (Colunga-GarciaMarin, et al. 1999).

So when and how did agaves take on such an important role in the subsistence patterns of pre-Columbian peoples? Mesoamerica is one of three most important areas of origin and diversity of cultivated plants in the world, and in its seasonally dry regions, agaves are the most important and widely used pre-Columbian food plants (Colunga-GarciaMarin and Zizumbo-Villarreal 2007). **Ironically, there is a lack of data for pre-Columbian use of agave, including their cultivation in Mesoamerica, where it is correctly assumed that agaves were extensively used and farmed (see Smith 1965).** On the other hand, over the past three decades significant advances in research have negated the previously assumed theories implying that agaves were of little importance and not cultivated in southwestern U.S. and northern Mexico.

Before the development of agriculture, agave represented a basic food source for gathering in arid and semi-arid areas from north of the Isthmus of Tehuantepec as far north as the Mohave and Great Basin Deserts of southwestern U.S (Colunga-GarciaMarin and Zizumbo-Villarreal 2007). Agaves in Mesoamerica have been used for food since at least 11,000 years ago (Callen 1965; Smith 1965), the peduncles and heads pitbaked and used in the same way since 9,000 B.C. (Callen 1965; Smith 1986). Agaves formed the main part of the diet in cultures at least from 5200 B.C. to 1540 A.D. in arid and semiarid regions of Mexico (Callen 1965). There is also evidence for cultivation (and long-distance exchange) of other types of plants 5,700 to 4,800 years ago (Smith 1965). Certain agaves were the basic food source to which other plants, such as maize, beans and squash were eventually added (Colunga-GarciaMarin and Zizumbo-Villarreal 2007). Agave cultivation in Mesoamerica may have been the first agricultural attempt of agriculture in Mesoamerica, to be later followed by maize, beans and squash (Gentry, 1982). Over time, the agave's importance as a food item declined and it became a famine food, replaced by corn, beans and squash, (Colunga-GarciaMarin and May-Pat 1993). The most important use of agaves shifted from food to fiber, beverage (particularly with the introduction of the Filipino still) and medicine (Colunga-GarciaMarin and Zizumbo-Villarreal 2007). The relatively smaller agaves of the more arid and semiarid regions north of Mesoamerica continued to be an important food and fiber source to those who had access to the plants.

Colunga-GarciaMarin and Zizumbo-Villarreal (2007) describe how the human-agave symbiosis evolved. Such human-plant dependency comes at a cost. Cultivation of important plants that provide a multitude of uses with limited germplasm is not a favorable situation for the farmer. By continually selecting for different, favorable

characteristics developed via somatoclonal mutations or hybridization/introgression events, farmers created new entities while also maintaining existing favored phenotypes and hence, germplasm, as explained by Gentry (1982:6):

> In Mesoamerica, the many evolving varieties and forms of *Agave* species were selected by man, moved from place to place with him, and inadvertently crossed. As man lived with these varietal eventualities through the centuries, he was provided with new genetic combinations that he could check empirically for yield and quality of fiber, food, beverage, and other special products. As he specialized with civilization, he specialized agave, selecting characteristics according to his wants… He quite innocently fostered an explosive evolution in agave diversification.

It is not known how many different types of agaves pre- and post-Columbian farmers grew at any one time. Archaeological studies remain one of the most important areas of research to discern at what time and what types were cultivated and by whom, best achieved from long-inhabited areas and where archaeological features could be better preserved, such as in arid or semi-arid regions (Smith 1965). The presence of seemingly distinct and disjunct (historically extirpated or extant) taxa that are often in association with archaeological features linked with agriculture can also provide a great amount of information. Molecular analysis of extant populations suspected to be involved at some level in the evolution of the cultivar is also critical. However, such data are limited or in some cases, virtually lacking in Mesoamerica, an area otherwise known for extensive agave use and cultivation. For example, on the Yucatan peninsula, there is no direct archaeological evidence that can shed light on the diversity of agaves in the pre-Columbian era (Colunga-GarciaMarin and May-Pat 1993). However, by comparing historic and present day use of agaves and studying their molecular and morphological characteristics, it was determined that the diversity of agaves has gradually been lost as a consequence of agricultural intensification of one type of the fiber-producing henequen, or *Agave fourcroydes* Lem. (Colunga-GarciaMarin and May-Pat 1993). In the past, selection for different characteristics, in this case those relating to fiber, that were better adapted to local climate and edaphic conditions, resulted in variants with different morphological characteristics and life cycles.

