

CACTUS AS XEROPHYTES FOUND IN DESERT DUE TO SUCCULENT NATURE

¹Prof. (Dr.) Dhrubo Jyoti Sen, ^{2*}Prof. (Dr.) Deepak Kumar¹School of Pharmacy, Techno India University, Sector-V, Salt Lake City, EM: 4/1, Kolkata-700091, West Bengal, India.²Krishna Institute of Pharmacy, Satkira, Topchachi, Dhanbad-828401, Jharkhand, India.***Corresponding Author: Prof. (Dr.) Deepak Kumar**

Krishna Institute of Pharmacy, Satkira, Topchachi, Dhanbad-828401, Jharkhand, India.

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ABSTRACT

Cactus secrets include their modified leaves (spines) for protection and shade, their ability to store water in thick stems, and unique adaptations like areoles where spines and flowers grow. Many desert cacti are endangered due to habitat loss, while certain jungle cacti, like the Christmas cactus, need specific conditions to bloom, including consistent watering and filtered light, as detailed.

Christmas cactus: Needs specific care to bloom, like consistent watering and indirect light.

Pros: Blooms beautifully, can be a long-lasting plant.

Cons: Sensitive to overwatering, requires specific lighting conditions for flowering.

Desert Cacti: Storing water in their stems and modified leaves (spines) are key to survival in harsh environments.

Pros: Extremely resilient and low-maintenance in the right climate.

Cons: Many species are endangered due to habitat loss.

Cactus Root Trimming: A horticulture secret to promote healthier, more efficient root systems.

Pros: Stimulates new growth, prevents root rot, and can encourage flowering.

Cons: Can be intimidating, but is beneficial and a long-standing practice.

For health and skincare

Cactus Pear (*Opuntia ficus-indica*): A fruit with benefits beyond just nutrition.

Pros: Rich in antioxidants and vitamins A, C, and E, with anti-inflammatory properties.

Cons: Not as widely available as other skincare ingredients.

Cactus Extracts: Can be found in skincare products to help with various skin concerns.

Pros: Soothes skin, reduces redness, strengthens skin barrier, and brightens skin tone.

Cons: Some products contain fragrance or other irritants, so checking the ingredient list is important.

For spiritual and symbolic purposes:

Feng Shui & Symbolism: Cacti and succulents are seen as auspicious plants.

Pros: Represent resilience and stability, and are believed to attract positive energy.

Cons: Spiritual symbolism can be subjective and may not appeal to everyone.

KEYWORDS: Cactus, xerophytes, spines, waxy layer, succulent, Crassulacean Acid, ribulose-1,5-bisphosphate (RuBP), calvin cycle.

Overview: A cactus is a succulent plant known for its adaptations to arid environments, such as spines instead of leaves to reduce water loss and thick stems or pads to store water. Belonging to the family Cactaceae, most cacti originated in the Americas but can now be found worldwide and are popular for both indoor and outdoor decoration. They are resilient, flowering plants, though

some species are threatened by removal from the wild. A cactus is a member of the plant family Cactaceae, a family of the order Caryophyllales comprising about 127 genera with some 1,750 known species.^[1-3]

Spines: These are modified leaves that help reduce water loss and protect the plant from predators.

Water storage: Cacti are succulents that store water in their stems or pads, allowing them to survive long droughts.

Roots: Most have shallow, wide-spreading root systems to quickly absorb rainwater.

Flowers: They are flowering plants that can bloom, often in response to heavy rains.

Fruit: Many species produce fruit, such as the dragon fruit or prickly pear, which can be eaten.

Adaptations and habitat

Xerophytes: Cacti are a type of xerophyte, a plant adapted to live in dry conditions.

Habitat: While often thought of as desert plants, they grow in various habitats, from deserts to forests.

Geographic origin: Almost all genera of cacti originated in the Americas.

Common uses and care

Ornamental plants: Many species are popular as houseplants or for landscaping because they are resilient and require minimal care, thriving in bright sunlight and needing less watering than other plants.

Edible parts: The pads (nopales) and fruit of some species are edible and can be cooked in many ways, such as boiled, roasted, or fried.

Soil: A well-draining soil mix, often called a "cactus mix," is best for them.

