College of Agriculture and Life Sciences
Cooperative Extension

Backyards & Beyond

Winter 2014 RURAL LIVING IN ARIZONA Volume 8, Number 1

Featured Plant

Common Name: Creosote Bush, Greasewood
Scientific Name: *Larrea tridentata*

Art Meen

Curt Peters, Extension Agent 4-H, University of Arizona Cooperative Extension, Pima County

After a summer rain in the desert, there is a familiar, distinctive scent in the air. It is the wet foliage of the creosote bush that produces a pungent aroma.

The creosote bush is a resinous evergreen shrub typically reaching a height of 3' - 6' tall and almost as wide. Many flexible stems rise from the base at an angle. Small, leathery leaves are borne at the tips of the stems with the remainder of the stem bare. Leaves are a rich green color when young, fading to a yellowish-green with age. Flowers are small, yellow in color with 5 petals and inconspicuous individually, but under favorable conditions, such as after a rain storm, are numerous and give the shrub a yellowish hue. The fruit is small, roundish and covered with short, white fuzz.

Creosote bush is an extremely tough plant. It is one of the most drought tolerant perennial plants found in North America. It readily grows in the hottest, driest areas and can survive as long as two years without rain. It is tolerant of most soils and is hardy to 5 degrees F.

While the creosote bush has few pests, it harbors many insects. Some, such as the Creosote Bush Katydid (Insara covelleae) and Creosote Bush Grasshopper (Bootettix argentatus) are specific to Creosote bush. Ball shaped galls are often found on the stems, produced by the Creosote Gall Midge (Asphondylia sp.). These insects do minimal damage to the creosote bush. As for mammalian pests, the jackrabbit is the only one that will feed on creosote bush, and then only in times when there is a severe lack of alternate foods.

Creosote bush is very long lived. Some plants in the Mojave Desert are thought to be thousands of years old. An individual stem may grow for hundreds of years. New stems are continuously produced from the outer edge of the root crown. As stems die in the inner part of the root crown, a hole is left in the middle of the plant. Over hundreds of years a ring of stems is formed that eventually grow to appear to be separate plants. An area containing what appears to be many creosote bushes, may indeed be connected and all have the same DNA as they are all from the same original plant.

Given the harsh conditions that creosote bush grows in, it has developed a mechanism for reducing competition with other plants. The roots exude a resin that inhibits the growth of most plants. The roots also secrete a germination inhibitor that prevents germination of its own seeds. With sufficient rainfall, the toxins are temporarily washed away, allowing seeds to germinate if other favorable conditions are present.

In the wild, creosote bush is a rangy, sparse shrub. In a maintained landscape with adequate irrigation, it can be multi-functional -- used as a formal hedge, grown as dense single shrubs or even pruned as a small, multi-trunk tree. When used in a landscape, plant in well-drained soils. Since creosote bushes are difficult to propagate and do not transplant well when salvaged from the wild, they can be difficult to find in nurseries. Check with nurseries that specialize in native plants.

Over time the leaves of the Creosote bush have been used for many medicinal purposes. In various forms it has been used as a treatment for colds, influenza, upset stomach, anemia, fungus infections, auto-immune diseases, and arthritis. A very bitter tea can be made from dried, ground leaves. The medicinal uses have been controversial and use is not recommended.

Overall, creosote bush is a wonderful, hardy, tough shrub that can be successfully grown in a wide variety of settings, from dry desert to a landscaped yard.

Featured Bird

Common Name: Ash-throated Flycatcher
Scientific Name: *Myiarchus cinerascens*

Dan L. Fischer

Dan L. Fischer - Author of Early Southwest Ornithologists, 1528-1900. University of Arizona Press

Searching the desert for birds in early spring can be quite challenging, exciting and rewarding, especially when looking for migrants returning north to nest. Most species follow stream courses and riparian corridors, while others spread over the vast arid region. In many instances they call or sing while others remain silent, only to be noted by quick movements or a flitter of wings among thickets and trees. Still others fly high nearly out of sight, or close to the ground, often undetected.

Because of the variety of field observation difficulties, voice can become a very important aid in locating, and identifying many bird species. The grayish brown Ash-throated Flycatcher with pale gray underparts and rufous tail certainly falls into this category. Occurring from open to rather dense desert scrub, riparian woodlands into chaparral and pinyon pine-juniper woodlands, it usually announces its presence with short, spaced, almost soft musical notes. These are usually given several times before the bird is finally located and viewed. Except for its song, the bird may hardly be noted except when it darts into the open to catch a flying insect. When perched it is poised erect with little movement, carefully scanning the surroundings for prey before taking another short sortie. It seldom returns to the same perch.

Among the over twenty distinctive and easily recognized flycatchers that nest in Arizona, the Ash-throated Flycatcher and a slightly larger relative, the Brown-crested Flycatcher, can and often do present identification problems. Because of their similar physical appearances and habitat choices, they pose difficult challenges in separating one species from another. Voice, therefore, becomes one of the major clues. The song of the Brown-crested Flycatcher is not at all similar to its smaller relative, but has a much louder, sharper, and more raucous tone. The two songs are quite distinctive, and once mastered, their identities are instantly recognized. A third Myliarchus, the Dusky-capped Flycatcher, which is much smaller but also similar to the previous two, sings a series of high-pitched, very soft, prolonged descending whistles and occurs mainly in oak woodlands.

All three species are cavity nesters, generally using old woodpecker holes in cactus and trees to lay their eggs. Any small opening with a chamber of sufficient space will also do, and in the case of the Ash-throated Flycatcher, even grass stuffed vertical fence pipes are used as nesting sites. Usually four to five eggs are laid beginning in mid-April to May and are incubated for about 15 days. The young are tended by both parents and leave the nest after 16 days.

In 1844, Jean L. Cabanis, a German ornithologist at the Berlin Museum, applied the name Myiarchus to a new genus taken from classical Greek myia, "a fly" and archos, "a ruler," no doubt because of their aggressive manner. Then Captain John P. McCown, a West Point Graduate and field officer, who served during the war with Mexico in 1847, discovered the Ash-throated Flycatcher while being later posted in southern Texas. McCown sent a specimen to George N. Lawrence, a New York businessman and prominent naturalist, who added it to the genus Myiarchus by describing and naming the species in Latin cinerascens, "ashy" for its whitish-gray throat in 1851.

Backyards & Beyond
rural living in Arizona

Winter 2014
Volume 8 Number 1

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Backyards and Beyond is partially funded by the Renewable Resources Extension Act. Financial gifts may be contributed online at http://extension.arizona.edu/state/donate-arizona-cooperative-extension or to make your gift by telephone, please contact the CALS Development Office at 520-621-7190. Gifts can be made payable to:"University of Arizona Foundation" and mailed to: Arizona Cooperative Extension, 301 Forbes Building
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Backyards & Beyond is refereed and published quarterly by a cooperative team from the University of Arizona Cooperative Extension.

Yearly subscription price $10.00
http://cals.arizona.edu/backyards


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Cover Photo credit: Greg Kush


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MESQUITE AND PALO VERDE TREES FOR THE URBAN LANDSCAPE

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MESQUITE

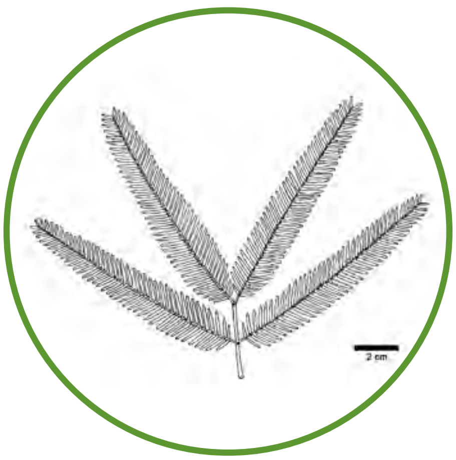

Figure 1: Leaf of *Prosopis alba*

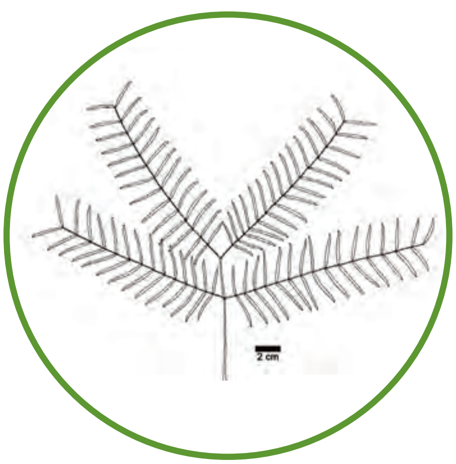

Figure 2: Leaf of *Prosopis chilensis*

Mesquite trees are members of the genus *Prosopis* and the *Fabaceae* (legume or bean) family. Because of their attractiveness and drought tolerance, they are one of the "backbone" plants of many xeriscape plantings. They tolerate most soils with good drainage and grow well in full to reflected sun as well as in partial shade. They range in size from shrubs to large trees that grow to over 30 feet (10 meters) in height. They are native to North America, South America, Africa, India, and the Middle East.

