Review: *Cynara cardunculus* L. var. *sylvestris,* a weed with great potential uses

Revisión: *Cynara cardunculus* L. var. *sylvestris,* una maleza con grandes usos potenciales

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Abstract: *Cynara cardunculus* L. var *sylvestris* is a native plant from the Mediterranean. Several studies indicate that this variety is the common ancestor of the two cultivated varieties: scolymus and altilis, which are used as edible plants to obtain different products due to their characteristics. Alternatively, although the var. *sylvestris* has globally been considered as an invasive weed, some authors have recently reported that this wild cardoon has an enormous aptitude for obtaining different agro-industrial products or to be used for different purposes. Likewise, cardoon can grow in adverse environmental conditions, having competitive advantages compared with other crops. In this article, we have included information about the var. *sylvestris* and its genetic relation with the other varieties, its potential to generate different products, the characteristics that allow its adaptation and competitiveness as well as its worldwide distribution and in Argentina.

Keywords: Domestication; agro-industrial uses; bioenergy; adaptability; competitiveness.

Resumen: *Cynara cardunculus* L. var *sylvestris* es una planta nativa del Mediterráneo. Varios estudios indican que esta variedad es el ancestro común de las dos variedades cultivadas: scolymus y altilis, que se utilizan como plantas comestibles para obtener productos diferentes por sus características. Alternativamente, aunque la var. *sylvestris* ha sido considerada a nivel mundial como una maleza invasora, algunos autores han reportado recientemente que este cardo silvestre tiene una enorme aptitud para la obtención de diferentes productos agroindustriales o para ser utilizado para diferentes fines. Asimismo, el cardo puede crecer en condiciones ambientales adversas, teniendo ventajas competitivas frente a otros cultivos. En este artículo hemos incluido información sobre la var. sylvestris y su relación genética con las demás variedades, su potencial para generar productos diferentes, las características que permiten su adaptación y competitividad, así como su distribución a nivel mundial y en Argentina

Palabras clave*:* Domesticación; usos agroindustriales; bioenergía; adaptabilidad; competitividad.

Introduction

The genus *Cynara* belongs to the *Asteraceae* family (ex Compositae) (Winklud, 1992) and among the species of this genus, *Cynara cardunculus* L. is the most important and widely distributed (Calabrese, 2016). It includes three varieties: the "*globe artichoke*" [var. *scolymus* (L.) Fiori], the "cultivated cardoon" (var. altilis *DC*) and the "wild cardoon or Castilla cardoon" [var. *sylvestris* (Lam.) Fiori] (Gatto *et al*., 2013). According to experimental evidence, the first two varieties have derived from a common ancestor: the *wild cardoon* (Sonante, 2007). Nowadays, there are several techniques which allow the study of the intra and intervarietal genetic relationships which provide information about the places of origin of the varieties, their genetic relatedness, their domestication and how they have evolved overtime to become what we know today (Lahoz *et al*., 2011).

Since ancient times, the traditional application of *C. cardunculus* cultivated varieties, is the use the large fleshy heads from *scolymus* and the stalks and part of the central leaf nervure from *altilis* as an edible vegetable (Cravero *et al*., 2012; Gominho *et al*., 2018). Besides, they are utilized for medicinal purposes against diverse diseases such as hepatic failure, hypercholesterolemia (D'Antuono *et al*., 2018), hypertension (Ardalani *et al*., 2020), hyperlipidemia (Gatmiri *et al*., 2019), diabetic (Turkiewicz *et al*., 2019) and in some inflammatory processes, among others (Ahmed *et al*., 2019). Moreover, seed cultivated cardoon is of great interest for animal feed (Cabiddu *et al*., 2019; Buccioni *et al*., 2020) and bioenergy production (Sengo *et al*., 2010; Alexandre *et al*., 2012; Pesce *et al*., 2020; Köse and Acaroğlu, 2020).

