Are Mediterranean trees well known? "*Juniperus turbinata*" (Cupressaceae), a common but misunderstood taxon

Les arbres de Méditerranée sont-ils bien connus ? « Juniperus turbinata » (Cupressaceae), un taxon commun mais incompris

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Abstract

Among Mediterranean trees, "Juniperus turbinata" *remains a little-known taxon. Described in 1844 (*J. turbinata *Guss.) it was ignored in many floras and checklists until very recently despite the fact that since the 1980s morphology and phytochemistry studies have confirmed its taxonomic individuality. The conclusions of recent molecular studies also point in this direction. The present work specifies its chorology by country or geographical sectors, allowing an updated world distribution map. Another map illustrates the distribution of the other two taxa in this group ("*J. phoenicea*" and "*J. canariensis*"). Aspects concerning karyology, reproductive biology and biological interactions are discussed, as well as its ecology: we thus present a summary table of the main phytosociological groups up to the level of alliance in which this taxon is characteristic or in which it just fits. Another focus concerns threats and conservation. Finally, a discussion on the complex taxonomy of red junipers (*J. phoenicea *sensu lato) allows us to justify our taxonomic treatment for the taxa of this group. Three subspecies (subsp.) are recognized here, a new nomenclatural combination is proposed and an identification key of infraspecific taxa is provided. Thus,* Juniperus phoenicea *L. subsp.* turbinata *(Guss.) Nyman should be considered as a remarkable circum-Mediterranean taxon often endangered or declining in its range which stretches along the Mediterranean coast from southern Portugal and Morocco to the eastern Mediterranean (large islands included), including the high continental mountains of North Africa, then ending to Middle-East in Saudi Arabia. Various pictures illustrate this juniper in different landscapes, ecological and geographical situations.*

Keywords: Mediterranean region, Middle-East, coastal regions, steppic mountains, islands, refugia, cryptic taxa, taxonomy, chorology, biotic interactions, ecology, threats.

Résumé

Parmi les arbres de Méditerranée, « Juniperus turbinata » *reste un taxon méconnu qui fait ici l'objet d'une synthèse des connaissances. Décrit en 1844 (*J. turbinata *Guss.), il sera longtemps oublié de nombreuses flores et checklists jusqu'à une date très récente malgré des travaux de morphologie et de phytochimie qui, dès les années 1980, vont confirmer son individualité taxonomique. Les conclusions des études moléculaires récentes vont aussi dans ce sens. Le présent travail précise sa chorologie, aussi bien dans sa globalité que par pays ou secteurs géographiques, permettant de dresser une carte de répartition mondiale actualisée. Une*

Mots-clés : bassin méditerranéen, Moyen-Orient, littoral, montagnes steppiques, îles, refuges, taxon cryptique, taxinomie, chorologie, interactions biologiques, écologie, menaces.

carte supplémentaire illustre la répartition des deux autres taxons du groupe (« J. phoenicea *» et «* J. canariensis *»). Les aspects concernant la caryologie, la biologie de la reproduction et les interactions biologiques sont abordés, de même que son écologie, ce qui permet de dresser un tableau récapitulatif des principaux groupements phytosociologiques jusqu'au niveau de l'alliance dans lesquels il s'insère ou intervient. Un focus particulier permet de s'intéresser aux menaces et à sa conservation. Enfin, une rapide discussion sur la taxonomie complexe des genévriers rouges permet de justifier le traitement retenu dans ce travail pour les taxons du groupe de* J. phoenicea *selon trois sous-espèces, en validant une nouvelle combinaison nomenclaturale et en proposant une clé de détermination des taxons infraspécifiques. Ainsi,* Juniperus phoenicea *L. subsp.* turbinata *(Guss.) Nyman doit être considéré comme un taxon circum-méditerranéen remarquable souvent en danger ou en régression dans son aire de répartition, qui s'étend le long du littoral méditerranéen depuis le sud du Portugal et le Maroc jusqu'en Méditerranée orientale (grandes îles comprises), en passant par les hautes montagnes continentales d'Afrique du Nord, puis débordant jusqu'en Arabie Saoudite. Des photographies permettent d'illustrer ce genévrier dans diverses situations paysagères, écologiques et géographiques.*

Introduction

The Mediterranean basin constitutes a biodiversity hotspot (Médail & Quézel 1997; Myers 1990; Myers *et al.* 2000) in which a recent census of trees confirms the presence of nearly 290 taxa (species and subspecies), 245 of which are present in Mediterranean Europe (Quézel & Médail 2003; Médail *et al.* 2019).

These first reports reveal a lack of knowledge in a large number of them, both in terms of taxonomy and distribution. Some of them only lack a fine chorological knowledge but other taxa present problems of taxonomic delimitation distorting some work and limiting many potential subjects of study. This is the case of gymnosperms of the genus *Juniperus* L. in which for example a new species, *Juniperus deltoides* R.P. Adams (sect. *Juniperus*), has recently been described (Adams 2004a) in a Euro-Mediterranean floristic region that has been studied for a long time and was apparently well known.

This genus constitutes a monophyletic group of probably very ancient origin from the Oligocene with a diversification in the Pleistocene (Fernández Palacios *et al.* 2011; Little 2006; Mao *et al.* 2010). Its recent monograph is now in its fourth edition (Adams 2004b, 2008, 2011, 2014) and it includes nearly 100 taxa, constituting the most diverse genus in its family and the second most common genus of conifers on Earth after *Pinus* L. (Adams & Schwarzbach 2013). Mediterranean species are divided into the 3 currently recognized sections:

- Sect. *Caryocedrus* Endlicher: acicular leaves only, three seeds fused into a false nut (only one species, *Juniperus drupacea* Labill., in the eastern Mediterranean).
- Sect. *Juniperus* (= sect. *Oxycedrus* Spach): acicular leaves only, free seeds (*Juniperus communis* L. sensu lato, *Juniperus oxycedrus* L. sensu lato).
- Sect. *Sabina* (Miller) Spach: young leaves acicular but adult leaves squamiform (*Juniperus excelsa* M. Bieb. sensu lato, *Juniperus foetidissima* Willd., *Juniperus phoenicea* L. sensu lato, *Juniperus sabina* L., *Juniperus thurifera* L. sensu lato).

Despite their abundances, easy access to many populations and the large amount of samples available in herbarium collections, errors in identification and taxonomic approximations are recurrent. This is particularly the case of red junipers, *Juniperus phoenicea* sensu lato, because of their tenuous morphological characters often not much decisive on herbaria (De Coincy 1898) arising from cryptic speciation phenomena (Adams *et al.* 2005). Red junipers constitute a complex, which generated various descriptions of taxa with taxonomic and nomenclatural wanderings due to the various treatments according to authors and periods (species, subspecies or varieties, or even simple synonyms for unrecognized entities).

