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Distribution, ecological role and symbioses of selected shrubby species in the Mediterranean Basin: a review

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Abstract

Among the Mediterranean ecosystems, shrublands are a characteristic type of vegetation, widespread in different habitats. Owing to different factors such as the physiological, morphological, reproductive, phenological, and regenerative properties, as well as the inter-intraspecific interactions, each shrubby species represents an important element within the plant community and plays a specific ecological role. In this review, attention was focused on the ecological functions and type of plant-microsymbiont interactions in respect of selected shrubby species within the Mediterranean Basin: *Amelanchier ovalis*, *Astragalus nebrodensis*, *Crataegus laciniata*, *Lycium intricatum*, *Prunus spinosa*, and *Viburnum tinus*.

Keywords: ecology, inter-intraspecific interactions, Mediterranean area, shrublands, plant associations.

Introduction

The Mediterranean Basin represents one of the five Mediterranean-climate regions of the world and occupies only 1.6% of the earth surface (Melendo et al. 2003). Nevertheless, it is characterized by a particularly rich and diverse flora (Mittermeier et al. 2004; Médail et al. 2019), composed of 25.000 plant species (Cowling et al. 1996; Médail and Quézel 1999), 60% of which are endemics (Thompson 2005). Particularly, there is a great wealth of endemism in trees and shrubs, (290 indigenous woody species and subspecies, 201 of which are endemic to the Mediterranean, Fady-Welterlen 2005), that are also the main constituents of different vegetation types such as matorrals or shrublands (*maquis*, *garrigue*, *phrygana*) and forests (Médail et al. 2019). Scrublands, which can be considered a mixture of several sclerophyllous shrubs and tree species, a Mediterranean-type of vegetation rarely found in other ecosystems (Ozenda 1982; Mangas et al. 2007).

The floristic diversity of the Mediterranean region is determined by various factors, such as a topographic, biogeographical, ecogeographical and climatic heterogeneity, as well as human influence that has strongly impacted community structures; in fact the current level of endemism and biodiversity is the result of these interactions (Blondel and Aronson 1999; Comes 2004; Rundel and Cowling 2013; FAO 2018). The geographical position of the Mediterranean Basin and the presence of many peninsulas and islands represent important drivers of biodiversity in the area (Blondel et al. 2010; Tavşanoğlu and Pausas 2018). Moreover, the basin is at the intersection of three continents (Europe, Asia, Africa), (Warhol 2007), representing a huge “tension zone” where biotic elements of various biogeographical regions converge (Comes 2004; Manafzadeh et al. 2014). The climatic features of the Mediterranean Basin are also differentiated.

Generally, the adjective “Mediterranean” is referred to the climate-type that is characterized by dry summers contrasting with wet and mild winters (di Castri 1981). In the Mediterranean Basin this weather pattern is discontinuous, in fact its climate is notable for high interannual variation in both rainfall and temperature extremes (Rundel and Cowling 2013). In particular, the climatic factors (temperature and precipitation) combining with the biological factors, are at the basis of the bioclimatic approach. This last identifies the typical plant associations in addition to climatic analysis, indicating specific series of vegetation zones that follow one other according to altitude, latitude, and slope exposition (Blondel et al. 2010). Therefore, climatic factors and climate modifications are crucial in the current organization of vegetation structures (Quézel 1999), in fact more groups of plant species have evolved precisely as a function of climate change (Rundel and Cowling 2013). Moreover, the vegetation structures dynamics are also influenced by some threats such as changes in land use and fire regime, and by other human activities (such as overgrazing, non-regulated cultivation techniques, deforestation, etc.) (Manaut et al. 2011; Venturella et al. 2012; Mandracchia et al. 2017; Gargano 2018; Tavşanoğlu and Pausas 2018).

Consequently, a mosaic of plants communities that follows different stages of degradation and regeneration has developed (Gallego Fernandez et al. 2004; Lombardo and Maetke 2019). This is particularly evident for shrub communities. In relation to bioclimatic type and altitude, they form, in the Mediterranean region, different types of vegetation such as pre-forestal structures, mantle communities, matorral, and high-level matorral. In fact, they occur in various environments, for example in open woods, in clearings of woods, in marginal slopes, at the border of forests forming the vegetation mantle and hedges, and in different dynamic pre-forestal stages more or less in contact with the woods (Canullo 1993).

Scrublands occupy extensive areas of the Mediterranean region (Riera et al. 2007), that will likely increase in the future (Castro et al. 2004), because the spread of these formations is the result of frequent disturbances in Mediterranean forests (Riera et al. 2007), for example the occurrence of forest fires, the increased temperatures and drought, as well as abandonment of cultivated fields (Pasalodos-Tato et al. 2015). In fact, the increase of shrub formations is prevalently associated with the stages of degradation of mature forests as well as stages of vegetation recovery in abandoned agricultural lands (Grove and Rackham 2001). The spread of these shrub species is also linked to regeneration strategies such as seeding and resprouting that allow them to resist to disturbances (Verdú 2000). Indeed, in some cases, threats are decisive to characterize ecological systems, for example natural and anthropogenic causes of fire play a major role in shaping the Mediterranean Basin vegetation, and some species depend on fire for reproduction (Valavanidis and Vlachogianni 2013).

In other cases, these shrub formations are constituted by some “cryptic trees” namely species that generally occur as shrubs but can form true trees under certain environmental conditions or in circumstances where the disturbances have been absent or very reduced for at least several decades (Médail et al. 2019).

Consequently, a high local plant diversity occurs in these disturbed areas and especially in shrubland communities (Cowling et al. 1996; Médail and Quézel 1997). Moreover, shrubs play a vital ecological role (Pasalodos-Tato et al. 2015) in many ways, for example in soil protection (Bochet et al. 2006), but also in terms of biodiversity (Mangas et al. 2007), in nutrient and carbon cycles (Chapin 1983), and in ecosystem restoration (Castro et al. 2004; Rey et al. 2009). Often the shrubland stage constitutes a secondary succession that can stimulate, facilitate or positively interact with community dynamics. In fact, the shrubby species, performing a nurse-plant role, can facilitate the germination and growth of forest woody species beneath their canopies, improving water status of seedlings through reduction of radiation, lowering soil temperature, conserving soil moisture and protecting them from herbivory damage, also thanks to their functional traits and their morphological characteristics (Bruno et al. 2003; Castro et al. 2004; Manaut et al. 2011). This is particularly evident

in pre-forestal structures. In fact, pre-forests correspond to transitory stages and they constitute ecotones that lie between matorral and forests according to the classic dynamic model of forest establishment in the Mediterranean region (Quézel 1999). A similar function is also played by forest edges, constituted by a belt of shrubs termed mantle (Carni 1998). These mantle communities, usually, are usually classified within the *Prunetalia spinosae* (Carni 1998; Weber 1998) and they are distributed between the Mesomediterranean and the Supramediterranean belts (Poldini et al. 2002). These vegetation structures are characterized by the co-evolution of social and ecological systems (Martín-López et al. 2016), and represent a suitable habitat to observe forest dynamics, because in the absence of strong alterations they contribute to increase the surface covered by woods (Delelis-Dusollier 1985; Cutini and Blasi 2002). Furthermore these vegetation patches that constitute “fertility islands” or “resource islands” can promote the tree species development also through their positive influence on soil microbiota, especially on symbiotic microorganisms (rhizobia and mycorrhizal fungi), in fact often the majority of them is made up of mycotrophic shrubs (Manaut et al. 2011). This is particularly important in the Mediterranean region, which as stated above, it is an area very susceptible to climate change and anthropogenic degradative activities that represent the main threat to the sustainability of Mediterranean ecosystems (López-Bermúdez and Albaladejo 1990).

In fact, mycorrhizal and rhizobial symbioses not only enhance the establishment of key plant species but also increase soil fertility and quality. Therefore, these dual symbioses enhance the ability of plants to establish and to cope with stressful situations, for example drought, nutrient deficiency, and soil disturbance (Herrera et al. 1993), especially with regard to the mycorrhizal symbiosis. On the other hand, the symbiotic associations with rhizobial bacteria, determine an increase of soil nitrogen content, of organic matter and of hydrostable soil aggregates (Requena et al. 2001; Goh et al. 2013). Thus, these microbial associations represent a key ecological factor, because they play a role in sustaining a vegetation cover in natural habitats (Azcón et al. 1997).

