GSC Biological and Pharmaceutical Sciences

eISSN: 2581-3250 CODEN (USA): GBPSC2

Cross Ref DOI: 10.30574/gscbps

Journal homepage: https://gsconlinepress.com/journals/gscbps/

(Review Article)

Botany and uses of cacti

Domenico Prisa *

CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Researchand Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.

GSC Biological and Pharmaceutical Sciences, 2022, 21(01), 287–297

Publication history: Received on 19 September 2022; revised on 25 October 2022; accepted on 27 October 2022

Article DOI: https://doi.org/10.30574/gscbps.2022.21.1.0405

Abstract

In common parlance, succulents are all fleshy plants with swollen stems and leaves. Instead, it would be more correct to use the term succulent, as their characteristic feature is that they have succulent tissue inside them, i.e. a soft, spongy fleshiness saturated with water that produces a typical swelling in the plant. Usually, the swelling of the plant is in the aerial parts, i.e. the stem and leaves. There are, however, some cases of succulence at the roots and intermediate variants with succulence distributed in the leaves, stem and roots simultaneously. These plants represent a world apart in terms of their characteristics, resistance, vegetative behaviour, flowering and many other features. In this review, we would like to describe some aspects of these plants that make them as strange as they are extraordinary.

Keywords: Cactus; Flower cactus; Sustainable agriculture; Ornamental plants; Climate change

1. Introduction

1.1. The Cactaceae

The fascination with cacti is as mysterious as their origins, as multifaceted as the plants themselves, and it intensifies as one deepens one's knowledge of them. The most prominent family of succulent plants, with more than 2000 species, is considered, in systematics, to be remarkably ancient. Although very few fossils of succulents remain to tell us about their history, one has been found of a strange plant, very similar to a modern *Consolea*, in Utah, dated to approximately 50 to 35 million years ago [1]. This plant, called Eopuntia, is the only trace that allows us to go back to a time before the four great ice ages, which saw the appearance and evolution of man, and raises the big question of what were the upheavals in the earth's crust that led to such different adaptations in plants that have retained their botanical characters [2]. Taking a leap and arriving at a date that seems almost insignificant compared to the previous ones, we know that between 35,000 and 10,000 years ago, North America was joined to Asia by an isthmus that existed in the place of what is now the Bering Strait, a land bridge, as geographers called it, that narrowed and widened as glacial periods gave way to a milder climate, and that through this bridge animals and humans descended into the valley carved out of the ice towards the south [3,4]. Fossils of the former and the oldest settlements of the latter, dating back 15,000 years, have been found in New Mexico. Perhaps across the same bridge, new forms of *Cactaceae* arrived from Asia, which then had to adapt to the arid climate [5]. Botanists have adopted a classification that takes into account not only the affinities of the various genera but also their presumed temporal development. This classification comprises four categories:

- Plants that still have leaves despite family-specific characters;
- Plants that show leaves but almost always lose them quickly;

* Corresponding author: Domenico Prisa
CREA Research Centre for Vegetable and Ornamental Crops, Council for Agricultural Researchand Economics, Via dei Fiori 8, 51012 Pescia, PT, Italy.

- Plants with rudimentary leaves reduced to scales or on which leaves do not show at all;
- Plants with leaf-like stems (cladodes), epiphytes or semi-epiphytes.

However, this is not necessarily the case for cacti; instead, there was no simultaneous adaptation to different climates. The fact is that the mystery remains as to how and why, in a family that appears exclusively in the Americas, there is a species of the genus *Rhipsalis* that occurs wild in equatorial Africa, Madagascar, the Mascarene Islands and Ceylon. The assumption that these are introduced plants is not very convincing because, if it is true of many tropical plants, they have always been ornamental plants or plants of economic importance. It is unclear who could have introduced epiphytes to trees in tropical forests, nor, if by chance they escaped cultivation, why they were planted in those particular places, which form almost a belt towards Asia or, conversely, Asian forests towards Africa [6,7]. However, a subdivision of the different types cannot be dispensed with a description of the whole family. All *Cactaceae* are xerophytes, plants that tend to reduce the surface area subject to transpiration and water accumulation in the tissues. All the members of the family also have a particular characteristic that distinguishes them from any other concerning the emission of secondary vegetative parts: whatever the shape of the plant and in whatever position they may be placed, there are formations, which are called areoles and replace the normal nodes of the other plants, on which buds form, giving rise to leaves or flowers, and where, at the base of the leaves, with or without appendages, called stipules, a second bud forms, giving rise to new branches [8,9]. On the areoles, hairs, thorns, spines and bristles form, taking the place of all standard elements: the hairs and bristles replace the small protective scales of the regular bud; the thorns are stipules or modified leaves; the new branches are made up of segments joined at the base by a little knot, take the name of articles. Since the entire surface of the areola replaces the node, the flowering buds are superior to those with spines and generally coexist with them. However, in some species, the flowering areolae are different from the others, and in several genera, they are more or less spaced apart. This set of organs also has another peculiarity: whereas, for example, if a thorn of *Euphorbia* is detached, the tissues are injured since it is part of them, in cacti, the thorns are superficial productions not connected with the underlying tissues [10].