In relation to the non-domesticated perennial variety, *sylvestris*, it is known and studied as a relevant weed with high capacity of worldwide distribution (Portis *et* *al*., 2005(a); Acquadro *et al*., 2014; Pomés *et al*., 2016). In Argentina it is considered as a National Plague, being cited by the Ley de Sanidad Vegetal N°5.770, decreto 4328/55, artículo N°2 [Plant Health Law N°5.770, decree 4328/55, section N°2] (Falasca and Ulberic,h 2006). However, according to the specialized weed website WeedScience (2021), no herbicide resistance has been recorded in this species so far, thus simplifying its control. Nevertheless, in recent years, the view of this variety has changed in some countries and several studies present it as a plant with great potential for obtaining various products, especially bioenergy in a similar way to that observed in *altilis* variety (Koutsouki *et al*., 2015).

Likewise, certain morphological and physiological characteristics of var. *sylvestris* give it the ability to adapt and compete under different climatic conditions and abiotic stress factors, being able to grow with low or null inputs and in reduced or marginal productivity soils (Ierna *et al*., 2020). Furthermore, unlike other crops, and even other varieties of the same species, *wild cardoon* has advantages such as high perenniality (≥ 10 years), it does not compete with food production and could improve soils in marginal areas, preventing from erosion and increasing their fertility (Raccuia and Melilli, 2007; Mauromicale, 2014; Ierna, 2020). Simultaneously, this variety originally from the Mediterranean, is widely distributed, being naturalized in many countries (Gutierrez *et al*., 2020).

The aim of this work is to provide a more detailed description of the *sylvestris* variety by reviewing its genetic relationship with the other varieties of the same species, and highlighting the abrupt change from being considered for decades as a perennial and highly invasive weed, to the present, when it is deemed as a potential source for different purposes. In addition, the main morphological and physiological traits that make its adaptability and competitiveness, as well as its current distribution in the world and in Argentina, are described.

Section 1: Taxonomic classification and genetic relationship of the *wild cardoon* with other varieties.

According to the classification revised by Wiklund (1992), the genus *Cynara* includes eight diploid species (2n=2x=34): *C. cardunculus* L., *C. syriaca* Boiss, *C. auranitica* Post (for some authors, is it included in the variation of C. syriaca) *C. cornígera* Lindley, *C. algarbiensis* Cosson, *C. baetica* Pau, *C. cyrenaica* Maire and Weillery and *C. humilis* L, subsequently including a *C. tournefortii* in a new genus, by Robba *et al*. (2005). For its part, *C. cardunculus* has two subspecies; the subsp. *cardunculus* and the subsp. *flavescens,* both differentiated by the characteristics of the bracts (color, form, presence or absence of thorns) and its geographical distribution (Winklud, 1992). Likewise, Winklud (1992) included three varieties within *cardunculus* subsp.*,* wild cardoon (var. *sylvestris* Lam.), and two cultivated ones, *artichoke* (var. *scolymus* (L.) Fiori) and *altilis* (var. *altilis* DC).

In order to estimate the degree of relatedness between the three *cynara cardunculus* varieties, studies based on phenotypic considerations (Foury, 1978; Wiklund, 1992), inferences based on isoenzyme (Rottenberg and Zohary, 1996), intercrossing and sexual compatibility (Basnizki and Zohary ,1994; Rottenberg *et al.,* 1996) have suggested that *wild cardoon* is the progenitor of *artichoke* and cultivated cardoon (Sonnante *et al*., 2007). The three are fully cross-compatible with each other, obtaining fertile intervarietal hybrids (Basnizki and Zohary, 1994). There also exists reproductive barriers between these three varieties and the other *Cynara* species (*C. syriaca, algarbiensis, baetica, humilis*) since their crossing produce few seeds and their hybrids are generally sterile (Rottenberg *et al.,* 1996). Furthermore, scientific evidence supports this hypothesis with molecular markers (Pesce *et al.,* 2017). These techniques provide more precise estimates of genetic relatedness in contrast to morphological and cytogenetic studies, which are influenced by environmental conditions and are not sufficient by themselves to reach a conclusion (Lanteri *et al.,* 2004a). Thus, Portis *et al.* (2005a) and Lahoz *et al.* (2011) based on amplified fragment length polymorphism (AFLP) analysis, reported that both *cultivated cardoon* and *globe artichoke* have evolved separately from *wild cardoon* as a result of different selection. *Altilis* was selected to obtain stalks and fleshy leaf petioles whereas *scolymus* was selected for the production of inflorescences (Lanteri *et al.,* 2004b). Concurring with these results, Sonnante *et al.* (2007) demonstrated that the domestication process happened independently of time and space. *Scolymus* would have originated before *altilis*, attributing this fact to the strong vegetative propagation selection pressure (Hancock, 2012; Gatto *et al.* ,2013). In this context, its domestication is supposed to have begun 2000 years ago, at the beginning of the first millennium, while *cultivated cardoon* appeared later, in the first half of the second millennium, probably in Spain and France (Sonnante *et al.,* 2012; Gatto *et al*., 2013).