In Arizona, native mesquites grow along dry stream beds, in washes, flood plains, along rivers, on plains and hillsides, and in grasslands. Where water is not a limiting growth factor, the trees reach their true majestic size. At elevations above 5000 feet (1525 meters) their growth is retarded due to cold and plants may appear as low growing shrubs. All mesquites are heat tolerant and grow rapidly during hot weather provided there is adequate water available. Mesquites are deciduous, and foliage is shed in response to cold temperatures and prolonged drought conditions.

The different species of mesquite can be distinguished by tree form, size, shape, and bark characteristics, but foliage is particularly useful in determining the species. Line drawings of leaves for the mesquite species discussed accompany the descriptions of the plants *(Fig. 1 – 6, and 8)*. Leaves are bipinnate, meaning that leaflets are arranged along a central axis (pinna) similar to a feather, and each leaf has one or several pairs of pinnae. Flowers of all mesquites are catkin-like and develop into seed pods of various shapes and sizes.

Historically, mesquite wood has been used by early peoples as a source of food, building materials and firewood. A nutritious meal is made from ground mesquite seed pods which helped sustain early Native Americans. Owing to the high protein content of the seeds, shoots and pods, it is an important food for range cattle. Currently there is a resurgence in the manufacture of mesquite furniture and flooring due to the natural beauty of the wood, its intricate grain, coloration and durability. Many trees are converted into charcoal and are sold as a favorite barbecue wood that is renowned for its unique southwestern flavor. This has taken its toll on some of the oldest and largest trees in the wild. Bees produce a fine quality honey from the mesquite flowers.

MESQUITE SPECIES AND HYBRIDS

Prosopis alba (Argentine mesquite)

The mature height and spread of this species may be 20 – 50 feet (6 – 16 meters). Argentine mesquite has been misidentified as Chilean mesquite for many years. Argentine mesquite is characterized by airy blue-green foliage on sometimes spiny stems *(Fig. 1)*. The tree may have thorns or may be thornless. It becomes leafless after the first hard freeze of winter and is typically dormant for 6 – 8 weeks. When planted at elevations below 2500 feet (762 meters), it may remain semi-evergreen through the winter. If the winter is exceptionally mild, leaf drop may not occur until March which coincides with the first flush of new growth. Leaves of Argentine mesquite have 1 – 3 pairs of pinnae each with 25 – 50 pairs of leaflets. Flowers are catkin-like 2 – 3 inches (5 – 8 cm) long and pale yellow, followed by 3 – 5 inch (8 – 12 cm) long seed pods which ripen in July and August.

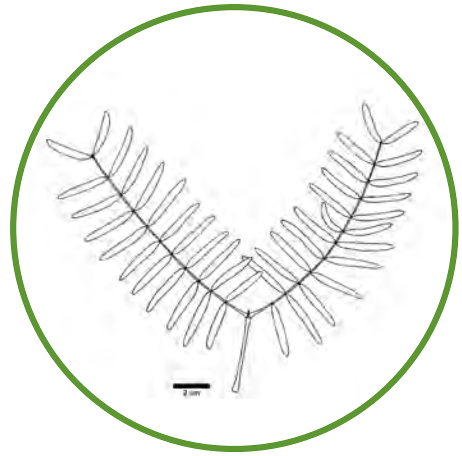

Figure 3: Leaf of *Prosopis glandulosa* var. *glandulosa*

Prosopis chilensis (Chilean mesquite)

This mesquite is characterized by a lacy crown of bluegreen foliage on spiny stems *(Fig. 2)*. Spines may be up to 2 inches (5 cm) in length which may limit its use in residential or high traffic areas. The trunk is typically dark brown and fissured. In the low and mid-desert, below 2,500 feet (762 meters), the tree will lose most of its foliage except in years of mild winter temperatures when foliage may remain on the tree until March. Old leaves do not fall from the tree until new growth is well underway. During cold winters the tree will be dormant and leafless for 6 – 8 weeks during winter. New foliage will appear in late March or early April and is fern-like and a beautiful light green. Leaves are characterized by 1 – 3 pairs of pinnae each with 10 – 29 pairs of widely spaced leaflets. Flowers are 1 – 3 inches (2.5 - 7.6 cm) in length and light yellow. Flowers are followed by 2 – 5 inch (5 – 13 cm) bean pods that ripen in July.

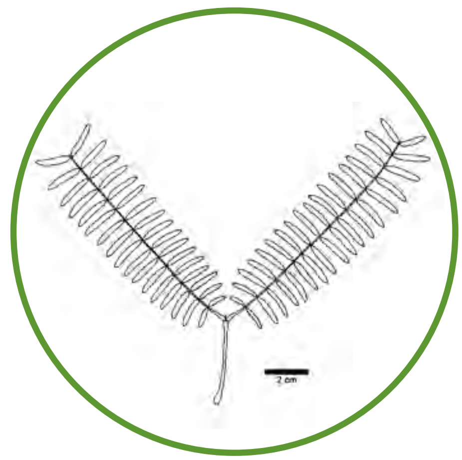

Figure 4: Leaf of *Prosopis glandulosa* var. *torreyana*

Prosopis glandulosa var. *glandulosa* (Texas honey mesquite)

This attractive ornamental tree grows to a mature height of 15 – 30 feet (5 – 10 meters) and is characterized by its weeping habit and shiny foliage which resembles *Schinus molle* (California pepper tree). It has small reddish thorns and creamy white flowers. Leaves have 1 – 2 pairs of pinnae with 6 – 17 pairs of secondary leaflets per pinna (Fig. 3). The trunk is tan and smooth when young but becomes rougher and darker as the tree matures. Texas honey mesquite is native to the southwestern U.S. including Texas, Oklahoma, Kansas and into northern Mexico. Due to its ornamental popularity, several selections have been made for foliage, form and thornlessness. These cultivars are vegetatively propagated to insure the integrity of the clone. Texas honey mesquites require well drained soil and tolerate full sun or partial sun. Once established, plants irrigated monthly develop into larger trees with a dense canopy.

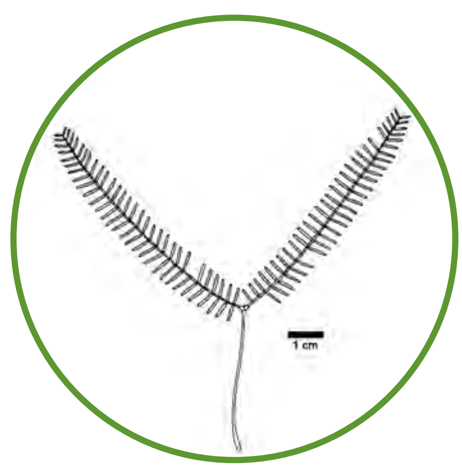

Figure 5: Leaf of *Prosopis nigra*

Prosopis glandulosa var. *torreyana*

Prosopis glandulosa var. *torreyana* is similar in character to Texas honey mesquite, but has smaller leaves with one pair of pinnae and 8 – 24 pairs of leaflets per pinna (Fig. 4). It is native to west Texas, California, New Mexico and parts of Arizona and Mexico. This variety can sometimes be found in nurseries.

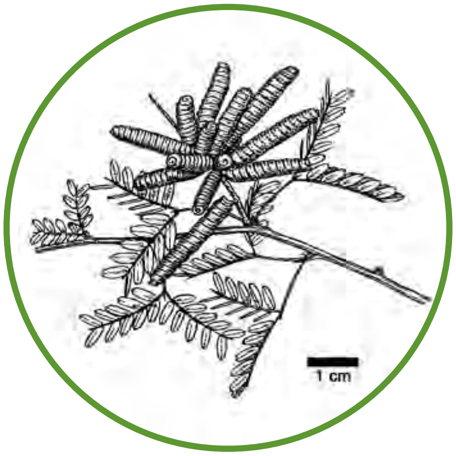

Figure 6: Leaf and seed pod of *Prosopis pubescens*

Figure 7: Prosopis velutina in winter (above) and spring (below)

Figure 8: Leaf and seed pod of *Prosopis velutina*

Prosopis nigra (Black mesquite, Algarrobo negro)

P. nigra is native to Argentina, Paraguay and parts of Uruguay. It resembles *P. alba* in many respects and has very similar form and foliage *(Fig. 5)*. The leaflets of *P. nigra* are closely packed in dark green compound leaves. Leaves have 1 – 3 pairs of pinnae with 20 – 30 pairs of leaflets per pinna. Trunk color is dark brown to black. Unlike many members of the *Prosopis* genus, black mesquite is evergreen under most conditions. The plant form is quite variable and may be heavily thorned. With deep soil and adequate moisture the tree may grow to 30 feet (10 meters) in height and width. It will tolerate being grown in irrigated turf areas and full-sun exposure. The wood is prized because of its beautiful brown streaking and is used to make furniture and barrels. Flowers are typical catkin-like up to 2.5 inches (6 cm) long and yellow, and are followed by seed pods that are 4 – 6 inches (10 – 15 cm) long and are often streaked with pink. P. nigra is currently underused as it is not commonly available in the trade, although it is an excellent tree for the low and mid-elevation desert.