2. Cactus structures

In cacti, the various plant parts are highly specialized and structured to survive in extreme water and thermal environments.

2.1. Roots and Stems

The roots may be pretty shallow, although they extend very widely, or they may be taproots, sometimes swollen in the shape of a carrot, and constitute an accumulation of reserves. This is especially the case in small cacti in highly arid areas in which the reduced stem corresponds to an abnormally large root system; in some species, this reserve is cautiously divided, and the root takes shape similar to the legs of a dahlia so that if one part dries out, the others can continue to function [11].

The stem is woody in the persistent-leaved type and changes in the others, taking over all exchanges with the atmosphere and the chlorophyll function. Its shape can then be cylindrical, semi-cylindrical or globular to reduce the transpiration surface; the presence of spines also limits the latter, bristles and hairiness that, when it is very pronounced, maintains a layer of air close to the epidermal tissues and at the same time defends them both from the cold and the incidence of powerful ultraviolet rays [12]. This form of protection is particularly conspicuous at the top of the stem or at its apex, where the tissues are most delicate and where flowers generally form. The area known as the cephalium is very conspicuous in columnar forms with a solid production of bristles and hairs because it is densely covered with them and is particularly conspicuous in the genus *Melocactus*, which develops a particular structure that even seems to overlap the apex, densely covered with hairs and bristles, even coloured ones, between which the flower buds form. The characteristic rounded shape of stems and articles, whatever their length, allows the sun's rays, which only briefly hit a particular spot, to rotate, and minimal permanent exposure to the north [13]. In many species, over time, the base of the stem seems to lignify, but this is never natural wood but rather spongy tissues that harden and between which the vessels continue to pass, protected by a surface that we say is suberose, in fact much more similar in structure to cork than to natural bark. Sometimes the tissues of the stems grow in an abnormal form, or the articles grow together along their entire length or nearly so, distorting, fanning out or flexing as they grow. This phenomenon, known as fasciation, gives rise to so-called 'monstrosities', much sought after by collectors, and can occur for various causes, both physical and bacteriological, and is not only not hereditary but can also regress. Generally, monstrous forms are grafted because, except for concrete plants such as *Cereus*, they live precariously on their roots or reversion to the typical type [14].

2.2. Leaves, flowers and fruits

The leaves of the cacti are only persistent in the first category, comprising only the genus *Pereskia* (Fig. 1), which is considered a transitional form between typical plants and xerophytes; the stem is equipped with normal areolae, also very spiny, on which the more or less petiolate leaves appear in, the lower part, while new branches start from their axils [15]. In the second category, represented by the *Opuntiaeae*, one genus still has more or less persistent leaves. However, in the others, they are usually small, fall off very early and do not perform any assimilatory function, functions now all delegated to the stem. Moreover, in all genera, the areoles are equipped with minute, hooked bristles, the glochids, which are very annoying and painful because they get under the skin even at the slightest touch; they do not appear in any other type of the family [16,17,18]. Finally, the leaves are rudimentary, reduced to scales, and often very minute or absent in the cacti of the other two categories. What remains of them is an expansion of the leaf base, which, welded together with the others in successions of various kinds, forms what we call ribs or tubercles, and on which the areoles are formed [19]. These often appear at the apex, but in some genera, particularly in *Mammillaria* (Fig. 2), flowers and articles arise in a thornless areola that appears at the base of the tubercle (axil).

In contrast, the one at its apex remains detached from the vegetative functions. In other genera, on the other hand, a connection still exists because, despite appearing to be separate, the two areolae are an extension of each other and are connected by a very thin groove. In this case, new articles may also appear at the apex of the tubercle [20,21].

The flowers are usually solitary (Fig. 3), and in the perianth, there is no clear distinction between calyx and corolla, but rather a gradual transition between sepaloid and petaloid leaves, spirally arranged and often fused at the base or joined to form a tube of varying shape and length. They may be oval, lanceolate, obtuse, acuminate, toothed and even jagged; their colour varies from white to yellow, red and purple, but the outer sepals may be greenish or brownish [22,23]. The flowers are almost always regular, and the perianth is inserted at the apex of the ovary, which is usually round or oval (in some species, it becomes elongated when ripe) and almost always furnished with areoles, scales, spines or hairs [24]. The stamens are always numerous, with long filaments, and the pistil maybe even longer, with the stigma often stellate and sometimes coloured. Some genera have sensitive stamens: when touched by an insect or even a finger, they move and close over the pistil to rise again a few minutes later. In general, the experiment can only be done when the flower is open in full sun, as almost all genera have flowers that close if the sun does not shine directly on them; they even close if the sky becomes cloudy, to reopen when the clouds have passed [25,26].