Oddly enough, such a loss in genetic diversity may in part be due to the domestication process begun in pre-contact times, assuming that the first farmers experimented only with a small fraction of the variation present within the progenitor's species of today's crops (Colunga-GarciaMarin et al. 1999). There should have occurred further loss of genetic variation with further selection of only the best phenotypes but introgression from wild relatives and selection against loss of fitness due to inbreeding have probably counterbalanced the expected loss of genetic variation (Colunga-GarciaMarin et al. 1999). Traditional agricultural practices favored these competing forces but in recent henequen production using limited genetic material, such practices have not been promoted. In traditional pre-contact Mayan cultivation of *A. fourcroydes*, selection and maintenance of diverse properties were probably closely linked to a multipurpose use of this resource, as well as with its cultivation within a wider range than at present (Colunga-GarciaMarin and May-Pat 1993). A similar loss of genetic diversity in the production of tequila is due to the exclusive cultivation of the blue agave, *Agave*

*tequilana* Weber var. *azul*. Selection of different phenotypes produced by somatoclonal mutations and hybridization or introgression events as initiated in the past by indigenous peoples no longer occurs (Colunga-GarciaMarin and Zizumbo-Villarreal 2007; Valenzuela-Zapata and Nabhan 2003; Vega, et al. 2003). Except for occasional cultivation from seed (Colunga-GarciaMarin et al. 1986, 1999), somatoclonal mutations are the only other source of genetic variation for cultigens under the usually limited cultivation practices of today (Colunga-GarciaMarin et al. 1999).

## Agave Cultivation in the Southwest and Northern Mexico

Although the extensive literature implies agaves were an important food source to people inhabiting southwestern U.S. and northern Mexico (Castetter et al. 1938; Gentry 1982; Hodgson 2001a), little or no evidence suggested their cultivation. It would only make sense that a plant so important to people would also be cultivated, as their use was too extensive to be sustained by gathering alone (Bohrer 1991). Evidence suggesting cultivation of a wild plant includes 1) that plant's expanded range by anthropogenic means, 2) changes in the morphology of the plant, and 3) archaeological data (Bohrer 1991). Minnis and Plogg (1976) theorized that certain populations of *A. parryi* Engelm. were found north of their natural range away from the Mogollon Rim near archaeological sites and features, representing a range extension by human activity (Minnis and Plog 1976). **Recent studies indicate that** Archaeological features associated with agave cultivation were found in the Phoenix basin (Bohrer 1987; Gasser and Kwiatkowski 1991), the Tucson Basin (Fish et al. 1985, 1992; Miksicek 1987) and the Safford Basin (Fish et al. 2004). Such features may include agave fragments, roasting pits, core scrapers/pulping planes, agave tabular knives, numerous rock piles and rock-bordered grids (Bohrer 1987; Fish et al. 1985, 1992; Fish et al. 2004).

The distribution and development of varietal cultivars of a number of agaves in northern Mexico was a result of anthropogenic activities. *Agave applanata* Koch ex Jacobi, in Gentry's (1982) subgroup Ditepalae, appears to be indigenous to the cool highlands of Veracruz and Puebla. Because of its probable use for food, fiber and ceremony, this species may have been disseminated as far north as Casas Grandes, Chihuahua by people in historic or pre-Columbian times (Gentry 1982). Agave *angustifolia* Haworth is the most wide-ranging and variable of all agaves and was an important source for food, beverage and fiber. Plants sucker prolifically and their small pups and bulbils were easily carried and planted by people as far north as northwestern Sonora and as far south as Costa Rica (Gentry 1982). It is a highly variable complex (Gentry 1982; Colunga-GarciaMarin et al., 1999), no doubt influenced by varying climates, different habitats and "man's intervention," (Gentry 1982:563), creating not only a number of varieties and forms but other species such as the important fiber-producing *A. fourcroydes* (Colunga-GarciaMarin et al. 1996; Colunga-GarciaMarin and May-Pat 1997). *Agave angustifolia* is considered a "dono species" *sensu* Gentry (1967) in that many forms have evolved from this plant through somatoclonal mutation, hybridization, followed by their artificial selection.

Despite the increasing evidence substantiating that agave cultivation in the Southwest was practiced as far back as 600 A.D. on a broad scale by pre-Columbian peoples, it was not known how many and what types of agaves were grown. At least five and as many as seven different extant types of agave have now been identified as being

farmed by Arizona pre-Columbian groups (and undoubtedly, this number is low). The extent of cultivation may also eventually include northern Mexico and New Mexico agaves and cultures. We are afforded a rare opportunity to study extant populations whose genetic lineage can be traced back to its pre-Columbian ancestors because of the agave's attributes, no doubt selected for by farmers. All of these rare agaves have been able to persist unattended and minimally altered through vegetative reproduction following cultural abandonment (around 1450 A.D.) and subsequent absence of agrarian cultures until after European contact. Thus, we are given a narrow window into the past and an important opportunity to examine the effects of cultivation within a prehistoric cultural context, an unexplored area of crop evolution (Parker et al. 2007).

