

## A review of the massive Chilean palm *Jubaea chilensis*

Una revisión de la enorme palma chilena *Jubaea chilensis*

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### ABSTRACT

Diverse information about the Chilean palm *Jubaea chilensis*, an endemic species to the Chilean Mediterranean ecosystem, has been generated along the two last centuries. The objective of this review is to bring together in a single document all the information to date on this species. Diverse sources of information were considered, from where the information gathered was systematized and analyzed to be presented in five broad themes. *J. chilensis* belongs to the Arecaceae family, and can reach 33 m height and two m in diameter, making it one of the most massive palms. Is the southernmost palm in the Americas, and because of its massiveness, it can resist prolonged periods of drought and low temperatures. Therefore, the species is used ornamentally in many countries. Its original population has decreased dramatically in recent centuries due to land use conversion and harvesting. Although it is now a protected species, the Chilean palm is classified as having vulnerable preservation status. Its principal threats, as indiscriminate fruit harvesting and the decreased of vegetal cover, have led to the aging of the palm population without proper regeneration. More research at the species level is highly recommended. Three broad thematic areas should be the focus for deepening the knowledge about the species: biology, specifically in terms of ecophysiology and reproduction; determine its environmental requirements; and, resulting from the application of the knowledge of the first two themes, the reconstruction of its natural populations.

**Key words.** Arecaceae, *Butia*, mediterranean ecosystem, palm honey, *Parajubaea*.

### RESUMEN

Diversa información sobre la palma chilena *Jubaea chilensis*, una especie endémica de los ecosistemas mediterráneos chilenos, ha sido generada a lo largo de los dos últimos siglos. El objetivo de esta revisión es reunir en un documento toda la información a la fecha sobre esta especie. Variadas fuentes de información fueron consideradas, desde donde la información reunida fue sistematizada y analizada para ser presentada en cinco temas generales. *J. chilensis* pertenece a la familia Arecaceae, y puede alcanzar 33 m de altura y dos metros de diámetro, convirtiéndola en una de las más masivas del mundo. Es la palmera más austral de América, y debido a su masividad, puede resistir periodos prolongados de sequía y bajas temperaturas. Es por esto que esta especie es utilizada como ornamental en muchos países. Su población original ha disminuido drásticamente en los últimos siglos debido al cambio de uso de suelo y las cosechas. A pesar de que ahora es una especie protegida, la palma chilena presenta un estado de conservación vulnerable. Sus principales amenazas, como la cosecha indiscriminada de sus frutos y la disminución de la cobertura vegetal, han permitido que las poblaciones de palmas envejezcan sin una regeneración apropiada. Más investigación al nivel de especie es altamente recomendada. Tres áreas temáticas deberían ser el foco para

profundizar el conocimiento sobre la especie: su biología, específicamente en términos de ecofisiología y reproducción; determinar sus requerimientos ambientales; y, como resultado de la aplicación del conocimiento de las primeras dos temáticas, la reconstrucción de sus poblaciones naturales.

**Palabras clave.** Areaceae, *Butia*, ecosistema mediterráneo, miel de palma, *Parajubaea*.

## INTRODUCTION

Areaceae, the palm tree family, has 181 genera, classified in five sub-families, with more than 2,600 species (Baker and Dransfield 2016). Although the Areaceae family has a wide distribution and a large number of species, the endemic Chilean palm, *Jubaea chilensis* (Mol.) Baill., is the only palm among continental native Chilean flora and therefore is considered a singular and important element of Chilean Mediterranean ecosystems (González *et al.* 2009). Despite these characteristics, the Chilean palm population has been decreasing steadily. The current population is estimated to be only 2.5% of the population at the beginning of the 19<sup>th</sup> century (González *et al.* 2009). In 1853 the famous French naturalist Claude Gay (1800 – 1873) pointed out that the Chilean palms formed rather dense stands that unfortunately were rapidly diminishing as a result of their indiscriminate harvesting for the extraction of palm honey or sap.

Diverse information about the Chilean palm has been generated in the last 160 years, which it is important to systematize and analyze. The objective of this review is to bring together in a single document all the information to date on the species *J. chilensis*, describing it in relation to its taxonomic family, its natural context, and its productive and ornamental uses. A base text has been developed, which for the first time highlights the unique position of this species among palm species. The exhaustive analysis of existing information has allowed for generating a more complete and critical view of the species. Finally,

after systematizing and analyzing the information, we seek to identify the priority areas for further research to improve decision-making in public policies and planning for management and conservation of the species.

## MATERIALS AND METHODS

Diverse sources of information were considered for the review, including old texts, university theses, articles in popular magazines and mainstream scientific journals, government and university websites and botanical gardens in different parts of the world, as well as websites of Chilean and international greenhouses that market the palm species. The information gathered was systematized and analyzed to be presented in five broad themes that are presented below with their respective methodologies.

The first theme is the characterization of *J. chilensis*, which is divided into (a) taxonomy and phylogenetic relationships; (b) the size of the species compared to its peers; and (c) a morphological and anatomical description. Information about the species was reviewed exhaustively for the three sub-themes. The size of *J. chilensis* was compared to that of other palm species based on Balslev *et al.* (2011), who described it as part of the large tall-trunked palm group (LT-Tp), characterized by trunks 20–35 m in height and diameters of 0.2–1 m. Based on Balslev *et al.* (2011) and diverse bibliographical sources, a database was constructed with the heights and diameters reported for American

palm species. The results are presented as histograms of frequency for each size group. This analysis seeks to provide statistical support for otherwise unsupported statements in the literature claiming *J. chilensis* is the largest palm.

The second theme is the natural distribution and ecology of the species in which, based on diverse texts and sources, the natural conditions under palms of the species *J. chilensis* develop and the plant communities it is associated. To confirm that *J. chilensis* is, in fact, the southernmost palm species in the world, as several authors have stated, we compared its natural distribution with those of other species in the Americas and worldwide. We also compare the original distribution of the species to current populations, which makes evident the magnitude of the decline of the species. To determine the climatic ranges in which *J. chilensis* currently grows, we gathered and analyzed climatic data from meteorological stations closest to current populations of the species. We also sought to provide statistical support to statements in the literature regarding the resistance of the species to cold and drought.