Prosopis pubescens (Screwbean mesquite, Tornillo)

Screwbean mesquite grows to about 25 feet (7.6 meters) with an equal spread. *P. pubescens* is native to the Sonoran and Chihuahuan deserts in parts of southern Arizona, Texas, and New Mexico. The tree is characterized by unique seed pods that appear as a tightly wound spring or a screw, hence the common name *(Fig. 6)*. "Tornillo" means screw in Spanish. The tree is typically multi-stemmed and the bark on older branches is shaggy, flaky and easily peels from the tree. Typical form of the tree is vase-like, very open and spreading. The leaves are smaller than the other mesquites described above and are characterized by one pair of pinnae with 5 – 9 pairs of leaflets per pinna. Each leaflet is approximately 3/8 to 1 inch (1 – 2.5 cm) in length (Fig. 6). The small ¾ inch (2 cm) spines are whitish, slender and appear as pairs along the branches. Catkinlike flowers are bright yellow. This tree grows very slowly without irrigation.

Prosopis velutina (Velvet mesquite)

Mature size of velvet mesquite is 30 – 50 feet (9 – 15 meters) height and spread (Fig. 7) when grown with adequate water and in deep soils. Growth rate is slow to moderate but moderate to rapid under irrigation. Velvet mesquite is native from central and southern Arizona into Mexico. It grows as a shrub on dry rocky upland sites but will grow much larger under ideal conditions. This tree may be found as a single-stemmed tree in bosques (thickets) or as a multi-stemmed tree in open areas. The bark is fissured, dark brown and rough. The wood is prized for furniture because of its unique coloration and intricate grain. Trees may grow up to 4 feet (1.2 meters) in trunk diameter and live for several hundred years. Velvet mesquite foliage is covered with dense short gray hairs that cover most parts of a younger plant (Fig. 8).

Filtered shade from velvet mesquites is light and often serves as a nurse tree for other slower growing plants such as cactus and shrubs. Leaves have one or two pairs of pinnae (Fig. 8) with 12 – 30 pairs of leaflets each. In late fall or early winter after the first hard freeze, the graygreen, fine textured leaflets turn light green or tan and fall from the tree revealing a beautifully sculptured trunk and scaffold branches. In spring two to three inch (5 – 7.5 cm) long cream-colored flowers adorn the tree followed by tan seed pods which ripen in mid to late summer. Young velvet mesquites have small thorns which become less problematic as the tree matures. Velvet mesquite trees are drought tolerant yet will flourish with moderate irrigation. They may become unstable due to rapid crown growth and a limited root system in lawn conditions.

HYBRID MESQUITES

Mesquites cross-pollinate quite readily and as a result there are a group of plants that are simply called "hybrid mesquites". They are often the result of natural hybridization of *Prosopis alba* (Argentine mesquite), *P. chilensis* (Chilean mesquite) and native *P. velutina*. Because of this hybridization, it is almost impossible to obtain pure species seed. Most hybrids are typically fast-growing, attractive, thorny or thornless, may have delicate blue green or green foliage or may have small leaves and have intermediate characteristics of the above described species. Many of the hybrid mesquite leaves persist until the new growth begins in spring, giving the tree an almost evergreen appearance. These hybrids are often sold in the trade as "Chilean" mesquite or "South American Hybrids". Hybrid mesquites are noted for their rapid growth and can attain a mature height of 9 – 40 feet (3 – 13 meters) with a spread of up to 30 feet (9 meters). They make an excellent large shade tree but given their size, are often unsuited for the smaller yards found in newer subdivisions. Many homeowners seek out the thornless hybrids and as a result, selections of trees having no thorns and superior structural and aesthetic characteristics have been made. To preserve these characteristics, trees either are grown from cuttings, are air layered, or are grafted. Thorns, which are modified leaves, often disappear as the tree matures. In situations where thorns (which can be up to 2 inches (5 cm) long) are objectionable, they may be pruned off young trees and will not re-grow from this location again.

Figure 9. True mistletoe aerial shoots with berries.

Culture

All mesquites are very tolerant of hot south and westfacing walls, are valuable trees in parks or large public areas, and are an asset in low water-use landscapes. They may be planted in groups or as solitary specimens and add a lush appearance to the landscape. Mesquites are well suited to heat, low humidity, alkaline and poor soils. Mesquite trees are not well suited as street trees due to their multi-trunk character. The cold tolerance of many species has been established but this tolerance is quite variable owing to the condition of the plant at the onset of winter. Heavily fertilized and irrigated trees will not tolerate the cold as well as those that have been conditioned with less water and no fertilizer late in the summer. Honey mesquite (Prosopis glandulosa) and screwbean mesquite *(P. pubescens)* can survive temperatures to 0 ºF (–18 ºC); velvet mesquite *(P. velutina)* is reliably cold hardy to at least 10 ºF (–12 ºC); Chilean mesquite *(P. chilensis)* and black mesquite *(P. nigra)* are hardy to at least 15 ºF (–9 ºC); Argentine mesquite *(P. alba)* and many South American hybrids suffer damage and dieback when temperatures fall below 15 – 20 ºF (–9 to –7 ºC). Where there is abundant water present, mesquite specimens will be largest when grown in deep, uniform, sandy soils in and along streambeds, and alluvial plains. With proper irrigation, these trees will grow satisfactorily on any well drained soil.

Figure 10: Slime flux on *Prosopis* sp.

Problems

There are few problems of mesquites. Mistletoe (*Phoradendron californicum)* can be a nuisance or develop into a more serious problem for heavily infested trees. True mistletoe contains chlorophyll and carries on photosynthesis, but being a parasite it also lives off the nutrients of the host plant *(Fig. 9)*. It can develop into plants that are several feet in diameter. Mistletoes may be a problem if left unmanaged and while it generally does not kill a tree, it can cause significant decline over time. If not pruned out, the weight of the mistletoe can become great enough that the branch may break off. Manual removal of mistletoe is the only practical control however, removal does not kill the mistletoe as it continues to grow inside the wood. Since mistletoe is a part of the desert ecology, it is an aesthetic decision whether to remove it or not on lightly infested trees. Mistletoe berries are a primary food source of desert birds and only in few situations the mistletoe becomes large enough to warrant removal.

Figure 11: A shelf-shaped mushroom of a wood decay fungus(*Ganoderma* sp).

Figure 12: Nymph of giant mesquite bug (*Thasus neocalifornicus*)

Slime flux

This is caused by the infection of sapwood by several bacteria and is a problem with mature mesquites. The disease causing microorganisms are found in the soil and probably gain entry through above or below the soil line wounds or pruning cuts. After several years, affected areas will exhibit a water-soaked appearance (wet wood). Gas is produced by the bacteria (and possibly yeasts) which force out a foul smelling liquid from cracks and wounds. The liquid is dark brown to black in color *(Fig. 10)*. Infected trees live many years and slime flux is more of a nuisance that requires periodically a strong, hard stream of water to prevent staining of patios and cars. Seriously infected branches may need removal if they present a safety hazard. The old remedy of placing drainage tubes into the infected areas is not recommended and may in fact, present more entry sites for the disease.

Ganoderma root rot *(Ganoderma)*

This is caused by a soilborne fungus and enters mesquite roots primarily through wound sites. Root rot causes slow decline and eventually death of mature trees. There is no recommended treatment for infected trees. Fruiting bodies at the base of the tree are most common during the summer rainy season. They start as white structures at the base of the tree and develop into light brown, shelf like fruiting bodies *(Fig. 11)*.

Giant mesquite bug *(Thasus gigas)*

During the summer months, the giant mesquite bug *(Thasus gigas)* makes its appearance. Although it looks threatening because of its size and dramatic markings, it is just another insect that is part of the desert ecology. No control is recommended for these insects as their damage is minimal. The adults are up to two inches (5 cm) long and have brown and yellow markings on their forewings and red and black banding on their legs. What makes these insects interesting is that the immature insects (nymphs) are banded an attractive red and white and may appear in large numbers in early April (Fig. 12). Although menacing looking, they are not considered a damaging pest of mesquites.

Mesquite twig girdler *(Oncideres rhodosticta)*

Another minor pest of mesquite is the mesquite twig girdler (Oncideres rhodosticta) which may appear in early to mid-summer. The adult cuts a channel around the stem and deposits her eggs in now girdled portions. The resulting damage is “flagging” or browning of the girdled stems. Since the damage is cosmetic, no control is recommended. Miscellaneous wood borers may appear from time to time in older, neglected or stressed trees. These beetles are typically drawn to trees that are under severe stress and are considered secondary pests.

Irrigation related issues

Irrigation related issues can cause problems for mesquite trees or surrounding vegetation. Infrequent shallow watering for turf will encourage surface rooting rather than the deep root development that proper irrigation of trees will provide. Mesquite trees can become unstable with excess irrigation, such as in lawns, due to rapid crown growth and limited root system development.

Another irrigation related problem is improper placement of drip emitters. By placing emitters close to the trunk, roots primarily develop in these areas. Placing the emitters further out (at the dripline of the tree and beyond) will help establish a root system which gives stability to the tree and reduces the occurrence of tree toppling and possible tree loss.