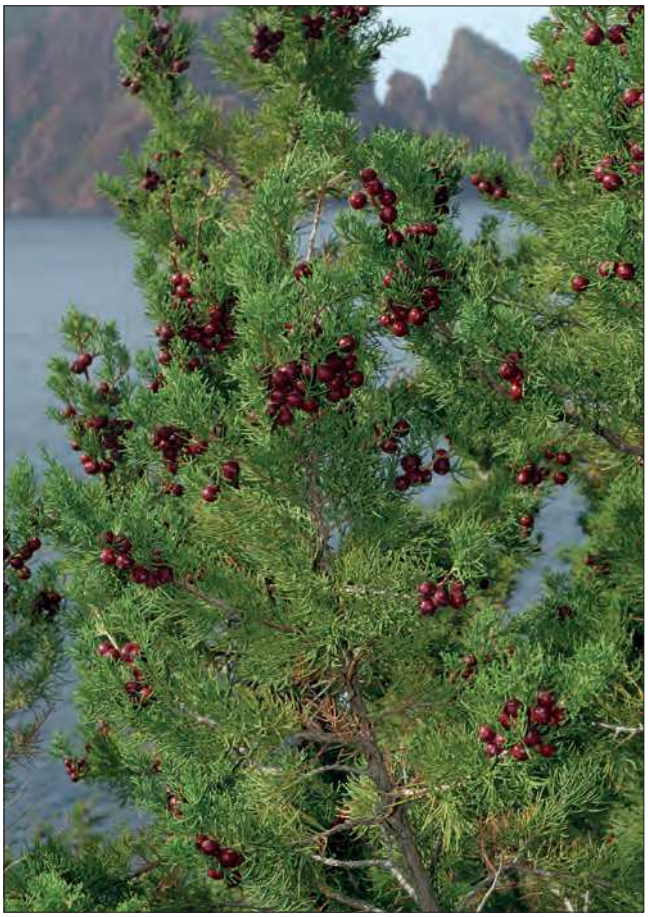
The objective of this work is to constitute a multi-disciplinary synthesis of knowledge relating to "*Juniperus turbinata* Guss.", a circum-Mediterranean taxon still often overlooked, although it was described in the middle of the 19th century.

Methodology

Bibliographical analysis

This brief bibliographical review concerns red junipers in the broad sense and more specifically "*Juniperus turbinata*", focusing on its taxonomy, general and regional chorology, biology, ecology and conservation.

Young specimen showing typical leaf dimorphism in the "Calanques National Park", Marseille, south-east France *(© D. Pavon).*



Specimen with autumn mature cones in the acid rocky coast the "Scandola Nature Reserve", west Corsica *(© D. Pavon).*

***Atlantic coast of Portugal at Cabo da Roca with invasive* Carpobrotus sp.** *(© D. Pavon).*

The literature being very important we limited ourselves to the articles, flora and other checklists which seemed the most relevant to carry out this synthesis. We did not scour the abundant literature on chemical compounds and uses (pharmacopoeia, ethnobotany, etc.), limiting mentions to rare studies presenting an added value to the general understanding of the specific themes concerned here.

Online databases: nomenclature and maps

Euro+Med Plantbase (http://ww2.bgbm.org/EuroPlusMed/query.asp) currently constitutes an essential taxonomic repository for the Mediterranean region and allows the visualization of presence maps by country for each taxon. However, many other nomenclatural databases are available on the Internet. These are mainly the French "Inventaire National du Patrimoine Naturel" (https://inpn.mnhn.fr/), Tela Botanica (www.tela-botanica.org), Plants of the World Online (http://powo.science.kew.org/) or the African Plant Database (https://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php). The latter also offers mapping possibility, however, maps are of heterogeneous quality in terms of precision.

In addition, various cartographic tools now offer the visualization of more or less precise distribution maps, which must sometimes be interpreted with caution, in particular those of the "Global Biodiversity Information Facility" (https://www.gbif.org/fr/) as well as those of the collaborative platform "INaturalist" (https://www.inaturalist.org/home). The most robust for France are the "SILENE-Flore" (www.flore.silene.eu) and "SiFlore" (http://siflore.fcbn.fr/) databases, for the Iberian Peninsula the "Anthos" project (www.anthos.es), for Portugal "Flora.On" (https://flora-on.pt/), for Croatia "Flora Croatica Database" (https://hirc.botanic.hr/fcd/) and for Greece "The Flora of Greece Web" (http://portal.cybertaxonomy.org/flora-greece/intro). This same type of base is being developed for North Africa (https://efloramaghreb.org/). In Italy, various regional databases are also being used and compiled in the "Wikiplantbase #Italia" meta-site (http://bot.biologia.unipi.it/wpb/italia/index.html) while in Spain there are also regional plant bases for Catalonia (http://biodiver.bio.ub.es/biocat/index.jsp), Aragon (http://floragon.ipe.csic.es/) or the Valencia region (http://www.bdb.gva.es/va/).

Finally, note that we find on Internet a database exclusively devoted to gymnosperms (https://www.conifers.org/).

634 DIOECIA - MONADELPHIA.

1. *J.* PHOENICIA. *Lin. sp. pl. 1471 — Ucria H. Pan. p. 420.*
J. foliis ovatis ovalibusque obtusiusculis omnibus quadrifariam arcte imbricatis dorso foveola oblonga notatis, junioribus acutiusculis, baccis globosis.
J. Sabina. *Ucria H. Pan. p. 421*, non *Lin.*, ex loco — Sabina folio Tamarisci Dioscoridis, et S. folio Cupressi. *Cup. H. Cath. p. 194.*
Ic. *Duham. arb. ed. 2. v. 6. t. 17* — J. major Dioscoridis. *Clus. hist. 1. p. 58*; sed Cedrus phoenicia altera Plinii et Theophrasti. *Lob. ic. 2. p. 221* minus exacte hanc nostram refert.
In arenosis vel lapidosis maritimis, rupibusque vulcanicis calcareisve mari proximis; *Secciara*, *Castellammare*, *Montallegro*, *Siculiana*, *Terranova*, *Braccetto*; *Siracusa* (*Cosentini*) = et in *Pantellaria*, *Lampedusa*, *Linosa*.
Novembri, Decembri. ♄
Arbuscula ramosissima, in arenosis maritimis 10 pedalis et ultra; in rupibus vero frutex humilis, ramis saepe ad saxa adpressis: *ramuli* graciles, filiformes, confertissimi: *folia* convexa, minima, non raro viridi-glaucescentia, etiam juniora imbricata, sed illa quae amentis masculis numerosis terminalibus vix lin. longis subjecta nonnihil acutiora: *baccae* immaturae virentes, inde fusco-rufescentes, *Pisi* magnitudine, breviter pedunculatae.
Cl. *Lam.*, *Spr.* aliique, sed praesertim Cl. *Viv.* in *ann. bot. 2. p. 187*, magni momenti rationibus suffulti *J. lycium Lin.* ab hac non separant; sed Cl. *Reich.* adhuc ut diversas habet in *fl. germ. excurs. 2. p. 462.*

2. *J.* TURBINATA. *Guss.*
J. foliis ovatis obtusiusculis omnibus quadrifariam arcte imbricatis dorso foveola oblonga notatis, junioribus acutusiusculis approximatis, baccis ovato-turbinatis.
Ic. Sabina baccifera, bacca turbinata. *Cup. panph. 1. t. 54* — *Bon. t. 45* — *Raf. t. 11. f. 1.*
In arenosis, vel rupestribus maritimis; *Montallegro*; *Secciara* (*Gasparr.*)
Octobri, Novembri. ♄
Habitus omnino praecedentis; sed *baccae* immaturae oblongae, inde turbinatae; tuberculis pluribus instructae, et color totius plantae laetius virens.