The third aspect reviewed is the propagation and management of the Chilean palm, under which more up-to-date information was gathered about propagation and management of the species, mainly university thesis and local studies.

The fourth theme is the ornamental uses of the Chilean palm and the commercial harvest of palm honey. The main sources of information on the uses of the species were synthesized and analyzed, with emphasis on extraction of palm honey and the ornamental use of the Chilean palm. It should be noted that to determine the presence of the Chilean palm worldwide required an extensive

review of official sources like mainstream magazines and unofficial sources like the lists of collections of botanical gardens and the webpages of institutions dedicated to the study of plants that mention *J. chilensis* in their respective geographic areas. For the first time, a map was generated with the confirmed presence of this species in different parts of the world.

Finally, we discuss the main threats to this species based on the results of several publications. We also consider existing and proposed legislation for the conservation of this species.

## RESULTS

### Characterization of *Jubaea chilensis*

#### Taxonomy and phylogenetic relations

The species *J. chilensis* belongs to the subtribe Attaleinae, and with another ten genera to the tribe Cocoseae, subfamily Arecoideae, family Arecaceae and order Arecales ([Baker and Dransfield 2016](#)). *Jubaea* is a monotypic genus and the only genus endemic to the Pacific coast of South America ([Pintaud and Ludeña 2008](#)). It is named after King Juba II, who ruled Numidia between 85 and 46 BC, because of his great interest in botany ([Muñoz-Schick \*et al.\* 2012](#)). Table 1 shows the names given to this species and the authors that have described it, to the last accepted name: *J. chilensis* by Henri Ernest Baillon in 1895. There was a native palm species in Easter Island, now extinct, that botanists named *Paschalococos dispersa* ([Dransfield \*et al.\* 1984](#)), which other authors added later to the *Jubaea* genus ([Mieth and Bork 2010](#)).

The monotypic characteristic of *Jubaea* genus is probably due to the prolonged isolation of Chilean forests from those of the

**Table 1.** Synonymy of *J. chilensis* and its describers.

Scientific name	Descriptor	Publication
<i>Palma chilensis</i>	Molina	Geogr. Nat. Hist. Chile : 124 (1808)
<i>Cocos chilensis</i>	(Molina) Molina	Sag. Stor. Nat. Chili , English (2) 1: 146, 292 (1809)
<i>Jubaea spectabilis</i>	Kunth	Nov. Gen. Sp. 1: 308 (1816)
<i>Molinaea micrococos</i>	Bertero	Merc. Chil. 13: 606 (1829), <i>nom. illeg.</i>
<i>Micrococos chilensis</i>	(Molina) Phill	Bot. Zeitung (Berlin) 17: 362 (1859)
<i>Jubaea chilensis</i>	(Molina) Baillon	Hist. Pl. 13: 397 (1895)

rest of the continent, especially from tropical forests. This isolation is associated with the development of the “Arid Diagonal” (Villagrán and Armesto 2005) that describes a strip of territory with low rainfall crossing South America from northern Peru to the Atlantic Patagonian coastal range (Bruniard 1982). This phenomenon disconnected *J. chilensis* from other species of the family in the Tropical regions, including Tropical Andes, specifically from its related genera *Parajubaea* (Bolivia), *Syagrus*, and *Butia* (Brazil and Uruguay) (Henderson *et al.* 1995), all in tropical areas with dry winters.

Based on morphological and molecular evidence of all the genera belonging to the Attaleinae subtribe, *Butia* is considered the

closest to *Jubaea* (Gunn 2004). *Butia* and *Parajubaea* (Seubert 1998a) are very close to *Jubaea* in their morphologies, particularly their root anatomies and the presence of lateral pores in the endocarp (Gunn 2004). However, there are some general differences among the three species (Fig. 1). In detail, while *J. chilensis* has smooth petioles and pedunculated male flowers with 18 stamens, *Butia* has conspicuously toothed petioles and only six stamens and *Parajubaea* has between 13-18 stamens (Moraes and Henderson 1990, Seubert 1998b, Dransfield *et al.* 2008). *Jubaea chilensis* lacks raphide bundles and raphide containing idioblasts in the staminate petals, as observed in *Butia* (Martel *et al.* 2013).



**Figure 1.** a. *Jubaea chilensis*, b. *Butia capitata* (Photo: Ramón Vallejos) and c. *Parajubaea torallyi* (Photo: Janine Gray).

An analysis of maximum parsimony (Gunn 2004) and a molecular phylogeny of Bayesian approach (Meerow *et al.* 2009) place *Butia* and *Jubaea* in their own clade (100/100% BP) and suggest that *Butia capitata*, *B. eriosphata* and *J. chilensis* are closely related. The three genera, *Jubaea*, *Parajubaea* and *Butia*, have 32 chromosomes (2n), as do most of the species of the Attaleinae subtribe (77%) (Dransfield *et al.* 2008, Meerow *et al.* 2009).

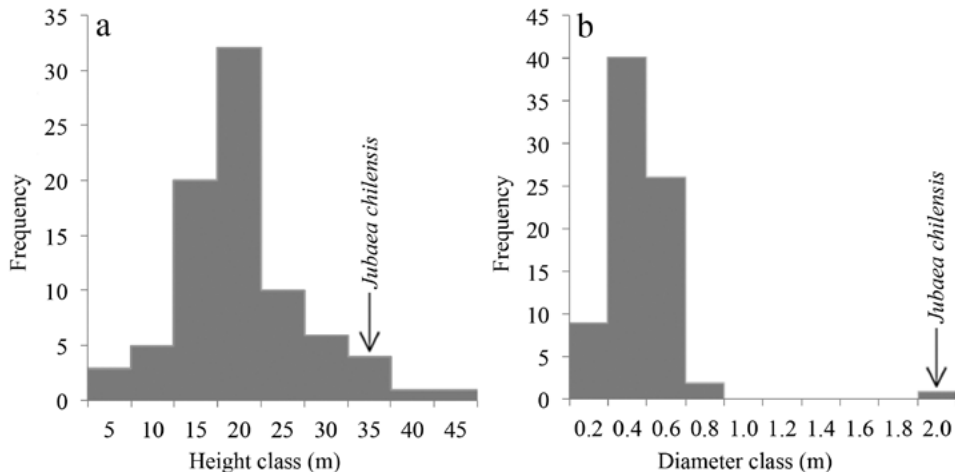
#### Size of the species compared to its peers

