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Saguaro Horticulture
Saguaro Problems, Pests And Disease

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Figure 1. Repeated bottlenecks on adjacent plants indicate these plants were planted together and experienced similar conditions (left and center). A saguaro with a weak point at the bottleneck (right).

The saguaro cactus (*Carnegiea gigantea*) is a distinctive and desirable plant for southern Arizona landscapes. When a saguaro is deformed or diseased it is no longer an asset and it may present a danger of collapse. Unfortunately it is usually not possible to remedy a sick or damaged saguaro. Saguaro problems may originate from cultural issues such as improper planting, failure to establish, and physical damage. Saguaro cultivated in Arizona are not troubled by many pests and diseases. However, a rot disease called bacterial necrosis is a common cause of death. Most of the saguaro problems and pests discussed here can be accompanied by bacterial necrosis.

Cultural Problems

Saguaro problems may start with poor planting or improper watering. Saguaro with a visible "bottleneck" in the stem are usually transplanted saguaro which had a difficult time establishing (Figure 1). The constricted growth can be due to the loss of a root system during transplanting, planting too deep, or lack of irrigation for establishment. Stems which have grown wider above the bottleneck indicate the plant has grown some new roots and is recovering. The constriction remains as a weak spot and will not widen to normal proportions.

Overwatering can threaten a saguaro. An overwatered plant may appear fat or over-inflated. The epidermis may split, most often as vertical cracking in the trough between the stem pleats (Bill Peachey, pers. comm. 2021). The splitting offers an entry point for bacteria. Scarring of the stem remains. The greater danger from overwatering is the possibility of root rot (Arizona Game and Fish Department, 2019). A transplanted saguaro is vulnerable to root rot due to overwatering without showing signs of bloating, if it is watered excessively before having time to develop new roots.

Figure 2. Impact damage to saguaro (left) and graffiti with silver paint (right).

Human Impacts

Saguaro in urban settings and heavily-visited natural areas face various kinds of abuse and vandalism such as gunshots, golf ball strikes and graffiti (Small, 2014) (Figure 2). Shooting at saguaro has become a problem in Arizona. The state has made this activity punishable by a hefty fine and jail time. Shooting saguaro is not just harmful to the cactus, there is at least one account of a shot up saguaro falling and killing the shooter (Small, 2014). Impacts and abrasions are potential entry points for bacterial infection (Steenbergh, 1970).

Graffiti on urban saguaro has sometimes been covered up with green spray paint, with unknown long-term effects. A commercial graffiti removal product called Elephant Snot® went through a trial process but was discontinued when it caused cracking on the saguaro (Kreutz, 2007). These disfigurations may not be lethal, but the stems cannot heal in a way that erases the unsightliness of the damage. Such plants should be considered for removal from high-visibility sites.

Storms And Windfall

Saguaro often appear precariously balanced. They are rarely prone to falling over under natural conditions while healthy. Even when the distribution of arms is irregular, saguaro remain upright due to a strong internal woody skeleton anchored by a wide shallow root system. The roots are usually stabilized by rocks and hard dry soil. When healthy saguaro fall, it is often after a heavy rainfall has deeply saturated the soil, giving it a soft muddy consistency. In these situations a saguaro with an existing imbalance may start to tilt and pull roots from their anchorage. Rare wind events such as microbursts can fell multiple saguaro in a local area (Bill Peachey, pers. comm. 2021). Monsoon thunderstorms in summer can bring heavy rain coupled with strong winds and possibly microbursts. Together these forces may topple saguaro. Plants with multiple arms are more likely to fall (Alcock, 1990).

A fallen saguaro offers a poor prospect for righting and re-establishment in the landscape (Chamberland & Kelly, 2020). A saguaro often cracks on impact. Resulting wounds are invaded by rot bacteria and are soon followed by insect larvae and microorganisms which advance the decomposition process (Alcock, 1990).

Lightning strikes can be a major cause of death for tall saguaro (Yetman et. al. 2020). Saguaro are the tallest plants within their habitat and act as lightning rods. A lightning strike can boil the water inside a saguaro, causing the plant to literally explode (Banks, 2008). Because lightning is a fickle phenomenon which varies in intensity, some lightning strikes are said to leave the plant intact, possibly in a weakened state more vulnerable to bacterial infection (Yetman, 2007). A strike may impact several nearby saguaro simultaneously. In urban situations saguaro are rarely the tallest plants around, and palm trees face a greater likelihood of this fate.

