



Dragon Fruit and Beyond: Harnessing the Diversity of Cactaceae

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This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

The intensification of environmental stressors due to climate change has positioned the Cactaceae family as a vital frontier in sustainable, climate-resilient agriculture. These plants rely on Crassulacean Acid Metabolism (CAM), which confers exceptional water-use efficiency and allows them to match the yields of conventional crops while requiring significantly fewer inputs. Their structural adaptations, such as specialised succulent stems and areoles, enable survival in xeric landscapes. Several species, such as dragon fruit, prickly pear, and saguaro, possess notable nutritional and medicinal value owing to their high antioxidant and betalain content. Among these, dragon fruit has gained increasing importance among farmers worldwide, driven by its rising market demand, profitability, and suitability for cultivation on marginal lands. Genomic advances and innovative breeding strategies, such as polyploidy induction and light-based photoperiod management, highlight the importance of studies on this topic, particularly studies of their role in overcoming biological barriers such as self-incompatibility to enhance productivity. Despite ongoing challenges in post-harvest handling and market infrastructure, the integration of traditional knowledge with modern biotechnology

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positions Cactaceae fruit crops as essential tools for global food security and the economic resilience of rural communities in arid regions. This review explores the botanical diversity and economic potential of these "living jewels," with a primary focus on the global rise of dragon fruit as a commercially significant crop.

Keywords: *Cactaceae; dragon fruit; saguaro; prickly pear cactus; peruvian apple cactus.*

1. Introduction

A blend of resilience and beauty, the fruits of the Cactaceae family are living treasures shaped by nature. They are colourful gems, full of flavour and nutrition from the dry areas where they grow (Mizrahi *et al.*, 1996; Nobel, 2002). From the exotic dragon fruit (*Selenicereus* spp.) with its striking pink and white flesh sprinkled with tiny black seeds to the sweet and tangy prickly pear (*Opuntia ficus-indica*), these fruits offer a unique taste experience (Nerd, Tel-Zur, & Mizrahi, 2002; Paull & Duarte, 2012). They are rich in antioxidants, vitamins, and dietary fibre (Arivalagan *et al.*, 2021; Esquivel *et al.*, 2007). Cactaceae fruits not only excite the taste buds; they also support health and wellness, which makes them increasingly popular in global markets (Ali *et al.*, 2024; Stintzing & Carle, 2005). Their strength and distinctive beauty represent their desert origins, showing that even in tough conditions, life can thrive with remarkable variety and benefits. In recent decades, the domestication, genetic improvement, and worldwide spread of dragon fruit (*Selenicereus* spp.) have made it a crop of increasing importance in horticulture, nutrition, and commerce (Mizrahi, 2014; Tel-Zur, 2022).

Recent reviews have further documented the expanding cultivation and climate-resilient potential of dragon fruit and have summarised current production practices relevant to its sustainable management (Ali *et al.*, 2024; Pavan *et al.*, 2025).

Complementary evidence has also consolidated the nutritional and bioactive attributes of dragon fruit (Chen *et al.*, 2024).

Recent review literature has synthesised advances in dragon fruit production, nutraceutical attributes, and morphological characteristics (Lakshmeshwara *et al.*, 2024).

Recent propagation research has evaluated auxin treatments for improving shoot development and survival of dragon fruit stem cuttings, indicating the importance of nursery-stage management in crop establishment (Patel *et al.*, 2026).

However, the literature discussed in this manuscript addresses botanical diversity, fruit characteristics, cultivation, reproductive biology, nutritional importance, commercial potential, and production constraints largely as separate themes. An integrated synthesis that places dragon fruit within the wider diversity of edible Cactaceae is therefore needed to connect these themes and clarify the broader horticultural relevance of the family.

1.1 Objective of the Review

This review aims to synthesise current knowledge on the diversity, biology, cultivation, nutritional significance, commercial importance, constraints, and future prospects of edible Cactaceae fruit crops, with particular emphasis on dragon fruit.