The fruit is almost entirely a berry with several or many seeds, rather large in Opuntia but small and often very minute in the other genera. In some, the fruit elongates and remains umbilicate, with a slight depression, at the apex, where the perianth was inserted on the ovary; in other cases, the point of attachment was so narrow that only a tiny hole remains on which the remnant of the desiccated corolla remains for a long time. The berry is indehiscent in several cases and less dehiscent in others, and then the seeds fall prey to ants which, at least partially, encourage their dissemination [27].

Figure 1 Detail of the leaves and spines of *Pereskia aculeata*

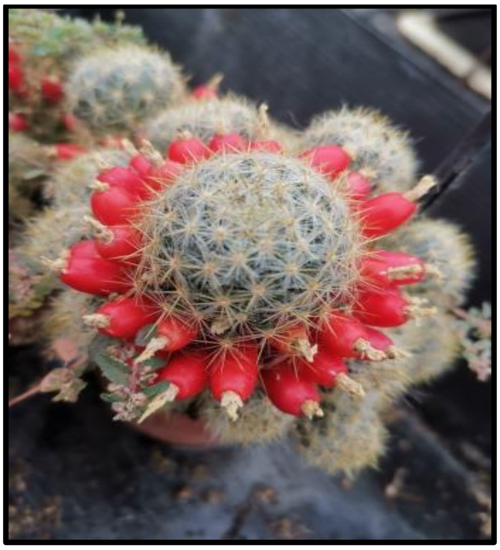

Figure 2 Flowers and fruits of *Mammillaria prolifera*

Figure 3 Colourful blooms of *Echinopsis* and *Trichocereus*

3. Cactus distribution in the world

The members of the family *Cactaceae* are all native to the Americas, with one exception of no practical importance. However, the American continent is enormous, stretching as far as the Arctic Circle, has mountain ranges that determine different orographic systems, and is influenced by winds. Sea currents that can cause violent hurricanes alternating with dry or mild weather in the north and icy air descending from the high peaks of the Andes in the south (Fig.4). Among the significant adaptations of cacti is tolerance to periods of drought; this tolerance is, however, relative, as it always relates to the amount of water contained in the substrate and, above all, the length of time during which it stagnates [28]. Strange as it may seem, the apocalyptic floods that occasionally hit Texas and Colorado or the cyclones over Florida do not cause the cactus carnage one might imagine, firstly because they grow mainly on very well-drained hillsides and secondly because they are sporadic. On the other hand, the dryness of the Arizona air would be fatal, in a relatively short time, to Epiphyllum, which has its habitat in warm, humid wooded areas. We can therefore divide the members of the *Cactaceae* into four types:

- Plants of the desert or pre-desert environment;
- Plants of the mountainous environment;
- Plants of the steppe or grassland environment;
- Plants of tropical and subtropical forests

It must be said at once that what seems to have the gift of ubiquity is the genus Opuntia, with its many species and varieties. *Opuntia polyacantha*, with its flat blades, grows in Canada in the provinces of Alberta and British Columbia at more than 50° latitude; while Opuntia australis, with its more or less oval or spherical articles and several others of the same type, grow in Patagonia; naturally, to resist better, they are all low and prostrate. Opuntia of different species is found along the coasts of Florida and the Carolinas, in the Antilles, in the Galapagos Islands and, of course, in all desert areas and the Andes. The largest genus of the family is, therefore, the one that, albeit with different forms, can live in three of the four environments [29].

The more or less desert environment, where periods of absolute drought often alternate with torrential rains, is found essentially in the southwestern United States: an immense expanse stretching from Montana and Utah in the north to the Mexican border. No cactus in the United States can truly be defined as a mountain environment plant, despite its presence on plateaus and elevations, being in a sheltered position since the Rocky Mountains are covered by forests, mainly spruce, and the Coast Range is home to the great Sequoias. It should also be remembered that in deserts, the temperature range between day and night is extensive and provides for even slight moisture produced by the soil cooling [30]. This is particularly true in the highlands, and it is this fact that determines the survival and also the particularities of Mexico's cacti. In the states of Hidalgo and San Luis Potosi, the number of species belonging to the family is impressive; even the strangest and lesser-known genera appear there, rarely in cultivation since the other effects of the climate include prolonged growth or rarely accompanied by suckers for propagation [31]. Many are small and globose, so cuttings cannot be taken and have disproportionately enlarged taproots in relation to the epigeal part. They are the hard-to-find collector's buds: the callous, flat *Ariocarpus,* which almost buries itself, sometimes merging with the soil; the characteristic *Leuchtenbergia*, which has solved its problems by dividing its surface into long, Agave-like tubercles so that it collects the available night moisture in the centre; the *Obregonia* which, although much less conspicuously, also has leaf-like tubercles; *Pelecyphora* and *Aztechium* with bizarrely raised and formed tubercles so that moisture flows to the ground, but not as quickly as in the types that have placed them vertically or spirally. If one passes through South America, one finds several genera also present in North America, albeit with different species.