Taxonomy

Kingdom: Plantae

Clade: Tracheophytes

Clade: Angiosperms

Clade: Eudicots

Order: Caryophyllales

Family: Cactaceae

Succulent plants *Crassula impericales* (left) and *Crassula marnieriana* (Crassulaceae) *Cleistocactus samaipatanus* (Cactaceae)

Cacti are classified as xerophytes because they are plants with adaptations for survival in dry, arid environments with scarce water. Their xerophytic features include water-storing, fleshy stems; leaves modified into spines to reduce water loss; a waxy coating on their stems; and extensive root systems to absorb moisture. These adaptations allow them to thrive in deserts and other water-limited habitats. A xerophyte 'dry' and 'plant' is a species of plant that has adaptations to survive in an environment with little liquid water. Examples of xerophytes include cacti, pineapple and some gymnosperm plants. The morphology and physiology of xerophytes are adapted to conserve water during dry periods. Some species called resurrection plants can survive long periods of extreme dryness or desiccation of their tissues, during which their metabolic activity may effectively shut down. Plants with such morphological and physiological adaptations are said to be xeromorphic. Xerophytes such as cacti are capable of withstanding extended periods of dry conditions as they have deep-spreading roots and capacity to store water. Their waxy, thorny leaves prevent loss of moisture.^[4-6]



Figure 1: Cactus the Xerophytes.

Water storage: Cacti have fleshy, succulent stems that are green and photosynthetic, storing large amounts of water and nutrients.

Reduced water loss

Spines: Their leaves are modified into spines, which dramatically reduces the surface area for transpiration (water loss).

Waxy coating: A thick, waxy cuticle on the stem's surface acts as a barrier to prevent water evaporation.

Efficient water absorption

Extensive root system: Cacti possess a shallow but wide-spreading root system to quickly capture rainwater or dew, along with a deep taproot to access subsurface water.

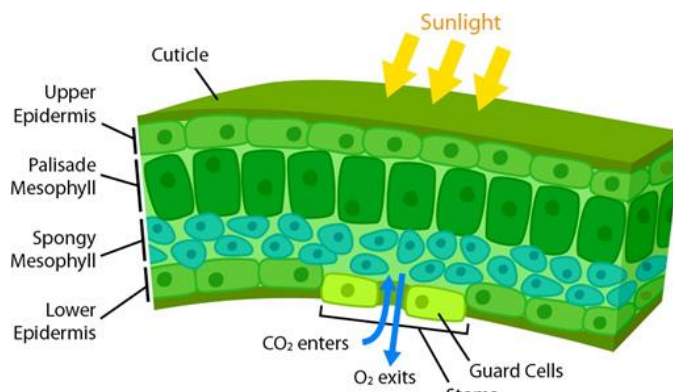


Figure 2: Outer layer of cactus for photosynthesis.

Photosynthesis

Photosynthetic skin: The stems contain chlorophyll and perform photosynthesis, as the leaves are no longer available for this function.

CAM photosynthesis: Many xerophytes use a special type of photosynthesis where they open their stomata at night to take in carbon dioxide, which minimizes water loss during the hot day. CAM (Crassulacean Acid Metabolism) is a carbon fixation pathway in plants adapted to dry environments that separates photosynthesis into a two-part cycle based on time of day rather than space. At night, the plant opens its stomata to take in carbon dioxide CO_2 and store it as malic acid in vacuoles. During the day, stomata remain closed to conserve water, and the stored malic acid is broken down to release CO_2 , which is then used for the Calvin cycle.

Nighttime process

Stomata open: Plant opens its stomata in the cool, humid night. **CO_2 fixation:** Carbon dioxide CO_2 diffuses into the leaf and is fixed to a four-carbon compound called oxaloacetate by the enzyme PEP carboxylase [phosphoenolpyruvate carboxylase], a process similar to that in C_4 photosynthesis. **Malic acid storage:** Oxaloacetate is converted to malic acid and stored in the plant's large vacuoles for the next day.