2. Cactaceae

The Cactaceae family includes about 1,400 to 1,500 species in 130 to 190 genera. Most of these species are native to the Americas, especially Mexico and South America (Anderson, 2001; Barthlott *et al.*, 2015; Hunt *et al.*, 2006; Nyffeler & Eggli, 2010). The genus *Rhipsalis* is the only cactus found naturally outside the Americas; it likely spread to Africa and parts of Asia through birds (Anderson, 2001; Nyffeler, 2002). Key diversity centres such as the Chihuahuan and Sonoran Deserts exhibit high levels of endemism and evolutionary diversity (Hernández & Bárcenas, 1995; Ortega-Baes & Godínez-Alvarez, 2006).

Cactaceae show various growth forms, including globose, columnar, shrubby, epiphytic, and climbing forms, and display strong ecological adaptability (Hunt *et al.*, 2006; Nobel, 2002). Their leaves are reduced, and photosynthesis occurs mainly in succulent stems that store water. The areole is a key feature that produces spines, flowers, and fruits. Pollination by bats, birds, and bees, as well as self-pollination, supports successful reproduction in dry and semi-dry environments (Nobel, 2002; Valiente-Banuet *et al.*, 1997).

3. Different Fruits of Cactaceae Family

The Cactaceae family comprises a diverse range of edible fruits with considerable nutritional, ecological, and economic importance. These fruits vary widely in size, shape, colour, flavour, and biochemical composition among different genera and species. Major edible fruits of Cactaceae, including dragon fruit, prickly pear, saguaro, organ pipe cactus, and Peruvian apple cactus, are presented in Fig. 1.

1. Dragon Fruit

The dragon fruit (*Selenicereus* spp.), commonly known as "Queen of the Night," is an economically important cactus crop originating in Mexico and Central America, with Southeast Asia serving as a major secondary centre of cultivation (Mizrahi *et al.*, 1996; Nobel, 2002; Mizrahi, 2014). It is diploid ($2n = 22$) and is named for its nocturnal flowering habit (*Selene* = moon) (Lichtenzweig *et al.*, 2000; Wu *et al.*, 2006). The fruit possesses a thick, brightly coloured scaly rind resembling a dragon, which inspired its common name (Wu *et al.*, 2006; Hunt *et al.*, 2006). Dragon fruit nomenclature has undergone taxonomic revision, with species formerly classified under *Hylocereus* now generally placed in *Selenicereus*. This review follows the currently accepted *Selenicereus* nomenclature while retaining *Hylocereus* when referring to earlier studies. The tribe *Selenicereus* includes

morphologically diverse species that are represented in Table 1 (Crane & Balerdi, 2005). This diversity reflects the wide structural variation within climbing and columnar cacti associated with dragon fruit and related taxa (Nobel, 2002; Mizrahi, 2014).

Table 1. Taxonomic behaviors of dragon fruit

Type	Species	Colour	
		Peel	Pulp
Climbing type	<i>Selenicereus undatus</i>	Red	White
	<i>Selenicereus triangularis</i>	Yellow	White
	<i>Selenicereus costaricensis</i>	Red	Red
	<i>Selenicereus polyrhizus</i>	Red	Red
	<i>Selenicereus ocamponis</i>	Red	Red
	<i>Selenicereus megalanthus</i>	Yellow	White
Columnar type	<i>Cereus triangularis</i>	Yellow	White
	<i>Acanthocereus pitajaya</i>	Yellow	White
	<i>Cereus ocamponis</i>	Red	Red

3.1 Major Species of Dragon Fruit

While there are many varieties, most commercially grown dragon fruits belong to a few key species, primarily differentiated by their skin and flesh colour.

A. *Selenicereus undatus* (Haworth) Britton and Rose

White-fleshed pitaya, also known as strawberry pear (*Selenicereus undatus*), is the most widely grown species of dragon fruit (Mizrahi *et al.*, 1996; Paull & Duarte, 2012). It features bright pink to red skin with green scales and white, translucent flesh filled with many small black edible seeds (Hoa *et al.*, 2006; Nerd *et al.*, 1999). The fruit has a mildly sweet taste, often compared to a mix of kiwi and pear (Paull & Duarte, 2012). Because of its appealing appearance, broad consumer acceptance, and ability to grow in tropical and subtropical climates, it is widely cultivated around the world and is an important dragon fruit species in India (Arivalagan *et al.*, 2021; Wakchaure *et al.*, 2020).