*Jubaea chilensis* has been described as a giant herb, a giant grass or an arborescent monocotyledon species (Senerman 1970, Tomlinson 2006). According to the classification of growth forms of palm trees (Balslev *et al.* 2011), the growth habits of *J. chilensis* corresponds to “large tall-trunked palms”, LT-Tp, which species characterized

by trunks 20-35 m in height and trunk diameters of 0.2-1 m.

The LT-Tp category represents approximately 4% of all palm species in the world, but if we consider only the 789 species in the Americas, this rises to 13%. Considering the maximum heights for the species of the LT-Tp category (Fig. 2), *J. chilensis* is in the height class of 35 m which represents the percentile 98 (Fig. 2a) and in the diameter class of 2 m or percentile 100 (Fig. 2b). This gives the species the record for being the largest and most massive American palm, also confirming the description by Dransfield *et al.* (2008) as one of the most massive palm species in the world.

Hurtado (2013) developed a volume function for a group of 52-year-old palms at the National Botanical Garden in Viña del Mar:



**Figure 2.** Frequency distribution of **a.** maximum heights (n = 82) and **b.** maximum diameters (n = 78) of the American palm species classified in the group of “large tall-stemmed palms”. Data source: Edwards (1903), Parish (1907), Bernal and Henderson (1986), Henderson (1990), Henderson *et al.* (1995), Joyal (1996), Moraes (1996), Zona (1996, 2000, 2002), Borschsenius *et al.* (1998), Evans (2001), La Torre-Cuadros and Islebe (2003), Gentil and Ferreira (2005), Del Cañizo (2011), Sanin and Galeano (2011).

$$V = 0.5821 + (\text{DBH} * H)^{1.0979} \quad (R^2 = 0.96)$$

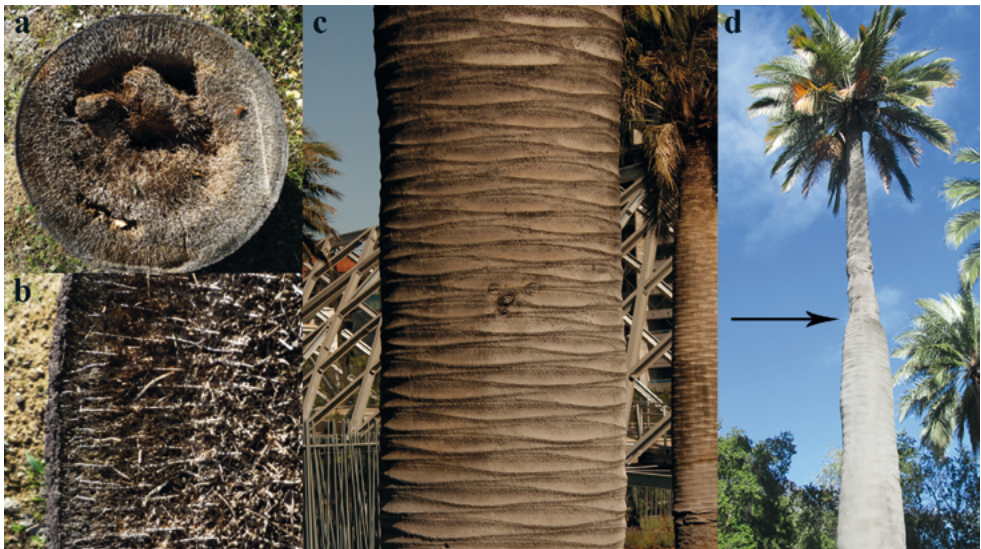
Where V is the volume in m<sup>3</sup>; DBH is diameter at breast height (1.3 m) in m; and H is the total height in m. According to this function, a palm tree 2 m in diameter and 33 m high has a stem volume of 57.9 m<sup>3</sup>.

### Morphological and anatomical description

The Chilean palm has a massive and smooth trunk up to 33 m in height ([Edwards 1903](#)), and a diameter of between 0.43 to 2 m ([Rubinstein 1969](#), [Muñoz 1971](#)). The trunk has a distinctive cylindrical shape with irregular swelling at or near the base and generally tapered toward the apex; unramified, dark gray, with a thinner part in the upper portion of the trunk in mature palms. Leaf scars can be distinguished for many years (Figs. 3a-c) ([Rodríguez et al. 1983](#), [Henderson et al. 1995](#)). The thinnest part in mature individuals (Fig. 3d) is explained as a physiological variation produced after the first flowering and

fruiting, which generates a loss of vegetative vigor and a reduction in meristematic activity in the apex ([Rubinstein 1969](#), [Senerman 1970](#)). Consequently, the height at which the thinnest portion of the trunk begins indicates when the first flowering occurred, when the plant changed from the mature vegetative to mature reproductive stage. This happens when the plant is 10 to 13 m high and circa 40 years old ([Rubinstein 1969](#)).

The only shoot apical meristem is in the upper part and is protected by leaves. The trunk is composed internally of base tissue with many randomly distributed vascular bundles, covered by a combustion-resistant bark ([Senerman 1970](#)). The internal structure of the trunk is compact, with a high air content that avoids heat propagation harming internal tissues and offering protection from fire ([Urban 1934](#), [Senerman 1970](#)). In its first 20 years, the Chilean palm grows mainly in diameter and after that increases in height ([Álvarez de Araya and Matte 1964](#)).