Daytime process metabolic process

Stomata close: During the day, the stomata remain shut to prevent water loss from the leaf. **Malic acid release:** The stored malic acid is transported out of the vacuole into the cytoplasm. **CO_2 release:** Malic acid is broken down, releasing CO_2 . This concentrates the CO_2 around the enzyme RuBisCO. **Calvin cycle:** The released CO_2 enters the Calvin cycle, where it is used for photosynthesis, allowing the process to continue even

with closed stomata. **PEP regeneration:** The remaining molecules are recycled back to regenerate phosphoenolpyruvate (PEP) to be used again that night. **Adaptations and benefits** **Water conservation:** CAM is a crucial adaptation for plants in arid environments, allowing them to minimize water loss through transpiration. **Reduced photorespiration:** By concentrating CO_2 around RuBisCO during the day, CAM plants reduce photorespiration, which is an inefficient process where RuBisCO binds with oxygen instead of CO_2 . **Crassulacean acid** is primarily malic acid, a four-carbon organic acid C_4 that is synthesized at night and stored in the large central vacuoles of plant cells. During the day, the malic acid is released from the vacuole and decarboxylated, which releases CO_2 to be used in photosynthesis even with closed stomata. The Calvin cycle is a series of chemical reactions in photosynthesis that converts carbon dioxide CO_2 into glucose (sugar) using the energy from light-dependent reactions. Also known as light-independent reactions, it occurs in the stroma of chloroplasts and consists of three main stages: carbon fixation, reduction, and regeneration.^[7-9]

Chemical Structure: Malic acid is an organic acid with the chemical formula $\text{C}_4\text{H}_6\text{O}_5$. It is a dicarboxylic acid, meaning it CO_2 has two carboxyl groups COOH . In the context of Crassulacean Acid Metabolism (CAM), it is the end product of CO_2 fixation at night. **Formation:** At night, plants open their stomata and take in CO_2 . An enzyme called phosphoenolpyruvate carboxylase fixes this CO_2 to a three-carbon molecule, phosphoenolpyruvate (PEP), forming a four-carbon molecule called oxaloacetate. Oxaloacetate is then reduced to malate. **Storage:** The malic acid is then transported and stored in the large central vacuole of the mesophyll cells. This storage allows the plant to

conserve water by keeping its stomata closed during the hot, dry day. Release: In the morning, the malic acid is transported out of the vacuole and into the cytoplasm. It is then decarboxylated, releasing CO_2 which is concentrated in the cell. This concentrated CO_2 is then refixed and used in the Calvin cycle for photosynthesis, even with the stomata still closed. Crassulacean acid metabolism: a continuous or discrete trait? Crassulacean acid metabolism (CAM) is a water-conserving mode of photosynthesis and one of three photosyn. Crassulacean acid metabolism species differ in the. Crassulacean acid

metabolism (CAM) is a specialized photosynthetic pathway with an inverse day/night pattern of stomatal opening. The "crassulacean acid" referred to in CAM is malic acid, a product of nocturnal CO_2 fixation that is stored in plant vacuoles. This storage and release cycle allows plants to perform photosynthesis during the day while minimizing water loss through closed stomata. Typical plants: This pathway is found in plants like cacti, succulents, pineapples, and some orchids, all of which are adapted to survive in dry or water-scarce conditions.