B. *Selenicereus polyrhizus* (F.A.C. Weber)

Red-fleshed pitaya has pink to red skin and deep red to magenta flesh filled with small black seeds. The intensity of the colour varies among different varieties (Nerd, Tel-Zur, & Mizrahi, 2002; Hunt *et al.*, 2006). Generally, it is sweeter and more flavourful than white-fleshed pitaya (*Selenicereus undatus*) (Mizrahi *et al.*, 1996; Paull & Duarte, 2012). The red colour comes from high levels of betalains and lycopene, which provide strong antioxidant benefits and nutritional value (Stintzing & Carle, 2005; Wu *et al.*, 2006). Because of its appealing colour and health benefits, the cultivation of and demand for red-fleshed pitaya are increasing in India and other tropical and subtropical areas (Mizrahi, 2014; Arivalagan *et al.*, 2021).

C. *Selenicereus costaricensis* (F.A.C. Weber)

Costa Rican or purple-fleshed pitaya is characterised by pink to red peel and deep violet-red to purple pulp (Hunt *et al.*, 2006; Mizrahi *et al.*, 1996). It is recognised for its relatively high soluble solids content and rich, berry-like flavour profile (Nerd *et al.*, 1999; Paull & Duarte, 2012). The intense pigmentation is attributed to high betalain content, contributing to strong antioxidant capacity and nutritional value (Stintzing & Carle, 2005; Wu *et al.*, 2006). Owing to its attractive colour, sensory quality, and health-promoting properties, its commercial cultivation is expanding in India and other tropical regions (Mizrahi, 2014; Arivalagan *et al.*, 2021).

D. *Selenicereus megalanthus* (K. Schum)

Yellow pitaya, also known as yellow dragon fruit, has bright yellow skin with small, soft spines that fall off when the fruit ripens. Inside, it contains white pulp filled with many black seeds (Hunt *et al.*, 2006; Mizrahi *et al.*, 1996). It is often considered the sweetest type of cultivated dragon fruit owing to its high sugar content and unique tropical taste (Nerd *et al.*, 1999; Paull & Duarte, 2012).

E. *Selenicereus stenopterus*

Selenicereus stenopterus is a climbing cactus known for its sweet, mildly flavoured pinkish-red fruit and large white flowers that bloom at night (Hunt, 2017; Mizrahi *et al.*, 1996). The star-shaped blooms are 8 to 10 inches long. They have slightly curved tubes, purplish linear bracts with white edges, short stamens, and a prominent white style. In addition to its use as food, the species is also believed to have medicinal benefits (Nobel, 2002; Crane & Balerdi, 2005).

F. *Selenicereus anthonyanus* (Alexander)

Selenicereus anthonyanus, known as the fishbone cactus, zig-zag cactus, or orchid cactus, is a popular houseplant. It stands out for its decorative stems (Anderson, 2001; Hunt *et al.*, 2006; Nyffeler & Eggli, 2010). The stems are said to have anti-inflammatory and pain-relieving effects. They are traditionally used to support skin health and ease joint pain (Mizrahi *et al.*, 1996). This plant thrives in well-drained potting soil, making it easy for hobbyists and indoor gardening enthusiasts to grow indoors (Crane & Balerdi, 2005).

G. *Selenicereus flagelliformis* (L.)

Selenicereus flagelliformis, also known as rat's tail or whip cactus, produces red to purplish-pink flowers that grow on the sides of the plant. These flowers are 5 to 8 cm long and bloom in mid to late spring, lasting for several days (Hunt *et al.*, 2006; Anderson, 2001). The fruit is small, round, red, and bristled, measuring about 10 to 12 mm long. It contains yellowish pulp and oval brownish-red seeds. The species is appreciated for its ornamental beauty and edible fruit (Mizrahi *et al.*, 1996; Nobel, 2002).