***Figure 1 – Gussone's description of* Juniperus turbinata.**

Results

Taxonomy and nomenclature: contributions of morphology, phytochemistry and genetics

The individualization and description of *Juniperus turbinata*, a new species closely related to *J. phoenicea*, was carried out by the Sicilian botanist Giovanni Gussone (1787-1866) in his *Florae Siculae Synopsis* (Gussone 1844). However, its description remains succinct and with only one discriminating character according to him: the «turbinated» shape of its young cones or galbulus (in form of spinning-top or cone). More disturbing, he recognizes that this new species shares in Sicily the same locations and the same habitats

***With* Rosmarinus officinalis*,* Erica multiflora *and* Coronilla juncea *on basic rocky coast of the "Calanques National Park", Marseille, south-east France** *(© D. Pavon).*

as *J. phoenicea* (Figure 1). Two years later, Kunze (1846) describe *Juniperus oophora*, a later taxonomic synonym, from coastal sand dune populations of southwestern Spain (near Doñana). Thus, *J. turbinata* will be very often ignored thereafter, remaining for a very long time cited under the name of *J. phoenicea* in many later reference or work (Battandier & Trabut 1902; Bonnet & Barratte 1896; Briquet 1910; Cuénod *et al.* 1954; Fiori 1923-1925; Fournier 1946; Munby 1847). However, some work mention the existence of *J. turbinata* in a note or remark, even as a variety and under the ambiguous name of "*J. phoenicea* var. *lycia*" (Coste 1937; Rouy 1913) or at best "*J. phoenicea* var. *turbinata*" (Boissier 1884; Fiori & Paoletti 1896-1898; Maire 1952). In addition, forms with larger or smaller cones that were not turbinated were described as new under *J. phoenicea* var. *phoenicea*, namely "f. *mollis* Maire & Weiller" and "f. *megalocarpa* Maire" (Maire 1952). Only few ancient floras cite it as a well-individualized species, like Willkomm & Lange (1861) and Willkomm (1893) for Spain under the name of *J. oophora*. In this last work, the synonymy between *J. oophora* and *J. phoenicea* var. *turbinata* is confirmed by Mauritius Willkomm.

It was not until the end of the 20th century and the 1980s that various phytochemical and morphological studies confirmed the high taxonomic value of *J. turbinata* after a certain nomenclatural wandering and in particular the creation of *J. phoenicea* subsp. *eumediterranea* P. Lebreton & Thivend, another posterior synonym (Lebreton & Thivend 1981; Lebreton 1983; Lebreton & Rivera 1988; Rivas Martinez *et al.* 1993; Lebreton & Pérez de Paz 2001; Mazur *et al.* 2010, 2016, 2018; Adams *et al*. 2014). Subsequently, molecular biology work also concluded that it is a distinct taxon from *J. phoenicea* sensu stricto (Adams *et al.* 2002, 2010, 2013; Adams & Schwarzbach 2013; Boratyński *et al.* 2009; Dzialuk *et al.* 2011; Sánchez Gómez *et al.* 2018). Finally, the Macaronesian populations (*J. canariensis* Guyot) were also considered as deserving a high taxonomic rank by Romo *et al*. (2019), contrary to previous opinions (Adams *et al.* 2010). These island populations seem morphologically, chemically and genetically closer to *J. turbinata* than to *J. phoenicea* (Lebreton & Pérez de Paz 2001; Sánchez Gómez *et al.* 2018). To this we can add for *J. turbinata* three "microtaxa" (invalid names) proposed by Lebreton & Pérez de Paz (2001) also supported by results of Mazur *et al*. (2018):

– "var. *occidentalis"* in the western coastal Mediterranean;
– "var. *orientalis"* in the eastern Mediterranean and characterized by a very low number of seeds per cone;

Sand dunes at Rondinara bay, south-east Corsica *(© D. Pavon).*

– "chemovar. *montana*" in the continental mountains of the Maghreb where populations present specific chemical compounds that differ significantly from coastal populations (see also Bekhechi *et al.* 2012; Mansouri *et al.* 2011).

This juniper is rarely mentioned at the species rank under the name of *Juniperus turbinata* in more or less recent floras and checklists (Arrigoni 2006; Bartolucci *et al.* 2018; Cabezudo 2011) because it is most often treated as a subspecies of *J. phoenicea* (African Plant Database, consulted in November 2020; Amaral Franco 1986, 1993; Bolòs & Vigo 1984 sub "subsp. *lycia*"; Dobignard & Chatelain 2010; Euro+Med Plantbase, consulted in November 2020; Jeanmonod & Gamisans 2013; Le Floc'h & Boulos 2008; Pignatti 2017; Tison & De Foucault 2014; Tison *et al.* 2014; Valdés *et al.* 1987). Sometimes it is not even separated from *J. phoenicea* (Barina *et al.* 2018; Boulos 2009; Fennane *et al.* 1999; Pignatti 1982; Sherif & El-Taife 1986; Turland *et al.* 1993; Valdés *et al.* 2002).

Its typification is very recent (Ferrer-Gallego *et al.* 2017).

Chorology

Despite the numerous studies carried out on these junipers, the geographical distributions of the taxa of the group of *Juniperus phoenicea* s.l. remain blurred by the difficulties of identification in the field, the heterogeneous taxonomic treatments as well as by the repetition of the erroneous citations contained in various floras or reference indexes.

Juniperus turbinata is considered as a strictly West Mediterranean entity by Amaral Franco (1986, 1993), an erroneous chorology but taken up by most of the later authors, even in recent work. Lebreton & Pérez de Paz (2001) as well as Adams *et al*. (2013) and Mazur *et al.* (2016) confirm the wide distribution of *J. turbinata*, which they consider to be present from the Macaronesian islands to Sinai. On the other hand, *J. phoenicea* s.s. becomes a strictly northwestern Mediterranean taxon present only from the south of Spain to the north-west of Italy (Liguria and the Apuan Alps) with interesting and disjointed locations in some islands. To this must be added the conclusions of the work of Lebreton & Pérez de Paz (2001) then of Romo *et al*. (2019) which adopt and reinforce the positions taken by Rivas-Martinez *et al*. (1993) and Asensi *et al*. (2007), and recognize the Macaronesian taxon respectively as a subspecies of *J. turbinata* or as an autonomous species under the name of *J. canariensis* Guyot.

Thus, in the strict sense *J. turbinata* should be considered as a circum-Mediterranean taxon with a wide distribution, occurring from the Atlantic coasts of southern Portugal and Morocco to the Middle-East. The global map of *J. phoenicea* s.l. illustrated by Bolòs & Vigo (1984) is more or less the one accepted today for *J. turbinata*, except for the Iberian Peninsula and the south of France where it remains fairly localized on the coast. It is also interesting to specify that the respective biogeographical types of *J. phoenicea* s.s. and *J. turbinata* were completely reversed in Flora Europaea (Amaral Franco 1993).

Using more specifically regional literature but also cartographic databases available on the Internet, we attempted to summarize the distribution of *J. turbinata* by country and sector:

- Portugal (mainland): *J. turbinata* is not mentioned for this country in Flora Iberica (Amaral Franco 1986), probably due to ignorance although it is the only representative of the scaly junipers (sect. *Sabina*). Thus, according to the online atlases like Flora of Portugal Online (https://flora-on.pt, sub "*J. turbinata* subsp. *turbinata*") and Anthos (www.anthos.es/, sub. *J. phoenicea* subsp. *turbinata*) this taxon is present from the Figueira da Fos sector in the north to the Spanish border in the south, showing here and there continental and more or less isolated locations (see for example Costa *et al.* 1993).