As regards *wild cardoon*, molecular studies carried out by Sonnante *et al.* (2007) and Gatto *et al.* (2013), confirmed that var. *sylvestris* does not represent a homogeneous taxon. In fact, it contains two gene pools, as Winklud (1992) had indicated based on morphological studies. The eastern one, mainly diffused in Italy, Greece, Malta, and Tunisia, is characterized by being a smaller spiny plant with smaller leaves and capitula. Conversely, the western gene pool, which is distributed in the Iberian Peninsula, is distinguished by having less and smaller spines, and for being more robust.
According to Gatto *et al.* (2013), the *artichoke* would proceed from the eastern gene pool, being genetically close to the wild populations of Sicily, Tunisia and Malta, but considering Sicily as the main possible center of origin due to its higher genetic diversity. *Wild cardoon*, on the contrary, would come from the western gene pool (Spain and Portugal) due to the fact that it shares a higher number of alleles with the cultivated thistles (Sonnante *et al.,* 2008; Gatto *et al.,* 2013).

Section 2: Importance and uses of *C. cardunculus* L. var *sylvestris*

First and second-generation biodiesel

The production of biodiesel from *C. cardunculus* oil has been subject of experiments (Fernández *et al*., 2006). The oil accumulated in its achenes presents quality and composition characteristics comparable to those of soybean crops and some genotypes of sunflower and rapeseed currently used for this purpose. Authors indicated that achenes present a fatty acid profile where unsaturated predomin over saturated ones: 23-40.7% oleic, 48-61% linoleic vs 9.8-13.9% palmitic and 3-4.5% stearic (Raccuia *et al*., 2011; Mauromicale, 2014; Mancini *et al*., 2019, Abril *et al*., 2019, Chihoub *et al*., 2019; Ierna, 2020; Khaldi, 2021). Regarding the total oil content, seeds have 18-26%, being this value similar to soybean (23%) but lower than sunflower (40%) and rapeseed (35%) (Maromicale,

2014; Francaviglia, 2016; Mancini *et al*., 2019; Khaldi, 2021). Additionally, Mancini *et al*. (2019) determined that other parameters such as its acidity (which is related to transesterification reaction yield) is closer to soybean, its viscosity is lower than soybean (this is desirable), and its density is similar to sunflower as well as to rapeseed and soybean. In this context, Rahman *et al*. (2021) exposed that, according to density, viscosity, calorific value, flash point, cetane number and oxidation stability, cardoon proved to be one of the most desirable species for biodiesel production. Regarding the grain yield of var. *sylvestris*, authors indicated values between 1.14 and 3.0 Tn/ha (Fotti, 1999; Raccuia and Melilli, 2007; Francaviglia, 2016).
A decade ago, the lignocellulosic material of *C. cardunculus* was proposed as an economic, abundant and renewable source for "second generation" biodiesel. Its biomass could be used as a carbon source for lipids production (in the form of triacylglycerols) through oleaginous yeasts (Sitepu *et al*., 2020). Promising results are shown in terms of its production and bio combustion characteristics as well as the environmental impact, showing that cardoon biodiesel has the potential to become a competitive alternative (Tasselli *et al*., 2018; Barbanera *et al*., 2021).