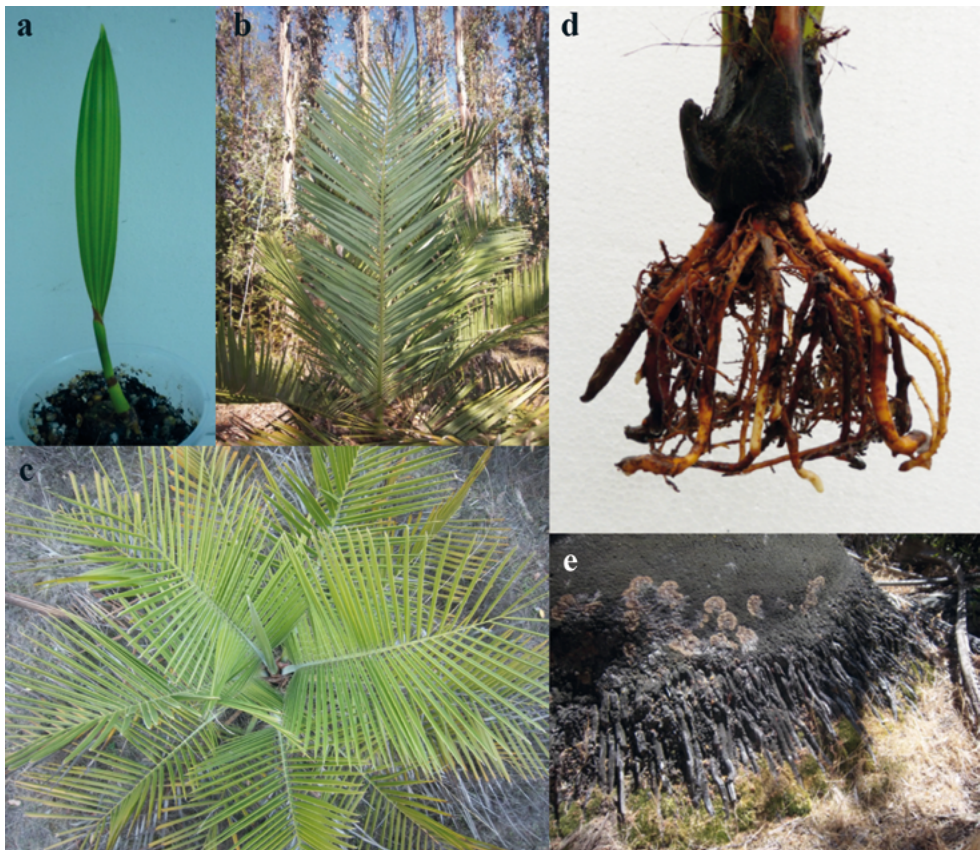


**Figure 3.** Details of a *J. chilensis* stem. **a.** complete cross section (diameter = 0.6 m), **b.** close-up of the cut, **c.** leaf scars on the trunk surface (Photo: Ramón Vallejos), **d.** stem thickening in and adult specimen (Photo: Eduardo Guzmán).

In the early years of the Chilean palm, the leaves are simple, smooth, 15 to 20 cm long and approximately 1 cm wide (Fig. 4a). With time the leaves grow longer and wider. The first pinnate leaves appear after five years, and from then onwards new leaves are all pinnate and steadily larger in size (Angulo 1985). The leaves are perennial (Angulo 1985), feathery and grouped in the upper extreme of the trunk forming a dense crown (Muñoz 1971, Henderson *et al.* 1995). They are 2 to 3 m long and in some cases can reach 5 m, they can be 50 to 60 cm wide (Rubinstein 1969, Muñoz 1971) (Figs. 4b-c). The rachis has a triangular section in its distal portion and is rounded in the underside (Dransfield *et al.* 2008) with 110 to 120 stiff leaflets

forming a plane with their margins folded in the direction of the base. The leaflets vary in length, with the shortest ones in the leaf apex (Rodríguez *et al.* 1983, Angulo 1985). The hook-shaped leaflets are tightly packed together, but irregularly grouped (Dransfield *et al.* 2008). Unlike species of other genera of the subtribe, the leaf of *J. chilensis* is anatomically distinct because of its 3-to-4-cell layers-deep adaxial hypodermis, larger vascular bundles attached to both leaf surfaces by fiber girders, adaxial girders and often massive and non-vascular fiber bundles (Tomlinson *et al.* 2011).

The first roots of *J. chilensis* in its early growth stage are replaced by secondary roots



**Figure 4.** Leaf and root morphology of *J. chilensis*. **a.** seedling single-leaf, **b.** adult leaf, **c.** upper side view of a juvenile palm apex, **d.** six-year old palm root, **e.** adult palm root (Photo: Eduardo Guzmán).

in the entire trunk base (Urban 1934) that are 1 cm in diameter and 2-3 m long (Senerman 1970) (Figs. 4d-e). The deep roots fasten the plant firmly to the ground, allowing it to resist extreme wind conditions (Urban 1934). The roots of the Chilean palm exhibit in their outer section a solid cork that replaces the rhizodermis, exodermis structures, and the outside bark area, while its inner bark area consists of thick homogeneously distributed fibers and a solid hollow cylinder formed by brachysclereids (Seubert 1998b). Finally, the endodermis has U-shaped cells with inner walls that are slightly thicker than the outer walls (Seubert 1998b).

Inflorescences, which are produced 3-12 times per year in the Chilean palm, emerge from the leaf base. Its flowers are short (2.5– 3 cm), actinomorphic, unisexual, and diclino-monoecious. Staminate flowers (Fig. 5a), located towards the apex, have three petals and 18 erect stamens in two series and anthers with two linear cells that are opened by longitudinal grooves (Muñoz 1971). The pollen is asymmetrically ellipsoidal, with a distal opening groove and a longer axis of 46 – 54 µm. Pistillate flowers are globular and slightly larger than the male flowers and have three sepals, three rounded and overlapping petals, as well as a trilobulated and triovulated gynoecium (Dransfield *et al.* 2008). The development of inflorescences consists of two bracts (Figs. 5b – d), first, a fibrous bract that falls away and then a ligneous bract 1 – 1.2 m in length that remains until the fruit ripens (Urban 1934, Rubinstein 1969, Muñoz 1971). Within the bracts there is a racemose inflorescence 1.1 m in length, with an average of 142 pins distributed helically (Manríquez *et al.* 1992 cited in Cabello 2006).