In view of all these considerations, the main objectives of this review are: (i) to examine the spatial distribution, in the Mediterranean Basin of selected shrubby species, such as: *Amelanchier ovalis* Medik., *Astragalus nebrodensis* (Guss.) Strobl., *Crataegus laciniata* Ucria, *Lycium intricatum* Boiss., *Prunus spinosa* L., *Viburnum tinus* L.; (ii) to perform, for each species, a screening of plant species-microsymbiont interactions typology, also providing general information on the ecological role of symbioses; (iii) to illustrate their ecological functions through mechanisms that determine community assemblage for each species, some botanical aspects and functional traits, such as their morphological, reproductive and phenological characters reported in many publications, as well as their occurrence in different bioclimates and habitats. This because the relationship between the symbiotic status of plant species and other plant traits can be of fundamental importance for the understanding of a plant's ecology and distribution (Hempel et al. 2013).

Materials and Methods

The information has been collected from many sources such as scientific papers, books, reports, thesis, monographs, contributions on web sites and online databases. In particular, for every aspect investigated, various sources were used, both on an international, national and regional scale, considering that the investigated species are distributed in different areas of the Mediterranean Basin.

As geographical reference to define the border of the study area, the limits of Mediterranean climate by Quézel and Médail (2003), and the definition of terrestrial ecoregions of the world from Olson et al. (2001), have been followed, considering the Mediterranean Basin as the land and the islands around the Mediterranean Sea with a Mediterranean climate (Tavşanoğlu and Pausas 2018). With regard to taxonomy and nomenclature, and the distributive data and biogeographic information too, the primary sources of data used were: the international database Euro + Med PlantBase (Euro+ Med 2006-), The Plant List database (2013), The International Plant Names Index

(2012), TROPICOS Missouri Botanical Garden (Tropicos.org), ILDIS- International Legume Database & Information Service (Roskov et al. 2005), PAN-European Species directories Infrastructure (de Jong et al. 2015), LycieaeWeb (2017), Flora Europaea (Tutin et al. 1964–1993), Atlas Florae Europaeae (Kurtto et al. 2013), followed by Bartolucci et al. (2018), Pignatti (2017–2019), Portale della Flora d'Italia (Available from: <http://dryades.units.it/floritaly>), Conti et al. (2005), Giardina et al. (2007) (for the Italian territory), Flora of Greece Web (2018) (for Greece), Anthos (2019), Flora Iberica (Muñoz Garmendia and Navarro Aranda 1998; Devesa Alcaraz et al. 2007; Castroviejo Bolibar 2012), Sociedade Portuguesa de Botânica (2014) (for the Iberian Peninsula), Nikolić (2004) (for Croatia), Le Floc'h et al. (2010), African Plant Database (Conservatory and Botanical Garden of Geneva and South African National Biodiversity Institute, 2019) (for the North African territory), Lebanon flora (2019) (for Lebanon), Silene-Flore database (2006) (for France), Hand et al. (2011) (for Cyprus), Cretan Flora (2019) (for Crete), MaltaWildPlants.com (Mifsud 2002–2014) (for Malta). For the analysis of symbiotic associations and especially to assign mycorrhizal types (arbuscular mycorrhizae- AM, vesicular arbuscular mycorrhizae - VAM, ectomycorrhizae-ECM, non-mycorrhizae- NM) for each plant species, reference was made to these main datasets: Trappe (1962); Harley and Harley (1987); Akhmetzhanova et al. (2012); Wang and Qiu (2006); Hempel et al. (2013); Bueno et al. (2017); Curto and Allen (2011); Correia et al. (2018). Regarding some functional traits, reference was mainly made to the BROT 2.0 database (Tavsanoglu and Pausas 2018), chromosome data were retrieved from: The Chromosome Counts Database (Rice et al. 2015), Bedini et al. (2010) (specific for the Italian flora), CromoCat database (Simon and Blanché 2016) (specific for the Spanish vascular flora), Goldblatt and Johnson (1981-). Moreover in order to investigate, in detail, the geographical distribution and also to obtain historical distribution data for each selected species, distribution maps have been developed, according to botanical literature and by geo-referencing the species location data obtained from the labels of digital herbaria samples housed in: B, CAT, P, PAL, W, and WU (acronyms follow Thiers 2019) and from GBIF (2017) (again in relation to herbarium samples). The studied species have been selected because they are representative of different Mediterranean vegetation types, distributed in relation to the bioclimate type and the elevation. In fact, various habitats have been considered in relation to the selected species that characterize them, for example coastal and sub-coastal environments for *L. intricatum*, sclerophyllous woodlands for *V. tinus*, mantle vegetation and pre-forest structures for *P. spinosa*, *C. laciniata* and *A. ovalis*, and orophilous thorny-cushions vegetation for the Sicilian endemic *A. nebrodensis*.

Distribution of the selected species in the Mediterranean region

Information on the distribution of species is useful for an understanding of their history and taxonomy (Argus 2007). The selected species are widespread in various countries of the Mediterranean Basin of which they are also native. For each of them, considering also the relative subspecies, the spatial distribution accompanied by maps, is examined below, with particular reference to the Sicilian territory. The geographical scope considered mainly refers to the Mediterranean climate area by Quézel and Medail (2003), represented in grey colour on the distribution maps.

Lycium intricatum (Solanaceae) is native in northwestern Africa, in the Balearic Islands (Stafforini et al. 2001), S and SE of the Iberian Peninsula (Spain and Portugal) (Gallego 2012). In Tunisia, this species is reported both as cultivated and sub-spontaneous (Pottier-Alapetite 1981; Le Floc'h et al. 2010). *Lycium intricatum* has two subspecies: *L. intricatum* subsp. *pujosii* Sauvage, endemic to Morocco (Dobignard and Chatelain 2013; Rankou et al. 2013) and *L. intricatum* subsp. *intricatum*, native to Algeria, Morocco, Mauritania, S Portugal, SE Spain and Balearic Islands (Carazo-Montijano and Fernández-López 2006; Dobignard and Chatelain 2013) and also present in the Italian territory. Galasso et al. (2018) reported the presence of *L. intricatum* subsp. *intricatum* in Sardinia (where it is considered a casual alien), Calabria (where it is no longer recorded) and in Sicily (where it is reported as a cryptogenic species). Puddu et al. (2016) consider this species

doubtfully present in Sardinia. Specifically, in the Sicilian territory it grows in Pantelleria, Favignana, Lampione, Lampedusa, Linosa, Gela and Scoglitti (Minissale and Sciandrello 2005; Giardina et al. 2007; Lo Cascio and Pasta 2012). The distribution of *L. intricatum* with its subspecies is reported in Figure 1, also considering the occurrence status in the Mediterranean area such as: cryptogenic, casual, endemic, native, cultivated and sub-spontaneous.

Viburnum tinus (Adoxaceae) is native to the Mediterranean region (especially southern Europe and North Africa, Moura et al. 2013) with a wide distribution (Dirr 1998; Darras et al. 2010), and also present in the Macaronesian archipelago with two endemic subspecies (Moura et al. 2015). For this species, three subspecies have been recognised: *V. tinus* subsp. *tinus*, *V. tinus* subsp. *subcordatum* (Trel.) P. Silva (= *V. treleasei* Gand.), *V. tinus* subsp. *rigidum* (Vent.) P. Silva (= *V. rugosum* Pers.). *Viburnum tinus* subsp. *tinus* is distributed throughout the Mediterranean Basin including most of the Mediterranean islands. In fact, it is native in North Africa (Morocco, Algeria, Tunisia, and Libya,) (Dobignard and Chatelain 2011), in Europe (mainland Portugal, Spain, France, Italy, Slovenia, Albania, Croatia, Greece), in the Middle East (Turkey and Israel, Danin & Fragman-Sapir 2016) and in the Mediterranean islands (Balearic islands, Corsica, Sardinia, Sicily, Elba, Corfù, Lussino, Rab, Mljet, Lokrum, Cyprus) (Saéz et al. 2011; Moura et al. 2015; Catalogue of Life 2019). In particular in Cyprus, where a rare indigenous population on Pentadaktylos has been found (Crivellaro and Schweingruber 2013), it is included in the IUCN Red List as VU (Vulnerable) (Hand 2009; Crivellaro and Schweingruber 2013; Hand 2015). In Sicily, it has a fragmentary and relict distribution, mainly in the Palermo Plain, in the Sicani Mountains and in punctual localities of Mt Etna (Gianguzzi et al. 2016; Domina et al. 2019). In some areas of the Mediterranean Basin it was introduced, for example in Malta, (DAISIE 2008; Mifsud 2002-2014), in Crete (Barclay 1986), in the Cyclades islands and in the eastern Aegean islands (Vladimirov et al. 2016; Flora of Greece Web 2018). Also in other areas outside the Mediterranean basin, such as the Macaronesian islands (especially the Island of Madeira, Portugal), *V. tinus* was introduced as ornamental plant and it is perfectly naturalized (Gonçalves Silva et al. 2009), as well as in southern Switzerland and northern Italy, around the Insubrian lakes, where it is naturalized in deciduous forests with laurophyllous underwood as a result of climate change (Berger and Walter 2006). *V. tinus* subsp. *subcordatum* is endemic to the Azores, and occurs in the islands Corvo, Flores, Faial, Pico, São Jorge, Terceira, São Miguel, and Santa Maria (Schäfer 2005). *V. tinus* subsp. *rigidum* is endemic to the Canary Islands (El Hierro, La Palma, La Gomera, Tenerife, Gran Canaria) (Acebes Ginovés et al. 2004). Figure 2 shows the distribution of *V. tinus* subsp. *tinus* differentiating areas where it is considered native from localities where it is considered naturalized.