Root binding

Root binding can be a problem of mesquite and palo verde trees when purchased in containers. Most mesquite but also some of the palo verde species grow very fast under cultivation. If not transplanted to larger containers in a timely manner, roots start circling around the outside of the root ball and in some cases close around the trunk. If not corrected by pruning circling roots at transplanting, this condition can lead to problems of tree failure.

Acknowledgements

Line drawings are courtesy of Matt Johnson (except for one drawing done by Lucretia Hamilton), photo in fig. 12 (giant mesquite bug nymph) courtesy of Carl Olson, photos in fig. 9 and fig.11 are courtesy of Dr. Mary Olsen.

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PALO VERDE SPECIES AND CULTIVARS

Palo verdes are popular, drought tolerant landscape trees in the genus *Parkinsonia* (formerly *Cercidium*) and the family Fabaceae. Palo verdes range from large shrubs to medium sized trees and are native in the Sonoran Desert except for *P. praecox* which is native from Mexico to South America. Along with saguaro cactus, they are a staple of the Sonoran Desert and are used in many xeriscape plantings. *Parkinsonia florida*, blue palo verde, and *P. microphylla*, the Foothill palo verde, share the title of Arizona's official state tree.

Palo verde trees prefer full sun and well drained soil in cultivated landscapes. Growth rates vary depending on supplemental irrigation and species. Conspicuous green, smooth bark dominates the plant's appearance during periods of drought and cold when trees are leafless and gives them their common name "palo verde" which in Spanish means "green stick". Shoots are armed with small thorns at the nodes or the end and leaves are small, bipinnate. The green bark allows photosynthesis and with age turns from smooth with yellowish green color to rough with gray color. Besides the striking green bark, a profuse show of yellow flowers in spring makes palo verdes popular landscape trees. Line drawings of leaves, flowers and seed pods are presented with each species to aid in identification *(Fig. 14, 15, 17 – 19)*.

Palo verde plays an important role in the desert ecosystem providing habitat for wildlife and serving as a nurse plant for small cacti. Flowers produce much nectar for honey. Pods are sought by wildlife and livestock and provided a staple for indigenous people in the Southwest. Pods can create heavy litter.

Figure 13: Profuse bloom on *Parkinsonia florida*

Parkinsonia aculeata (Mexican palo verde)

Parkinsonia aculeata (Mexican palo verde) is found in older landscapes, but is no longer considered a desirable landscape tree. Although a showy blooming tree, it is well armed, short-lived, produces heavy leaf litter, and reseeds freely on road sides, vacant lots, and in washes.

Parkinsonia florida (Blue palo verde)

The blue-green color of stems, branches, and densely growing twigs and the prolific bright yellow flowers in spring *(Fig. 13)* have made it one of the most popular palo verde species. Foliage is fine textured and consists of one pair of pinnae with 2 – 4 pairs of leaflets *(Fig. 14)*. Blue palo verde flowers in mid-spring, about three weeks earlier than P. microphylla (Foothill palo verde). Blue palo verde has a moderate growth rate. It is adapted to desert soils, but can also tolerate lawn conditions. Native to washes and plains with deep soil, trees benefit from additional irrigation once or twice during the hot, dry season. This plant is native to the Sonoran Desert, northern Sinaloa and Baja California, Mexico, and can be found at elevations from sea level to 4,000 feet (1,220 meters). Cold hardiness is reported to 10 ºF (–12 ºC).

The profuse amount of flowers and seed pods can create heavy litter under the tree canopy. Short thorns on twigs can be a problem near walkways. Blue palo verde generally require more pruning than other cultivated palo verdes, because they tend to spread more and have more secondary branches. Blue palo verde is susceptible to the palo verde borer, mistletoe, and witches' broom *(see under problems)*.

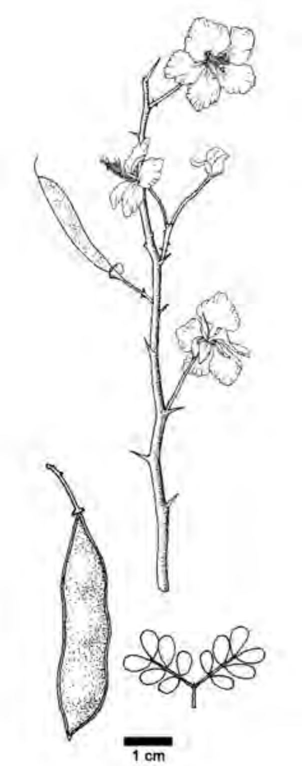


Figure 14: Leaf, flower and seed pod of Parkinsonia florida

Figure 15: Leaf, flower and seed pod of Parkinsonia microphylla

Parkinsonia microphylla (Foothill palo verde, littleleaf palo verde)

Foothill palo verde trees grow 10 to 20 feet (3 to 6 meters) tall with equal spread. They are the slowest growing species among the Parkinsonia in cultivation. The canopy is dense with spiny branches and bark color is yellowish green. Leaflets are smallest among the species described here; leaves have one pair of pinnae with 4 – 8 pairs of leaflets each and appear on the tree only for a short time after summer or winter moisture in natural settings (Fig. 15). Flowers appear briefly and are pale yellow in color. Intensity of flowering varies by year and is generally heavier after a wet winter (Fig. 16).

P. florida and *P. microphylla* can be differentiated by their flower colors. *P. florida* has five deep yellow petals whereas *P. microphylla* has four yellow and one whitish petal which give the plant an overall pale yellow color while in bloom. Seed pods of *P. microphylla* are 1.2 – 5 inches (3 – 13 cm), oblong, and are constricted between seeds *(Fig. 15)*. They can create heavy litter.

P. microphylla is native to the Sonoran Desert including Baja California in Mexico. This species requires well draine soil and does not tolerate lawn or well-watered conditions. Although extremely drought tolerant, trees might shed branches during prolonged drought. *P. microphylla* is tolerant of temperatures to 15 ºF (–9 ºC). Maintenance in the landscape generally includes pruning of dead branches, mistletoe, witches' broom or to expose lower stems.

Similar to blue palo verde, *P. microphylla* trees are also susceptible to the palo verde borer. Foothill palo verde trees are available in cultivation and large specimens are successfully moved from the wild to developed areas.

Figure 16 : Parkinsonia microphylla in full bloom

Parkinsonia praecox subsp. *glauca* (Argentine palo brea)

This tree grows up to 20 feet (6 meters) tall and originated in Argentina. It has the characteristic green bark, yellow flowers, and tan pods of the genus. It looks very similar to the Sonoran palo brea (*P. praecox* subsp. *praecox*) but has smaller leaflets. The subspecies *glauca* is considered to have greater drought tolerance than the Sonoran palo brea, because it is native in areas that receive as little as 4 inches (80 – 100 mm) of annual rainfall. Supplemental irrigation will increase growth. Argentine palo brea is also thought to have greater cold hardiness to 10 ºF (–12 ºC) based on observations where the Sonoran palo brea suffered greater cold damage after frost than the Argentine palo brea. This open shrub is often trained to a small tree by removing lower limbs and can be used in areas such as medians and patios where space may be limited. No problems have been observed on trees in the landscape. "Brea" is the Spanish word for tar or pitch and refers to the waxy coating of the bark that can be scraped off and used as glue. The exudates from the bark are sweet and edible and have been used to make soap. Medicinal use of bark has been reported.

Figure 17: Leaf, flower and seed pod of Parkinsonia praecox subsp. praecox

Parkinsonia praecox subsp. *praecox* (Sonoran palo brea, Brea)

This small tree grows 15 to 30 feet (4.5 – 9 meters) tall with almost equal spread. This subspecies has the largest leaves of the genus *(Fig. 17)*. Flowers are golden yellow, the bark is bright green to lime green with foliage of blue green color. Seed pods are tan colored, oblong and 1.2 – 2.5 inches (3 – 6) cm in length and can create heavy litter. Growth rate is moderate to rapid and increases with supplemental irrigation. Plants tolerate a wide range of soil conditions.

Subspecies praecox is native to the widest range of the genus and occurs from northwest Mexico in disjunct populations as far south as Argentina, and from near sea level to 6,560 feet (2000 meters) elevation. This subspecies is considered less tolerant to drought and cold temperatures than the subspecies *glauca*. Hardiness of plants from Sonora has been reported at 20 ºF (–7 ºC). Hybrids of *P. praecox* with *P. microphylla* or *P. florida* have been observed.

PARKINSONIA HYBRIDS AND CULTIVARS

Parkinsonia x (Desert Museum)

Parkinsonia x 'Desert Museum' is the most popular hybrid of the genus and is a natural three- way cross of (*P. aculeata* x *P. microphylla*) x *P. florida*. Desirable horticultural characteristics of this tree include its upright growth habit, no thorns, fast growth with irrigation, smooth light green bark, and large masses of yellow flowers produced from March to May. Leaf size is intermediate between the parent taxa. P. x 'Desert Museum' has one or two pairs of pinnae that are 2 – 4 inches (5 – 10 cm) in length and have 9 – 19 pairs of leaflets per pinna. Trees reach a height of 21 to 25 feet (7 – 8.3 meters) and grow as wide in canopy. The plant is hardy to 15 °F (–9 °C). Plants need to be propagated vegetatively to retain the characteristics of the parent tree.