The fruits are drupes with fibrous and smooth 2.2-cm-long spherical exocarpe and a green-yellow skin towards yellow-

orange (Figs. 5c – f) (Urban 1934, Muñoz 1971, Camilo 2008). The mesocarpe is fleshy and eatable. Inside the fruit there is a smooth spherical seed 2 cm in diameter and weighing approximately 2.6 g (Rodríguez *et al.* 1983, Camilo 2008). The seed (Figs. 5g – h) is closely attached to a woody endocarpe composed of three pores on its widest part. The seed has a homogeneous endosperm and an embryo in front of one pore (Urban 1934, Gunn 2004). Two of the pores are elliptically shaped, while the third one is circular (Urban 1934). It is in the latter where germination occurs (Figs. 5i– j). The woody endocarpe with the seed inside is called a “coquito” (little coconut in Spanish). The seed can be eaten after breaking open the endocarpe. An individual produces 10,000 fruits in a good year (Urban 1934).

The seed of the Chilean palm has a very high fatty acid content (68.6%) predominately saturated fatty acids (85%) (Masson *et al.* 2008). Also notable is the significant linoleic acid content (2.15%), which is essential for human wellbeing (Masson *et al.* 2008). Moreover, the fatty lauric and mistiric acids present in the seeds have nematocidal effects on *Caenorhabditis elegans* Maupas, 1900 (Gu *et al.* 2005).

### Natural distribution and ecology

The Chilean palm is currently found from La Serena city, in the Coquimbo Region, (29° 54' S, 71° 15' W), to Curicó city in the Maule Region (35° 15' S, 71° 47' W) (Urban 1934, Rodríguez *et al.* 1983, Henderson *et al.* 1995) (Fig. 6a). Although several authors have described *J. chilensis* as the southernmost palm species in the continent (Urban 1934, Parsons 2007, Pintaud and Ludeña 2008), this is not true, which is in fact *Rhopalostylis sapida* H.Wendl and Drude, 1878, located 43° - 44° S on the





**Figure 5.** Chilean palm flower, fruits and seeds. **a.** staminate flower, **b.** racemes of fruit (Photo: Paulina Fernández), **c.** racemes of fruit protected by bracts, **d.** bract varieties, **e.** fruit, **f.** halved fruit showing the endocarp inside, **g.** endocarp with pores, **h.** halved endocarp and internal seed, **i.** germinated seed, **j.** germination boxes from Oasis la Campana (Photo: Eduardo Guzmán). Scale bar = 1cm.

Chatham Islands, New Zealand (Dugand 1965, Parsons 2007, Dransfield *et al.* 2008).

*Jubaea chilensis* grows in dry areas, mainly with a Mediterranean climate with low-to-medium rainfall (Rodríguez *et al.* 1983,

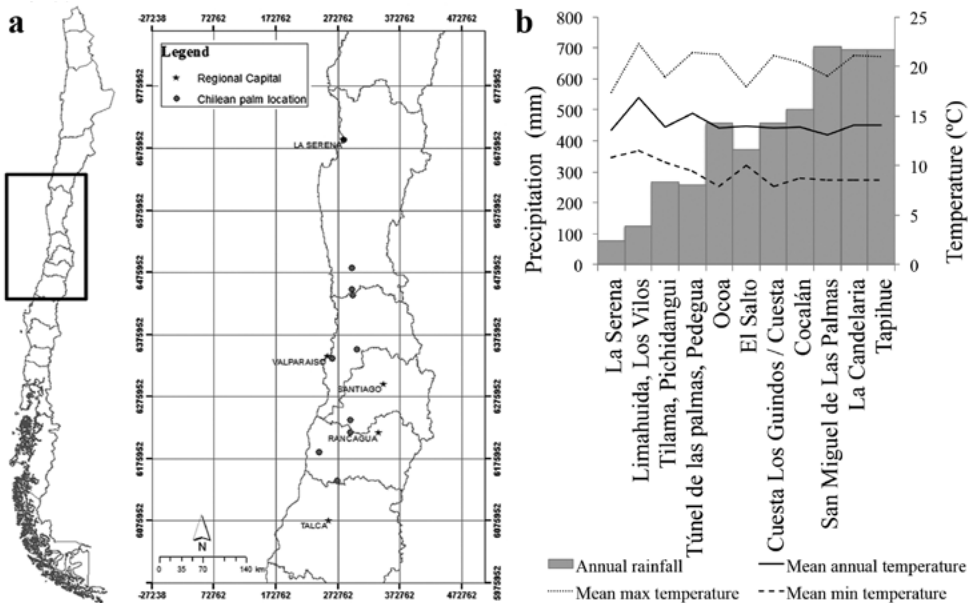
Henderson *et al.* 1995). The species is found in valleys, close to streams and hillsides from the Chilean coastal mountain range (Urban 1934) to 1,600 m above sea level (Rundel and Weisser 1975). Moreover, it is among the few pinnate-leafed palm species

that can survive temperatures from -10 to -12°C, withstanding temperatures as low as -22°C, like in Perpignan, France, in the year 1956 (Del Cañizo 2011).

Its natural distribution, including areas with extreme temperatures, indicates that *J. chilensis* is tolerant to cold, a marked difference from many tropical palm species. This feature has enabled the Chilean palm to grow successfully in some places quite far south in Chile like Frutillar (Region of Lagos, 41° 7' S, 73° 3' W), with a mean temperature of 7.5 °C in the coldest month and a minimum extreme temperature of 4.1 °C (CLIMATE-DATA.ORG 2015) and other places in the world as described in the section “Uses around the world”. Within its natural range, the species withstands a mean temperature range of 8.8 °C to 20.2 °C (Santibáñez *et al.* 1990, 1993) (Fig. 6b). Rainfall can be as low as 78.5 mm y<sup>-1</sup> on

average with extreme values like 8.5 mm y<sup>-1</sup> that occurred in 1969 in the northern part of its range (Rioseco and Tesser c2014) to 696 mm y<sup>-1</sup> on average in the southern part of its range (Santibáñez *et al.* 1993).