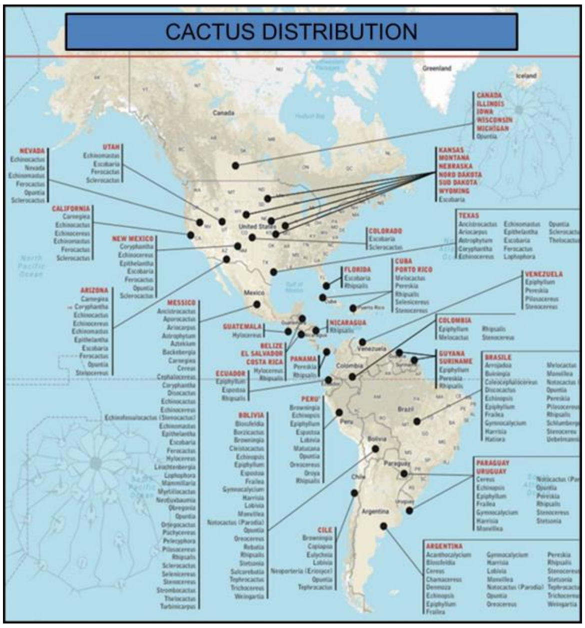

Figure 4 Cactus distribution in America

First and foremost, the ubiquitous Opuntia, whose species are more likely to have cylindrical or globular than flat articles [32]. Here, the types we call mountainous and steppe or prairie types live above all. In reality, South America is not very mountainous in size. However, the Andes, which run north-south along the Pacific, have the highest peaks in the world after those of the Himalayas, and even among them, the altitude remains remarkable. On the slopes of the Andes, therefore, down in Venezuela, Ecuador, Peru, parts of Bolivia, Cila and western Argentina, we find the large waxwings that cover themselves with wool or bristles to protect the epidermis from the cold, such as *Espostoa* and *Oreocereus* or keep the stem relatively low by branching from the base to resist the wind, such as some Trichocereus. In the Bolivian and northern Argentinian highlands, they descend from 3630 m in La Paz to almost steppe-like plains or grasslands. Many species of cacti well known in cultivation, such as *Rebutia, Lobivia, Parodia, Cleistocactus* and *Haageocereus*, originate from these environments furrowed by the great rivers that later flow into the Amazon. Some *Lobivia*, in particular, has been found at more than 3000 m altitudes. It is, therefore, logical that they love the full sun as they are not accustomed to any shelter, while other genera, including Echinopsis, which also grows in the grasslands of central Argentina, prefer a little shade during the summer as in the native places they manage to get through the dry season by being covered by the dry grass that protects them [33]. Southern Brazil, Paraguay, and Uruguay are home to the mountainous *Cereus*, which is widespread in cultivation, the floriferous Chamaecereus, and the *Gumnocalycium*;

inland from Rio de Janeiro, in the coastal forests, sheltered from the north winds, grows the now widespread *Zygocactus* along with other epiphytic cacti. The habitat of *Gymnocalycium* is almost transitional between mountains and forest: they generally prefer light shade and much richer soil than desert cacti. Introduction into cultivation has sometimes been followed by naturalization, as some *Opuntia* species have become pests in Australia, and *Opuntia ficus-indica* is now part of the Mediterranean landscape, an area in which, although they have not become spontaneous, many cacti find conditions more than congenial to their growth [34].

4. Cactus discovery and nomenclature

Although it has sometimes been claimed that the first Cactus was brought to Europe by Christopher Columbus, it is only in the fourth decade of the 16th century that we begin to have some precise information: it was in 1535 that the first volume of 'Historia de las Indias Occidentales' appeared, in which cacti that we would today call *Cereus* and *Opuntia* are depicted. The latter is today the symbol of Mexico and is part of the ancient legends, among which is the one according to which the Aztecs founded their capital, Tenochtitlan, following a 1325 incident by one of their priests, where a cactus had grown from a rock in such a way as to become a luxuriant tree where an eagle had come to rest. The missionaries were naturally the authors of the best accounts of the indigenous civilizations, particularly in Mexico; as they had to convert the natives, they also had to learn their language, learn their religion and customs and understand their earlier civilizations. The Franciscan friar Bernardino de Sahagun learnt in 1529 that a plant was used to obtain hallucinatory states during religious rituals, the Lophophora williamsii, and other cacti such as today's *Ariocarpus, Pelecyphora* and *Obregonia*, all small enough to look like a mushroom and all containing a hallucinogenic alkaloid. In 1576, plants such as the Opuntia ficus-indica and a Melocactus communis arrived in Europe from the New World, while in 1597, one of the most famous herbals, 'The Herball or Generall Historie of plants' was published in London, depicting two *Cereus* (the torch or *Euphorbia Spinosa* and the Peruvian spiny cane), a *Melocactus* and an *Opuntia* [35].