Figure18: Leaf of Parkinsonia x 'Desert Museum'

Parkinsonia x sonorae (Sonoran palo verde)

Another palo verde hybrid, *Parkinsonia* x *sonorae* (Sonoran palo verde) is a cross of *P. microphylla* x *P. praecox*. This small tree grows 10 to 20 feet (3.3 to 6.3 meters) high and as wide, but is not widely available in the trade. A few other cultivars available in the trade have been selected by nurseries for desirable aesthetic appearance or improved cold hardiness.

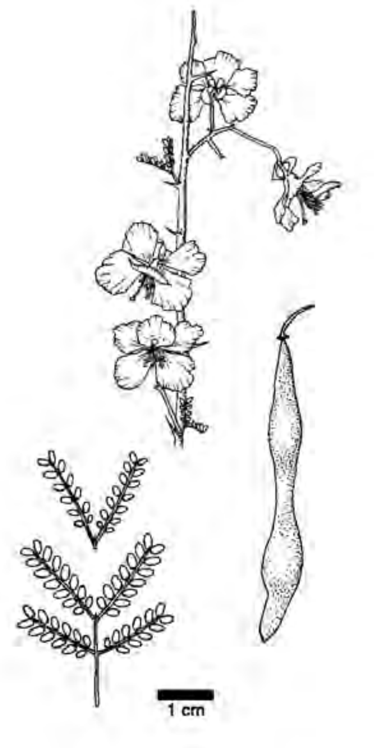


Figure 19: Leaf, flower and seed pod of Parkinsonia x sonorae

Culture

Palo verde trees are extremely drought tolerant once established, but vary in their tolerance to irrigation. *P. florida* is most tolerant of the genus of frequently irrigated conditions such as lawns, while *P. microphylla* does not tolerate frequent irrigation. Even when tolerant of turf conditions, desert trees including palo verde are not recommended in turf. The shallow frequent irrigations to maintain turf can lead to possible tree toppling and loss. In addition, sun-loving grass species such as bermuda grass do not grow well in the shade below the tree.

P. microphylla is extremely susceptible to deep planting or having the base of the trunk covered with soil. Prolonged exposure to soil at the trunk base predisposes the tree to rot and tree failure.

Problems

Witches' broom

Witches' broom causes a proliferation of dense twig growth, but the cause of the problem is unclear at this time (Fig. 20). Removal of affected branches is the only management method to date, but the broom regrows soon after removal. P. florida (blue palo verde) is the primary species affected by this disorder.

Figure 20: Witches' broom on palo verde

True mistletoe

True mistletoe can affect all Parkinsonia species. Description and control methods are the same as described under the mesquite problem section.

Palo verde root borer *(Derobrachus geminatus)*

Palo verde root borer (*Derobrachus geminatus*) is the larval grub stage of the 3 – 3.5 inch (8 – 9 cm) palo verde beetle. The adult beetle is dark brown to black and has prominent antennae approximately half the overall length of the insect. The larval stage is up to 5 inches (12.7 cm) in length and attacks the roots of many desert trees including palo verdes. Adult insects emerge from 1 inch (2.5 cm) wide holes in the soil during summer rains. Upon the removal of dead palo verde trees, the grub is usually present in the roots, hence the name. No control measures are recommended.

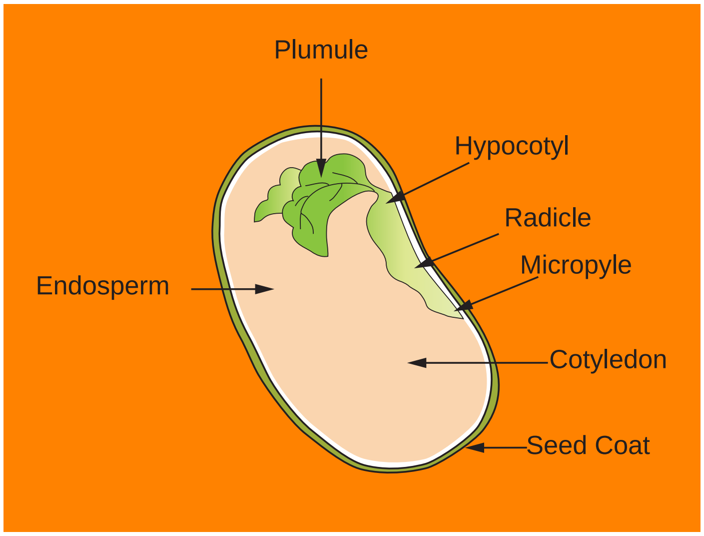
Palo verde webbers *(Bryotropha inaequalis)*

Palo verde webbers (*Bryotropha inaequalis*) emerge in spring and become apparent because of the silken tubes in which they live. The fine webbing appears soon after leaves emerge after winter rains on P. *microphylla*. Small caterpillars are up to ½ inch long and slender. Palo verde webbers appear only seasonally and are not a pest warranting control measures.

How Seeds Work

Jeff Schalau, Area Extension Agent, Agriculture & Natural Resources, University of Arizona Cooperative Extension, Yavapai, Coconico, and Mohave County

As various seed catalogs begin arriving in the mail, gardeners plan their vegetable gardens and flower beds. As you visualize the flowers and fruits to come, think about the complexity and elegance of the seeds themselves. Seeds are plant embryos packaged in a small container with stored food. Mother Nature provides the technology and packaging. Seed companies just breed the plants, collect and process the fruits, put them in and envelope, and sell them to us.



Seeds are the products of sexual reproduction. They contain DNA from a pollen grain and an ovule. The male and female parents can be different plants or the same plant depending on the species. As with all biological systems, there are many variations on this theme. Understanding the reproductive cycle for a given plant is critical to successful plant breeding and seed saving.

As mentioned above, a seed contains the embryo of the new plant, with a supply of food for the embryo until it has formed sufficient roots and leaves to obtain its own food. The embryo is a miniature plant in a state of arrested development. The food, endosperm, may be in the seed leaves (also called cotyledons) or it may be outside the seed leaves and be absorbed as the seed germinates. Endosperm food sources can be in the form of carbohydrates, proteins, or fats. Seeds also have a seed coat (testa) to protect them from disease and insects. The seed coat also prevents water from entering the seed which would initiate the germination process before the proper time.

The process of seed germination is the resumption of active growth of the embryo so that it can become a plant. Prior to any visual signs of growth the seed must absorb water through the seed coat and/or an area of the seed called the micropyle. In addition, the seed must be in the proper environmental conditions; that is, exposed to oxygen, favorable temperatures, and for some, specific light conditions.

Seed germination occurs in three stages. The process of water absorption (called imbibition) reactivates enzymes present in the seed. These enzymes break down storage compounds in the seed to make them available for the embryo. For example, when barley absorbs water, enzymes are activated that convert starch into sugars. Some industrious individuals use these processes to their advantage to produce malt which is used to make beer.

The second stage is digestion and translocation. In this stage, enzymes that were synthesized or activated previously begin to break down storage material within the seed into simple compounds which are translocated to the embryo. The embryo begins to grow as cells elongate and divide. In the final stage, the germinating seed continues to undergo metabolic changes which transform the embryo into a seedling.

The radicle is the first part of the seedling to emerge from the seed. It will develop into the primary root from which root hairs and lateral roots develop. In most broad-leafed plants, there are two seed leaves (called cotyledons) which encase the embryo and are usually different in shape from the leaves that the mature plant. The hypocotyl is the portion of the embryo which becomes the stem. These plants are often referred to as dicots. Plants producing one cotyledon are called monocots. Monocots include grasses, lilies, orchids, palms, agaves, and yuccas.

The processes described above are simplified and generalized. The bottom line is that seeds are alive. Respiration requires an energy source and some minute amount of oxygen. Seed viability can be extended under cool, dry storage conditions. While there are a lot anecdotal reports of seeds remaining viable for a 1,000 or more years. Controlled experiments have documented seed viability of 100 years for a handful of species investigated. Myself, I'm happy when seeds I purchased last year germinate.

Using Gypsum and Other Calcium Amendments in Southwestern Soils

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Soil aggregate formation and stability, the primary features of soil structure, are two of the most important manageable soil physical properties. Water, air, and roots primarily move between soil aggregates, which are clumps of soil particles cemented together. The pores between aggregates are fairly large, whereas the pores between particles within aggregates are often too small for effective water movement or root penetration, and sometimes even too small for bacteria to enter. In all but the sandiest soils, good aggregate structure is required for adequate root penetration, water infiltration, air exchange, and soil drainage.

Calcium (Ca) can help stabilize aggregate structure of some soils; using Ca in other soils will not improve soil physical or chemical properties. Therefore, it is helpful to understand how Ca interacts with soil particles.