Microclimate and topography determine the density of the Chilean palm population (Rubinstein 1969), while the density of understory associated with palm trees is determined by the density of the palm tree population, environmental conditions, grazing intensity and the use of accompanying vegetation for fuel (Donoso 1982). The differences in height and age are mainly defined by earlier exploitation (Rubinstein 1969) and regeneration conditions. The natural structure of a properly regenerated stand is open (Vita 1989), with a high canopy of adult palms, followed by different strata of regenerating



**Figure 6.** Natural distribution of Chilean palm populations. **a.** Chile territory and Chilean palm main locations. **b.** temperature and rainfall conditions of the natural distribution of the Chilean palm. Data sources: Santibáñez *et al.* 1990, 1993, Rioseco and Tesser c2014.

palms of different ages and associated bushy Mediterranean species.

In 1550 the Chilean palm population was estimated at 5 million trees (Hechenleitner *et al.* 2005). In The History of the Kingdom of Chile, the Jesuit priest Alonso De Ovalle stated that these palm trees grow so densely in mountains and ravines that from afar they appear placed there by magic (De Ovalle 1646). This enabled the species to have a continuous population throughout its natural distribution. Nowadays, the Chilean palm population is drastically reduced to approximately 123000 trees (Alvarado 2009, González *et al.* 2009).

The Chilean palm is a representative species of the open forests of the Chilean Mediterranean zone (Vita 1989). Its importance is reflected in the fact that vegetational formations that include it are classified as Chilean palm-type forests, according to the classification of Donoso (1981). In these formations, *J. chilensis* is associated, for example, with *Lithrea caustica* (Mol.) Hook & Arn., *Cryptocarya alba* (Mol.) Looser, *Quillaja saponaria* Mol., *Acacia caven* Mol., *Peumus boldus* Mol. and *Maytenus boaria* Mol. (Donoso 1981). All of these species are also typical of the Mediterranean zone of Chile.

### **Propagation and management of the Chilean palm**

In its natural environment, *J. chilensis* seeds take between six months to four years to germinate. However, germination often occurs within 18 months (Angulo 1985), since Chilean palm seed suffers physiologic latency that is manifested by the immaturity of the embryo (Forcelledo 2006), corresponding to morphologic latency according to the latest dormancy classification. Under nursery conditions,

there is great variability in germination capacity, varying from four months at 12 °C, with 90% of seeds sprouting (Fernández, unpublished) to 21 months at 30 °C, with 68.7% of seeds sprouting (Cabello 1990). Under *in vitro* culture, embryos take 15 days to germinate, reaching 75% of germination capacity in 45 days at 30 °C (Cabello 1990). The woody endocarp delays water accessing the seed interior and therefore does not impede germination (Cabello and Infante 1994).

By soaking seeds in Ethrel it is possible to accelerate the germination process (Arrué 2000), obtaining sprouted seeds in 20 days (Vega 2001). This product accelerates the ripening process of the seed, and it may be beneficial to break the dormancy of the species (Forcelledo 2006). Solari (2002) proposed that the best nursery practice is to use a substrate of 70% leaf mold and 30% weathered granite, without additional fertilization, and 0% of shade. Under these conditions, 93.8% plant survival is reached. Solari (2002) proposed that the best nursery practice is to use a substrate of 70% leaf mold and 30% weathered granite, without additional fertilization, and 0% of shade.

A test establishing plants with and without irrigation in a Mediterranean environment showed no response to watering at Lolol in the Region of O'Higgins, 34° 43' 43" S, 71° 38' 41" W (Castillo 2000). However, we disagree with these results. The trial was measured during only one growing season. Later visits to the trial, by personal observation of one author, over the following 10 years have shown that plants irrigated during the summer as a local people initiative in some sections of the trial are remarkably different in size from non-irrigated plants. The irrigated plants also make an earlier transition from simple to pinnate leaves.

In other experiences, although there is no evidence about the effect of fertilization on palm survival at planting (Solari 2002, Lewin 2003), there was an increase in root biomass, which benefits plant growth and improves survival rates (Lewin 2003).

### **Ornamental uses of Chilean palm and palm honey harvest.**

#### Multiple uses

Historically, each part of the Chilean palm tree has had a domestic use (Gay 1853), the extracted sap being the most important (Rodríguez *et al.* 1983). Other examples are the use of palm leaves in basketry and handicrafts and trunk fibers in making paper (Urban 1934, Rodríguez *et al.* 1983). Haynes and McLaughlin (2000) noted that the *Jubaea* and *Parajubaea* genera are part of a small group of palm species whose seeds are used as food. In contrast, the fresh fruit of the *Butia* species is used as food, but not its seeds. Chilean palms are currently not being harvested for honey, but the fruit is becoming an important source for profitable businesses. In relation to medicinal uses, Chilean palm fruit has laxative and digestive properties, and high levels of terpene content have been found (Montenegro *et al.* 1994).

Salvatierra (2011) explored the production of monofloral bee (*Apis mellifera* L.) honey from the Chilean palm, evaluating the possibility to enhance the commercial value of the species by the production of certified monofloral honey. Unfortunately, its participation in the local honey was not significant.

#### Palm honey harvest

One of the most well known uses of the Chilean palm is honey production, which is made from the sap and extracted by turning

the palm, which ultimately kills the plant. Vicuña-Mackenna (1877) stated that it would be more profitable to extract the palm fruit than the honey.

The plants are selected for extracting sap based on accessibility, the amount of associated vegetation and the experience of the collector (Rubinstein 1969). The sap is extracted between October and April by raising the tree out of the ground and the apex is defoliated and a container is attached to collect the sap. The collected sap is concentrated at 66.6 °Brix, at which point it reaches a stable density (Rubinstein 1969). Sap yields per tree vary between 80 to 600 L and the conversion factor from sap to basic concentrated honey is 0.256 (Rubinstein 1969).