Prunus spinosa has a large distribution in the Euro-Siberian region. It occurs, in fact, in most of South-Central Europe, in NW Africa, reaching also Asia Minor, Caucasus and the Caspian Sea (Erturk et al. 2009; Popescu and Caudullo 2016). Specifically, it is reported as native from the Atlantic shores of Portugal to the Mediterranean Coast of Israel (Carazo-Montijano and Fernández-López 2006; Dobignard and Chatelain 2013; Rhodes and Maxted 2016). Eight subspecies have been described, mainly differentiated by the characteristics of the fruit (Hanelt 1997; Hübner and Wissemann 2004). These are: *P. spinosa* L. subsp. *spinosa*, *P. spinosa* subsp. *cerasina* Hrabětová, *P. spinosa* subsp. *dasyphylla* (Schur) Domin, *P. spinosa* subsp. *fechtneri* Domin, *P. spinosa* subsp. *insititioides* (Fic. & Coutinho) Franco, *P. spinosa* subsp. *megalocarpa* Domin, *P. spinosa* subsp. *moravica* Domin, and *P. spinosa* subsp. *ovoideo-globosa* Domin (Kurrto et al. 2013; Catalogue of Life 2019). *Prunus spinosa* subsp. *spinosa* occurs widely in various countries of the Mediterranean Basin: Portugal, Spain (Royo Plan 2006), France (Silene-Flore database 2006), Croatia (Nikolić 2004; Fadić 2016), Italy (mainland, Sardinia, Sicily, Bartolucci et al. 2018), Malta (as naturalized species, Mifsud 2002-2014), and Greece (on the Pindus, Flora of Greece Web 2018). In Sicily, it is ubiquitous; it occurs throughout on coastland and hills (Giardina et al. 2007). In North Africa (Morocco, Tunisia, Algeria), but also in the Balearic Islands (Algaida-Mallorca), *Prunus* × *fruticans* Weihe (*P. spinosa* × *P. domestica*), also reported as *P. spinosa* subsp. *fruticans* (Weihe) Nyman, is present (Le Floc'h et al. 2010; Dobignard and Chatelain 2013; Ribas and Gil 2018). Also, the other

subspecies are widespread in the countries of the Mediterranean Basin (Catalogue of Life 2019). In particular, compared to the others, *P. spinosa* subsp. *dasyphylla*, has a more limited distribution in the Mediterranean area, in fact, it occurs only in Albania (Barina et al. 2018), Greece (Flora of Greece Web 2018), and Turkey (Dönmez and Yildirimli 2000; Özcan 2008) as well as the *P. spinosa* subsp. *insititoides*, endemic to Portugal (Liberato et al. 2003; Rhodes and Maxted 2016). In Figure 3, the distribution of *P. spinosa* in the Mediterranean region is shown.

Crataegus laciniata (Rosaceae) is distributed in the central-western Mediterranean region, especially: Morocco and N Algeria (Valdés 2013) in several localities spreading across the Atlas mountains (Emberger 1938), SE Spain (where it has been assessed as vulnerable, Bañares et al. 2008), where it is native; its presence is doubtful in Tunisia and Libya (el Merj) (Jafri 1977; Le Floch et al. 2010; Dobignard and Chatelain 2013). In Italy, it is native only in Sicily: on the Madonie mountains (Bosco Pomieri, Portella Colla, Piano Battaglia, Portella Mandarinini, Mt Quacella, Mt Antenna Piccola) (Meusel and Kästner 1990; Raimondo 2004; Bagnato et al. 2012; Calvo et al. 2015) on the Sicani mountains (Mt Cammarata, Mt Carcaci) (Gianguzzi et al. 2007; Domina et al. 2012), on Rocca Busambra, on Mt San Giuliano (Erice) (Raimondo et al. 2004), and the Nebrodi mountains (Mt Soro-Torrente Martello) (Cristaudo and Galesi 2002). In fact, this species has also been found in the National Park “Foreste Casentinesi”, Badia Prataglia (Tuscany) (Nepi et al. 2008), as introduced species under the name *C. rhipidophylla* Gand. (Viciani et al. 2010; Arrigoni and Viegi 2011). The estimated extent of occurrence of this species in the Mediterranean Basin is 529,300 km² (Wilson 2018). In Figure 4 the geographical distribution of the species is illustrated, highlighting where the species is considered native and where naturalized.

Amelanchier ovalis (Rosaceae) naturally occurs in sub-Mediterranean and Mediterranean areas, throughout central, southern and southwestern Europe, along the northeastern coast of Africa and also in SW Asia (Ochmian et al. 2013; Indreica et al. 2016). For this species four subspecies are reported: *A. ovalis* subsp. *ovalis*, *A. ovalis* subsp. *integrifolia* (Boiss & Hohen.) Bornm., *A. ovalis* subsp. *cretica* (Willd.) Maire & Petitmengin (Opalko et al. 2015), and *A. ovalis* subsp. *embergeri* Favarger & Stearn. Kurrto et al. (2013) consider the tetraploid *A. ovalis* subsp. *embergeri* included in *A. ovalis* subsp. *ovalis*. In particular, *A. ovalis* subsp. *ovalis* is present in various countries of the Mediterranean Basin such as: Portugal, Spain, Balearic Islands (Mallorca), Morocco, Algeria, S of France, Corsica, Italy, Slovenia, Croatia, Montenegro, Albania, Greece, Turkey, (Sáez et al. 2011; Muñoz Garmendía et al. 1998; Dobignard and Chatelain 2013; Kurrto et al. 2013), and Lebanon (in Horsh Ehdén Nature Reserve, reported as *A. ovalis*, Abu-Izzeddin et al. 2000). *Amelanchier ovalis* subsp. *cretica* is endemic to Europe, with distribution in Italy (but not in Sicily, where it was recorded by mistake, Bartolucci et al. 2018), in southern and western Greece (where it is considered endemic in limestone mountains, Papanicolaou et al. 1983; Strid 1986), and rare on Crete (Catalogue of Life 2019; Cretan Flora 2019). *Amelanchier ovalis* subsp. *integrifolia*, is distributed in Turkey (Anatolia), Greece, and outside the Mediterranean area in Iran and Armenia (Serdar et al. 2014; Catalogue of Life 2019).

A. ovalis subsp. *embergeri* is present in: S France, Corsica, along the northern slope of the Pyrenees (El Turbón, Pico de Guara, Pico Gratal, Montserrat 1980) and in Sicily (Madonie mountains, Mt Quacella); outside the Mediterranean area it is distributed along the Alps, in Germany, Slovakia, Crimea, and the Caucasus (Baudiere 1972; Favarger and Stearn 1983; Raimondo et al. 2010a; Silene- Flore database 2006; Gregor et al. 2018). Figure 5 shows the distribution in the Mediterranean area of *A. ovalis* and its subspecies.