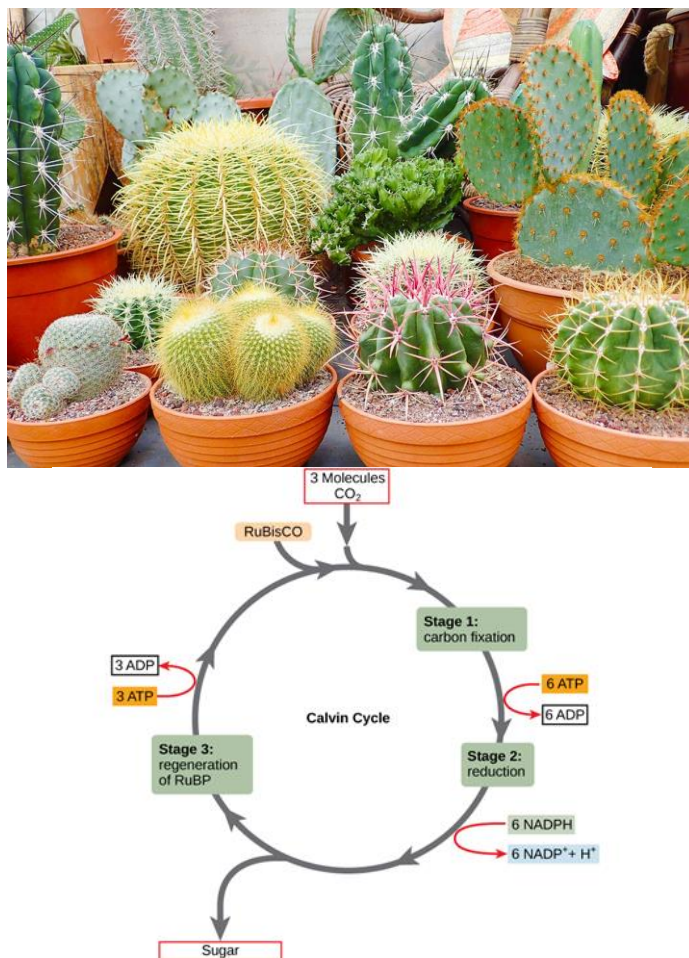


Figure 3: Decorative cactus and Calvin cycle.

The thick, waxy coating on a cactus is called a cuticle, which is a protective layer secreted by the epidermal cells. Its main functions are to prevent water loss through transpiration and to protect the plant from sun damage. This is a crucial adaptation for survival in arid, desert environments where water is scarce.

Functions of the waxy cuticle

Reduces water loss: The cuticle is a water-resistant layer that helps seal the plant's surface, preventing water from evaporating from the stem and other parts.

Protects against UV radiation: It acts as a shield against the harmful effects of ultraviolet rays from the sun.

Provides insulation: The waxy layer can help regulate the cactus's temperature, protecting it from becoming too hot or too cold.

Shields the plant: It protects the plant from damage, including the effects of water droplets that could otherwise encourage decay.^[10-12]

How the cuticle works: The cuticle is composed of a substance called cutin (often referred to as chitin in some sources, though chitin is a polysaccharide found in fungi and arthropods, while cutin is a polymer of fatty acids that is the main component of the cuticle). It forms a barrier on the outside of the plant's cells. In some succulents, there is a powdery, waxy substance known as

farina, which is a type of cuticle that can be rubbed off with handling. Cactus plants, which grow in deserts, have a thick waxy coating that helps prevent water loss. The plants' sharp spines provide protection from predators. The plant cuticle is an extracellular hydrophobic layer that covers the aerial epidermis of all land plants, providing protection against desiccation and external environmental stresses. Cacti are found in the arid and semi-arid regions of India, primarily in the states of Rajasthan and Gujarat, and also in other dry areas like Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka. They are increasingly cultivated for various purposes, including animal fodder and as a boundary hedge in villages.

Geographic distribution

Primary occurrence: Cacti are most prevalent in the dry regions of Gujarat and the Thar Desert in Rajasthan.

Other regions: They are also found in other states with arid or semi-arid conditions, such as Madhya Pradesh, Andhra Pradesh, Maharashtra, and Karnataka.

Wider presence: Certain types, like euphorbias, are also found in southern states like Tamil Nadu.

Cultivation and use

Fodder: Cultivation of spineless cactus is used to provide food for livestock like goats, sheep, cattle, and buffaloes in arid and semi-arid areas, with plantations serving as nurseries for more planting material.

Hedge: Euphorbia cacti are often planted as a natural, spiny barrier to prevent animals from entering villages.

Research and development: There is ongoing research into the promotion of spineless cactus cultivation, with government initiatives supporting its use in watershed projects.



Figure 4: Cactus varieties [courtesy: Biodiversity Park, Ranchi].

Horticulture: Some individuals are also involved in collecting and selling a wide variety of cacti for their aesthetic and horticultural value.

Cacti are native to the Americas, with species found from Canada to South America, with Mexico having the most diverse populations. The only native cactus species to the Old World is *Rhipsalis baccifera*, which is found in parts of Africa and Sri Lanka. Many other cacti have been introduced by humans and have become naturalized or invasive in regions like Australia, South Africa, and the Mediterranean.

Native range

Americas: Cacti are native to the entire Western Hemisphere, from southern Canada to the tip of South America.