Second-generation bioethanol
Wild cardoon exhibits suitability for bioethanol production as an alternative to that currently obtained from sugarcane or cereal grains. Regarding the biomass quality, it presents low lignin values (less than 10%) and a high content of polysaccharides composed mainly of hexoses which are easily fermentable to ethanol after hydrolysis, including cellulose (42-50%) and hemicellulose (12.8-21%) (Fernandez *et al*., 2015; Francaviglia, 2016; Chihoub *et al*., 2019).

Dry biomass yield of var. *sylvestris* is very variable in relation to the pedo-climatic conditions, the cropping techniques utilized and the genotypes compared. Authors have reported between 7.4 and 18.8 Tn/ha of DM (dry matter) (Raccuia and Melilli, 2007; Mauromicale, 2014; Francaviglia, 2016). Furthermore, several studies are focused on the different stages of the production process: pre-treatment, hydrolysis, and fermentation, being the former the most expensive and limiting but very important to improve the efficiency of the whole process (Rezania *et al*., 2020).Thus, through it the lignin-carbohydrate complex is separated and the lignin, which is recalcitrant to enzymatic hydrolysis, is eliminated, allowing the increase of the fermentable sugar concentrations in subsequent steps (Cotana *et al*., 2015; Mauromicale *et al*., 2019). This was demonstrated by Cavalaglio *et al*. (2021) by performing acid-catalyzed steam explosion pretreatments. In the same line of research, Fernandez *et al*. (2015) and Fernández *et al*. (2018) observed that saccharification increased and fermentation efficiency was higher when performing steam explosion followed by alkaline and dilute acid extraction. On the other hand, after the pretreatment stage, these authors determined that the simultaneous saccharification and fermentation (SSF) process, allowed higher ethanol yield, productivity and fermentation efficiency in contrast to separate hydrolysis and fermentation (SHF). Similar results were achieved by Cotana *et al*. (2015) when comparing SHF to semi-simultaneous saccharification and fermentation (SSSF).

However, from an environmental point of view, this biofuel produces greenhouse gas emissions and energy balance within the values reported for similar lignocellulosic feedstocks (Espada *et al*., 2021),

Biomethane

Studies carried out by Pesce *et al*. (2017), Oliveira *et al*. (2012) and Mauromicale *et al*. (2019) showed that wild cardoons can be considered as promising candidates for biomethane production via anaerobic fermentation of lignocellulosic biomass by silage. For its part, Pesce (2017) obtained a biogas yield of 248.7 Nm^3 (normalized biogas volume) per ton of DM, being this value lower than that obtained from maize but comparable to the volumes reported for other common crops commonly used for this purpose through silage such as ryegrass, triticale or wheat. Conversely, Olivera *et al*. (2012) evaluated the effect on biogas yield while performing mechanical, thermal and thermochemical pretreatments. They obtained increases in biomethane yields when the biomass was subjected to various pretreatments. Also, they highlighted that the thermochemical pretreatment with sodium hydroxide was the most efficient. Similar results were reported by Kalamaras and Kotsopoulos (2014).

However, the most adequate pretreatment, the form of conservation, and the optimal harvest time in terms of digestibility and sugar content in addition to economic profitability is still being evaluated (Pesce *et al*. 2017).

Phytoremediation of contaminated soils

Research carried out by Llugany *et al*. (2012), Sánchez-Pardo *et al.* (2015) and Leonardi *et al*. (2021) assessed the performance of wild cardoon for the remediation of contaminated soils with cadmium (Cd) and arsenic (As), which not only reduce the development of the crops, but also are dangerous for human health. In this context, their results led to the conclusion that this variety shows high tolerance and high fito-extraction of this metal(oid)s, since the plant growth was hardly affected by its toxic potential, and no visible symptoms such as organ death or defoliation were observed. Moreover, it was demonstrated that the arsenic found mainly in the roots is immobilized in their cells, while cadmium, on the contrary, shows mobility. Cadmium was found in higher concentrations in the leaves and also exhibited the highest value of translocation factor, suggesting that this variety has the capacity to translocate this metal from roots to leaves.

Wild cardoon, can therefore be considered as a low-cost, ecological sustainable phytoremediation plant for second-generation bioenergy (Papazoglou, 2011).