Astragalus nebrodensis (Fabaceae) is endemic to Sicily (Peruzzi et al. 2015). It belongs to the section *Rhacophorus* Bunge (Podlech 2008b), subgenus *Tragacantha* Bunge, (Pignatti et al. 1980; Nimis 1981), later reduced to subgenus *Astragalus* (Zarre-Mobarakeh 2000; Pirani et al. 2006; Zarre and Azani 2012). This section includes species that form remarkable vegetation types in alpine and subalpine areas in SW Asia (Pirani et al. 2006) but also other orophyte *Astragalus* species with

thorny cushion-like habit distributed in the Mediterranean region, for example: *A. granatensis* Lam. in the Iberian Peninsula and in Morocco, *A. creticus* Lam. and *A. dolinicola* Brullo & Giusso endemic to Crete, *A. cylleneus* Boiss & Heldr. in Greece, *A. rumelicus* Bunge in Albania and Greece, *A. psilodontius* Boiss., *A. bethlehemiticus* Boiss. and *A. argyrothamnos* (Boiss.) Greuter in Lebanon, *A. siculus* Biv. endemic to Sicily (Mt Etna) (Podlech 2008b; Kurtto 2017). Another section widespread in the Mediterranean mountainous habitats is *Tragacantha* DC. In fact, two complexes of this section, such as the eastern Mediterranean *A. angustifolius* group (diffused in the Balkans, Aegean Islands, Anatolia, Armenia, Syria and Lebanon) (Brullo et al. 2012) and the Adriatic *A. sirinicus* group (diffused in Italy, Sardinia, Corsica, Croatia) include in total 11 orophyte species (Hardion et al. 2016). Three species belonging to the *A. sirinicus* complex are considered vicariant of *A. nebrodensis*, namely *A. sirinicus* Ten. (in the northern, central and southern Apennines), *A. genargenteus* Moris and *A. gennarii* Bacch. & Brullo endemic to Sardinia (Cogoni et al. 2014; Sau et al. 2014), as well as *A. parnassi* subsp. *calabricus* (Fisch.) Maassoumi, endemic to Calabria (Peruzzi et al. 2015), belonging to the section *Pterophorus* Bunge and *A. siculus* (Pignatti 1986).

Astragalus nebrodensis is distributed in various areas of the Madonie mountains (Portella Colla, Mt Quacella, Mt Mufara, Piano Battaglia, Piana della Canna, Mt San Salvatore, Piano Zucchi, Pizzo Carbonara) (Pignatti et al. 1980; Podlech 1986; Giardina et al. 2007; Schicchi et al. 2013). In Figure 6 the distribution of *A. nebrodensis* and of its vicariant species in Italy is shown.

Morphology and phenology of the selected species

For each species, the main morphological and phenological features, such as habit and biological form (i.e. NP= Nanophanerophyte, MP= Microphanerophyte, P scap= Phanerophyte scapose, P caesp= Phanerophyte caespitose, Ch frut= Chamaephyte frutescentia; Raunkiaer 1934), features of stem, of leaves, of flowers and fruits, flowering period, pollination, fruit setting, seed dispersal and also the number of chromosomes, with the appropriate references, are reported in Table 1.

Habitats and ecological functions of selected species

The species distribution and species richness in vegetational communities are determined by various factors: pattern in physical factors (soil, microclimate), biological processes (competition, dispersal, colonization, extinction), disturbance and history (land use, anthropogenic impacts, and successional age) (Gilliam and Roberts 2003). These are the basis for maintaining spatial habitat heterogeneity. In particular, the multiple interactions between species (intra/interspecific interactions), strongly influence the community structure and dynamics, playing a key role in “habitat modification” (Stachowicz 2001; Padilla and Pugnaire 2006). In this way, complex ecological networks develop, where single plants can fulfil their ecological role.

The selected species are components of different plant communities, (Table 2), but in some cases, some of them are linked by similar functions that they perform within their habitat or by successional dynamics that occur between them.

Associations and interactions

Types of symbioses of the selected species

Mutualistic symbiotic microbial interactions are important factors contributing to plant biodiversity, and in structuring plants communities, by affecting colonization, competition, coexistence and soil nutrient dynamics (Clay and Holah 1999). Two important groups of mutualists are represented by nitrogen-fixing bacterial associates of Fabaceae and mycorrhizal fungi. The bacteria, in general rhizobia, induce root nodules and fix atmospheric nitrogen into ammonium that is delivered to their leguminous hosts (van der Heijden et al. 2006). The term mycorrhiza describes different root-fungus

associations (Bonfante and Anca 2009). Mycorrhizal symbioses are fundamental for plant nutrition (acquisition of water and mineral nutrients such as nitrates and phosphates from soil), for plant health (protection against environmental biotic or abiotic stresses such as pathogen attack, drought, salinity, heavy metals, organic pollutants), and soil quality (they improve soil aggregation and litter decomposition) (Barea et al. 2011). As shown in Table 3, the selected species present different types of symbiosis.

Conclusions

This review summarizes the distribution and the ecological role of selected shrubby species, also in relation to their habitat, to their functional traits and the presence of symbioses. As regards these last two aspects, it is necessary to conduct more detailed research. In particular for *Astragalus nebrodensis*, there is insufficient data from the literature, especially with respect to some phenological features such as pollination, seed dispersal strategy, and fruit set. As regards the symbioses, especially the mycorrhizal ones, most of the species investigated present arbuscular mycorrhizae, but there is not enough taxonomic and morphological information concerning the fungal partners and the specific ecological role that they perform in relation to their interaction with the investigated shrub species. For these reasons, questions concerning the interaction of the mycorrhizae with these shrubby species should be investigated as well as their effects on the different vegetational structures that these species constitute.

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Table 1. Main morphological and phenological features of selected species

Species	Habit	Stem and leaves	Flowers and fruits	Number of chromosomes	Phenology	References
<i>Lycium intricatum</i> Boiss.	Bushy, NP, summer-deciduous	0.3-2 m height, much-branched, very spiny. Leaves 3–15 × 1–6 mm, oblanceolate, alternate, ovate, elliptical and fleshy.	Flowers are solitary or in clusters of 2-3, hermaphrodite. Corolla 13–18 mm, blue-violet, purple, lilac, pink or white with five welded petals. Calyx 1.5–2 mm, shallowly 5-dentate. Stamens included; filaments glabrous. Fruit 3-7 mm, globose, orange-red or black with antioxidant activity.	$2n=24$	Leaf bud formation: October/November Leaves fall: June Flowering: August/November Fruit setting: September Fruit maturation: December/February Pollination: entomophilous Dispersal strategy: endozoochory/diploendozoochory (reptiles and birds).	Martin and Escarre 1980; Blanca et al. 2011; Lo Cascio and Pasta 2012; Boulila et al. 2015; Hamalainen et al. 2017; Yao et al. 2018.
<i>Viburnum tinus</i> L.	Bushy, MP, evergreen	2-6 m height, richly ramified with a dense rounded crown. Leaves coriaceous, with ovate to elliptic blade, in opposite pairs, 4-10 × 2-4 cm, persist 2-3 years.	Flowers are hermaphrodite, white or light pink, grouped in flat corymbs, 4-9 cm diameter composed of 3 to 9 main branches. Corolla campanulate, pentamerous 6-9 mm, with five stamens inserted on the corolline tube. The ovary is inferior. Fruit is a one-seeded drupe, globose, fleshy, metallic blue, 5-7 × 4-5 mm.	$2n=36$	Vegetative growth: March/July Flowering: from December to June Fruit setting: April Fruit maturation: October Pollination: entomophilous Dispersal strategy: endozoochory (mammals and birds)	Debussche et al. 1987; Thébaud and Debussche 1992; Castro-Diez and Montserrat 1998; Herrera 1998; García-Fayos et al. 2001; Pérez-Latorre and Cabeduzo 2001; Cervelli 2005; Karlsson et al. 2005; Moura et al. 2015; Alkurdi and Supuka 2016.
<i>Prunus spinosa</i> L.	Thorny shrub, P caesp, winter-deciduous.	1-5 m height, with a dense canopy and intricate branches and numerous suckers; bark dark grey to blackish slightly grooved. Leaves 2-5 × 1-2 cm long, alternate obovate to oblanceolate, with margins finely toothed, green in color.	Flowers are white, hermaphrodite, solitary, appearing before leaves with triangular-ovate sepals, 5 petals, 20 stamens, yellow/red anthers. Fruit is a purple globose drupe covered with frostlike bloom, 1-1.5 cm, with antioxidant action, edible.	$2n=32$	Flowering: different periods in relation to altitude, generally in March/April. Fruit setting: spring/summer Fruit maturation: late summer/ autumn Pollination: entomophilous Dispersal strategy: endozoochory (mammals and birds).	Gyan and Woodell 1987; Guitian et al. 1993; Fernandez and Alejano 2013; Freschi et al. 2015; Popescu and Caudullo 2016; Cosmulescu and Călușaru 2018.
Species	Habit	Stem and	Flowers and	Number of	Phenology	References