Most diversity: Mexico has the highest number of cactus species and genera.

Habitats: They grow in diverse environments, from deserts like the Sonoran and Mojave to grasslands and even tropical rainforests as epiphytes.

Old World occurrences

Rhipsalis baccifera: This is the only cactus species that is native to both the New World and the Old World

(Africa, Madagascar, and Sri Lanka). It is believed to have spread through means like migratory birds.

Introduced/Invasive species: Many species have been introduced by humans and have become established in other parts of the world, sometimes becoming invasive.

Australia: Has a large number of invasive species.

South Africa: Also has numerous invasive species.

Other regions: Introduced cacti are also found in Spain and other parts of the Mediterranean.

Pharmaceutical Importance

Cacti have pharmaceutical importance due to their antioxidant, anti-inflammatory, anti-diabetic, and antimicrobial properties, which stem from bioactive compounds like flavonoids and polysaccharides. They are used in traditional medicine and are being studied for modern pharmaceutical applications, with potential benefits for chronic diseases like diabetes, cardiovascular issues, and cancer. Some specific examples include their use in supplements to manage blood sugar and their potential for topical wound healing treatments.

- **Antioxidant and anti-inflammatory:** Cactus extracts are rich in antioxidants like flavonoids and betalains that protect cells from oxidative damage. They also exhibit anti-inflammatory effects, with some compounds helping to reduce inflammation markers in skin wound models.
- **Blood sugar control:** Studies suggest cactus preparations can help lower blood glucose levels, with some products showing promise for pre-diabetic individuals. This is attributed to the high fiber and fructan content.
- **Cardiovascular health:** The antioxidant and anti-inflammatory properties can contribute to cardiovascular health. Extracts have shown the ability to decrease cholesterol and triglyceride levels in animal studies.
- **Antimicrobial activity:** Various cactus extracts have demonstrated antimicrobial properties against bacteria like *Campylobacter* and *Vibrio cholerae*, and some potential antiviral activity against viruses like influenza A.
- **Neuroprotection:** Some research points to neuroprotective effects, possibly through antioxidant mechanisms, which could help in preventing neurodegenerative diseases.
- **Wound healing:** Cactus polysaccharides are being researched for their role in promoting wound healing by reducing inflammation and increasing the expression of growth factors.

Applications and future potential

- **Supplements:** Cactus is available in various supplement forms, such as capsules and powders, for dietary support.
- **Traditional medicine:** Many cacti have a long history of use in folk medicine to treat a variety of ailments, including burns, asthma, indigestion, and urinary tract infections.
- **Future research:** Ongoing research aims to provide

scientific evidence for traditional uses and to explore new applications in the food, cosmetic, and pharmaceutical industries.

- **Drug development:** The diverse range of bioactive compounds in cacti, such as saponins and phenolic compounds, makes them a promising source for the development of natural medicines.^[13-15]

CONCLUSION

Cacti have several special features for survival in dry environments: thick, waxy stems for water storage and reduced evaporation; modified leaves that are spines for protection and to provide shade; and a specialized root system, with shallow, widespread roots to capture rain, and sometimes deep roots to access groundwater. They also have other adaptations like sunken stomata and CAM photosynthesis, which allow them to perform photosynthesis at night to reduce water loss.

Water storage and retention: Thick, succulent stems: Stems are fleshy and expanded to store large amounts of water.

Waxy coating: A thick, waxy skin or cuticle on the stems helps prevent water loss through evaporation.

Protection and water loss reduction

Spines instead of leaves: Leaves are modified into sharp spines that deter animals from eating the stored water, reduce air flow, and provide shade.

Sunken stomata and night-blooming photosynthesis: Stomata, the pores on the plant, are often sunken and open at night to take in carbon dioxide while minimizing water loss during the hot day.

Water absorption: Shallow, widespread root systems: Roots spread out just below the surface to quickly absorb any rainfall.

Deep roots (in some species): Some cacti also have deep roots to tap into underground water sources.

Other features

Areoles: These are small, cushion-like structures on the plant's surface from which spines, flowers, and branches grow.

Dormancy: Some cacti can remain dormant for years, waiting for rain to fall before becoming active.

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