Freezing And Cold

Catastrophic freeze events for saguaro occur when the minimum temperature falls below the range of 17°F to 22°F for a duration of 15 to 20 hours (Orum et al. 2016). Saguaro may endure colder temperatures for shorter durations. Survival of a catastrophic freeze (Figure 3) can hinge on the microclimate of the site, orientation and cover, and the age of the saguaro

Figure 3. The one-sided scarring on these saguaro in the Baboquivari Mountains is likely the result of freeze damage from exceptional cold winds experienced across southern Arizona in February, 2011.

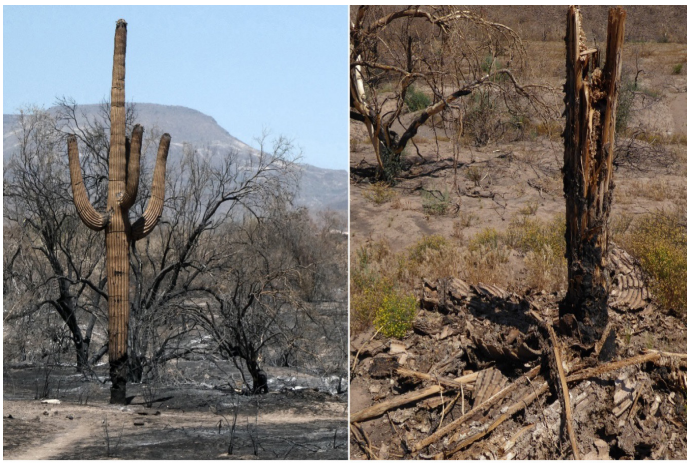

Figure 4. A burned saguaro in the Phoenix Sonoran Preserve (left). The same plant one year later (right).

(Orum et al. 2016). Mortality associated with catastrophic freeze events may not occur until a year after the event (Orum et al. 2016) or may require several years to be evident (Matt Johnson, pers. comm. 2021). Mortality is accompanied by bacterial necrosis. Vulnerability to cold defines the northern and upper elevation limits of saguaro. The range of saguaro has fluctuated considerably with altering climates in the past, with northern limits constrained by cold (Yetman et. al. 2020).

Fire

Saguaro cacti are not adapted to fire. The living cactus is not flammable, but it can suffer lethal burns from wildfires (Figure 4). Increasingly these fires have occurred in urban and exurban locations, fueled by dry tinder, mostly from invasive weed species such as buffelgrass and red brome (Small, 2014) as well as a new invader, stinknet (Chamberland, 2020). A grill or fire pit should not be placed close to a saguaro because of this sensitivity to heat from flames.

Twisted Arms

Saguaro may begin to produce arms (branches) after the plant reaches about seven feet in height (Banks, 2008). Arms rarely emerge close to the ground, and almost never occur on undamaged young saguaro. Some saguaro display downward-arching arms, which may bend upward again near their tips (Figure 5). These arms have become sprained and twisted from the normal vertical orientation. Freezing weather is suggested as the cause (Banks, 2008). No horticultural practice is recommended to initiate the bending of arms, nor to stop it if it is undesired. Twisted arms are compromised and more prone to break than normal upright arms.

Figure 5. Saguaro arms showing twisting (left), twisting and splitting (center) and stubs of fallen arms (right).

Sunburn

Although adapted to life in full sun, saguaro can sunburn. This can occur after moving a saguaro from a shady site to a sunnier site, or removing a tree which shaded a saguaro. Cacti may sunburn if their orientation towards the sun is changed during transplanting, or even if a plant grown in a container is rotated to a different orientation towards the sun (Chamberland & Kelly, 2020). Danger of sunburn is highest when changes occur in summer. Light sunburn is shown as a pale yellowing of the epidermis. It may be reversed if noticed early and shading is applied (Figure 6). Severe sunburn will cause death of the outer epidermis, which will brown and may crack, resulting in a bark-like scarring. The wounding caused by sunburn can be an entry point for bacteria.

Figure 6. Pale yellow bleaching of a saguaro indicates sunburn.

Figure 7. A saguaro laying on the ground is prone to sunburn on its upturned side.

A fallen saguaro will sunburn quickly on its upturned side (Figure 7). This shows the importance of shading a saguaro during the transplant process, should it be laid on its side for any extended time while being moved or during site preparation (Arizona Game and Fish Department, 2019).

Saguaro may show a reddening of the epidermis in winter, a condition called "marooning" (Bill Peachey, pers. comm. 2021) (Figure 8). Although this is seen usually on the south or west-facing side of the plant, it is not sunburn. Marooning has been attributed to stress from cold (Bill Peachey, pers. comm. 2021). Plants typically do not suffer from the condition if the growing environment improves.