- Spain (mainland): the taxon is present in the south and east of the country (Amaral Franco 1986; Anthos: www.anthos.es), not only on the coast but also inland, in particular on sectors which correspond at the margins of the ancient Pliocene Sea (Hidalgo *et al.* 2014). It is fairly well represented on the coast of western Andalusia in the provinces of Huelva and Cádiz (Galiano 1987) as well as in eastern Andalusia in the province of Málaga. Towards the east, *J. turbinata* seems to disappear on the coast of Andalusia where it becomes very rare or localized in the province of Almería (Cabezudo 2011). It is also very rare in Murcia at the Mar Menor near the northern regional limit of this region (Sánchez-Gómez & Guerra 2011) and therefore also in the province of Alicante (Valencia county), occasionally or historically present in the municipalities of Elche, Guardamar del Segura and Santa Pola (Mateo Sanz *et al.* 2011; Mateo Sanz & Crespo 2014; Banco des datos de Biodiversidad: http://www.bdb.gva.es/va/). It seems a little more abundant but located in Catalonia on the coast of Tarragona between Hospitalet and Torredembarra (Bolòs & Vigo 1984). Finally, a population located in a continental position very far from the coast was recently detected in the region of Extremadura (Orellana & Galán de Mera 2019). Let us recall that elsewhere in the eastern half of the country, in the rocky limestone hills generally inland but sometimes closed to the coast (Cabo Cope in the region of Murcia for example), it is replaced by *J. phoenicea* s.s. which remains the most widely represented taxon in this country. It is naturally in Spain that there are many chorological problems due to the long historical confusion between these entities. Thus, *J. turbinata* must be systematically searched for throughout the Iberian Peninsula, in particular on the coast (eastern Andalusia or Alicante) but also in continental locations.
- Balearic Islands: this juniper seems exclusively coastal, present and mentioned on the five main islands, Ibiza, Formentera, Mallorca, Menorca and Cabrera (see for example: Bolòs & Vigo 1984; Rivas-Martinez *et al.* 1992; Fraga i Arguimbau *et al.* 2004; Asensi *et al.* 2007; Llorens & Gil 2017; Anthos: www.anthos.es). Note that on Mallorca, the presence of *J. phoenicea* s.s. is also confirmed but in the Sierra Tramuntana and at least at its western part (L. Sáez Gonyalons pers. com.).

Fixed dunes with* Phillyrea angustifolia, Lotus creticus *and* Helichrysum stoechas *matorral in south Mallorca, Balearic Islands *(© D. Pavon).*

- France (mainland): the presence of *J. turbinata* is confirmed only on the Mediterranean coast (Tison & De Foucault 2014). This juniper forms more or less large and localized populations, currently located between Sète in Hérault province and Saint-Tropez in Var province (SILENE-Flore: www.flore.silene.eu). It was already listed under the name "*J. phoenicea* var. *lycia*" in the catalogs of Var (Albert & Jahandiez 1908) and Bouches-du-Rhône (Molinier, 1981) provinces. Despite vague quotes by Roux (1881), «it can be seen in the Var, from the beach of Saint-Cyr to Monaco, Èze, Menton», its historical or current presence is not confirmed for the Alps-Maritimes province (see also Charpin & Salanon 1985) nor even for Pyrénées-Orientales (Tison *et al.* 2014) where it should be sought more actively on the coast. On the other hand, and elsewhere in the whole Mediterranean region, *J. phoenicea* s.s. abounds in the internal massifs but sometimes also near the sea from the Pyrénées-Orientales to the Italian border, going up the lower Rhône valley to the north-central Drôme province (Garraud 2003).
- Corsica: in this island *J. turbinata* is fairly common but mainly present on the coast and small islands, in particular in the thermo-mediterranean bioclimatic belt (Paradis 1993; Jeanmonod & Gamisans 2013).
- Italy (mainland): the taxon is only reported in Puglia, Basilicata and Calabria by Conti *et al*. (2005) who did not include its presence in Tuscany and Campania. Mazur *et al*. (2018) did not include the sector of the promontory of Gargano on the Adriatic coast however

illustrated in the map of Lebreton & Pérez de Paz (2001) and where its very localized presence is confirmed by Galié *et al*. (2015). Thus, this juniper seems to be present and scattered on the western coasts of the country from Tuscany to Campania, then in eastern Calabria, Basilicata and Puglia (see for example Bombino *et al.* 1997; Forte *et al.* 2002; Biondi *et al.* 2010; Mazur *et al.* 2016). Consequently, *J. turbinata* is the most widely represented red juniper in Italy while the presence of *J. phoenicea* s.s. is only confirmed in a few locations in the north-west (Liguria near the French border and disjuncted populations in the Apuan Alps). Many confusions persist in Flora d´Italia (Pignati, 1982, 2017) as well as online atlases.

- Sardinia: the presence of *J. turbinata* is confirmed in this island by numerous recent authors (see for example: Bartolo *et al.* 1992; Conti *et al.* 2005; Bacchetta 2006; etc.). An overview of its geographic distribution can be found on the Wikiplantbase Sardegna website (http://bot.biologia.unipi.it/wpb/sardegna/index.html). According to Arrigoni (2006) the species is mainly found on the coast both in dunes and rocky habitats then becomes «rarer inland where it is found more specifically on limestone mountains». This last statement should be verified for all inland hills because *J. phoenicea* s.s. is also present, at least on Monte Albo where its presence has only recently been confirmed which explains why it does not appear in the most recent indexes (G. Bacchetta pers. com. December 2020).
- Sicily: it is on this island that *J. turbinata* was first described. Its presence is still confirmed (Conti *et al.* 2005; Giardina *et al.* 2007; Raimondo *et al.* 2010) but the taxon currently seems rare and scarcely present, mainly in the west, south and east of the island (Brullo *et al.* 2009; Minisale & Sciandrello 2013; Mazur *et al.* 2016). This juniper is also present on the islands of Lampedusa (Bartolo *et al.* 1988), Linosa and Pantelleria (Gianguzzi 1999) while its absence on many other islands and peri-Sicilian small islands and islets is surprising (Aegadian Islands, Aeolian Islands, etc.).
- Malta: in this country, *J. turbinata* is naturally and curiously absent but was introduced and seems to be in the process of naturalization (http://www.maltawildplants.com/). Conversely, another rare species of the same family, *Tetraclinis articulata* (Vahl) Masters, is present in this island (Haslam *et al.* 1977).
- Croatia: the taxon is well represented on the whole Croatian coast and its islands according to Flora Croatica Database (https://hirc.botanic.hr/fcd/) where it is mentioned under the name «*J. phoenicea*» (consultation in October 2020). See also Kovačić *et al*. (2001).
- Bosnia-Herzegovina and Montenegro: this juniper seems very rare there and located in a few coastal areas and islands of the Adriatic coast, in continuity with the Croatian populations and locations (Jasprica *et al.* 2016; Operta *et al.* 2018). It was seen, for example, in northern Montenegro in a coastal scrub near Herceg-Novi (F. Médail & A.C. Monnet unpublished obs. VI.2018).
- Albania: its occurrence is reported with a recent citation in the checklist of Barina *et al*. (2018) under the name "*J. phoenicea*". The map in Browicz (1982) illustrates various points along the coast. It was recently seen for example on the small island of Sazani (Strait of Otranto), in the south of the country (F. Médail *et al.* unpublished obs. IX.2012).
- Greece (mainland) and the Aegean islands: its presence is reported as "*J. phoenicea*" by Dimopoulos *et al*. (2013). This error was corrected and the name changed to «*J. turbinata*» three years later (Dimopoulos *et al.* 2016). Likewise, this juniper appears under the name "*J. phoenicea*" in Flora Hellenica (Strid & Tan 1997) where the authors specify in a note that the Greek taxon corresponds to subsp. *eumediterranea* Lebreton & Thivend (synonym of *J. turbinata*). Thus, in this country this taxon is found in most of the large regions of the south, seeming rarer or even absent in its northern part or in the high mountains of the Peloponnese. A distribution map by sector can be found in the consulted online database (http://portal.cybertaxonomy.org/flora-greece/). Furthermore, Strid (2016) illustrates a map of locations specifically focusing on the Aegean Islands and where the species appears once again as "*J. phoenicea*". See also the map of Browicz (1982).
- Crete: its presence is confirmed by Turland *et al*. (1993) under the name «*J. phoenicea*». They indicate that it usually grows in the coast but can go up to 750m of altitude. The map shown by Strid (2016) also confirms its presence on this island. According to Zaffran (1990), this juniper «participates in the plant

groups that extend behind the coastal communities, both on the south coast and on the north coast of Crete».