		leaves	fruits	chromosomes		
<i>Crataegus laciniata</i> Ucria	Thorny shrub or small tree P-NP scap/caespitose, winter-deciduous	Height up to 8 m. Leaves lanate on both surfaces, caducous, cuneate, and rhombic to obovate-oblong, 23-29 × 20-28 mm, margin with 2-3 narrow oblique lobes.	Flowers are cymose inflorescences with 6-10 white, hermaphrodite flowers at the end of lateral branches, bracts 1-3; 5 triangular, lanate sepals, 15-22 stamens with red-purple anthers; 3-5 styles. Fruits are globose or pyriform, fleshy, brick-red to yellowish-orange, lanate while young, crowned by deflexed sepals; 8-14 mm in diameter, edible; 2-3 pyrenes, (the latter feature differentiates it from the species <i>C. monogyna</i> var. <i>lasiocarpa</i>).	<i>Unknown</i>	Flowering: April to June Fruit setting: summer Fruit maturation: autumn, September/October Pollination: entomophilous Dispersal strategy: endozoochory (mammals and birds)	Bartha 1999; Prados et al. 2000; Valdés et al. 2002; Lopez-González 2007; Navarro et al. 2008; Lara Ruiz 2009; Calvo et al. 2015; Fennane and Rejdali 2016.
<i>Amelanchier ovalis</i> Medik.	Bushy shrub or small tree, P caespitose, winter-deciduous	1-3 m height, straight or tortuous trunk with a reddish brown bark. Leaves 2-5 × 1.5-3 cm, ovate, oblong to obovate or almost orbicular, rounded or emarginated at apex, lanate beneath when young.	Flowers are in erect lanate racemes, hermaphrodite. Pedicels, 6-13 mm long, are bracteate at the base and bearing a second bract at or near the middle. Hypanthium is campanulate or urceolate, lanate at first, soon glabrous. Petals 5, white, or rarely pink, oblanceolate to narrowly oval, 9-14 mm. Sepals are lanceolate, 2-2.5 mm long. Stamens 10-20, short. Styles 2-5. The ovary is inferior.	$2n=34$	Vegetative growth: March/May Flowering: April/May Fruit setting: May Fruit maturation: August Pollination: entomophilous Dispersal strategy: endozoochory (birds and mammals)	Favarger and Stearn 1983 ; Milla et al. 2005 ; Tejedor López 2008, Matías et al. 2010 ; Pemán García et al. 2013 ; Indreica et al. 2016.
<i>Astragalus nebrodensis</i> (Guss.) Strobl	Perennial thorny pulvinate subshrub, Ch fruit-NP	10-60 cm height, stems prostrate or ascending. Leaves 0.7-5 cm long, crowded, obliquely erect, in 5-8 pairs, greyish, narrowly oblong, obtuse, with a mucro 0.2-0.7 mm long, on both	Flowers are globose synflorescences 1.5-2.5 cm in diameter. Calyx thinly membranous, yellowish white, densely hairy, glabrous at the base. Petals with yellowish, white claws, tinged with pink or purple at blade margins. Stamens 10-14 mm long. Fruits are	$2n=16$	Flowering: June/August The reproductive biology of this species has not yet been investigated and there is no information on pollination and dispersal strategy.	Pignatti et al. 1980; Podlech 1986; Podlech 2008a; Giardina 2010; Pignatti 2017-2019.

		sides covered with short, appressed curled hairs.	ovoid-ellipsoid legumes, 4-5 mm long with a hairy beak.			
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Table 2. Habitat, ecology and functions of the selected species

Species	Habitat	Ecology and functions
<i>Lycium intricatum</i>	Open thermophilic halo-nitrophilous matorrals, next to the coastal dunes, on calcareous and saline soils, (Sánchez et al. 2008; Gómez-Zotano et al. 2017), from 0 to 500 m a.s.l., in the Infra-Thermomediterranean belt with dry sub-humid ombrotype (Pedrotti 2012). Characteristic of the <i>Periplocion angustifoliae</i> alliance, <i>Periploco angustifoliae-Euphorbietum dendroidis</i> , <i>Periploco angustifoliae-Rhoetum tripartitae</i> , <i>Ephedro fragilis-Pistacietum lentisci</i> associations (Brullo et al. 2008), or of the <i>Artemision arborescentis</i> alliance, <i>Lycio intricati-Salsoletum oppositifoliae</i> association (Brullo et al. 2013), especially in the coasts of southern Sicily and in southern Spain.	It is a mid-successional species, with some functional traits that can be considered very important for the success of restoration programs in dry environments. In fact, it avoids drought stress by shedding its leaves to reduce evaporative water loss and it tends to root deeper at the seedling stage (Padilla et al. 2007; Padilla et al. 2009; Miranda et al. 2010). In associated plant communities, it induces a large decrease in photosynthetically active radiation and soil moisture in its understorey (Pugnaire et al. 2004; Hortal et al. 2017). For these features it is often used as a hedge and as wind break plant (Sánchez et al. 2008; La Mantia et al. 2012; Boulila and Bejaoui 2015).
<i>Viburnum tinus</i>	Sclerophyllous woodlands and shrublands (Nebot and Mateau 1991), forest and pre-forest formations of <i>Quercus ilex</i> L. and <i>Q. suber</i> , laurel forests (Arévalo and Fernández-Palacios 2004; Gianguzzi et al. 2010), deciduous forests, hedges and riverine areas (Valdés et al. 1987; Nobre et al. 2000), from 0-700 m a.s.l., in Thermo-Mesomediterranean belt with Subhumid or dry ombrotype, on fresh soils rich in humus, with neutral/sub-acid pH. Characteristic of the <i>Viburno tini-Quercetum ilicis</i> and of the <i>Rhamno alaterni-Quercetum ilicis</i> associations (Biondi et al. 2003).	It is a moderately heliophilous species (Cervelli 2005). It shows an indifferent edaphic nature (Torres et al. 2002) and little tolerance for salt soils. It tolerates drought in deep shade through mechanisms to reduce resource demand. In fact, it reduces the demand for water or irradiance, thanks to a moderate below-ground mass fraction, the protected and long-lived parts, a high water content, a low stomatal density, a higher specific leaf area in shade, the deep roots (Sack et al. 2003). After a disturbance, it can be considered a resprouter species, associated with late successional stages (Verdú 2000). It exhibits the ability to recover readily after fire (García-Fayos et al. 2001), manifesting a very high post-fire resprouting ability (100%) (Quevedo et al. 2007). In these terms, it is often used in forest restoration (Cervelli 2005; García-Fayos et al. 2001), especially in Mediterranean evergreen woods (Pérez-Latorre 1996), or in disturbed areas (Siles et al. 2010) to reinstate ecological processes. It represents a forage plant for various species. In fact, it is a potential bee forage plant (Ennabili et al. 2000; Gaspar et al. 2002; Cervelli 2005), mildly attractive to <i>Apis mellifica</i> and <i>Bombus terrestris</i> (Nebot and Mateu 1991; Keasara and Shmidac 2009). Moreover it is a dietary component of avifauna (especially of robin <i>Erithacus rubecula</i> and blackcap <i>Sylvia atricapilla</i> , Debussche and Isenmann 1985; Thébaud and Debussche 1992; Herrera 1998), but also of some wild and domestic mammals, such as the red deer, goats and sheep (Paton et al. 2002; Rogosic et al. 2005).
Species	Habitat	Ecology and functions