3.2 Growing Conditions and Phenological Stages of Dragon Fruit

Dragon fruit (*Selenicereus* spp.) grows well in tropical and subtropical areas with annual rainfall between 1,100 and 2,500 mm and temperatures ranging from 20 to 29 °C. It can tolerate short-term temperature extremes of 0 to 40 °C (Nerd, Sitrit, *et al.*, 2002; Nobel, 2002). Sandy loam soils rich in organic matter are most suitable. The use of vermicompost-based propagation media improves the rooting and survival rates of stem cuttings (Anagha *et al.*, 2025; Mizrahi *et al.*, 1996). For planting, stem cuttings are often treated with IBA (Singh & Kaur, 2024). The plants are typically trained on trellis systems with a spacing of 3 m × 3 m. They usually begin producing flowers and fruit within 1 to 2 years (Crane & Balerdi, 2005). In Kerala, types with purple and dark pink flesh (*Selenicereus costaricensis*) are most common. They flower from March to October and fruit from April to November, with harvest taking place about 23 to 25 days after fruit set (Sethunath *et al.*, 2023). As the fruit matures, the peel and pulp colours become more vibrant. Betalain content peaks at maturity, while fruit weight increases and peel firmness decreases. Antioxidant activity is highest early on, providing useful indicators for determining when to harvest (Shameena *et al.*, 2024).

3.3 Reproductive Biology and Flowering Management in Dragon Fruit

Dragon fruit (*Selenicereus* spp.) produces large, fragrant flowers that bloom at night and attract pollinators such as bats and moths (Valiente-Banuet *et al.*, 1997; Nobel, 2002). Many commercial varieties are partially or completely unable to self-fertilise. They require cross-pollination with different plants to produce fruit effectively (Mizrahi *et al.*, 1996; Crane & Balerdi, 2005). Natural pollination is often insufficient, so growers commonly use hand pollination to ensure high yields, consistent fruit quality, and dependable harvests (Crane & Balerdi, 2005; Paull & Duarte, 2012).

3.4 Self-incompatibility

Self-incompatibility (SI) in dragon fruit (*Selenicereus* spp.) limits fruit set. It requires cross-pollination for effective fertilisation (Lichtenzweig *et al.*, 2000; Mizrahi *et al.*, 1996). Transcriptome studies show that SI involves complex interactions between pollen and pistil. Thousands of genes show differential expression during self- and cross-pollination (Li *et al.*, 2022). Key genes related to recognition, signalling, hormone regulation, and programmed cell death, such as S-RNase and F-box, play important roles in SI responses. Pathways such as ubiquitin-mediated proteolysis and plant-pathogen interactions are closely linked to self-pollination responses. These findings offer a molecular basis for understanding reproductive barriers. They also inform breeding strategies, hybrid development, and pollination management to improve fruit set and yield in commercial dragon fruit cultivation (Nobel, 2002; Paull & Duarte, 2012).

3.5 Artificial Pollination

Artificial pollination in dragon fruit (*Selenicereus* spp.) helps to improve fruit set, particularly in self-sterile or poorly pollinated varieties (Crane & Balerdi, 2005; Mizrahi *et al.*, 1996). The process includes bagging unopened flowers, collecting fresh pollen from compatible donor plants, and transferring it to the stigma with a brush or swab. After pollination, flowers are re-bagged to avoid contamination, and fruit development is monitored as a sign of success. Fresh pollen is preferred, but stored pollen can be used when flowering times do not overlap (Jadhav *et al.*, 2025; Paull & Duarte, 2012; Crane & Balerdi, 2005).

3.6 Off-season Dragon Fruit Production through Artificial Lighting

Rashid *et al.* (2021) studied the impact of artificial night-breaking with LED and incandescent bulbs on off-season flowering and fruiting in red-fleshed dragon fruit (*Selenicereus* spp.) in Bangladesh. They exposed eight-year-old plants to either 6, 8, or 10 hours of artificial light for 74 days. The results indicated that 6 hours of lighting with 100 W incandescent bulbs resulted in the highest number of buds and fruits, as well as larger fruit size and total yield (19.85 t/ha). In contrast, control plants without lighting did not flower owing to the short natural day length. These findings show that extending the photoperiod can effectively increase off-season dragon fruit production, increasing yield, market availability, and grower profitability (Paull & Duarte, 2012; Rashid *et al.*, 2021).