Bioherbicide

Recent studies aimed to assess the effects of different species as biological alternatives to chemical weed killers in order to mitigate the plague resistance to various active ingredients and its negative environmental and human health impacts (Bordin *et al*., 2020). In this context, Kaab *et al*. (2020a) and Kaab *et al.* (2020b) found consistent results when presenting *C. cardunculus* var. *sylvestris* as an alternative. They showed that extracts of certain compounds present in wild cardoons demonstrated to have phytotoxic effects, and could be considered as potentially components for natural herbicides. Besides, they also proved that the methanolic extract of *C. cardunculus* inhibits the growth of *Trifolium incarnatum,* *Silybum marianum* and *Phalaris minor* post-emergence germination, obtaining the same effect compared to a commercial chemical herbicide. In this sense, *wild cardoon* plants were evaluated in the field to study the allelopathic effect on the soil weed seed bank and have generated significant decreases in the amount of weeds (Scavo *et al*., 2019(a); Uddin *et al*., 2020). Furthermore, studies on the action mode, the most efficient extraction mechanisms of the active components and the use of solvents for its stability are currently in progress for their potential use as a bioherbicide (Scavo *et al*., 2018; Scavo *et al*., 2019(b); Uddin *et al.,* 2020).

Bioplastic

Turco *et al*. (2019) demonstrated that seed oil derived from var *sylvestris*, gave successful results when used as a raw material for the production of bio-plasticizers with the objective of improving "Eco-friendly, Cost-effective Bioplastics". So, they suggested that cardoon could be considered as a good eco-sustainable, biodegradable, non-toxic, renewable, cheap and non-edible source unlike those traditionally used derived from petroleum. In the same way Mirpoor *et al*. (2022) obtained promising mechanical characteristics by using as raw material solutions based on leaves extracts and proteins obtained from achenes.

Cheese production

Extracts from the flowers of *wild cardoon* are commonly utilized as raw material for cheese manufacturing of cow, goat or sheep in rural areas of Portugal, Spain and Morocco (Zikiou *et al*., 2020). The stigmas of its flowers, due to their high aspartic proteases contents and high milk coagulant activity (Barbagallo *et al*., 2007; Dias *et al*., 2018), are utilized as a substitute for animal proteases obtained from the stomach of ruminants (Zikiou, 2019). For the last 50 years, a way to replace them has been sought mainly due to their limited supply and high value in the market (Shah *et al*., 2014). In this context, Zikiou and Zidoune (2019) by evaluating the properties of cheeses made from wild thistle flowers and industrial cheeses, reached the conclusion that both present similar properties. In addition, as reported by Gomes *et al.* (2019), this coagulant provides the cheese with particular structure and flavor (Gomes *et al*., 2019).

Bioactive activity: antioxidant and antimicrobial

Khaldi *et al.* (2021) proved that the oil extracted from *C. cardunculus* var. *sylvestris* achenes exhibits antimicrobial activity against three human pathogenic strains: *Staphylococcus aureus*, *Escherichia coli and Enterococus feacalis*, being *S. aureaus* the most sensitive strain and *E. coli* the most resistant one. They also determined that, according to the ratio of minimum inhibitory and bactericidal concentrations, the cardoon oil is defined as an oil with bacteriostatic properties against the three strains tested. On the other hand, Dias *et al*. (2018) and Chihoub *et al*. (2019) indicated that either, its inflorescences as well as its leaves, present bioactivity compounds whit antioxidant and antimicrobial effects. These properties are strongly correlated with the content of phenolic present in the plant tissues (Dias *et al*., 2018; Chihoub *et al*., 2019; Muto *et al*., 2020). Therefore, these results envisage *wild cardoon* as a potential and natural source to be used in the area of human nutrition, nutraceuticals, and pharmaceutical.