- Turkey: its scattered presence is confirmed by Davis (1965) under the name "*J. phoenicea*" (west coast of the country and various islands).
- Cyprus: it is mentioned on this island under the name «*J. phoenicea*» in the flora of Meikle (1977). This juniper is widespread and sometimes abundant there, in particular in coastal areas, and is lacking only in large high inland mountains.
- Morocco: the presence of *J. turbinata* is confirmed by Fennane *et al*. (1999) as well as Valdés *et al*. (2002) under the name "*J. phoenicea*". More recently, Fennane & Ibn Tatou (2005) only mention for Morocco "*J. phoenicea* subsp. *mediterranea* [sic!]" (incorrect name referring to *J. turbinata*). In this country, this juniper is found on the Atlantic and Mediterranean coastlines but also in inland mountains where it colonizes exposed slopes of the Middle Atlas and more especially of the High Atlas and the Anti-Atlas (Benabid 2000 sub *J. turbinata*). It probably presents in this country its most important areas of occurrence. The presence of the other taxon, *J. phoenicea* s.s., should be confirmed (to be sought for example in the limestone reliefs of the Rif where the two taxa could rub shoulders at short distances as it is the case elsewhere in Spain, France, Mallorca or Sardinia).
- Algeria: this taxon is cited in the flora of Quézel & Santa (1962) under the name "*J. phoenicea*". These authors consider it like a common species in this country from the Mediterranean coast to the Saharan Atlas but does not go beyond towards the South. Important confusion reigns in the *Flora of North Africa* in which Maire (1952) lists several forms and varieties that do not allow this author to formally rule out *J. phoenicea* s.s. for this country. The latter is nowaday presumed absent (E. Véla pers. obs. 2002-2020) but deserve to be sought (Babors mountains for example).
- Tunisia: it is formerly cited under the name "*J. phoenicea*" by Cuénod *et al*. (1954) who considered it as widespread throughout the country but rarer in central Tunisia. More recently, Le Floc'h & Boulos (2008) only cite for this country "*J. phoenicea* subsp. *turbinata*" based on the work of Lebreton & Pérez de Paz (2001). Unfortunately, the confusion came back later when Le Floc'h *et al*. (2010) repeated a probable erroneous mention for this country (Farjon 2005). In southern Tunisia, *J. turbinata* reaches the Matmata mountains which host very punctual and degraded populations, located on the slopes exposed to the north, above 500m altitude and where the average annual precipitation is between 200 and 300 mm / year (Le Houérou 1962; Chaieb & Boukhris 1998).
- Libya: the presence of *J. turbinata* is first reported in this country by Viviani (1824) under the name «*J. lycia*». It is reported in Cyrenaica under the name "*J. phoenicea*" by Durand & Baratte (1910), Pampanini (1931) and El-Barasi *et al*. (2011). Its first mention in Tripolitania seems have been made by Pampanini (1914). Its exact identity was

North coast of Montenegro *(© F. Médail).*

Nikouria island near Amorgos in the Cyclades, Greece *(© F. Médail).*

Anemo-morphosed matorral with* Pistacia lentiscus *and* Corydothymus capitatus*, north-west Cyprus *(© F. Médail).*

confirmed recently in Cyrenaica (Brullo & Guglielmo 2001 sub *J. turbinata*). See also the African Plant Database (https://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php), where the errors made in volume 1 (Dobignard & Chatelain 2010) were only partially corrected in the "Supplements and Corrigenda" in volume 5 (Dobignard & Chatelain 2013). Others potential populations should be sought between southern Tunisia and Tripoli region.

- Egypt: its presence is confirmed by Boulos (1999, 2009) under the name "*J. phoenicea*". In this country, *J. turbinata* represents the only species of juniper and occurs exclusively in the north of Sinai (El-Halal, El-Maghara and Yelleq mountains) where its relictual presence is very interesting (El-Bana *et al.* 2010; Farahat 2020).
- Israel: this juniper is mentioned under the name "*J. phoenicea*" in *Flora Palaestina* by Zohary (1966) who specifies "S. Edom, NW Arabia and Sinaï". The region of Edom is in fact located in the southwest of Jordan and we could not conclude to the presence of this juniper in this country.
- Jordan: its presence is confirmed by Al-Eisawi (1982) under the name "*J. phoenicea*". More recently, it is still the "subsp. *phoenicea*" which is mentioned in this country by Euro+Med Plantbase (http://ww2.bgbm.org/EuroPlusMed/query.asp/, consultated in November 2020). *Juniperus turbinata* is therefore not considered by Abu-Darwish *et al*. (2014) who argue that only *J. phoenicea* s.s. is present. This is also the opinion of Ar-Ramamneir *et al*. (2012), whose work shows however that the cones of the Jordanian taxon contain only about 5 seeds which is in contradiction with the data of European authors for *J. phoenicea* sensu stricto. Thus, *J. turbinata* in found in the mountains of the southwest of the country where it is rare because in decline. Beautiful individuals still exist, for example near the edge of the wadis in the Dana Natural Reserve (F. Médail pers. obs. I.2019).
- Saoudi Arabia: its presence was announced by Zohary (1966). It is represented by a single point on the map of Browicz (1982) and recently confirmed in the same sector (sub "*J. phoenicea* subsp. *phoenicea*") by a photograph taken *in situ* in El Figrah, west of Medina, by Ali Mohammed Alzahrani (pers. obs. 2019, https://www.inaturalist.org/observations/59413151, accessed 25/11/2020). In this country, *J. turbinata* should be sought in all or parts of the mountains of the Hedjaz.

Following this chorologic synthesis it is now possible to draw a global and updated distribution map for *J. turbinata* (Figure 2). Some distribution patches are deliberately enlarged to allow good readability, especially on the coast where the taxon occupies a thin strip most often fragmented. In North Africa, the distribution of *J. turbinata* overlaps with the great mountain ranges, avoiding wide steppic or desertic plains. This taxon deserves to be sought because finding new locations is not to be excluded (Spain, Libya, Saudi Arabia).

To clarify the situation, we also present here an updated distribution map for the two other taxa of this group, *J. phoenicea* s.s. and *J. canariensis* (Figure 3).

We hope that the distributions presented in this work will evolve soon thanks to the improved knowledge and corrections of many atlas projects.

Caryology

The different species of junipers are generally diploid with a base number equal to 11 (2n = 2x = 22 chromosomes), although some tetraploid taxa (2n = 4x = 44) were reported, such as *Juniperus thurifera* or even *J. chinensis*. In reality, polyploidy seems to have been underestimated in this genus (for more information see Vallès *et al*. 2015, Farhat *et al*. 2019).

For *J. turbinata*, Valdés *et al*. (1987) report 2n = 22 chromosomes, most certainly according to the count carried out by Valdés-Bermejo (1979) on «*J. oophora*» from Huelva (Andalusia, Spain).