3.7 Approaches to Improving Dragon Fruit Quality

Sweetness, largely determined by soluble sugar content, is a key quality trait in pitaya (*Selenicereus undatus*) fruit. Glucose, fructose, and sucrose are the primary sugars, influencing not only flavour but also the synthesis of amino acids, pigments, and vitamins, which drive consumer preference (Pott *et al.*, 2020; Ma *et al.*, 2017; Yamaki, 2010). Recent studies have highlighted the role of two Dof transcription factors, HpDof1.7 and HpDof5.4, in regulating sugar accumulation in pitaya (Mou *et al.*, 2022). These TFs bind specific cis-elements in the promoters of sugar metabolism-related genes, including HpSuSy1, HpINV2, HpTMT2, and HpSWEET14, thereby activating their transcription and promoting sugar synthesis, transport, and metabolism. Expression analyses showed that HpSuSy1 and HpINV2 peaked during mid-maturation (27–35 DPA), while HpTMT2 and HpSWEET14 increased sharply at later stages (32–35 DPA), correlating with the accumulation of glucose and fructose. These findings identify valuable targets for breeding pitaya varieties with enhanced or balanced sugar content, improving fruit taste and consumer appeal.

Chromosome manipulation has been explored to improve dragon fruit (*Selenicereus* spp.) traits. Hybridisation between *S. undatus*, *S. polyrhizus*, and *S. megalanthus* can combine large, attractive fruits with sweeter, smaller yellow fruits, but differences in ploidy

(diploid $2n = 22$ vs. tetraploid $2n = 44$) create challenges (Tel-Zur *et al.*, 2003; Nobel, 2002). Pollen analyses show uniform diploid grains and larger, variable tetraploid grains, indicating unreduced gametes (den Nijs & Peloquin, 1977). Crosses produce triploid, pentaploid, hexaploid, and aneuploid hybrids, suggesting post-zygotic chromosome doubling. Inducing polyploidy at early stages can thus enhance fruit size, sweetness, and appearance, supporting the breeding of superior varieties (Tel-Zur *et al.*, 2003; Mizrahi *et al.*, 1996).

4. Prickly Pear Cactus

Opuntia ficus-indica L., or prickly pear, is well suited to arid and semi-arid regions because it can tolerate harsh environmental conditions (Bakar *et al.*, 2020; Nobel, 2002; Russell & Felker, 1987). The plant exhibits considerable genetic variation, featuring flattened, fleshy cladodes that have a thick outer layer and small spines called glochids. Its fruits are edible, sweet, and mildly acidic, with weights ranging from 43 to 220 g. Their skin colours vary from green to red-purple, depending on ripeness (Sabtain *et al.*, 2021). Nutritionally, prickly pear is high in dietary fibre, vitamins C, A, and K, essential minerals such as magnesium, potassium, and calcium, and antioxidants such as flavonoids and betalains. These compounds help reduce oxidative stress and inflammation (Hfaiedh *et al.*, 2008; Sabtain *et al.*, 2021). Research indicates that cladodes can lower blood glucose and insulin levels. In contrast, the effects of the fruit on blood sugar control are less clear (Gouws *et al.*, 2019). Other studies suggest possible benefits for weight management, liver health, and metabolic health, but more well-designed clinical trials are necessary to verify these effects (Hfaiedh *et al.*, 2008; Nobel, 2002).

5. Saguaro - *Carnegiea gigantea* (Engelm.) Britton and Rose

The saguaro (*Carnegiea gigantea*) is a large, tree-like cactus found in the Sonoran Desert across Arizona, California, and Mexico. It can grow over 12 metres tall (Nobel, 2002; Turner *et al.*, 1995). The cactus produces white flowers at night from late April to early June, mainly pollinated by bats. It also develops red, juicy fruits from late June to July, which are high in vitamin C, dietary fibre, and hydration (Nobel, 2002). Ecologically, saguaros are key species. They provide food, water, and nesting sites for birds such as woodpeckers, elf owls, and purple martins, as well as mammals such as tortoises, javelinas, and coyotes. Saguaro “boots,” created from empty woodpecker holes, were historically used by Indigenous peoples as water containers and storage vessels. This illustrates their cultural and ecological significance (Turner *et al.*, 1995).

6. Organ Pipe Cactus - *Stenocereus thurberi* (Engelm.) Buxb.

The Organ Pipe Cactus (*Stenocereus thurberi*) is native to Sonora, Baja California, and southern Arizona, including areas protected within the Organ Pipe Cactus National Monument, a UNESCO biosphere reserve (Turner *et al.*, 1995; Nobel, 2002). It grows in tall, multi-stemmed, candelabra-like forms up to 8 metres high, with ribbed, spiny stems. Its large, nocturnal flowers are primarily pollinated by nectar-feeding bats and produce sweet red fruits called pitaya dulce (Nobel, 2002).