When Linnaeus published the work that was to be considered the source of botanical nomenclature 'Species Plantarum' in 1753, he grouped all the members of the family under the name Cactus, from the Greek word Kaktos, which Theophrastus and Theocritus had used for an unidentified spiny plant, probably a type of thistle. However, in a later edition of the 'Gardener's Dictionary', Miller soon judged this bundling to be inadequate and established four genera, placing the three old names *Opuntia*, *Cereus* and *Pereskia* next to Cactus. Miller's four genera dominated the second half of the eighteenth century. They must undoubtedly have been considered sufficient for the 22 species that William Aiton indicates cultivated at Kew, in 1789, in the first edition of his 'Hortus Kewensis'. Throughout the 19th century, travel, discoveries and study of herbals and living specimens in collections multiplied. We can mention only a few of the many who made fundamental contributions: Prince de Salm-Dyck, Link, Otto, Martius, Lemaire, Riccobono, Engelmann, and Karl Schumann. Many of them attempted new classifications and natural systems. However, such a ferment of studies quickly led to a proliferation of genera and species with little benefit to overall clarity. Curt Backeberg, in the early 1900s, revolutionized everything that had been the system up to that time [36]. His new classification retained the three large groups but changed them to the rank of subfamilies and divided them into tribes, subtribes, groups and subgroups, grouping plants not only according to their affinity but also according to a geographical-environmental concept, creating a restricted number of genera. Many of his genera were not accepted; others simply remain as synonyms without questioning the scientific validity of his classification. The most exciting thing is that he starts the group of waxy cacti with the epiphytic genera, first and foremost the *Rhipsalis*, moving on to the *Hylocereanae* and then to the *Cereeae*, which he divides into *Austrocereeae* and *Boreocereeae*, and ending with the *Mammillaria*. All in all, the world of cacti still presents us with new surprises, and as interest in these strange plants continues to grow, there is bound to be new research showing these plants' possible uses and properties [37].

5. Utilisation of cacti

In the decidedly inhospitable areas that constitute the habitat of most *Cactaceae*, several of them are used locally in one way or another (Table 1). Where there is a complete lack of trees, and therefore of wood, the desiccated stems of *Cereus* are used as replacements, boards and logs for the construction of huts or shelters; where there is a lack of grass, *Opuntia* blades freed from glochids are used as fodder. Very young ones, whose glochids are easily scraped off, the so-called 'nopalitos', are eaten fried in Mexico and boiled in Texas. The latter method was adopted by 18th-century sailors to avoid scurvy, as the blades kept fresh for a long time due to their succulent nature and were a substitute for vegetables, which were impossible to preserve. Everyone is familiar with the fruit of *Opuntia ficus-indica*, the prickly pear, since southern Italy, and Sicily in particular is a strong producer of the fruit of this plant that is so well naturalized that it is often even exported (Table 2). However, although it certainly has the sweetest and most pleasant fruit, the prickly pear is not the only Cactus that has it edible. Several other Opuntia species (Fig. 5), including *Opuntia tuna*, *Opuntia streptacantha* and *Opuntia Cardona*, are also often cultivated for the same purpose. In their places of origin, natives regularly eat the fruits of various *Cereus*, those of *Hylocereus undatus* (Table 3), and the bluish berries of *Myrtillocactus geometrizans* are sold in Mexican markets under the names of garambullos [38]. The fruits of the giant saguaro, *Carnegia gigantea*, are also considered excellent; they are probably good enough to justify the enterprise of picking at a height that can exceed 10 m. This majestic plant, which is more or less matched in height by some South American Cereus, including *Cereus peruvianus* and *Cereus Jamacaru*, has a curious peculiarity: round holes are often seen on the stem and branches, which are nothing more than the nest openings of the *Campylorhynchus bruneicapillis*. Some species of *Echinocereus* are called by the common name 'strawberry cactus', as the fleshy fruits in the entire genus are edible. They are spiny, but the thorns become soft when the fruit ripens and are easy to remove. However, no one would expect to see the formidable spiny apparatus of Echinocactus that these cacti can also have some use [39]. The fact is that beneath their spiny covering, they have a sweetish, watery pulp vaguely reminiscent of watermelon or watermelon, from which preserves are made that are called 'dulce de viznaga'. This term is commonly used for several species and not only for *Echinocactus visnaga*, to which it was given due to its popular name.

Nevertheless, the most extensive use of cacti in all their countries of origin is as defensive fences since many form virtually impassable obstacles. Many are the waxy species used for this purpose, partly because several of them branch out at the base, thus thickening the hedge with stems of varying heights that make them even more challenging to avoid, and they are often so erect and regular that several species of *Pachycereus* and *Stenocereus* are called "organ pipe cacti", precisely because their scaled stems resemble organ pipes. Opuntias are often used for the same purpose, even in places where they are not native [40].