<p><i>Prunus spinosa</i></p>	<p>Open woodlands, hedgerows, holm oak woodlands, river valleys, rocky slopes, pastures (Rhodes and Maxted 2016), in the ecotone between woodland and grassland communities, in mantle vegetation as a constituent of the pre-climax stages on disturbed sites or stages of secondary succession in abandoned meadows or pastures at the borders of the agricultural landscape, (Vera 2000; Popescu and Caudullo 2016). It grows on dry or slightly humid, calcareous soils, on sunny slopes (Hübner and Wissemann 2004), in Meso-Supramediterranean belt with sub-humid/humid ombrotype, at either high or low elevations (from 0-1400 m a.s.l). Characteristic of the class <i>Rhamno-Prunetea</i> in association with other thorny species such as <i>Crataegus monogyna</i>, <i>Rubus ulmifolius</i>, <i>Smilax aspera</i>, <i>Rosa canina</i> (Guarino and Pasta 2017).</p>	<p>It is a pioneer species, colonizing degraded areas (Fernandez and Alejano 2013) with a very high post-fire resprouting ability (Quevedo et al. 2007). In fact, it is very useful for the repopulation and reconstruction of habitats (Fernandez and Alejano 2013), but also to improve plant cover in anti-erosion interventions (Fernandes et al. 2011). It is an important plant for wildlife (Sarigu 2014), its early spring flowers provide nectar for early emerging insects (Del Pilar de Sá-Otero et al. 2009), and its branches create a spiny thicket, providing secure nesting sites, protection and food for birds (Massa and La Mantia 1997), and for mammals (Serafini and Lovari 1993). It plays the role of plant nurse especially in temperate oak forests, thanks to its dense and thorny canopy that is difficult to penetrate by large herbivores and that protects young palatable seedlings, for example oak seedlings against browsing (Vera 2000; Bakker et al. 2004; Pausas et al. 2004). Often its establishment in grazed woodlands, and its role as a nurse plant, relies on the presence of tall unpalatable swards, which form suitable establishment niches when seeds arrive (Smit and Ruifrok 2011).</p>
<p><i>Crataegus laciniata</i></p>	<p>In thorny borders of pine forests and steep banks of crops in high altitudes (especially in Spain), in oak forests, maple and holm oak ecosystems, in marcescent forests, on high mountains, in mountains thickets, (Baonza 2006; García Río 2007; Pérez 2015; Wilson 2018). On the Atlas Mountains, in mantle forest species groupings, in the clearings of cedar forests, highlighting its pre-forest role (Quézel and Barbero 1989; Yahi et al. 2008). It is sometimes found on the rocky soils and surrounding the sink-holes, but it prefers open areas (Fa 1984). It is present in the Meso-Supramediterranean belt with sub-humid/humid ombrotype, in orophilous stations with elevation above 900-1000 m a.s.l, characterized by a great pedological evolution, with deep limestone soils, on lithotypes of carbonate nature, where it prefers northern exposures. It also grows in stations with siliceous soils, (Hamidouche 2017). Characteristic of the coenosis <i>Crataegetum laciniatae</i>, alliance <i>Berberido aetnensis-Crataegion laciniatae</i>, localized in the hilly and mountain areas in northern Sicily, where it constitutes a pre-forest aspect of the deciduous wood of the <i>Sorbo torminalis-Quercus virgiliana</i> <i>sigmetum</i> (Gianguzzi et al. 2011), or in the alliance <i>Lonicero-Berberidion hispanicae</i> (in the Iberian Peninsula), (Cano-Ortiz et al. 2012). In Madonie Mts the association <i>Crataegetum laciniatae</i>, constituted by tall thorny shrubs determines the conditions for the affirmation of the <i>Luzulo siculae-Fagetum</i> (Schicchi et al. 2013).</p>	<p>It represents a food source for many species. In fact its flowers are visited by various insects, for example <i>Apis mellifera</i>, <i>Bombus</i> spp., <i>Xylocopa</i> spp., <i>Cerceris</i> spp., <i>Andrena</i> spp. and flies of <i>Syrphidae</i> family (Lara Ruiz 2009, 2015, 2017), as well as its fruits, that are consumed by various vertebrates as birds for example <i>Turdus</i> spp., or carnivores mammals as <i>Vulpes vulpes</i>, <i>Martes foina</i>. Moreover, fruits also constitute part of the diet of <i>Macaca sylvanus</i>, especially in Morocco and Algeria, on the Atlas Mountains, in rocky slopes and cedar forests (Ménard and Vallet 1986; Ménard et al. 2014). On the other hand, this species is negatively affected in Spain, by grazing. In fact, the great herbivores, both domestic and wild, feed on juveniles and seedlings, trample on already established individuals, provoke an excessive nitrification of the soil compromising the populations of <i>C. laciniata</i> (Prados et al. 2000). So in order to comply with these problems, especially in the Murcia region, where <i>C. laciniata</i> represents a protected species, repopulations are carried out, using the species for the realization of hedges, which mark the boundaries of crops, protect from erosive processes and maintain biological diversity, offering shelter and food for a large number of animal and plant species, (García et al. 2005).</p>

Species	Habitat	Ecology and functions
<i>Amelanchier ovalis</i>	In forest clearings, on rocky hillsides, along streams, on the edge of the forests of mountain conifers and deciduous woodlands, in areas with inhospitable edaphic conditions such as limestone mountains and sunny and dry cliffs up to 2500 m a.s.l., on soils with basic or neutral pH (Loidi 1989; Tejedor López 2008), in Supramediterranean belt, sub-humid ombrotype, with xerophilous and heliophilous attitude. Characteristic of the class <i>Rhamno-Prunetea</i> (Gianguzzi et al. 2009).	It is a soil stabilizing species (Pemán García et al. 2013), in fact its root features favour exploitation of stony substrates (Milla et al. 2005) and it fixes the substrate to favour further colonization of more demanding forest species (Raimondo et al. 2010b); moreover it presents a resprouting ability after cut or fire (García-Fayos et al. 2001; Quevedo et al. 2007). Thanks to its pioneer features it can be used in land restoration, afforestation (Moraldi and Falcinelli 2000; Pemán García et al. 2013), in bioengineering for riverbank (Evette et al. 2012), or in general in the reconstruction of habitats, since its fruits represent a food source for many wild mammals (Padiá et al. 2002) and birds (Moraldi and Falcinelli 2000).
<i>Astragalus nebrodensis</i>	Orophilous thorny cushions of vegetation on the Madonie Mts (Nimis 1981; Brullo et al. 2005), beech forests and endemic oro-Mediterranean heaths with gorse, between 1200-2000 m a.s.l (Bonanno and Veneziano 2016), in the Supra-Oromediterranean bioclimate belt. Characteristic of the pioneer association <i>Astragaletum nebrodensis</i> that evolves in the less disturbed areas towards the <i>Cratagetum laciniatae</i> (Schicchi et al. 2013). On stony slopes, windy ridges and eroded soils rich in skeleton, especially carbonates and flaky clays, (Brullo et al. 2005).	Thanks to its morphological characteristics (spinescence, cushion-like growth form), it manages to grow in stations with intense solar radiation, persistent drought, wide-ranging temperatures and strong winds (Guarino et al. 2005). Its thorns constitute the nucleus for the condensation of water droplets, that flow along the branches and join the rootstock (Pignatti 2011), and also they represent a defence strategy against herbivory (Bagella et al. 2019). Moreover its pulvines play an important ecological role, providing shelter from the strong wind for some short-cycle herbaceous plants, favouring their germination and letting a slight accumulation of organic matter (Pignatti et al. 1980; Brullo et al. 2005). Also, various insects take shelter in the cushions, taking advantage of the internal microclimate, for example the Hemiptera <i>Aelia rostrata</i> (Pignatti et al. 1980) and the Sicilian endemic Orthoptera <i>Platycleis concii</i> (Massa et al. 2001).

Table 3. Type analysis of symbioses in selected species

Species	Types of symbioses	Notes	References
<i>Lycium intricatum</i>	AM, VAM; endophytic fungi <i>Microdiplodia</i> sp.	There are no detailed studies of mycorrhizae in <i>L. intricatum</i> , but for another species of the genus <i>Lycium</i> , <i>L. europeum</i> , constituting vegetation structures similar to <i>L. intricatum</i> , the presence of arbuscular mycorrhizae has proved to be of fundamental importance for the installation of the species and to fix the mobile dunes (Touati et al. 2013).	Honrubia et al. 1992; Kumar and Kausic 2012.
<i>Viburnum tinus</i>	AM, VAM	Gómez- Bellot et al. (2014, 2015), valued the positive effects of application of arbuscular mycorrhizal fungi, in particular the inoculation of <i>Glomus iranicum</i> var. <i>tenuihypharum</i> in <i>Viburnum tinus</i> roots, to mitigate the elevated salt levels of irrigation wastewater.	Honrubia et al. 1992; Matosevic et al. 1997; Maremmani et al. 2003; Wang and Qiu 2006; Azul et al. 2008; Curto and Allen 2011; Correia et al. 2018.
<i>Prunus spinosa</i>	AM, VAM, ECM, NM	Ectomycorrhizal association with <i>Amanita ovoidea</i> (Bull.) Link 1833. The presence of ectomycorrhizae can facilitate the development of the role of nurse plant (Padilla and Pugnaire 2006).	Trappe 1962; Harley and Harley 1987; Wang and Qiu 2006; Curto and Allen 2011; Akhmetzhanova et al. 2012; Hempel et al. 2013; Bueno et al. 2017; Correia et al. 2018.
<i>Crataegus laciniata</i>	AM	-	Pulgar Ramírez 2017.
<i>Amelanchier ovalis</i>	AM, VAM	-	Akhmetzhanova et al. 2012; Hempel et al. 2013; Correia et al. 2018.
<i>Astragalus nebrodensis</i>	NM, Rhizobial bacteria <i>Mesorhizobium</i> sp.	These symbionts can be used to improve the use of <i>A. nebrodensis</i> in re-naturalization interventions in the area where the species is widespread also through direct sowing and contemporary inoculation with bacteria.	Zimbaro et al. 2013.