The most commonly used Ca sources include gypsum, agricultural lime, and a few other Ca salts. In some soils, existing Ca minerals can be dissolved, releasing the Ca they contain. It is important to be familiar with the properties of these various Ca materials, and to understand the chemical processes that occur when amendments are applied to soil.

Why is calcium important?

Negatively charged soil clay particles can be bound together into clumps or aggregates by positively charged molecules (cations). The formation of stable soil aggregates, a process called flocculation, encourages water infiltration and drainage and prevents surface soil crusting. Flocculation is promoted by high levels of salinity (which may not be conducive to plant growth) and by the presence of cations that are strong flocculators. The dominant soil cations in medium to high pH soils are the monovalent cations (one positive charge per molecule) sodium (Na^+) and potassium (K^+), and the divalent cations (two charges per molecule) magnesium (Mg^{2+}) and calcium (Ca^{2+}). In highly acidic soils the trivalent aluminum cation (Al^{+3}) may be present.

The ability of the dominant soil cations to flocculate soil clays, a function of their charge and size, is shown in Table 1. In this table the flocculating power of Na^+ is assigned a value of 1, and the other cations assigned values relative to Na^+. We can see that K^+ is a stronger flocculator than Na^+, but that Mg^{2+} and Ca^{2+} are much more powerful flocculators than either of the monovalent cations. Calcium is clearly the cation of choice for flocculating soil clays.

We generally consider Na^+ to be the major 'weak' flocculator, and Ca^{2+} and Mg^{2+} to be the most common 'strong' flocculators. We can get a rough idea of how stable a soil's structure is by looking at the relative amounts of these weak and strong flocculators. This can be done by calculating the Sodium Adsorption Ratio (SAR), where cation concentrations are in millimoles per liter (mmol/L) or millimoles per kilogram (mmol/kg).

Table 1. Relative flocculating power of major soil cations (Rengasamy and Sumner, 1998).

Ion	Chemical Symbol	Relative Flocculation Power
Sodium	Na+	1.0
Potassium	K+	1.7
Magnesium	Mg^2+	27.0
Calcium	Ca^2+	43.0

$$SAR = \frac{[Na^+]}{\sqrt{[Ca^{2+}]+[Mg^{2+}]}}$$

An alternative equation for expressing the impact of Na^+ on aggregate stability is Exchangeable Sodium Percentage (ESP) with units of centimoles of charge per kilogram (cmolc/kg):

$$ESP = \frac{[Na^+]}{\text{cation exchange capacity}}$$

In addition to the relative proportions of flocculating cations, it is also important to know the total concentration of soluble salts in the soil. Cations are always accompanied by negatively charged ions (anions), and together they are called salts. Salts dissolved in water conduct electricity, so we can measure the electrical conductivity or EC of a soil-water mixture to determine the amount of salt.

Together, SAR and EC largely control soil aggregate stability. Figure 1 illustrates the effect of irrigation water quality on aggregate stability. If a soil has a combination of high SAR and low EC, the aggregates will tend to disperse. If it has a high EC and/or low SAR, the soil particles will be aggregated.

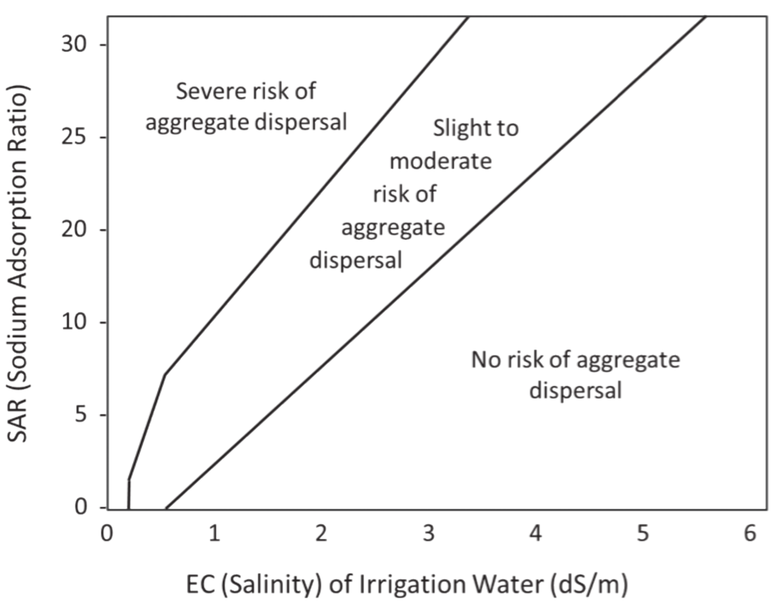

Figure 1. Soil and irrigation water electrical conductivity (EC) and Sodium Adsorption Ratio (SAR) determine aggregate stability (Ayers and Westcott, 1985)

In soils without adequate soluble Ca^{2+}, increasing the Ca^{2+} in solution will help to flocculate clay particles. Calcium acts as 'glue' that holds soil particles together into aggregates and stabilizes soil structure. There are two methods that can be used to increase soluble Ca. One is to solubilize Ca already present in the soil; the other is to add a supplemental Ca source.

How can you solublize Ca already present in the soil?

Let's look at the first option, solubilizing existing soil Ca. This strategy works only if there is an excess of calcium carbonate ($CaCO_3$) minerals in the soil. Soils with excess or solid-phase $CaCO_3$ are referred to as calcareous soils. They can be identified through a soil analysis. Look for 'free lime' on the soil test. It will usually be reported in general categories such as 'high', 'medium' or 'low'. You can test for the presence of carbonates yourself by putting a drop of dilute acid on them and observing whether or not they effervesce (Figure 2) as the $CaCO_3$ reacts with the acid (sulfuric acid in the equation below) to produce carbon dioxide (CO_2) bubbles:

$$H_2SO_4 + CaCO_3 \longrightarrow CO_{2(gas)} + H_2O + Ca^{2+} + SO_4^{2-}$$

In calcareous soils, acid can be applied to dissolve soil $CaCO_3$. The products of the reaction of $CaCO_3$ and sulfuric acid are CO_2, water (H_2O), sulfate (SO_4^{2-}), and Ca^{2+}. The Ca^{2+} released from the soil $CaCO_3$ can now act as a flocculant.

Any acid can dissolve soil $CaCO_3$ and release the bound Ca. Sulfuric acid is most common because it is relatively inexpensive and adds less salt to the soil than hydrochloric acid (HCl). Sulfurous acid (H_2SO_3) can be produced by combustion of elemental sulfur in a 'sulfur burner', which is a popular alternative to sulfuric acid. Additionally, acid-forming materials such as elemental sulfur can be used. Elemental sulfur is converted to sulfuric acid by sulfur oxidizing bacteria, producing the same effect as sulfuric acid. Sulfur conversion is a biological process, however, and requires several weeks to months to take place (depending on soil conditions), unlike acids, which react instantly.

Acids and acid-forming materials will only be effective in calcareous soils! The soil should effervesce when acid is applied, or have 'medium' to 'high' or 'very high' free lime soil test levels.

Calcium additives

Now let's look at Ca additives. There exist several Ca bearing salts that can be used to add Ca^{2+} to soil but in order to be effective they must be soluble. A salt is a compound made up of a cation and an anion. Calcium salts, of course, contain Ca^{2+} as their cation. The anion is sulfate (SO_4^{2-}) for calcium sulfates, carbonate (CO_3^{2-}) for calcium carbonate, chloride (Cl^-) for calcium chloride, and nitrate (NO_3^-) for calcium nitrate.

Gypsum and calcium sulfate anhydrite

The most widely used Ca soil additive is gypsum. Gypsum is one of the family of calcium sulfates. The chemical formula for gypsum is $CaSO_4 2H_2O$. This means that each gypsum molecule contains one Ca^{2+} cation, one SO_4^{2-} anion, and two waters. There are other calcium sulfates, such as calcium sulfate anhydrite ($CaSO_4$). Chemically, these two salts are closely

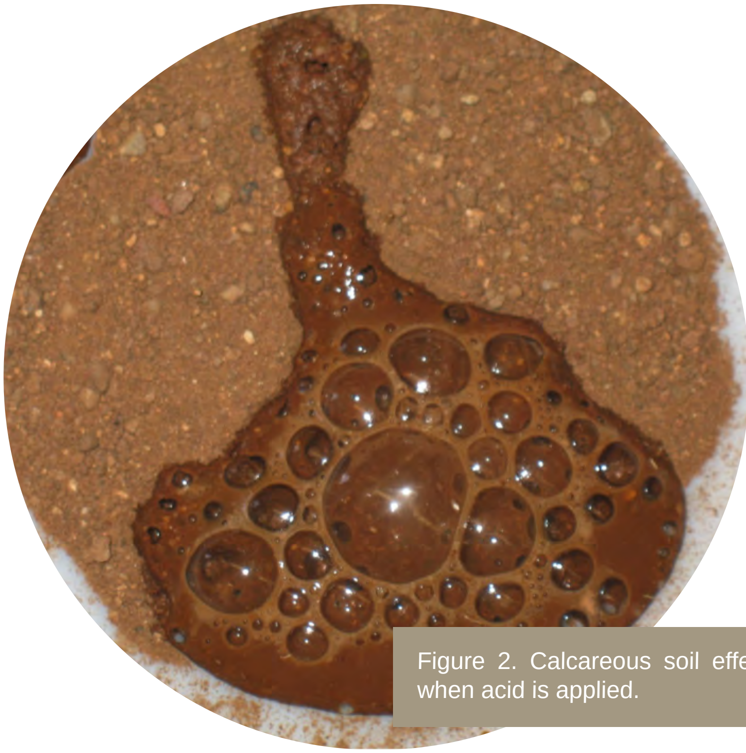

Figure 2. Calcareous soil effervescing when acid is applied.

related, the difference being that calcium sulfate anhydrite does not contain water. Consequently, calcium sulfate anhydrite contains more Ca on a weight basis than gypsum. Calcium sulfate anhydrite contains 29.4% Ca, whereas gypsum contains 23.2% Ca.