Table 1 Cactus for edible purposes

Genus	Species	Known name
Acanthocereus	*Acanthocereus tetragonus*	Sword pear
Browningia	*Browningia candelaris*	
Carnegia	*Carnegia gigantea*	Saguaro
Cereus	*Cereus repandus*	
Corryocactus	*Corryocactus brevistylis, Corryocactus pulquiensis, Corryocactus erectus*	Erdisia, tasty berrylike
Coryphantha	*Coryphantha robbinsorum, Coryphantha recurvata*	
Echinocereus	*Echinocereus engelmannii, E. bonkerae, E. Boyce-thompsonii, E. enneacanthus, E. cinerascens, E. stramineus, E. dasyacanthus, E. fendleri, E. fasciculatus, E. brandegeei, E. ledingii, E. nicholii*	
Echinopsis	*E. atacamensis, E. coquimbena, E. schickendanzii*	
Epiphyllum	*E. anguliger*	
Epithelantha		
Eulychnia	*E. acida*	
Ferocactus	*F. hamatacanthus, F. histrix, F. latispinus*	Borrachitos, pochas
Harrisia	*H. martinii, H. aboriginum, H. simpsonii, H. adscendens, H. fragrans, H. eriophora, H. pomanensis, H. balansae*	
Hylocereus	*H. undatus, H. costaricensis, H. megalanthus, H. guatemalensis, H. polyrhizus, H. tringularis*	Dragon fruits
Mammillaria	*M. prolifera, M. applanata, M. meiacantha, M. macdougalii, M. lasiacantha, M. grahamii, M. oliviae, M. mainiae, M. microcarpa, M. thornberi*	
Myrtillocactus	*M. geometrizans*	garambulos
Opuntia	*O. engelmannii, O. ficus-indica, O. matudae, O fragilis, O basilaris*	
Pachycereus	*P. pringlei, P. schottii, P. weberi*	Cardon, Senita, Candelabro

Peniocereus	*P. greggii, P. johnstonii, P. serpentinus*	Arizona queen of the night
Pereskia	*P. aculeata, P. guamacho*	Barbados gooseberry
Stenocereus	*S. fricii, S. griseus, S. gummosus, S. pruinosus, S. montanus, S. queretaroensis, S. standleyi, S. stellatus, S. thurberi, S. treleasi*	Pitayo de aguas, Pitayo de mayo, Pitahaya agria, Pitayo de Octubre, Pitaya colorada, Pitaya de queretaro, Pita marismena, Xonoconostle, Pitayo dulce

Table 2 Energy value and content of prickly pear fruit per 100 g of pulp

Energy value and contents	**Value**	**Energy value and contents**	**Value**
Calories (Kcal)	40,00	Fibers (g)	3,6
Water (%)	83,20	Cholesterol (mg)	0
Protein (g)	0,80	Mg (mg)	85
Lipid (g)	0,10	Zn (mg)	0,12
Sugars (g)	12,30	Cu (mg)	0,008
Vitamin B1 (mg)	0,01	Se (mg)	0,6
Vitamin B2 (mg)	0,03	Vitamin B3 (mg)	0,5
Vitamin C (mg)	17,00	Vitamin E (mg)	0,01
Vitamin A (mg)	10,00	Na (mg)	5
Ca (mg)	56,00	P (mg)	24
Fe (mg)	0,40	K (mg)	220

Table 3 Energy value and content of Pitahaya fruit per 100 g of pulp

Energy value and contents	**Value**	**Energy value and contents**	**Value**
Calories (Kcal)	60,00	Fibers (g)	3,0
Water (%)	87,00	Cholesterol (mg)	0
Protein (g)	1,1	Ca (mg)	8,5
Lipid (g)	0,4	Fe (mg)	1,9
Mg (mg)	40,00	P (mg)	22,5
Vitamin B1 (mg)	0,04	Vitamin C (mg)	20,5
Vitamin B2 (mg)	0,05	Vitamin B3 (mg)	0,16