Culturally, the O’odham people (“chuhuis”) use its fruit for syrup, wine, preserves, and medicine, and its woody ribs for construction. Ecologically, young plants rely on nurse trees for shade, emphasising its role in the Sonoran Desert ecosystem (Turner *et al.*, 1995).

7. Peruvian Apple Cactus (*Cereus repandus* (L.))

The Peruvian Apple Cactus (*Cereus repandus*), also known as *Cereus peruvianus*, is a tall, columnar cactus that grows naturally in South America, specifically in Argentina, Uruguay, and Brazil, as well as in parts of Central America and the Caribbean (Nobel, 2002; Anderson, 2001). It can reach a height of up to 10 metres and produces large, fragrant white flowers that bloom at night and attract bats and moths. The edible fruits, called “Peruvian apples” or pitahayas, are round to oval, thornless, and prized for their sweet, mild flavour and nutritional benefits, which include vitamins and antioxidants (Nobel, 2002).

Ecologically, the cactus plays a role in supporting wildlife by providing food for birds, small mammals, and insects, especially during the dry season. It also has ornamental and practical uses. Its wood is used in construction, while the fruits and other parts of the plant have been used in traditional medicine (Anderson, 2001).

8. Lemon Vine *Pereskia aculeata* Mill.

Pereskia aculeata, commonly called lemon vine, is a scrambling shrub belonging to the family Cactaceae and is considered one of the most primitive members of the cactus lineage because it retains well-developed leaves (Almeida *et al.*, 2014; Santos *et al.*, 2012). Commonly known as Barbados gooseberry, blade-apple cactus, leaf cactus, rose cactus, and lemon vine, the species is native to tropical regions of the Americas and has been widely introduced to other tropical and subtropical regions (Takeiti *et al.*, 2009; Pinto *et al.*, 2015). Unlike most cacti, *P. aculeata* exhibits a climbing or scrambling growth habit with woody stems, persistent leaves, and thorny branches (Almeida & Corrêa, 2012). The plant produces small, white, fragrant flowers followed by edible yellow to orange berries (D. O. Silva *et al.*, 2018).

The leaves and fruits are highly nutritious, containing significant amounts of protein, dietary fibre, minerals such as iron and calcium, and several vitamins, making the species valuable as an unconventional leafy vegetable (Takeiti *et al.*, 2009; Agostini-Costa *et al.*, 2012). In Brazil, particularly in the state of Minas Gerais, it is popularly known as “ora-pro-nóbis” and is traditionally used in soups, stews, and other regional dishes because of its high nutritional value (Almeida *et al.*, 2014). Studies have also reported antioxidant, anti-inflammatory, and antimicrobial activities in the leaves owing to the presence of bioactive compounds such as phenolics, flavonoids, and mucilage (Pinto *et al.*, 2015; D. O. Silva *et al.*, 2018). Owing to these nutritional and pharmacological properties, *P. aculeata* has attracted increasing interest as a potential source of functional food ingredients and is

also used in agroforestry systems and as a natural hedge because of its vigorous and thorny growth habit (Almeida & Corrêa, 2012; Pinto *et al.*, 2015).

9. *Mammillaria polythele*

Mammillaria polythele is a cylindrical cactus native to Mexico. It can grow up to 60 cm tall and has dark green to blue-green stems covered in conical tubercles with clusters of pale to reddish-brown spines. In summer, it produces rose to pinkish-purple flowers near the top of the stem. These are followed by small red, chilli-shaped edible fruits called “chilitos,” which have a mild citrus flavour (Breslin *et al.*, 2021; Anderson, 2001).

The genus *Mammillaria* is highly diverse and occurs mainly in Mexico. It features spirally arranged tubercles, different types of areoles, and shallow, spreading roots that help it thrive in dry environments. The fruits from this genus contain bioactive compounds such as betalains, phenolics, flavonoids, alkaloids, sterols, saponins, and coumarins, along with sugars that contribute to flavour (Breslin *et al.*, 2021). Although few studies have specifically examined *M. polythele*, related species suggest that it has similar nutritional and functional benefits.