The relationship between traditional forest variables like tree height, diameter and volume, and the amount of sap produced is not clear (Rubinstein 1969). Curiously, having an experienced labor force can be a major factor in determining the yield of extracted sap (Velásquez 1995). Only 16.7% of palm species (30 species) are used for sap extraction and with five of these, including *J. chilensis*, it is necessary to fell the tree, while a non-destructive method is used with *Parajubaea cocoides* and *P. torallyi* (Haynes and McLaughlin 2000).

#### Ornamental use

##### *Historical situation in Chile*

Since colonial times, around the XVIII century, the Chilean palm has been a valuable ornamental species. At that time, its slow growth was not considered an impediment and therefore it was commonly used for decorating avenues, the entrances of important buildings, churches and mansions, among others. There are still vestiges of

these uses throughout Chile as the entrance of the monastery of San Pedro de Alcántara at the Province of Cardenal Caro, Region of O'Higgins, which was built in 1725, and in a manor house at Cunaco, Province of Colchagua, Region of O'Higgins.

*Current revitalization in the use of the Chilean palm*

In recent decades there has been increasing use of the Chilean palm as an ornamental plant in squares, parks, and gardens (Campos 1998). Because of its size and great ornamental value, the Chilean palm is currently raised in nurseries, including for exportation, and even adult palms are transplanted for landscaping. As well, *J. chilensis* and *Butia odorata* have been used as parent plants to obtain the interspecific hybrid *Jubautia* and the species *Jubautia splendens* Hodel (Hodel 2011).

*Uses around the world*

Although some naturalists have reported the species in Europe, one of the most famous descriptions was that of Charles Darwin, who observed the species in Chile during his voyage on the Beagle. He wrote: “In a few places there were palms, and I was surprised to see one at an elevation of at least 4500 feet. These palms are, for their family, ugly trees. Their trunk is very large, and of a curious form, being thicker in the middle than at the base or top. They are excessively numerous in some parts of Chile, and valuable on account of a sort of treacle made from the sap... they tried to count them, but failed, after having numbered several hundred thousand... A good tree will give ninety gallons, and all this must have been contained in the vessels of the apparently dry trunk” (Fitzroy *et al.* 1839).



**Figure 7.** Map of *Jubaea chilensis* distribution around the world. Black dots indicate places where there are specimens of the species. As example, there are Chilean palms in cities in Australia (Intown 2014, Parsons c2013, Zona c2011), the USA (Fullerton Arboretum 2014, Goleta Valley Historical Society 2014, The Huntington c2014, Zona c2011), Spain (del Cañizo 2011, Plumed 2013, Sánchez 2011), France (Del Cañizo 2011, Dugand 1965, INRA 1998), Ireland (Kells Bay House and Gardens 2014), Italy (Plaumann 2001, Zona c2011), the Netherlands and Portugal (Zona c2011), the UK (Kew Royal Botanic Gardens 2014) and Russia (Nichols 2014).

Since then, and particularly during the 19<sup>th</sup> century, *J. chilensis* was exported and used as an ornamental plant. In an exhaustive review of original documents, [Zona \(c2011\)](#) describes the journeys of *J. chilensis* to and within Europe, from the 19<sup>th</sup> century onward, arriving first to the Kew Gardens in London between 1843 and 1846. Unfortunately, this first specimen was cut down in 2014, despite its 164 years, due to the remodeling of the Temperate House ([Kennedy 2013](#)). Later the species was reported in Portugal, France, Italy, Germany and other countries. The first records are from botanic gardens, arboretums, greenhouses, collectors or people that could afford a specimen for their personal gardens. Because of its longevity, living examples of the original Chilean palms can still be found in different parts of Europe ([Zona c2011](#)). Nowadays, Chilean palms are widely used as ornamental plants in warm, temperate, arid, and even cold regions ([Dransfield et al. 2008](#)).

Generally, Chilean palms are used ornamentally in squares and around important buildings, but above all as exhibit pieces in botanical gardens and arboretums (Fig. 7). In Ambato (Ecuador), in addition to its ornamental use, the Chilean palm is used for coconut production ([Pintaud and Ludeña 2008](#)).

The feasibility of using the Chilean palm has been considered and studied in other countries. For example, the Chilean palm can be used ornamentally in Turkey given its resistance to cold (Coskuner 2006 cited by [Hazir and Buyukozturk 2013](#)). Another example is a master plan of Santa Monica, California for an urban forest (USA), which involves replacing *Phoenix canariensis* hort. ex Chabaud with *J. chilensis* in streets and avenues to ensure the benefits of an urban forest for residents and tourists ([Santa Monica Public Landscape Division c2011](#)).

There are several individuals that serve an ornamental function on Helgoland Island in the German North Sea, where temperatures can fall to -2 °C. These palms are highly resistant to winter cold, with no need for protection from the cold, although they do need protection from salty sea winds. In the continent, the palm can resist temperatures as low as -15°C but does not tolerate permafrost ([Jäck 2011](#)).

## Threats and conservation

### Threats

From early days, Chilean palms were felled to extract sap for palm honey production ([Vicuña-Mackenna 1877](#), [Urban 1934](#)). [Vicuña-Mackenna \(1877\)](#) indicated that several thousand trees were felled every year for honey and to produce liquor. In fact, in the past this was considered the prime threat for the species ([González 1992](#)). Land use change from Mediterranean forests to agricultural use has been the other main threat to the species. As the species is now legally protected, the main four threats to natural populations today are indiscriminate fruit harvests, herbivorous feeding, decreased vegetal cover and fires.

The first threat, indiscriminate fruit harvesting is the most serious and is responsible for the ageing of palm tree populations ([González 1992](#)). Indiscriminate fruit harvesting is an issue for the regeneration of species related to the Chilean palm, in particular, *B. capitata* (Mart.) Becc. from Uruguay and Brazil ([Rivas 2005](#)), *Parajubaea sunkha* Moraes from Bolivia ([Enssle et al. 2006](#)) and *P. cocoides* Burret from Peru ([Roca 2010](#)).