Both of these Ca salts are mined, and then ground into a powder for use as soil additives. Additionally, by-product gypsum materials, waste products of phosphate fertilizer production (phosphogypsum) or from power plant stack scrubbers (flue gas desulfurization gypsum), are also used.

Gypsum is a good choice for Ca addition because it is inexpensive, non-toxic, and safe to handle, and it is relatively soluble. We are interested both in solubility (how much of the salt will dissolve in the soil water) and the rate of dissolution (how fast the salt dissolves in water). Mined gypsum is well-crystallized, having formed over millions of years. Waste gypsum, on the other hand, is formed rapidly during industrial processes, and is less crystallized. Although they have the same chemical formula, the waste gypsum materials dissolve more rapidly than mined gypsum. Sometimes powdered gypsum is prilled in order to reduce dust and to improve handling properties, and this slows its rate of dissolution. A study that compared dissolution rates of gypsum sources found that flue gas gypsum dissolved 3.6 times faster than mined gypsum, whereas phosphogypsum dissolved 2.2 times faster than mined gypsum. The rate of dissolution is particularly important for treatment of soil crusting, which is caused by dispersion of clay particles at the soil surface. In this situation, rapid dissolution is critical to maintain a high level of dissolved Ca^{2+} in the surface soil as raindrops or irrigation water leach cations from the uppermost layer of soil. However, for general treatment of soil structure, the rate of dissolution is less important than the overall solubility.

Calcium sulfate anhydrite can also be used as a Ca supplement. The solubilities of gypsum and calcium sulfate anhydrite are similar, however the dissolution rates differ. Published reports indicate that the dissolution rate of calcium sulfate anhydrite is slower than that of gypsum – anywhere from 5% to 72% that of mined gypsum. In addition to the chemical composition, the dissolution rates of both gypsum and calcium sulfate anhydrite are dependent on type and degree of crystallization, particle size, presence of impurities, and method of manufacture for non-mined salts.

Lime

Calcium carbonate or limestone is another mined Ca salt. It's often referred to as lime or agricultural lime, although agricultural lime may be a combination of calcium and magnesium carbonates if it is made from dolomitic rather than calcitic limestone deposits. The main use of lime is to raise soil pH (to reduce acidity). In the same manner that $CaCO_3$ neutralizes sulfuric acid in the equation above, it also neutralizes acidity in low pH soils. Unlike gypsum and calcium sulfate anhydrite, lime solubility is dependent on soil pH. Its solubility increases in acid soils and decreases as soil pH increases. When soil pH is above approximately 8.2, lime becomes very insoluble. This is why most soils with a pH above this threshold are also calcareous, meaning that they contain solid mineral $CaCO_3$. In acidic soils, supplemental $CaCO_3$ will dissolve, but in alkaline soils it will not; adding $CaCO_3$ to calcareous soils accomplishes nothing in terms of increasing soluble Ca levels.

Calcium chloride and calcium nitrate

Calcium salts that contain Ca^{2+} and a monovalent anion such as chloride ($CaCl_2$) or nitrate ($Ca[NO_3^-]_2$) are very highly soluble. They are not usually used as Ca amendments because of their expense and their high salt content. Applying enough of these salts to promote soil aggregation would generally increase soil salinity to unacceptable levels.

Summary of calcium supplements

Table 2 provides a concise listing of the circumstances where each of the soil additives is likely to be effective or ineffective. Regardless of source, these soil amendments will only improve soil physical properties in soils with poor structure.

Do calcium additives such as gypsum supply calcium for plant use?

Calcium is a critical component of cell walls and is therefore an essential plant nutrient. It is needed for cell division and growth and for redistribution of carbohydrates within the plant. Calcium

Table 2. Summary of conditions appropriate for various soil additives.

	Soil pH		Comments
Material	<7.0	>7.0	
Acids	NO	YES*	Only effective in calcareous soils (*calcareous soils usually have pH>8.0)
Gypsum	YES	YES	Will not change soil pH
Lime	YES	NO	Raises soil pH; not soluble in higher pH soils
$CaSO_4$	YES	YES	Dissolves more slowly than gypsum; will not prevent surface crusting
$CaCl_2$	YES	YES	Can raise soil salinity to unacceptable levels
$Ca(NO_3)_2$	YES	YES	Can raise soil salinity to unacceptable levels if used as a Ca source

Table 3. Gypsum requirements in tons per acre as influenced by soil texture and exchangeable sodium percentage.

Soil Texture	Exchangeable Sodium Percentage					
	10	15	20	30	40	50
	Gypsum (tons per acre)					
Coarse	1.1	1.7	2.3	3.4	4.6	5.7
Medium	1.9	2.9	3.8	5.7	7.7	9.6
Fine	2.7	4.0	5.4	8.0	10.7	9.6

Table 4. Gypsum requirements in pounds per one thousand square feet as influenced by soil texture and exchangeable sodium percentage.

Soil Texture	Exchangeable Sodium Percentage					
	10	15	20	30	40	50
	Gypsum (lbs per 1000 ft^2)					
Coarse	55	80	105	160	210	265
Medium	90	130	175	265	350	440
Fine	125	185	245	370	490	615

deficiency related to lack of available soil Ca is rarely encountered in moderate to high pH soils, and is usually limited to very acidic or sandy soils. Calcium supply and translocation within plants is dependent on an adequate and continuous supply of water and Ca deficiencies are usually the result of drought stress rather than low soil Ca levels. However, if the supply of available soil Ca is inadequate (exchangeable Ca less than 250 to 500 mg/kg, Jones, 2003; Simmons and Kelling, 1987), supplemental Ca can improve plant nutrition. In this case, any *soluble* Ca material can be used to alleviate Ca deficiency. Lime (in acidic soils only) and gypsum are the most widely used soil-applied Ca fertilizers, whereas $CaCl_2$ and $Ca(NO_3^-)_2$ are often used for foliar application.

How much gypsum do I need to apply?

The amount of gypsum that should be applied is best determined by a soil analysis. Soil analyses should be conducted to determine soil sodium status, either as “sodium adsorption ratio” (SAR) or as “exchangeable sodium percentage” (ESP). Either provides a good indication of the need for gypsum and the two measures are roughly equivalent. Approximate amounts of gypsum to add, based on soil analyses, are shown in Tables 3 and 4. These values were calculated based on cation exchange values of 15 $cmol_c$/kg coarse soil, 25 $cmol_c$/kg medium-textured soil, and 35 $cmol_c$/kg of fine-textured soil, bulk density 3.33 g/cm^3, soil depth 6 inches, and assume replacement of all the exchangeable Na. Application rates may need to be adjusted for actual soil conditions.

Summary

In soils with weak structure resulting from an imbalance between Na^+ and Ca^{2+}, increasing soluble Ca^{2+} can improve aggregation, water infiltration, soil drainage, and root penetration. Acid or acid-forming amendments are acceptable additives for increasing soluble Ca^{2+} in calcareous soils only. In all soils, regardless of pH, gypsum is a good Ca^{2+} additive when Ca^{2+} is needed. Calcium sulfate anhydrite will also supply Ca^{2+}, but it will dissolve more slowly than gypsum. With either gypsum or calcium sulfate anhydrite it is important to know the composition of the material you select, which can vary considerably depending on source. Soil analysis can help determine how much of these materials to apply to your soil.

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Assessment of Doneness in Cooked Ground Beef

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Because raw meat and poultry products may contain harmful bacteria, safe handling and proper cooking of meat and poultry is recommended. The goal of proper food safety practices is to prevent situations which promote bacterial growth, cross contamination, and food-borne illness. E. coli O157:H7 is a strain of bacteria that has caused numerous outbreaks of food borne disease. The majority of E. coli outbreaks since 1982 have been linked to undercooked ground beef. While this pathogen can survive both refrigeration and freezer storage, thorough cooking will kill it.

Recently, the Food Safety and Inspection Service (FSIS) of the USDA recommended consumers use a meat thermometer when cooking ground beef to assess doneness. When a thermometer is inserted into cooked ground beef, it should read 160ºF in order to be done and safe to eat. FSIS determined that the use of color (i.e., absence of red or pink in meat) to assess doneness is not reliable.