Figure 8. Marooning of the saguaro epidermis.

Figure 9. Epidermal browning on an older saguaro stem.

Epidermal Browning

Epidermal browning is a condition seen on older saguaro. The green epidermis transitions into a dry bark-like corky surface on lower portions of the trunk (Figure 9). The condition occurs on south-facing sides of stems correlated with maximum sun exposure (Evans et al. 1992). It begins with discoloration around the spine clusters and slowly spreads to the "ridge tops" of the stem pleats, eventually covering the stem surface (Turner & Funicelli, 2000). Epidermal browning appears to have a correlation with mortality. The damaged tissue deprives the saguaro of energy from sunlight and gas exchange through stomata in the epidermis (Turner & Funicelli, 2000). The cause of epidermal browning is a matter of speculation. Epidermal browning does not appear to result from internal causes, such as disease or fungi, nor from damage by insects or freezing (Evans et al. 1992). However, Bill Peachey attributes epidermal browning to accumulated freeze damage (pers. comm. 2021).

Insects And Pests

Young seedling saguaro are delicate and lack strong defensive spines. They can be consumed by many kinds of insects, birds and rodents, or damaged from rummaging and trampling (Steenbergh & Lowe, 1977).

Once several inches tall, healthy saguaro growing outdoors are much tougher and armed with stronger spines that can deter some animals. Rodents may tunnel through

Figure 10. Rodent galleries in a saguaro stem.

the stems of saguaro forming elevated galleries within the stem base. Remarkably, such saguaro can live and remain standing for some time (Figure 10). A cylinder of chicken wire or hardware cloth may be installed around the base of a saguaro to deter many kinds of gnawing animals.

Bird-excavated cavities are a potential entry point for bacteria (Emming, 2018). Gila woodpeckers and flickers will peck nesting holes in saguaro stems. The nesting cavity inside the stem will dry and heal with a barky lining called a callus (Figure 11). The cavity will remain for the life of the saguaro. Other birds, both native and introduced, may occupy the nesting cavities. The hardened shell of the cavity, called a saguaro boot (Small, 2014) will remain intact after the death and decomposition of a saguaro.

Figure 11. A nesting hole in a saguaro stem, showing corky healed tissue around its margin.

Bacteria may be spread by a number of insect vectors (Steelink et al. 1967). The tunneling activity of larvae of the cactus moth *Cactobrosis fernaldialis*, has potential to be a serious vector of bacteria (Alcorn et al. Undated). The larvae will exit the cactus when nearing maturity and leave behind a pocket of callus tissue resembling a miniature version of the saguaro boot (Plagens, 1999). The small bark beetle *Cactopinus hubbardi* may be active around callus tissue but has not been implicated with harming the saguaro (Olson, 2021). The cactus longhorn beetle *(Moneilema gigas*) is another potential threat, especially for seedling saguaro (Olson, 2021). The desert encruster termite *Gnathamitermes perplexus* can colonize the outside of saguaro on dead wood, bark and spines. They build mud tubes up the side of the cactus as a shelter for their activities. The termites only consume dry non-living tissue and are not a concern for the health of the plant (Warren, 2017). The termites and their mud tubes may be washed away with a hose.

Virus

An isometric RNA virus is widespread in saguaro but it does not appear to be damaging (Milbrath & Nelson, 1972). The virus was discovered during a screening of plants for viruses rather than being isolated from an obviously diseased plant.

Fungi

Fungi associated with saguaro include *Poria carnegiea* and *Phellinus texanus*. These appear to weaken saguaro wood and have been involved in wind-throws of older saguaro (Arizona Game and Fish Department, 2019). *Poria carnegiea* enters through the roots and causes a white rot, an important source of decay in saguaro (Gilbertson & Canfield, 1972).

Bacterial Necrosis

Bacterial necrosis is associated with most saguaro deaths. It may be a direct cause of death or an opportunistic infection on a plant dying from another principal cause (Steenbergh, 1970). Bacterial soft rot is the first part of the natural decomposition of saguaro. It is followed by a progression of other organisms feeding within the ecosystem created by the rotting cactus (Alcock, 1990). Healthy adult saguaro have an ability to seal off and contain the spread of localized introductions of bacteria. Weaker plants suffering from other problems or facing environmental extremes are more susceptible to infection (Emming, 2018).