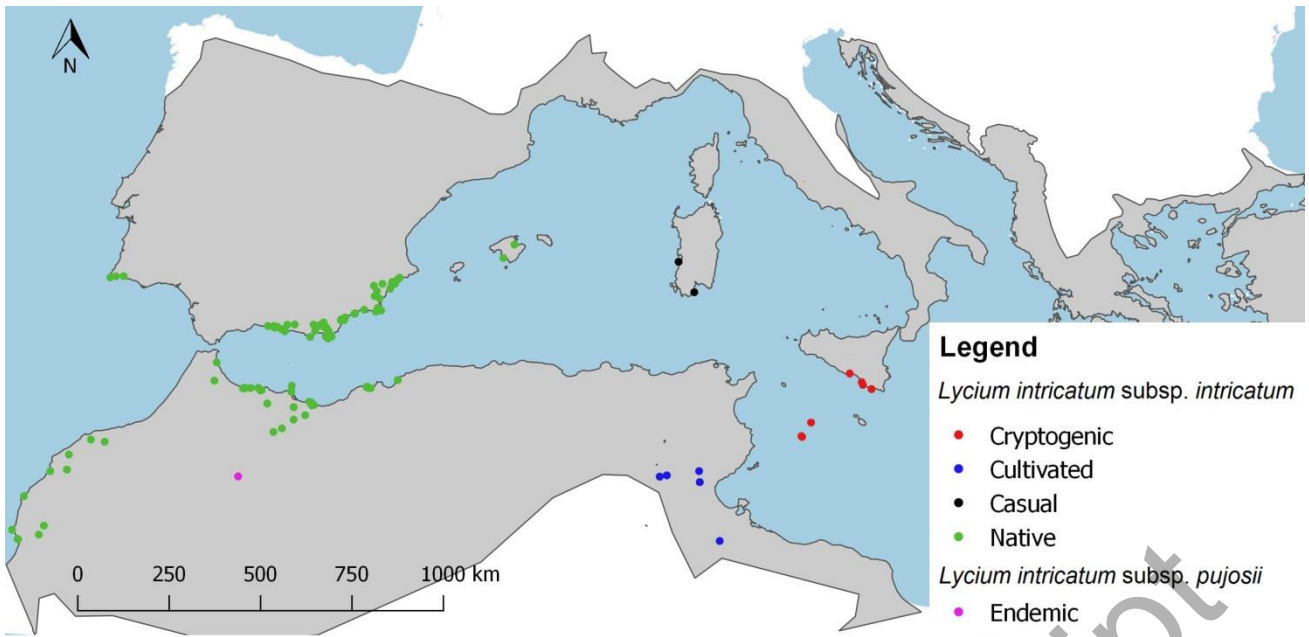


Figure 1. Distribution of *L. intricatum* subsp. *intricatum* and *L. intricatum* subsp. *pujosii*.

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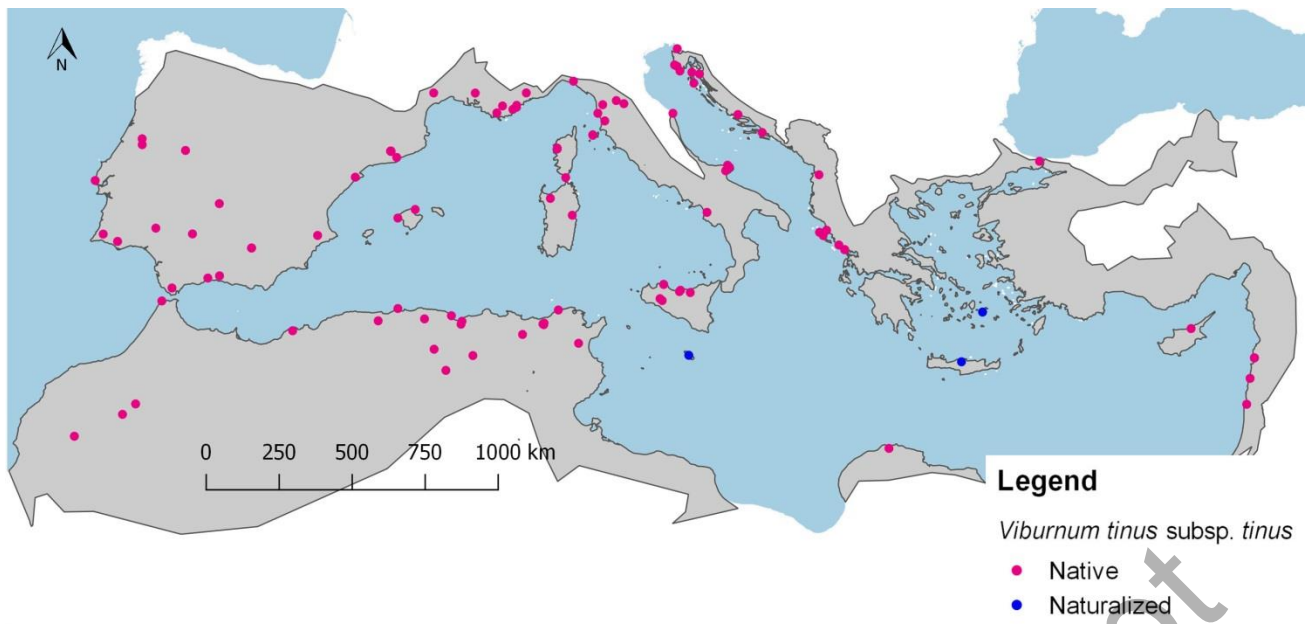


Figure 2. Distribution of *Viburnum tinus* subsp. *tinus*.

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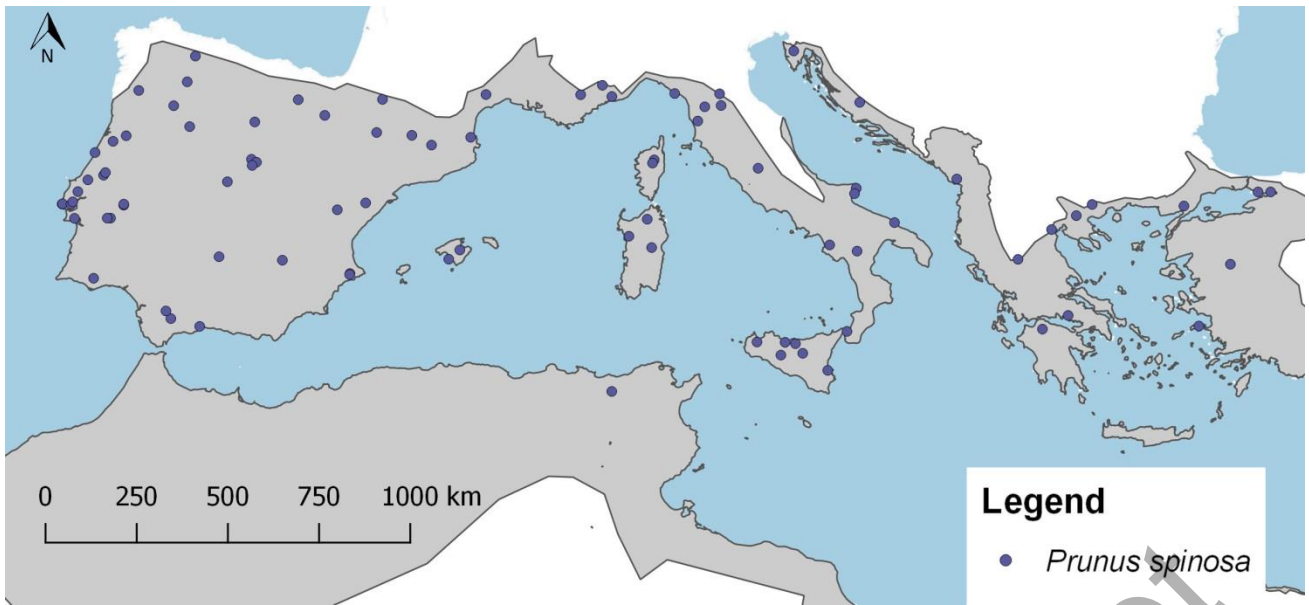


Figure 3. Distribution of *Prunus spinosa*.