There are two problems with using the color of ground beef to test for doneness and guarantee the destruction of pathogens:

1. Some ground beef may appear to have lost all pink color before it is fully cooked. If raw ground beef is somewhat brown already, it may look fully cooked before it reaches a safe temperature.
2. Some lean ground beef may remain pink at temperatures well above the 160°F final cooking temperature recommended for consumers.

Consumer Advice

- Use an instant-read thermometer: insert so sensitive end is in the center of patty. Check the thermometer instructions for correct use and calibration. Cook to a minimum temperature of 160°F in the center of the thickest part of the meat.
- For ground beef patties, a digital instant-read food thermometer may be used toward the end of the cooking time and inserted at least ½ inch into the thickest part of the patty. If the ground beef patty is not thick enough to check from the top, the thermometer should be inserted sideways. If uncertain about the temperature reading, take a reading in a second location. Ground beef should be cooked to an internal temperature of 160°F on an instant-read food thermometer.
- Consumers should not eat ground beef patties that are pink or red in the middle unless a food thermometer is used to verify the temperature.
- Fresh or thawed ground meat should be used quickly, within one day. You should either tightly wrap or freeze, or store ground beef for no more than one day in a 40°F refrigerator.
- When eating out, ask your server if ground beef patties have been cooked to at least 155°F for 15 seconds (as recommended by the U.S. Food and Drug Administration Food Code), which is a safe option for restaurants or food service operations.

For other questions about Food Safety or food borne illness, contact your county Cooperative Extension office.

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Arizona Wells:

Low Yielding Domestic Water Wells

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Arizona has stringent permit requirements for submitting a notice of intent to drill a new water supply well for domestic use. The construction diagram and geologic log of all wells in the state are recorded with the Arizona Department of Water Resources (ADWR). The ADWR website – www.AzWater.gov/AzDWR/ - provides a wealth of information for the private domestic well owner. Well owners are responsible for the repair and maintenance of their own wells and for monitoring water quality to assure safe drinking water.

The Arizona Groundwater Management Act of 1980 identifies wells having a pump capacity of not more than 35 gallons per minute (gpm) as "exempt wells" because owners are not required to report how much water they pump. These wells are also exempt from regulation, including those regulations requiring meeting drinking water standards. These wells are typically used for domestic or household purposes.

Domestic Well Yield and Aquifer Characteristics

Well yield is the rate at which a well can be pumped while ensuring that the pumping water-level is not drawn down to the pump intake. Well yield is reported as gpm. To develop a groundwater resource, it is necessary to design and construct a well capable of yielding a pumping rate compatible with the needs of the water well owner. Sufficient and sustained well yields are highly dependent on the characteristics of the aquifer, the construction of the well, and the maintenance of the well.

Aquifer characteristics in Arizona can vary between highly transmissive (high yielding) sands to low-yielding clays within the desert valleys. Wells completed in very coarse sand and gravel aquifers routinely result in high-yielding wells. Whereas, wells completed in fine silt and clay or bedrock aquifers can retard groundwater flow to wells to less than 5 gpm.

How Well Construction and Maintenance Affect Well Yield

Well construction is important when optimizing yield. The screened portion of the well allows for the movement of water into the well while reducing the transport of silt and sands into the well. An improperly sized screen (slots in the screen are too narrow or too wide) could allow sediment to clog the screen or grit (silt and finesand) to damage the pump. A submersible pump set at a too shallow a depth could draw-down water levels too quickly, requiring the pump to cycle on and offrepeatedly as the water table rises and falls, often damaging the pump. If water table elevations have dropped since initial well construction, well yield will decline.

The most common cause of a reduction in well yield is the development of scale within the well and screen, as shown in Figure 2. Similar to the deposits found inside a tea kettle,scale is the hard residue that coats the inside of pipes and the well screen as the result of precipitation of minerals composed of calcium and magnesium carbonates. Naturally occurring iron bacteria can cause plugging of the pores in the aquifer and the openings of the well screen. The bacteria produce accumulations of bio-slime within the well and increase the rate of scale precipitation, not unlike plaque buildup on your teeth. The combined effectof the growth of slime and precipitated mineral has been reported to reduce well yield by 75% within a year of well operation. (Johnson Division, 1972).

Potential Health Effects Associated with Low Yielding Wells

Pumps in low yielding wells are more likely to cycle on and off to meet water needs. Rapid and repeated water level changes in the area of the well screen allows for the introduction of oxygen in the aquifer. Changes in aquifer geochemistry can occur when water-saturated geologic materials are exposed to oxygen, and this can result in naturally occurring minerals dissolving into the groundwater. If the aquifer material includes arsenic minerals, an increase in dissolved arsenic may occur (Uhlman, 2008).

In addition to the potential for loss of well yield, bio-slime accumulation can allow for the growth of bacteria that can become a serious health concern. *E. coli* bacteria is the most common bacteria encountered in domestic wells. It can originate from naturally occurring bacteria found in the soils, but the most common source of *E. coli* in water well systems is fecal *E. Coli* from an adjacent septic system. In regions of warm groundwater (southwestern United States) an overgrowth of bacteria in a domestic well can become a food source for other organisms, such as the amoeba *N. fowleri*. (Artiola and Uhlman, 2009). Domestic wells should be tested annually to assure drinking water standards are met.

Options for Correcting Low Yield Wells

Wells constructed in low yielding aquifers are candidates for well deepening and pump lowering if the static water table elevations have dropped. Open-borehole wells, such as those constructed in bedrock, may exhibit increased yield if 'fracked'. 'Hydro-fracking' consists of sealing portions of the well and increasing the pressure sufficientlwithin the borehole to induce fracturing of the rock. Increasing the number and frequency of fractures around the borehole allows for the interception of a greater number of water-bearing fractures and may increase yield.

Shock-chlorination of a well exhibiting elevated bacterial contamination reduces bio-slime that may be plugging the well. Well owners should not try to chlorinate their own wells but hire a qualifed water well system contractor. Care should be taken to adequately flushthe well system after shock-chlorination because the introduction of chlorine can change the geochemisty of the aquifer and induce mobilization of naturally occurring minerals, such as arsenic and lead. In addition, when chlorine chemicals come into contact with organic residues (such as slime), disinfection by-products are produced. These toxic chemicals must be flushedout of the well and/or home water distribution system to reduce contamination.

Anecdotal reports of well owners have evidenced limited success with the introduction of dry ice into the well. As the carbon dioxide (CO_2) bubbles from the dry ice, the water becomes more acidic, which dissolves some of the carbonate-based scale and lowers bacterial count. The agitation of the bubbling dry ice in the borehole is also assumed to loosen some particulate scale. Larger municipal wells are beginning to design large capacity water well systems to use pressurized CO_2 gas to sanitize well systems. The downside of the use of CO2 is the acidificationof the water, which increases pipe corrosion. Additional well cleaning and disinfection procedures are described by Schneiders (2003).Surging and scrubbing the interior of the well piping and screen is the most efficienmeans by which to increase well yield after scale and/or slime formation. A licensed pump installer would mobilize a pump rig over the well, remove the pump and any interior plumbing, and scrub the well with equipment similar to a large botle brush. It is recommended that any pump maintenance activity that allows for open access to the well should include well surging and scrubbing to remove scale, slime, and other particulates from the domestic well.

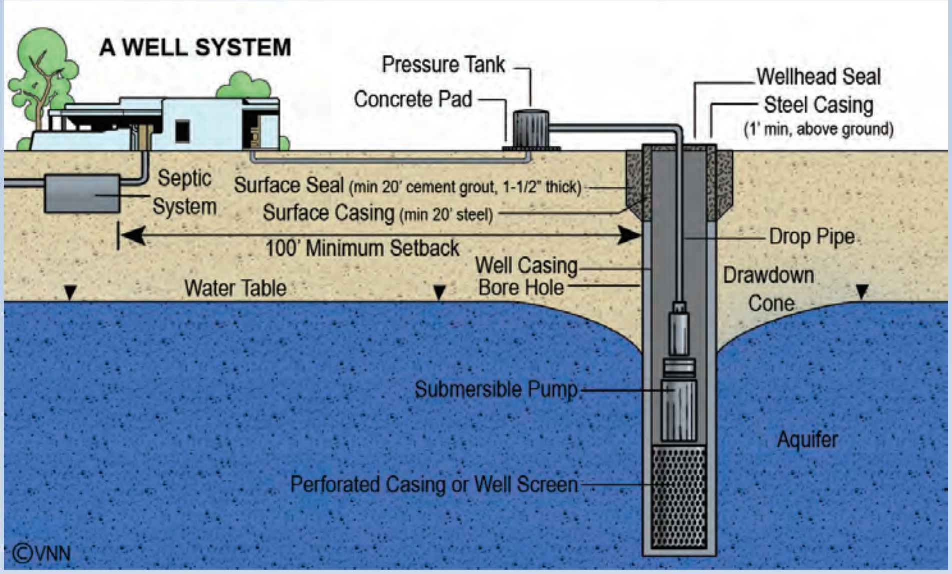

Figure 1: Domestic Well Components adapted from ADWR Well Owner's Guide (not to scale).

Figure 2: Scale formation on well screen.

References

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