
The Hard Life of a Desert Giant

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SAGUAROS COPE WITH THEIR NATURAL CHALLENGES OR DIE

photos: Dave Mills



Clockwise, from top left: saguaro growth exhibit at Arizona-Sonora Desert Museum in Tucson; very young saguaro volunteer in Mills backyard; crested saguaro on Trail 4 near Seven Springs; fallen and cut saguaro on exhibit at McDowell Sonoran Preserve; juvenile saguaro on Terravita Nature Trail; saguaro buds about to open; saguaro growth sign; interesting saguaro on Terravita Nature Trail

It is difficult to be a saguaro in the Upper Sonoran Desert. The probability of a seed growing into a mature adult is very low. A saguaro can produce 40 million viable seeds during its lifetime, but only about 0.4% survive predation by ants, birds and rodents to actually germinate. Seed germination is best when temperatures are near 77° F. So, as any year-round resident will tell you, most of the time it is either too hot or too cold for saguaro seeds to embark on their life's journey. Of the few seeds that do grow, 99% die during the first year. The lucky seedling that germinates under a bursage or other nurse plant and survives long enough to accumulate oxalates, which are poisonous to most animals, may live to the ripe old age of 100 to 200 years, but every day is a struggle for existence.



A saguaro must cope with long periods of drought resulting from erratic rainfall, extreme temperatures, the constraints of being shaped like a telephone pole, and dangers imposed by their most formidable enemy, us. The saguaro has mechanisms to cope with all its natural challenges, but it is up to us to protect these desert giants from *Homo sapiens sapiens*.

Several consecutive years with mild winters and above average precipitation are required to ensure saguaro seedling establishment. A string of “good” years does not happen very often in the upper Sonoran desert, but when conditions are favorable a cohort of plants may enter the population. When you are out walking, look for areas where there are groups of saguaros of a similar size. One location may even contain groups of several size classes, indicating a series of establishment events.

Small saguaros stay small for many years because they are caught up in a “Catch-22” dilemma. Seedlings have very little water storage tissue. After a rain their meager supply of stored water is quickly lost through stomates that must open at night to allow the diffusion¹ of carbon dioxide. When the plant cannot “afford” to lose any more water, stomates do not open at night, the plant cannot take up carbon dioxide, and therefore cannot grow additional water storage tissue that would allow it to keep its stomates open longer. It may take a saguaro ten years to grow 1½ inches tall. Larger plants with more water storage tissue relative to their surface area can keep their stomates open during more nights after a rain and so can continue to take up carbon dioxide and grow for several weeks.

Saguaros are one of the few cacti that occur north of the frost line in Arizona, but they are damaged by frost. Past severe cold spells are reflected in areas of constricted stem growth. Water storage tissue of saguaros can cool to 17.6° F before permanent damage occurs. This “super cooling” is possible because water moves outside the cell walls before it freezes; below 17° cell death is actually because of dehydration. After the tissue dies it turns black and starts to decay. In the past the normal decomposition of freeze-killed tissue was attributed to a bacterial disease which was thought to be spreading from plant to plant. It takes a long time for a saguaro to die; the freezing event and death may be separated by a

¹ movement of a substance from higher to lower concentrations



number of years. So careful observation was required to link cause and effect. During each of the five years following a hard freeze in 1978, 25 to 35 mature, ten-foot tall saguaros died at the Desert Botanical Garden near Tucson.

Saguaros do have some defenses against freezing temperatures. Growing under a nurse plant is the first line of defense. Even the meager leaf canopy of a bursage can protect a young saguaro from radiating to the cold, clear, winter night sky and can also offer shade from the summer noonday sun.

Saguaros also wear a “hat” to protect them from temperature extremes. The whitish fuzzy cap that crowns a saguaro stem is made up of trichomes or plant hairs that add a layer of thermal protection to the growing point of the cacti. Computer simulations of removal of this pubescence increased the daytime maximum temperature of the top of the saguaro by 10° F and decreased the surface temperature at night by 3.6° F. When the spines were removed the maximum and minimum temperatures were changed by only 1.8° F. So for saguaros, pubescence is more important than spines in providing thermal protection.

When it does rain in the upper Sonoran desert, saguaros are very efficient at capturing and storing available water. Depending on the depth of the soil where the individual is growing, the taproot of a saguaro can extend downward about two feet, but most of its roots are located in the upper six inches of the soil. Shallow roots radiate out from the plant in all directions, can be as long as the plant is tall and spread over a 50-foot radius. These roots allow the saguaro to take advantage of rains that only moisten the top few inches of the soil.

Saguaro roots can start to grow within hours after a rain. About 1/3 inch of rain is enough to stimulate cacti root growth. This rapid growth is because specialized fine roots called rain roots can elongate with little cell division. When the soil dries, rain roots shrivel and are shed; larger, older roots shrink and pull away from the surrounding soil matrix inhibiting water loss to the dry soil during periods of drought.

Saguaros are 98 to 99% water which is stored interior to the ribs in specialized cells called “ground tissue.” These cells have very large, water-filled vacuoles and thin cell walls. The water pressing on the sides of the cell walls is what actually



holds the saguaro stem erect. After a rainstorm a mature saguaro can soak up 200 gallons of water.

Another way that saguaros cope with desert conditions is that instead of drying out from the outside in, saguaros dry from the inside out. In most plants suffering from lack of water the outer part of a leaf dries out first and photosynthesis stops while the interior remains moist. Saguaros do just the opposite. The water storage tissues in the center of the plant somehow are able to reduce their concentration of solutes (salts) and water defuses along a concentration gradient from this water storage “ground tissue” into surface tissues where photosynthesis is maintained as the plant “dries out” and its diameter slowly shrinks.

We think of the Upper Sonoran Desert as being a very sunny place, so it might be surprising to learn that saguaros actually suffer from light limitation. Measurements indicate that vertical cacti that bear a striking resemblance to telephone poles intercept only about 35% as much light as do horizontal leaves at the summer solstice. Over a whole year, a saguaro only receives about half as much solar irradiance as horizontal leaves. This is much less than the energy they need during daylight hours to process the carbon dioxide that they take up at night when their stomates are open. Since a saguaro growing outside in full sunlight is light limited, it should be obvious that cacti confined to even a brightly sunlit room are slowly degenerating and will eventually die from lack of solar irradiance.

Saguaros can and do cope with the natural challenges to their continued existence, but they have no defenses against the challenges imposed by humans. Habitat destruction is the number one problem facing the natural vegetation of the upper Sonoran desert. For the saguaro, that means removal of nurse plants like the lowly and all too often unloved bursage. Pavement encroachment, cutting lateral roots by digging too close to their base, and worst of all transplantation of large individuals take a toll on saguaros. The five-year survival rate of transplanted saguaros over 15 feet tall is less than 10%. Smaller saguaros can be successfully transplanted if at least one foot of all the major lateral roots is retained, they are planted in well drained soil with their original orientation and are watered for at least the first year.



Just one additional tidbit. Saguaros go by two names in the cacti literature. The species was originally named *Cereus giganteus* in 1884, but was renamed *Carnegiea gigantea* in 1908 in honor of Andrew Carnegie.

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