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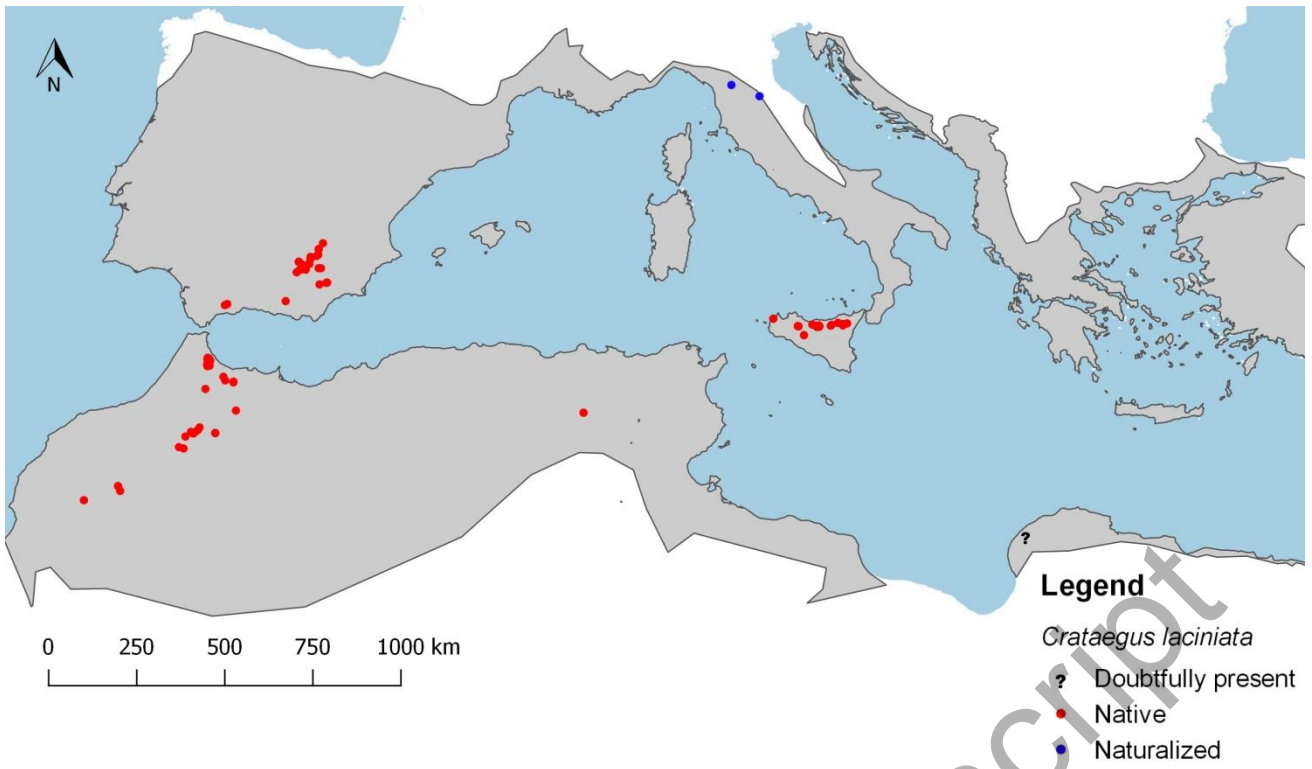


Figure 4. Distribution of *Crataegus laciniata*.

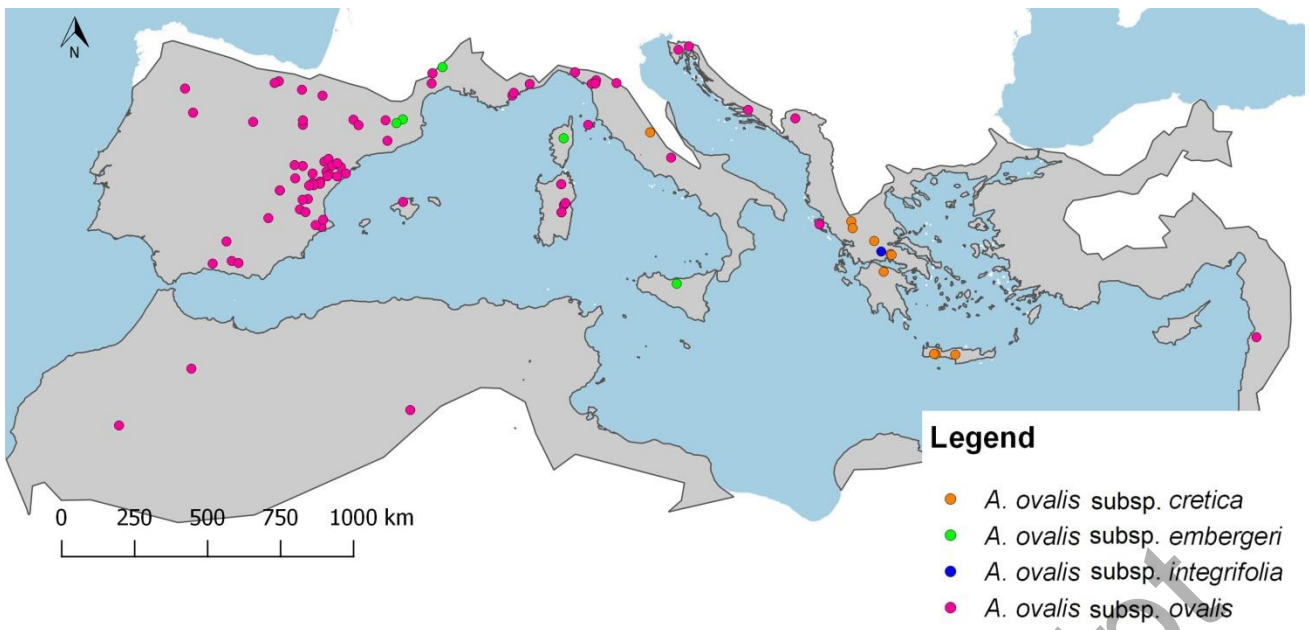


Figure 5. Distribution of the subspecies of *Amelanchier ovalis*.

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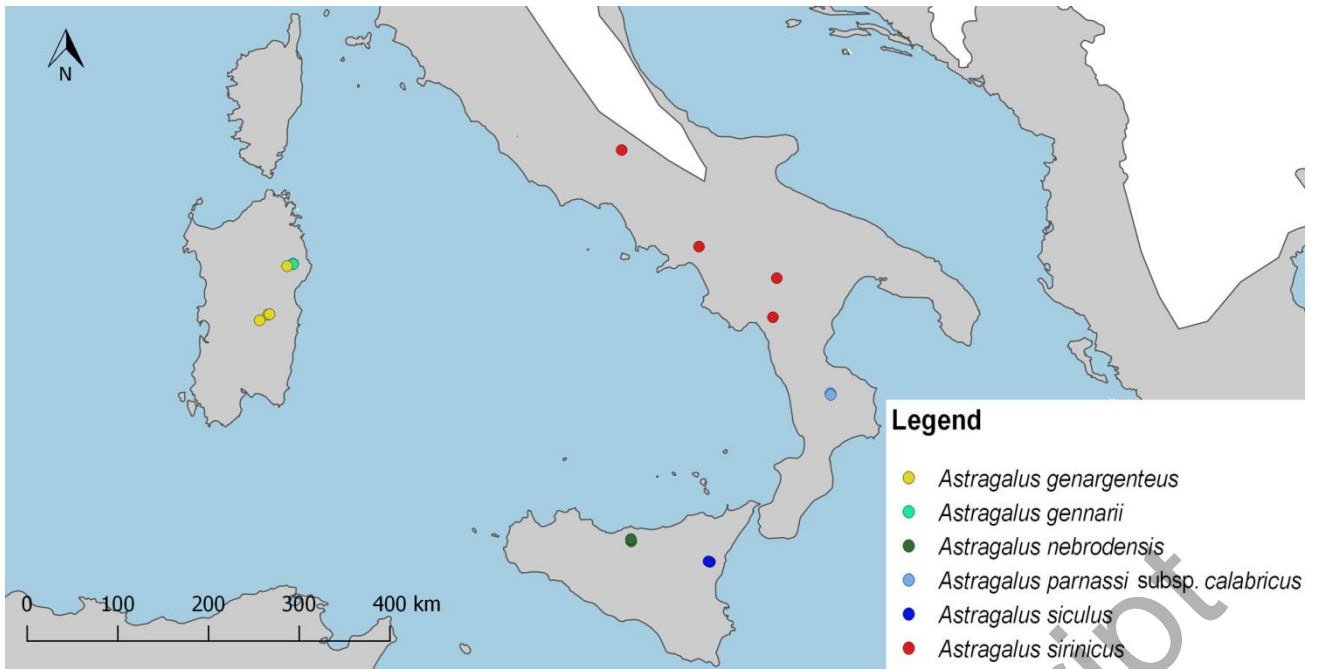


Figure 6. Distribution of *Astragalus nebrodensis* and of its vicariant species.