*Agave delamateri* is a relatively large, freely cloning plant with gray-green leaves flushed with maroon. Its marginal spines are large and reflexed while the terminal spine is long. Its broad panicle with long lateral branches perpendicular to the robust, thick, purple-brown main stalk produces large flowers that mature from late June to July (Figure 2). The erect, leathery tepals are light green-cream flushed with maroon and tipped with maroon-rust, characteristic of other members of the Ditepalae such as *A. palmeri* and *A. shrevei* Gentry. Capsules and seeds have never been observed and its chromosome number is unknown.

Susan McKelvey was the first scientist to document *A. delamateri* in the 1920s and early 1930s from the Sierra Anchas, Globe and Coolidge Dam (just west of Safford Basin) areas, Gila County (Hodgson and Slauson 1995). Rick DeLamater, for whom the plant is named, discovered numerous other clones in Tonto Basin. Additional clones have been located in Camp Verde, Tuzigoot and Sacred Mountain areas, Middle Verde Valley. All of the more than 90 clones have been documented within the Arizona Uplands or piñon-juniper woodlands, often on alluvial terraces or ridges overlooking major drainages at elevations between 700 and 1550 meters. It is more frequent in Tonto Basin, with outlier clones found far up the slopes of both the Mazatzal and Sierra Ancha mountains.

Plants persist in or near indigenous cultural landscapes modified by past cultures, having been selected and cultivated for favorable attributes. Their leaves are extremely easy to cut and possess very fine, strong fibers (Hodgson 2001a). Flowering is synchronous with the initiation of flower stalk production in early May (Table 1). Agave processing tools, as well as single and multi-room foundations are found with *A. delamateri* above drainages where check dams and linear alignments were constructed for growing more water-loving crops, an agricultural strategy different from how *A. murpheyi* was grown in the broad, hotter and drier Lower Colorado Valley region. However, plants required a certain amount of tending since populations are presumed to have greatly decreased in number over the past five to seven centuries following their lack of care. *Agave delamateri* may have its origins involving plants in northwestern Chihuahua or northeastern Sonora.

Understanding agaves in their cultural context may help us better understand migration and trading patterns and intergroup relations in the pre-Columbian Southwest and northern Mexico. Hohokam or Hohokam-influenced cultures extensively received and traded *A. murpheyi* and/or *A. delamateri* in Tucson, Phoenix, Verde Valley, Tonto and Safford basins, with connections as far south as northern Mexico. *Agave phillipsiana* has close ties with Verde Valley, Prescott, Sedona and Grand Canyon groups, its movement probably tied with interconnected networks of trade and migration from the

north (Flagstaff, Winslow-Hopi Mesa), south (northeastern Mexico) and southwest (Prescott). How agave research is seen in the context of recent migration studies (ex., Clark 2001; Lyons 2003) will be the subject of another paper.

Other questions include 1) how many and how extensively were plants cultivated in any given area and time, 2) why are only certain kinds of agaves cultivated in one area and not in another, seemingly appropriate area, and 3) how can these rare cultural and natural resources be protected given the fact that possible hybrids or plants whose existence depended on people are not protected by the Endangered Species Act?

Without question is that these recent findings, in conjunction with the increasing amount of archaeological and molecular data supporting agave cultivation, are painting a picture of agave cultivation at an extraordinary level in Arizona, putting the multi-purpose agaves in their proper place amongst different groups as an extremely valuable resource at one time or another. Everywhere that agaves could grow, farmers selected or encouraged plants with certain attributes for their particular climate, topography, soils and needs, involving indigenous agaves (*A. chrysantha* and *A. parryi*), hybridization of local species with cultivated agaves (Sacred Mountain and Page Springs agave) or plants that originated elsewhere, received through trade or migration activities (*A. murpheyi*, *A. delamateri* and *A. phillipsiana*).

Although we are seeing remnants of plants once grown on a large scale (and many other types were probably developed but have since disappeared), we are seeing a legacy effect. In attempting to identify different agave species within and adjacent to areas where there was extensive agave cultivation, the delineation between what are indigenous and what are direct or indirect descendents of ancient cultivars becomes indistinct (Parker et al., in prep.). We are now seeing the results of years of selection, hybridization and introgression as a result of human-manipulation of agaves (native or not) and the habitat, and subsequent "natural" genetic exchanges amongst plants brought into association with the descendants of these manipulated plants. Scientists must look at landscapes from a cultural perspective and evaluate "normal" wild species more critically within their cultural and "natural" landscape (Hodgson 2004).