The second threat is herbivorous feeding by native and other species. The degú (*Octodon degus* Molina, 1782) is a native rodent that feeds on fallen palm fruit. The life cycle of

this rodent fits with the phenological cycle of the plant species in the same habitat ([Zunino \*et al.\* 1992](#)). The European rabbit (*Oryctolagus cuniculus* Linnaeus, 1785) is a non-native species that feeds on Chilean palm seedlings ([Rubinstein 1969](#), [Marcelo \*et al.\* 2006](#)). There is also the presence of grazing cattle ([González 1992](#)).

The third threat is decreased vegetal cover. The vegetal cover provides the necessary microhabitat for seedling establishment. This feature is of the utmost importance for the survival and growth of individuals ([Vita 1989](#)). In the palm tree population located in Tapihue, Chile, seedlings were only found under cover of a boldo tree (*Peumus boldus* Mol.) ([Flores 2012](#)). [Marcelo \*et al.\* \(2006\)](#) also determined the crucial importance of vegetal cover in the recruitment and survival of Chilean palm seedlings. Vegetative cover is lost mainly with the conversion of forests to agricultural and grazing lands ([González 1992](#)) or the use of associated vegetation for fuel.

The fourth threat is fires. Regeneration is also affected by continuous fires in the habitats of the Chilean palm due to human negligence. An example of this is the analysis of the age structure based on morphologic attributes of two palm tree populations, at the locations of Ocoa and Las Siete Hermanas, Region of Valparaíso in Chile. One of the conclusions of this analysis is that the latter should be a high priority for conservation because the population is not regenerating naturally, with only 10% of individuals as seedlings and juveniles, resulting in the aging of the population in the context of continuous fires in the area ([Díaz 2009](#)). Fires affect both associated vegetation and palm seedlings ([Rubinstein 1969](#)). Fires do not greatly affect adult palm trees because their trunks are resistant to fire. Nevertheless, Chilean palm trees regularly regenerate themselves

after fires provided they are not located on bare ground ([Quintanilla and Reyes 1999](#)), and there are enough seeds available and low levels of herbivorous feeding.

Another threat are diseases, but with a minor impact. At the national level, some fungi attacks have been described in the leaves of *J. chilensis* ([Baldini and Pancel 2002](#)). At the international level, several pests have been described as affecting the Chilean palm. In France, *J. chilensis* can be affected by the caterpillars of the moth *Paysandisia archon* Burmeister, 1880 ([Peltier 2007](#)) and in Italy, the palm is sensitive to coleopteran *Rhynchophorus ferrugineus* Olivier, 1790 ([Raciti \*et al.\* 2013](#)).

#### Protection and conservation

Legal efforts to preserve *J. chilensis* began with the Supreme Decree No. 908 in 1941, which regulated the export of the plants and its products. In the 1970s a historic trend towards the complete elimination of the Chilean palm was identified, with indications of the cutting rates and age range of the remaining individuals ([Rubinstein 1969](#)). The Chilean palm is currently classified as a vulnerable species ([González 1998](#)). Experts suggest that the best way to preserve the Chilean palm over time is through its protection and sustainable use ([Bañados 1991](#)).

Among the plant species of the Chilean Mediterranean forest ecosystem, the Chilean palm is considered to have the greatest economic potential, more for its fruit than its honey ([Chile Forestal 1998](#)). Its use can be highly profitable under appropriate management, taking into account the products that can be obtained, the social benefits of preserving the species, the recreational uses, as well as direct products ([Rubinstein 1969](#)). In addition, Chilean

palm crops could be profitable in 49 districts of 29 towns in Chile, comprising a total of 86,615 hectares. After evaluating the related socioeconomic and physical-ecological factors, [González et al. \(2001\)](#) considered Chilean palm cultivation a feasible source of sustenance for low-income families.

### **Final Comments**

*Jubaea chilensis* is particularly interesting to study because of its unique features. The species is one of the largest in its family, with a limited but climatically varied natural distribution. The Chilean palm is highly resistant to extreme conditions like low temperatures. Proof of this is that the Chilean palm is the southernmost palm species in the continent, but not in the planet. Considering its beauty, longevity, feather-grass shape and color, and the products made from it, the Chilean palm is known nationally and internationally. This is also the basis for further genetic work with this species, including the hybrids obtained with *Butia* with features of *J. chilensis* of ornamental interest.

Despite all the characteristics that differentiate it from other palm species, such as size, geographic distribution, productive potential, presence around the world in places where other palm species do not survive, *J. chilensis* has had a low level of regeneration in its natural environment in recent years as a result of uncontrolled harvesting of its fruit. There is also greater knowledge and public recognition about the main threats to the species. However, this knowledge has not been applied in the design of new management plans. Therefore, *J. chilensis* remains in the category of vulnerable species.

In order to contribute to this issue, more research at the species level is highly recommended. Three broad thematic areas

should be the focus for deepening our knowledge about the Chilean palm. The first theme is the biology of the species, specifically in terms of ecophysiology and reproduction. In the ecophysiology area, deeper knowledge of metabolic and internal processes is necessary to better understand species dynamics and interactions with the environment. The second theme is to determine the environmental requirements of the species. Finally, and resulting from the application of the knowledge of the first two themes, is reconstructing natural populations. To do this, it is necessary to define protocols for the reproduction and reforestation of *J. chilensis*, establishing the best strategies for its reintroduction.

Once advances have been made in the aforementioned themes, public management and conservation policies and plans can be defined to improve the conservation of the species. It is also fundamental to involve communities close to populations of this species in their protection, because of which information and education should always be considered fundamental elements.

### **AUTHORS PARTICIPATION**

EG conception, design, collection of information, analysis and writing of the document. JAC and SC analysis and writing of the document. MPF conception, design, collection of information, analysis and writing of the document.

### **CONFLICT OF INTEREST**

The authors declare that they have no conflict of interest.

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