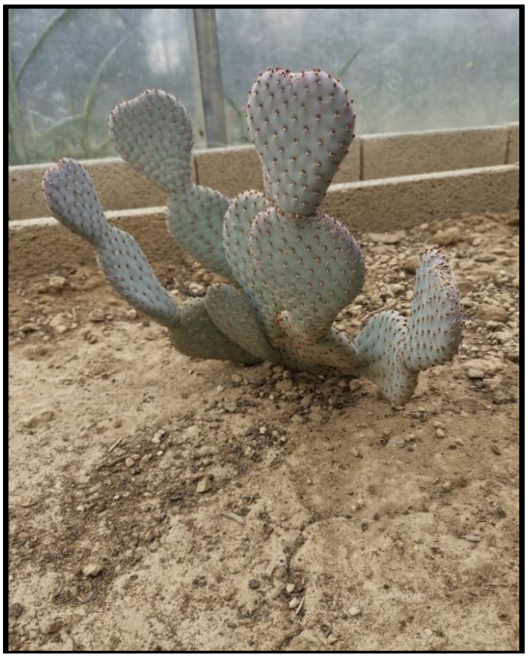

Figure 5 Opuntia basilaris plant

6. Conclusion

Thanks to their incredible adaptability, succulents have also spread in nature in extremely difficult and inhospitable environments where different types of species cannot survive: from the uninhabitable African sub-deserts to the cold semi-desert mountainous regions of South America, from the arid Central American plains to the rainforests where humidity is extremely high, from alpine environments to the brackish Mediterranean environments. Most species have adapted to survive in particular climatic zones where the sunshine is extreme for most of the day, and the heat is very high, with marked temperature fluctuations between day and night. In these regions, prolonged periods of drought are interrupted by short, often intense periods of rain during which the plants can store water in their tissues to such an extent that it becomes a strategic survival reserve to be used during dry periods, even for several months. The incredible ability to adapt to extreme conditions leads many species to withstand even unpredictable low temperatures. Therefore, this review aims to provide information on the characteristics and places of origin of cacti to prepare the most suitable conditions for them to grow, flourish and be used for edible or industrial purposes.

Compliance with ethical standards

Acknowledgments

The research is part of the project "MicroSuc: microorganisms for the growth and protection of cacti and succulent plants".

Disclosure of conflict of interest

The author declares no conflict of interest.

References

[1] Cacioppo O. Fico d'India e Pitaya. I libri di vita in campagna, L'informatore agrario. 1991.

[2] Reynolds SG, Arias-Jimenez E, Mondrago C, Perezgonzales S. El nopal (Opuntia spp.) como forraje.Estudio FAO Produccion y Proteccion Vegetal. 2003; 169: 344–345.

[3] Piga A. Cactus pear: A fruit of Neutraceutical and Functional Importance. J.PACD. 2004; 9–22.

[4] Stintzing FC, Carle R. Cactus stems (Opuntia spp.): A review on their chemistry, technology, anduses. Mol. Nutr. Food Res. 2005; 49: 175–194.

[5] Jiménez-Aguilar DM, Mújica-Paz H, Welti-Chanes J. Phytochemical Characterization of Prickly Pear (Opuntia spp.) and of its Nutritional and Functional Properties: A Review. Current Nutrition & Food Science. 2014; 10: 57-69.

[6] Saenz C. processing technologies: an alternative for cactus pear (Opuntia spp.) fruits and cladodes. Journal of Arid Environments. 2000; 46: 209-225.

[7] El-Mostafa K, El KharrassiY, Badreddine A, Andreoletti P. Nopal Cactus (Opuntia ficus-indica) as a Source of Bioactive Compounds for Nutrition. Health and Disease review, Molecules. 2014; 19: 14879-14901.

[8] Barbera G, Inglese P, Pimienta-Barrios E. Agro-Ecology Cultivation and Uses of Cactus Pear. FAO Plant Production and Protection Paper No. 132, Food and Agriculture Organization of the United Nations, Rome. 1995.

[9] Butera D, Tesoriere L, Di Gaudio F, Bongiorno A, Allegra M, Pintaudi M, et al. Livrea. Antioxidant activities of Sicilian prickly pear (Opuntia ficus-indica) fruit extract and reducing properties of its betalains: betanin and indicaxanthin. Journal of Agriculture and Food Chemistry. 2002; 50: 6895-6901.

[10] Diaz F, Santos M, Filardo S, Villagómez R, Scheinvar L. Colorant extraction from red prickly pear (Opuntia lasiacantha) for food application. Journal of Agriculture and Food Chemistry. 2006; 5: 1330-1337.

[11] Feugang M, Konarski P, Zou D, Stintzing C, Zou C. Nutritional and medicinal use of Cactus pear (Opuntia spp.) cladodes and fruits. Fruit Bioscience. 2006; 11: 2574-2589.

[12] Inglese P, Basile F, Schirra M. Cactus pear fruit production Cacti: Biology Uses, P. S. Nobel, University of California Press, Berkeley. 2002; 163–183.

[13] Kuti O. Antioxidant activity of Opuntia cactus pear. Journal of Horticulture Science. 2000; 35: 433-438.

[14] Matsuhiro B, Lillo E, Sáenz C, Urzúa C, O Zárate. Chemical characterization of the mucilage from fruits of Opuntia ficus-indica. Carbohydrate Polymer. 2006; 63: 263-267.

[15] Balendres MA. Institute JCB. Diseases of dragon fruit (Hylocereus species): Etiology and current management options. Crop Prot. 2019; 126:104920.

[16] Kumar SB, Issac R, Prabha ML. Functional and health-promoting bioactivities of dragon fruit. Drug Invent Today. 2018; 10.

[17] LeBellec F, Vaillant F, Imbert E. Pitahaya (Hylocereus spp.): a new fruit crop, a market with a future. Fruits. 2006; 61(4):237-50.

[18] Choo WS, Yong WK. Antioxidant properties of two species of Hylocereus fruits. Adv Appl Sci Res. 2011; 2(3):418-25.