Section 3. ***Wild cardoon*: a highly adaptable and competitive variety.**

Cynara roots have a rapid growth; in fact, by the end of the first year it already has a competitive root system that gives it the ability to explore several meters in depth to extract nutrients and water, competing strongly with other species for these resources (White and Holt, 2005; Fernandez and Curt, 2005). At the same time, they store fructans (inulin), which are the main reserve component of the roots (as high as 80% on a DM). These reserves contribute to initiate another growth cycle after the summer because, as an escape from drought, the senescence of the entire aerial portion occurs. Growth resumes from formed buds and from reserves accumulated in underlying organs, thus decreasing stored inulin levels (Raccuia and Melilli, 2010). Besides, inulin plays an important role in overcoming stressful conditions of drought, cold or salinity by protecting the integrity of the lipid bilayers of cell membranes during temperature changes or while drying. Furthermore, its production does not only occur during normal plant growth but also under stressful conditions where enzyme activity is induced for inulin synthesis (Ritsema and Smeekens, 2003; Ni *et al*., 2019, Barrascosa *et al*., 2019).

Regarding the aerial part, although seedlings are frost sensitive, when the plant develops the rosette phyllotaxis and has at least 4-6 well-developed-leaves, it becomes rather tolerant to cold, so it can support the low winter temperatures down to -5°C (Fernandez and Curt 2005; Archontoulis *et al*., 2010). On the other hand, it generates a large ground coverage and therefore an inhospitable environment for the growth of many other species. The basal leaves are very large up to 80 cm long and 35 cm wide (Fernandez and Curt, 2005; White and Holt, 2005) and the plant can reach in the second year of growth a height between 0.85 m and 1.23 m and produce on average up to 3 shoots per plant (Raccuia and Melilli, 2007; Mauromicale, 2014; Ierna, 2020).

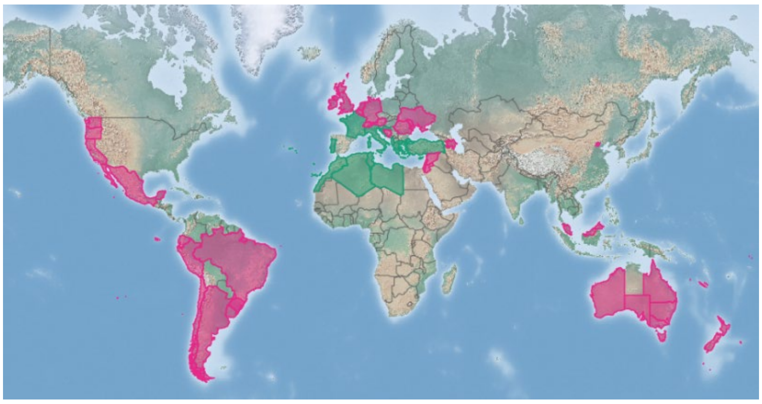
The var*. sylvestris* has the ability to generate many offspring and great dispersal, allowing it to conquer new habitats. Once induced, in mid to late spring, the main stem grows long and produces up to 11 heads in the first growth cycle and up to 23 heads in the second, which may contain up to 650 cypselae (Raccuia and Melilli, 2007; Archontoulis *et al*., 2010; Acquadro, 2014). These spread through the air facilitated by the papus thus conquering new habitats.

We can also mention allelopathic effects, seeds dormancy and the ability to tolerate saline environments among the competitive and adaptability strategies of this variety. On one side, *wild cardoon* can release allelochemicals (polyphenols and sesquiterpenes) in the rhizosphere, through leaching from plant foliage and by the foliage decomposition which cause changes in the physical, chemical or biological properties of the soil, thus influencing negatively the germination and development of surrounding species (Scavo *et al*., 2019a; Uddin *et al*., 2020). In terms of latency, it confers the capacity to avoid the competition, germinate out of place or in unfavorable conditions, since it consists of an hormonal process regulated by the temperature, which affects the expression of signaling genes and abscisic acid synthesis (Huarte *et al*., 2014). With respect to saline environments, Lag-Brotons *et al*. (2013) showed no symptoms of nutritional deficiency were on the leaves under such conditions. In fact, as sodium (Na) and chlorine (Cl) contents increased, there was an increase of these ions in tissues, attributing this to an osmotic adjustment ability through their accumulation in the vacuoles. Likewise, Pappalardo *et al.* (2020), reported that the synthesis of phenolic substances was induced in proportion to the salt increase, confirming the important role of these molecules to boost tolerance to this type of stress. Although *C. cardunculus* var *sylvestris* cannot be considered a typical halophyte, it was proposed as a facultative halophyte species due to the adaptive strategy used to cope with salt stress (Benlloch-González *et al*., 2005). In reference to heavy metals, Pappalardo *et al*. (2020) identified five cardoon genes which seem to be involved in metal stress responses. These genes encode for different mechanisms involved in the uptake and translocation of As and Cd, as well as in the synthesis of chelators that bind these metal(oid)s in a non-toxic form.