Bacterial necrosis was associated with a massive die-off of old saguaro cacti within Saguaro National Park (then Saguaro National Monument) in 1940. This generated predictions of doom for the saguaro. It was later determined that a catastrophic freeze in 1937 was the real culprit. It took several years for the impact of the freeze to be evident as rotting and collapsing cacti (Banks, 2008).

The Bacterial Organism

Bacterial necrosis of saguaro is caused by the bacterium *Erwinia cacticida*, with possibly other species or strains of *Erwinia* involved (Alcorn et al. 1991). Older literature attributes the rot to *Erwinia carnegieana*, but anomalies with the original description and its documentation have led to a recommendation to reject this name (Alcorn et al. 1991). Bacteria in the *Erwinia* genus are known for causing plant diseases across many species. Most notable is *Erwinia amylovora*, or fire blight, a destructive disease of pear and apple orchards (Agrios, 1988). Among host species, *Erwinia cacticida* has been identified in rot of saguaro, organ pipe cactus (*Stenocereus thurberi*), pitaya agria (*Stenocereus gummosis*), fishhook barrel (*Ferocactus wislizeni*), triangle cactus (*Acanthocereus tetragonus*), chain-fruit cholla (*Cylindropuntia fulgida*) and an assortment of prickly pear (*Opuntia* spp.) (Alcorn et al. 1991). It remains to be determined how widely *Erwinia cacticida* causes rot in other cacti.

The brown coloration of fluid from bacterial necrosis does not come from the bacteria. It is produced by the saguaro. When a saguaro stem is sliced, it first turns red, then turns black, due to chemical reactions. Injury to the saguaro cortical tissue results in an increase in dopamine concentration, followed by enzymatic oxidation to melanin (Steelink et al. 1967). These reactions are precursors to the formation of lignin, a major component of the callus tissue produced to seal an area against further penetration of a pathogen. When the saguaro does not successfully form callus tissue, rotting occurs and a dark-colored exudate comes from the wound site (Steelink et al. 1967).

Symptoms Of Bacterial Necrosis

Infected saguaro display an oozing brown or black fluid and softening of the outer tissue (Figure 12). Bacterial necrosis should not be confused with epidermal browning or hardened callus tissue on the saguaro epidermis. The first sign of infection may appear as a discoloration or a rupture leaking a brown smelly fluid. Infection may start on any part of the plant, including underground on the roots or stem base. The disease can progress quickly. Steenbergh (1970) documents the progression of rot from a puncture wound in late January to a dead plant with all soft tissues of the lower stem in an advanced stage of decomposition in mid-April.

Figure 12. Early (left) and late (right) stages of bacterial necrosis.

Protecting Saguaro From Bacterial Necrosis

There is no effective way to shield a saguaro from *Erwinia* bacteria. The bacteria are too ubiquitous in the Sonoran Desert environment. Birds, insects and other vectors that might penetrate the saguaro cannot be kept away. The *Erwinia* bacteria has been isolated from saguaro flowers, suggesting infection could be carried by pollinators and enter the plant through the soft tissue of flowers, as does *Erwinia* causing fire blight in apples (Agrios, 1988).

When transplanting saguaro, care should be taken to prevent punctures and abrasions of the saguaro stem. Proper treatment of the roots during transplanting is intended to minimize infection by bacteria and fungi (Chamberland & Kelly, 2020). Regular inspection of saguaro for lesions or dark soft spots on the epidermis can identify a bacterial infection while it is of treatable size. Treatment should be done immediately for any oozing wounds, as these are almost always bacterial infection (Emming, 2018).

Treatment Of Bacterial Necrosis

The rapid progression of bacterial necrosis, which may move for a time within the plant unseen on the outside, makes treatment of the disease difficult. If a small lesion is noticed, and not close to the base of the plant, surgery to remove the infected area may be attempted. The lesion is characterized as a zone of dark colored epidermis, or possibly a cavity in the stem, which is discharging a brown or black foul-smelling fluid. Using a firm sharp tool, such as an old metal spoon or knife, the discolored tissue should be scooped out from the stem. The diseased tissue should be placed in the trash, and not dropped on the ground near the saguaro. The rotted tissue should be entirely removed to where it meets clean firm whitish-green stem tissue. When cutting near the healthy tissue, it is wise to sterilize the cutting tool with a disinfecting solution so that each cut is made with a disinfected tool. When complete, the disinfectant will be applied to the entire area where tissue was excised. When making the final cuts, the lower part of the excised area should be cut forming a downward channel to allow the cavity to drain and not to hold water (Emming, 2018). Disinfect using isopropyl (rubbing) alcohol at 70% or higher, or use a 10% bleach solution, but do not use both these disinfectants in combination (Emming, 2018). After disinfecting, leave the treated area to air dry and continue