[19] Nurliyana R, Syed Zahir I, Mustapha Suleiman K, Aisyah MR, Kamarul Rahim K. Antioxidant study of pulps and peels of dragon fruits: a comparative study. International Food Research Journal. 2010; 17: 367-75.

[20] Lourith N, Kanlayavattanakul M. Antioxidant and stability of dragon fruit peel colour. Agro Food Ind Hi Tech. 2013; 24:56-58.

[21] Moshfeghi N, Mahdavi O, Shahhosseini F, Malekifar S, Taghizadeh SK. Introducing a new natural product from dragon fruit into the market. Int J Recent Res Appl Stud. 2013; 15(2):269-71.

[22] Ramli NS, Ismail P, Rahmat A. Influence of conventional and ultrasonic-assisted extraction on phenolic contents, betacyanin contents, and antioxidant capacity of red dragon fruit (Hylocereus polyrhizus). Sci World J. 2014;1–8.

[23] Ariffin AA, Bakar J, Tan CP, Rahman RA, Karim R, Loi CC. Essential fatty acids of pitaya (dragon fruit) seed oil. Food Chem. 2009;114(2):561–4.

[24] Nerdy N, Manurung K. Spectrophotometric method for antioxidant activity test and total phenolic determination of red dragon fruit leaves and white dragon fruit leaves. Rasayan J Chem. 2018; 11(3):1183-92.

[25] Thirugnanasambandham K, Sivakumar V. Microwave assisted extraction process of betalain from dragon fruit and its antioxidant activities. J Saudi Soc Agric Sci. 2017;16:41-8.

[26] Perween T, Mandal KK, Hasan MA. Dragon fruit: An exotic super future fruit of India. J Pharmacogn Phytochem. 2018; 7(2):1022-6.

[27] Sonawane MS. Nutritive and medicinal value of dragon fruit. Asian J Hortic. 2017; 12(2):267-71.

[28] Xu L, Zhang Y, Wang L. Structure characteristics of a water-soluble polysaccharide purified from dragon fruit (Hylocereus undatus) pulp. Carbohydr Polym. 2016; 146:224-30.

[29] Liaotrakoon W. Characterization of dragon fruit (Hylocereus spp.) components with valorization potential. Doctoral dissertation, Ghent University. 2013.

[30] Joshi M, Prabhakar B. Phytoconstituents and pharmaco-therapeutic benefits of pitaya: A wonder fruit. J Food Biochem. 2020; 44(7):1-15.

[31] Hernández YDO, Salazar JAC. Pitahaya (Hylocereus spp.): a short review. Comun Sci. 2012; 3(4):220-37.

[32] Prisa D. Rhizobacteria and zeolites for overcoming saline stress in the cultivation of succulent plants. The International Journal of Engineering and Science (IJES). 2019; 8(5I): 38-41.

[33] Prisa D. Effect of Glomus mosseae inoculation on growth and flowering improvement of Chamaecereus sylvestrii and Mammillaria laui. World Journal of Advanced Research and Reviews, 2019; 02(03): 31–38.

[34] Prisa D. Ascophyllum nodosum extract on growth plants in Rebutia heliosa and Sulcorebutia canigueralli. GSC Biological and Pharmaceutical Sciences, 2020; 10(01): 039–045.

[35] Prisa D. Comparison between sterilized zeolite and natural zeolite in the Cactus Pear (Opuntia Ficus-Indica L. Mill.) growing. GSC Advanced Research and Reviews, 2020; 04(03): 007–014.

[36] Prisa D. Gigaspora Margarita use to improve flower life in Notocactus and Gymnocalycium plants and roots protection against Fusarium sp. World Journal of Biology Pharmacy and Health Sciences, 2020; 04(01): 051–058.

[37] Sáenz C. Opuntias as a natural resource. In Agro-Industrial Utilization of Cactus Pear; Sáenz, C., Berger, H., Rodríguez-Félix A, Galletti L, García JC, Sepúlveda E, Varnero MT, García de Cortázar V, García RC, Arias E, et al., Eds.; Rural Infrastructure and Agro-Industries Division: Rome, Italy, 2013; 17–21.

[38] El-Mostafa K, El-Kharrassi Y, Badreddine A, Andreoletti P, Vamecq J, El-Kebbaj MS, Latruffe N, Lizard G, Nasser B, Cherkaoui-Malki M. Nopal Cactus (Opuntia ficus-indica) as a Source of Bioactive Compounds for Nutrition, Health and Disease. Molecules 2014; 19:14879–14901.

[39] Santos-Díaz MS, Balch EPM, Ramírez-Malagón R, Nuñez-Palenius HG, Ochoa-Alejo N. Mexican threatened cacti: Current status and strategies for their conservation. In Species Diversity and Extinction; Nova Science Publishers: Hauppauge, NY, USA, 2011; 1–59.

[40] Kamble SM, Debaje PP, Ranveer RC, Sahoo A. Nutritional Importance of Cactus: A Review. Trends Biosci. 2017; 10:7668–7677.