10. *Pilosocereus gounellei* (A. Weber ex K. Schum)

Pilosocereus gounellei, commonly known as “Xique-Xique,” is a columnar cactus found in Northeast Brazil. It can grow up to 4 metres tall and has a main stem with branches that resemble candelabra arms. The stems are olive to blue-green and covered in golden spines. This plant blooms at night, producing white, funnel-shaped flowers in the spring or autumn. After blooming, it bears small, pumpkin-like fruits. It thrives in the dry, rocky areas of the Caatinga biome and can tolerate drought well (A. A. Silva *et al.*, 2018; Anderson, 2001). Nutritionally, *P. gounellei* is rich in dietary fibre and essential minerals, including potassium, calcium, magnesium, and manganese. Studies indicate that its extracts can improve lipid profiles and glucose tolerance in cases of diet-induced obesity (A. A. Silva *et al.*, 2018).

11. *Acanthocereus*

The genus *Acanthocereus* includes species such as *Acanthocereus tetragonus* (Triangle Cactus), a tall columnar cactus that grows 2–7 metres high and has dark green stems with 3–5 angled ribs, spiny grey areoles, and nocturnal white flowers that attract hummingbird moths. It occurs across Florida, Texas, Mexico, Central America, and South America, is prized for its sweet, edible red fruits, and forms dense thickets in coastal areas (Anderson, 2001). The genus also includes *Acanthocereus tepalcatepecanus*, a caudex-forming cactus native to dry regions of Mexico, with purplish-grey stems, showy flowers, and edible globose to tubular reddish fruits; it is currently listed as Vulnerable on the IUCN Red List owing to habitat pressures (Anderson, 2001).

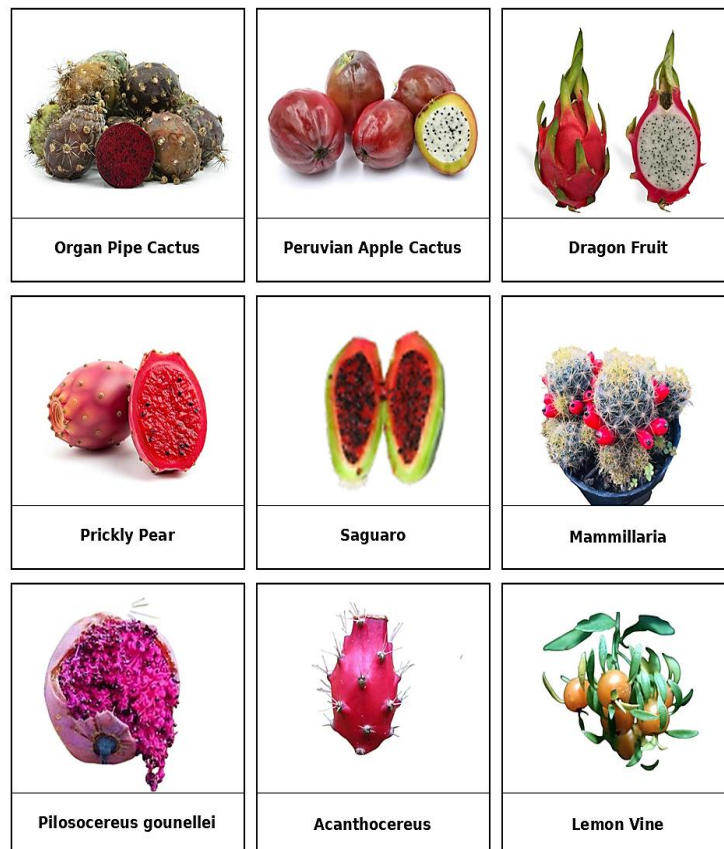


Fig. 1. Different fruits of cactaceae family

12. Importance of Cactaceae Fruit Crops

Climate change threatens food security, farm productivity, and income. This increases the need for climate-resilient crops (Food and Agriculture Organization of the United Nations, 2015). Fruit crops from the Cactaceae family are emerging as climate-smart options that can grow under limited water availability and harsh conditions (Nobel, 2002). This family includes key fruit species that thrive in arid and semi-arid regions, especially *Opuntia ficus-indica* (prickly pear) and *Selenicereus* spp. (Hunt et al., 2006; Mizrahi, 2014). Their Crassulacean Acid Metabolism (CAM) improves water-use efficiency and productivity during drought and heat stress. Cactus pear can yield as much as traditional crops while using significantly less water (Galizzi et al., 2004; Nobel, 2002). In addition to being climate-resilient, these crops offer environmental, nutritional, and economic benefits. Their growth aids land restoration, controls erosion, and captures carbon (Nobel, 2002; Ortega-Baes & Godínez-Alvarez, 2006).