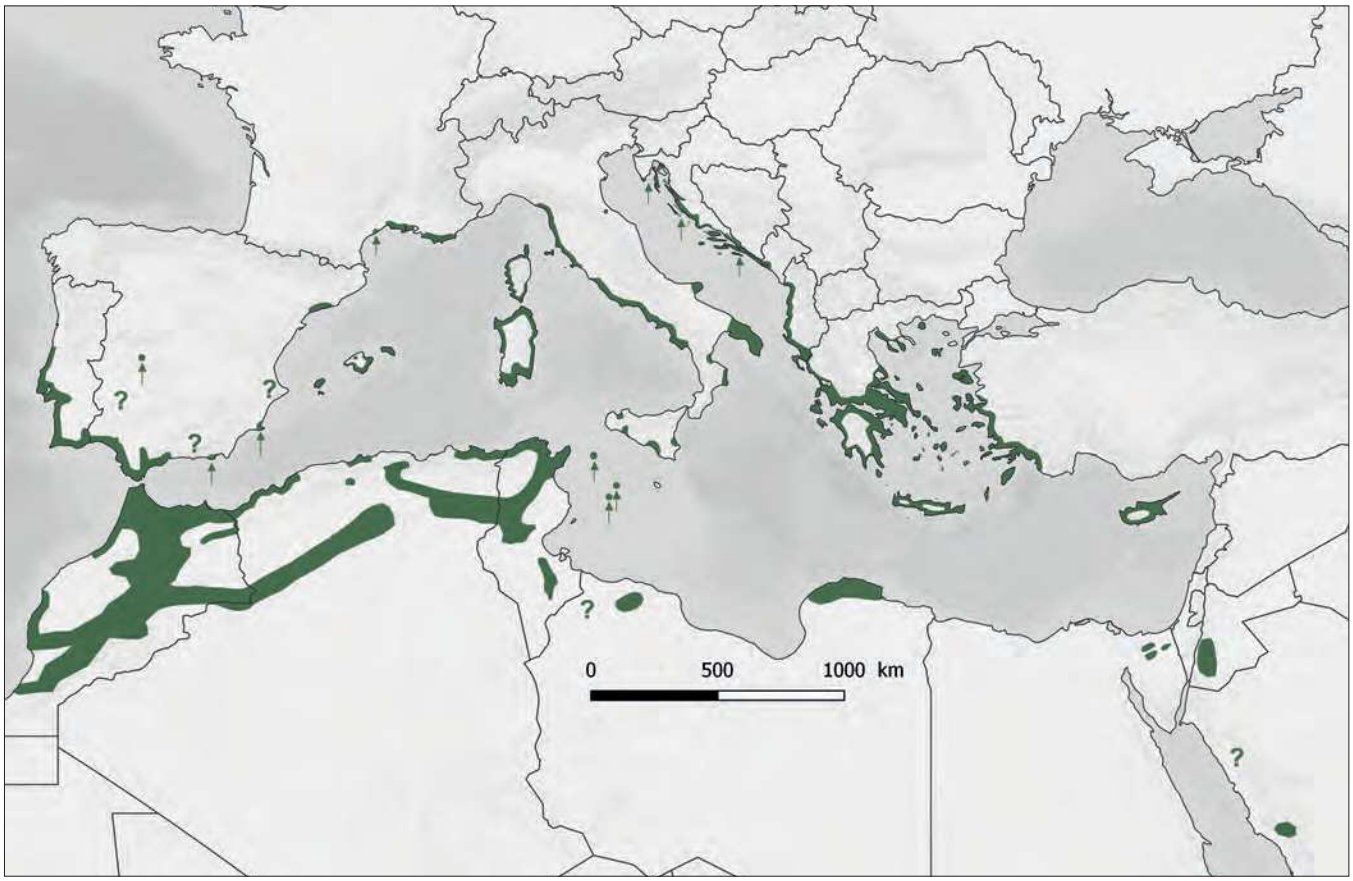


***Figure 2 – Distribution map of* Juniperus phoenicea *subsp.* turbinata.**

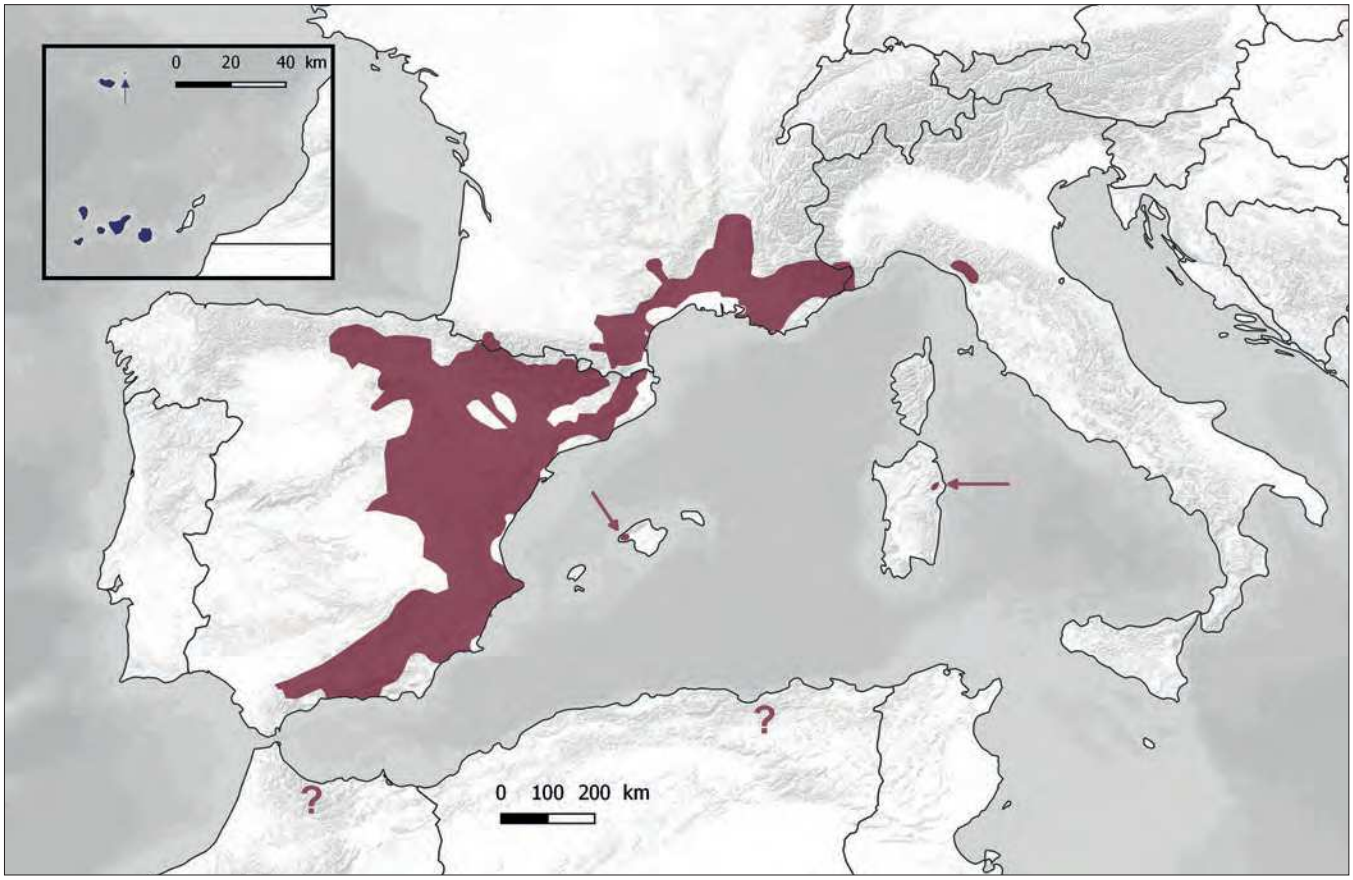


***Figure 3 – Distribution map of* Juniperus phoenicea *subsp.* phoenicea *and subsp.* canariensis.**

Reproduction biology

The majority of junipers is dioecious while *J. phoenicea* s.l. is usually considered monoecious (De Coincy 1898; Lemoine-Sebastian 1968). However, the sexuality of the group seems complex and depends largely on the geographical origin of populations and maybe also on the various taxonomical entities, some populations appearing functionally «subdioecious» (Jordano 1991; Mandin 2013).

Pollen production is typically autumnal in *J. turbinata* (Adams *et al*. 2013), its dissemination and pollination being ensured by the wind (anemogamy). This divergent phenology with *J. phoenicea* s.s., of which the pollen is dispersed at the end of winter and in spring, would largely explain their reproductive isolation and, to date, the absence of presumed hybrids according to Arista *et al*. (1997).