Section 4. Actual distribution of wild cardoon

C. cardunculus is undoubtedly the most widespread and transcendent among all the species that integrate the genus (Sonnante *et al*., 2012; Calabrese, 2016). It can be found from Portugal to western regions of Turkey as well as the Canary Islands and Madeira (Pandino *et al*., 2012). However, its distribution is not only limited exclusively to the European continent. In fact, colonization of America allowed *C. cardunculus* to reach the southern tip (e.g. Argentina, Chile, Uruguay) and the west coast of the United States of America. Also, it is found in other regions of the world such as New Zealand and Australia (Basnizki and Zohary, 1994; White and Holt, 2005; GISD, 2020). Nowadays, *C. cardunculus* can be found between the latitudes 26° and 54° in both hemispheres and due to its adaptation, competitiveness and disperse ability, it is naturalized in many countries (Figure 1) (Gominho *et al*., 2018; Gutierrez *et al*., 2020). Recently, López Anido (2016) compiled information that evidences its massive presence in the Pampas of Argentina relying on reports of the first European naturalists who arrived in this area. In fact, by the end of the 18th and at the beginning of the 19th centuries, Packe, dÓrbigny and Darwin reported its massive presence in the central area of the Cono Sur and attributed it to the climatic conditions and the absence of other competing plant species and herbivories. Likewise, some paintings also denote the presence of this plant (e.g. Pueyrredon, 1865). According to Amaral, (1997), cited by Falasca and Ulberich (2007), the arrival of the first *cardoon* seeds could be caused by its presence in the wheat carried by immigrants.

Figure 1.
Distribution of *C. cardunculus* in the world. References: green color indicates the countries in which the variety is native and in pink in which it was introduced. Source: CABI, 2021. http://www.cabi.org/isc



In Argentina, the cultivated areas of the *scolymus* variety, of crucial horticultural importance, are well defined, being the Horticultural Belt of La Plata (Buenos Aires) the area of greatest production (64%), followed by Rosario and Cuyo (both with 14%) (Calabrese, 2016; Pomés *et al*., 2016). Meanwhile, the distribution of *sylvestris*, being a non-cultivable plant and considered as a weed (Acquadro, 2014), has not been well delimited (Portis *et al*., 2005b). Falasca and Ulberich (2006) determined the potential geographic area in Argentina where it can be found and developed. For that purpose, they considered the thermal and water requirements of the center of origin (Mediterranean area) and used agroclimatic indices to indicate the suitable zones according to isohyets and isotherms. They concluded that wild cardoon could be found in the areas of the country with humid climate and also in the sub-humid to semi-arid sectors of the provinces of Salta, Jujuy, La Rioja, Catamarca, San Juan, San Luis, Mendoza, La Pampa, Neuquén, Río Negro and Chubut. Conversely, Busso *et al*. (2013) confirmed that this variety is distributed in addition, in the grasslands classified as Monte and Caldenal. These sectorizations coincide with the regions reported by the Instituto de Botánica Darwinion (2021) [Darwinion Botanical Institute] for this variety.

Conclusions

Cynara cardunculus var *sylvestris*, which is the common ancestor of both cultivated varieties, *scolymus* and *altilis*, has been marginalized as a weed for a long time. Nowadays, it is being considered as a species of interest since it proved to be a natural and renewable resource, with promising results to be used for different purposes. In addition, its characteristics of adaptation to marginal environments or abiotic stress situations make it a variety of interest for areas with low agricultural aptitude. Moreover, it could even replace crops used for human food to obtain different products.

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