The fruits are high in vitamin C, carotenoids, dietary fibre, and antioxidants such as betalains, which help reduce inflammation and manage blood sugar levels (Stintzing & Carle, 2005; Arivalagan et al., 2021; Monteiro et al., 2023; Shetty et al., 2012). Economically, cactus fruits provide income opportunities and diversify markets, enhancing rural livelihoods (Mizrahi, 2014; Bouazizi et al., 2020). In summary, Cactaceae fruit crops serve as sustainable, climate-adaptive resources for resilient agricultural and food systems.

13. Challenges in the Commercial Cultivation of Cactaceae Fruit Crops

Commercial cultivation of Cactaceae fruit crops faces major environmental and production challenges. Poor soil quality, high salinity, and limited water availability in arid regions reduce productivity and contribute to low yields. Pest and weed management is difficult, with invasive species and limited biological control options requiring less effective chemical and cultural methods (Humphries et al., 2022). Post-harvest losses are significant owing to the fruits' delicate nature, complicating storage and transport. Market growth is constrained by weak infrastructure, limited financing, and low consumer awareness. Industrial processing is hindered by costly technologies, low efficiency, and poor product standardisation (Corrales-García, 2009; Mondragón-Jacobo et al., 2009).

14. Future Thrust

Future prospects for Cactaceae fruit cultivation are favourable. This is due to their natural ability to thrive in dry and semi-dry climates and their various uses in food, animal feed, cosmetics, and medicine. Species such as *Opuntia ficus-indica*, or prickly pear, are becoming popular for their drought resistance, high water-use efficiency, and nutritional benefits. Recent advances combining traditional breeding methods with molecular tools, such as gene mapping, marker-assisted selection, and functional genomics, are helping to improve fruit quality, yield, and resistance to stress (Chen et al., 2021).

In India, especially in dry areas such as Gujarat, cactus cultivation shows promise for improving livelihoods through fruit processing and animal feed production. Organisations such as the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Indian Council of Agricultural Research encourage cactus farming on degraded lands to improve water use and diversify farm income (International Center for Agricultural Research in the Dry Areas, 2025).

Despite these encouraging developments, challenges still exist in standardised farming practices, post-harvest management, value chain development, and economic assessments. Future efforts should focus on genetic improvement, sustainable farming methods, product diversification, and stronger market linkages to establish cactus fruits as resilient crops for dryland farming.

15. Conclusion

The exploration of dragon fruit and other edible Cactaceae fruits represents an important advancement in sustainable horticulture and functional food research. Their adaptability to arid and semi-arid environments makes them promising crops for food security and income generation in regions affected by climate change, water scarcity, and soil degradation. Recent research on Cactaceae fruits, including prickly pear (*Opuntia ficus-indica*) and other species, demonstrates their potential beyond traditional consumption, particularly as sources of valuable bioactive compounds. Phenolics and betalains present in cactus fruits and cladodes exhibit strong antioxidant and anti-inflammatory activities, with promising potential for anticancer applications. Their distinctive biochemical profiles also offer opportunities as authenticity markers in food processing, supporting improved quality control, traceability, and functional food innovation. Future research should prioritise the development of effective post-harvest storage and processing technologies to extend shelf life while preserving nutritional and bioactive compounds, alongside the evaluation and breeding of high-yielding, climate-resilient cultivars specifically adapted to the tropical and subtropical conditions of India.

16. Limitation

As a narrative review, this manuscript synthesises findings from diverse Cactaceae species, production environments, and study designs; therefore, direct comparison across crops and locations is limited. Evidence is more extensive for dragon fruit and prickly pear than for several less-studied edible cacti, which restricts the depth of species-level conclusions. Reported nutritional, reproductive, and agronomic responses may also vary with genotype, climate, management, maturity stage, and analytical method. Accordingly, the review should be interpreted as an integrated overview of current evidence rather than a quantitative comparison of all edible Cactaceae.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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