The maximum size of juniperus cones (galbulus) seems to be reached in the first year, but full maturation takes place over two years in the case of *J. turbinata* (Arista *et al*. 1997). These fleshy cones have the same functionalities as some fruits and berries of angiosperms (Herrera 1992) thus their dispersal seems to be largely ensured by vertebrates (endozoochory) especially mammals and birds (see for example García 2001; Herrera 1989; Nogales *et al*. 1999; Santos *et al*. 1999). In the case of mountains regions and mountains juniper species, dispersal is almost entirely provided by birds of the Turdidae family (Jordano 1993). In the case of *J. turbinata*, the rabbit (*Oryctolagus cuniculus*) plays an important role for dispersal in southern Spain (Doñana) in autumn and winter, optimum fruiting season for this taxon (Muñoz Reinoso 1993). Conversely and according to Tallon (1955) this lagomorph could be a limiting factor for the regeneration of this juniper in Camargue's dunes (SE France) by consuming young plants. Furthermore, two vertebrates introduced in Mediterranean islands currently play a notable role (case of the black rat, *Rattus rattus*, in the Hyères archipelago in south-eastern France: Cassaing *et al*. 2005) or a primordial one (case of the red fox, *Vulpes vulpes*, in Sardinia: Farris *et al*. 2017) in the dispersal of *J. turbinata*. Nowadays, these allochthonous mammals probably play the dispersal role formerly played by the vertebrate native island fauna now extinct, such as the Sardinian pika, *Prolagus sardus* in Corsica and Sardinia (Vigne 1987, 1992). Finally, other vertebrates like lizards could also serve dispersal, or even secondarily the raptors that feed on these reptiles as it is the case of the junipers of the Canaries Islands (Padilla *et al*. 2012).

Biotic interactions

We here only mention a few examples of interactions, such as the parasitism of junipers by dwarf mistletoes (*Arceuthobium spp.*), plant-arthropod relationships (predation, host plant, etc.) or some remarkable associated lichens.

Within the Santalaceae family, the genus *Arceuthobium* M. Bieb. is an hemiparasite mistletoe specialize on the genus *Juniperus*. In the Mediterranean only one species is generally accepted, *Arceuthobium oxycedri* (DC.) M. Bieb. (see Euro+Med Plantbase, consultation in October 2020), but molecular studies showed that this name clearly applies to several cryptic taxa genetically that are well distinct (Nickrent *et al*. 2004). Thus, *Arceuthobium gambyi* Fridl. is a recently described species which seems to specifically parasitize *J. phoenicea* s.s. and that we only find in Spain and France according to his descriptor (Fridlender 2015). Despite rare and vague mentions of dwarf mistletoe on scaled junipers in various sectors of the Mediterranean, the synthesis carried out by the latter author shows that parasitism on *J. turbinata* by the genus *Arceuthobium* does not seem to be confirmed to date. In Morocco for example, only *Arceuthobium oxycedri* seems present and only parasiting *J. oxycedrus* despite the frequent cohabitation of these two species of junipers (Rhanem 2019). An occasional infestation by *Arceuthobium oxycedri* on an individual of *J. turbinata* growing in the immediate vicinity of an individual of *J. oxycedrus* cannot therefore be ruled out but remains to be proven.

Many arthropods (mites, hemiptera, coleoptera, diptera, lepidoptera, etc.) attack the cones (galbulus) of various species of junipers consuming the pulp or the seeds (see for example El Alaoui El Fels *et al*. 1999; Moraiti *et al*. 2019; Traveset & Sans 1994). These animals are qualified as "stenoconobionts" when all or part of their cycle is strictly dependent on conifer cones. Roques *et al*. (1984) showed that the ecological and distribution preferences of different species of junipers generate the existence of distinct arthropod communities, while the impact of these «pests» seems to limit the regeneration

With* Pinus halepensis *in central saharian Atlas, Djelfa, Algeria *(© E. Véla).*

capacities of populations. Thus, junipers represent more or less specific "host plants" or "preferential plants" for various mites (ex. *Trisetacus quadrisetus*), diptera (ex. *Arceuthomyia valerii*, *Oligotrophus spp*., *Schmidtiella gemmarum*), lepidoptera (ex. *Archips oporana*, *Argyresthia spp*., *Chionodes electella*, *Cydia duplicana*, *Dichomeris marginella*, *Lobesia reliquana*, *Sesia cephiformis*, etc.), hymenoptera (ex. *Megastigmus amicorum*) or beetles (ex. *Auletes tubicen*, *Nanodiscus transversus*, *Pachyrhinus lethierryi*, *Phloeosinasites spp*., etc.) (Plant Parasites of Europe: https://bladmineerders.nl; Balachowsky, 1949; Hoffmann 1950, 1954, 1958; Dauphin & Aniotsbehere 1993; Boivin & Auger-Rozenberg 2016; Lieutier *et al*. 2016). The list of invertebrates presented here is clearly not exhaustive nor specific to *J. turbinata* for which there is little information on this subject. It is interesting to note that the work of Ribera & Blasco-Zumeta (1998) showed that arthropod communities in NE Spain steppes present biogeographical relationships with those of the eastern Mediterranean and Asia, in particular when they relate to species specifically associated with junipers.

Finally, the coastal juniper woodlands (*J. turbinata* or *J. oxycedrus* subsp. *macrocarpa* (Sm.) Ball) represent specific habitats for some rare lichens like *Thelopsis isiaca* Stizenb. [= *Thelopsis subporinella* Nyl.] (Dughi 1950) or the threatened species *Seirophora villosa* (Ach.) Frödén (Benesperi *et al*. 2013).

Ecology and phytosociology

In the north of the Mediterranean, *J. turbinata* is generally considered as a bioindicator of the thermomediterranean bioclimatic belt (Quézel & Gast 1998; Gamisans 1999). Its overall distribution is indeed largely superimposed on this bioclimatic belt as defined by Quézel & Médail (2003). However, it has a more extensive ecological niche, since it is present from the coast and the thermomediterranean to the supramediterranean belt and under various bioclimates, from arid to subhumid (Asensi *et al*. 2007). In North Africa, despite an important extension, from the thermophilous coasts to the rather cold and steppic continental mountains, this juniper does not penetrate the Saharan domain (Ozenda 2004). At the eastern part of its range it leaves the Mediterranean domain to be found in the

On rocky coast (sandstone) at "Zembra island National Park", Tunisia *(© D. Pavon).*

Iranian-Turanian or Saharo-Arabian regions *sensu* Danin & Plitmann (1987), as in Egypt (Sinai), in Israel, in central Jordan and obviously in Saudi Arabia. Finally, it seems indifferent to the chemical nature of the substrate although it is more common and abundant on siliceous regions (pers. obs.).

In Mediterranean Europe, this taxon is found on coastal regions with a clear preference for fixed dune ecosystems while also scrublands of rocky coasts (Molinier 1954, 1981; Molinier & Tallon 1965ab, 1970; Rivas-Martínez *et al*. 1980; Gamisans & Murracciole 1984; Paradis 1993; Gamisans 1999). In the Balearic and in the Tyrrhenian Islands, its ecological amplitude seems quite large (Rivas-Martínez *et al*. 1992; Gianguzzi *et al*. 2012; Minisale & Sciandrello 2013) while in the south of Spain it penetrates inland in particular on gypsum substrate (Cabezudo 2011). Finally, in more arid sectors of the rest of the Mediterranean (Africa, Middle-East, etc.) it is often found in mountains where aridity seems to be compensated either by its location on the edge of wadis and thalwegs as in Jordan (F. Médail pers. obs.) or by lower temperatures (Mazur *et al*. 2016). Thus, it can rise to an altitude of 2000 m for example in Morocco ("chemovar. *montana*" *sensu* Lebreton & Pérez de Paz 2001). Let's not forget that in the south of Europe the *J. turbinata* matorrals are more or less localized and are not a dominant forest type, whereas they constitute (mixed with pines) the main part of the pre-forest or forest vegetations of North Africa (Quézel 2000) or the eastern Mediterranean (Quézel 1979).