to spray the treated area with disinfectant for a week or two (Emming, 2018). The surface of the cut stem tissue will darken rapidly. This is the natural oxidation of chemicals in the stem when exposed to air, and the start of callus formation, not a sign of re-colonization by bacteria. If rot is seen on an arm of the saguaro but not on the main stem, it can be reason to consider amputating the arm below the infected zone. The cut stump of the arm is best treated with disinfectant as a precaution (Emming, 2018).

Saguaro Removal

If the infected regions of the saguaro are too extensive to remove, or if the infection is near the trunk base (threatening the stability of the saguaro) then the saguaro will likely die and should be removed. A rotting saguaro is a hazard as it may collapse or drop arms without warning. It is easier to remove a saguaro before decomposition advances. Extreme caution must be exercised. The saguaro is heavy with its own weight, and may be unstable and structurally weakened due to rot. Saguaro removal is a service offered by tree care and cactus specialist companies which also install saguaro cacti. Removal is labor-intensive and can be expensive. The saguaro may be felled by dropping it with a cut across the base and pulled down with a rope from a safe distance. A felled saguaro may then be cut into cross-sections that are a smaller size and easily discarded in the trash (Figure 13). Saguaro are relatively easy to cut with a saw, with only the inner woody ribs causing resistance. Hay hooks are useful for lifting cut saguaro stem sections (Emming, 2018). It is legal for a land owner to discard a saguaro from their land. Regulations come into effect if a saguaro is to be sold or transported off the property (Native Plants, Arizona Department of Agriculture 2020). If a saguaro is rotting and located in a natural area well away from human traffic and utilities, it may be left to rot and decompose as it would in nature. Such plants may topple to the ground presenting a hazard when they fall. A saguaro left to rot is accompanied by a smell. It will attract flies and other insects.

Figure 13. A rotted saguaro sectioned with a chain saw to facilitate disposal.

A rotting saguaro does not present an imminent threat of infection to other saguaro in the vicinity (Emming, 2018). The causal bacterium, *Erwinia cacticida* has been described as a bacterium of low contagion despite its potential to infect many species of cacti (Alcorn et al. 1991) (Orem et al. 2016). A rotting saguaro in a cultivated landscape does not predict the infection of other cultivated saguaro nearby, unless all are impacted by a common cause, such as overwatering, severe freeze, or improper planting of a set of saguaro. Nonetheless, quick removal of the diseased saguaro is advisable. A rotting saguaro dripping fluid onto neighboring cacti risks spreading infection, though the greater risk comes from sections of the saguaro falling and crushing adjacent plants. The *Erwinia cacticida* bacteria has been isolated from soil beneath "leaking" saguaro (Alcorn et al. 1991). The degree to which the bacteria can persist in soil, or move in blowing dust is unknown. The dripping fluid from bacterial necrosis can be considered to "contaminate" the soil making it hazardous to plant new cacti in the same location, in the short term (Emming, 2018). If the rotting saguaro is removed before it has leaked on the soil, the risk to new plantings is less. Consider planting something other than a cactus in the spot (Emming, 2018).

Saguaro Skeleton

The death of a saguaro can leave behind a skeleton of long vertical woody poles or "ribs." An intact saguaro skeleton is sometimes used as a decorative landscape feature (Figure 14). A saguaro skeleton used in the landscape can last longer if it is kept away from moist soil, and if measures are taken to protect it from termites.

Figure 14. A saguaro skeleton.

A well-formed saguaro skeleton is an infrequent occurrence. Dying saguaro are prone to dropping arms or total collapse, ruining the form of the skeleton. A toppled saguaro can result in a fractured skeleton. The best-formed skeletons occur when the saguaro remains standing as tissue rots and sloughs off the woody ribs. The ribs splay out, creating a ragged look to the top of stems and arms. The ribs are never found to coalesce on top, as the ribs are still forming and never woody at the apex of the stems and branches. At the base, ribs grow wider and may coalesce into heavier wood. Individual ribs have found use in various tools, traditional items, and as building material (Yetman, 2007). Elaborate furniture and decorative items have been made from saguaro ribs or wood (Small, 2014). Removing and transporting a saguaro skeleton requires the same permits and tags for moving live saguaro (Arizona Department of Agriculture, pers. comm. 2020).

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