Due to its wide distribution and ecological preferences, *J. turbinata* contributes to many phytosociological groups. The literature on this subject is very abundant: it was specifically compiled in a first synthesis proposed in Lebreton & Pérez de Paz (2001) and then in the exhaustive work of Asensi *et al*. (2007). However, we can cite here various work, such as those of Costa *et al*. (2000) for Portugal, Diez-Carretas *et al*. (1996) for the Iberian Peninsula, Gianguzzi *et al*. (2012) for the Tyrrhenian region, Reymann *et al*. (2016) for Corsica, Tsiroulis *et al*. (2016) for Greece as well as those of Quézel (1979) for Crete and Cyprus. For North Africa, various studies were carried out in Morocco (Quézel & Barbero 1981; Quézel *et al*. 1987, 1988, 1992), Algeria (Dahmani-Megrerouche 1996; Djebaili 1990; Meddour 2010; Zaffran 1960) and Tunisia (Gounot & Schoenenberger 1966, 1967; El Hamrouni *et al*. 2020). Finally, the work of Danin (1972) concerns Egypt and the Middle-East.

We present a simplified table (Appendix Table 1) of phytosociological groups for the level of alliance, largely based on the work of Asensi *et al*. (2007) and Quézel & Médail (2003). The realization of this synthesis remains delicate because opinions differ according to specialists. In general, the species is only considered in forest habitats whereas we think that it is representative of various shrub communities. In this table, some remarks allow us to justify our choices and positions.

Threats, conservation and restoration

Throughout its current range, *J. turbinata* presents many populations each resulting from ancient and local processes of biogeography and plant dynamics. Indeed, its populations often seem to be located in refuge areas (Danin 1999; Médail & Diadema 2009; Ivanov *et al*. 2011; Hidalgo *et al*. 2014). Taking into account these characteristics is crucial to achieve a relevant conservation for this taxon and its various specific phylogenetic units (Moritz 1994; Waples & Gaggiotti 2006).

For Europe, this juniper is a remarkable taxon as an indicator of three habitats classified under the Habitats Directive 92/43/EEC (Natura 2000):

– Code 2250* – Coastal dunes with *Juniperus spp*. (priority habitat);
– Code 5210 – Arborescent matorral with *Juniperus spp*.;

– Code 5330 – Thermo-Mediterranean and pre-desert scrub.

We find in the example of "Coastal dunes with *Juniperus*" a synthesis of the main threats as well as various proposals for the evaluation of the conservation state and some conservation measures (Picchi 2008; Antoine 2014; Gómez-Zotano *et al.* 2017). We develop some of these aspects below.

Fires constitute a major and common ecological disturbance of Mediterranean ecosystems but hardly affect the vegetation in place in the medium and long term (Pausas & Vallejo 1999; Capitanio & Carcaillet 2008; Pausas *et al*. 2008). Indeed, the regeneration of woody species is rapid after fire because of two main mechanisms: resprouting and seeding (Le Houérou 1973; Keeley 1986; Lloret & Vilà 1997; Pausas & Verdù 2005). Conversely, many authors consider that Mediterranean scaled junipers (sect. *Sabina*) show very little resistance to fire (Alcahud *et al*. 1997; Riera & Castell 1997; Quevedo *et al*. 2007). Their presence would therefore be associated with a low incidence and low recurrence of this disturbance (Fernandéz-Gonzaléz *et al*. 2005). The post-fire regeneration of the various juniper species is reported to be poor (Moreno 2012) or even null (Martínez-Sánchez *et al*. 1997) with almost no germination and no sprouting (except very rarely in the case of young individuals). Only the work of Ayache *et al*. (2020) concerning a portion of the Algerian coast disagree with these results and conclude that moderate fire and moderate grazing pressure would rather be favorable to *J. turbinata*. In addition, Roques & Auger-Rozenberg (2006) showed that for *J. thurifera* the impact of fire could counterbalance the dominance of seed pests and therefore promote its regeneration in the short term. Faced with all these uncertainties, the impacts of this disturbance should be studied more specifically on *J. turbinata* in different socio-economic, bioclimatic and biogeographical contexts. In fact, most of the work cited above concerned *J. phoenicea* sensu stricto. From a paleoecological point of view, some studies suggest notable regressions of coastal junipers (*J. turbinata*?) because of historical anthropogenic impacts including the use of fire (Noti *et al*. 2009). An extreme situation exists on the Tunisian island of Djerba from where *J. turbinata* completely disappeared while macro remains dating from around 4200 years BP were found (Damblon & Vanden Berghen 1993). In this North African island, it is not sure that fire is the unique responsable of its local extinction. Inland, in mountainous regions or on the high Spanish plateaus, anthropization seems to have played an opposite and more beneficial effect historically on local junipers, in particular *J. thurifera* (Carrión *et al*. 2004).

The *J. turbinata* habitats are strongly threatened today by many other anthropogenic pressures throughout its range. We can cite in the first place the simple destruction of natural habitats by urbanization and intensive agriculture (in particular on the coast), but also overgrazing, logging, invasive species (*Agave spp*., *Carpobrotus spp*., etc.), tree plantation and human overcrowding (Mota *et al*. 1996; Zaafouri & Chaïeb 1999; Khaldi *et al*. 2000; Lebreton & Pérez de Paz 2001; Auclair & Saïdi 2002; Badano & Pugnaire 2004; Spanu *et al*. 2006; El-Barasi & Barrani 2013; Martinis *et al*. 2018; Farahat 2020; Mostari *et al*. 2020). The threats largely differ according to the sectors and especialy between the southern and northern parts of the Mediterranean. Finally, climate changes also represent a major threat, particularly in North Africa according to Arar *et al*. (2020).

To conclude, many populations of *J. turbinata*, whether continental or coastal, are currently threatened and endangered except when they are located in inaccessible or strictly protected areas (Natural Reserves or National Parks). According to the IUCN criteria, this species appears in many red lists at national levels as in Jordan where it is "EN" (Taifour & El-Oqlah 2014 sub *J. phoenicea*) or at regional level: "VU" in eastern Andalusia (Cabezudo 2011), "EW" in the region of Valencia (Laguna Lumbreras 1998), "VU"in Sicily (Conti *et al*. 1997), etc.. It strangely appears "NT" in the world red list (Farjon 2020) whereas in North Africa, a region which constituted its bastion (Maire 1952), the continental steppe communities with *J. turbinata* seem to have almost disappeared in less of a century according to Le Houérou (1995) or Quézel (2000). This last statement does not yet seem to apply to Morocco where this juniper occupies the most important areas in the world and still present beautiful populations in its high steppic mountains.

To our knowledge, there are no other large-scale conservation plan for *J. turbinata* than this of the Pyrenean thuriferous juniper (Cambecèdes *et al*. 2005). However, some localized ecological restoration projects

are run, for example in southern Spain in Andalusia (García-Novo *et al*. 2007; Muñoz-Reinoso *et al*. 2013). Also in Spain, this presumed extinct species from the Comunidad Valenciana was reintroduced in the province of Alicante (dunes of Guardamar and Marina d'Elche) where more than 200 planted individuals showed a very low survival rate after only 2 years (E. Laguna Lumbreras, per. com.).

Taxonomic position and identification key of *Juniperus phoenicea* complex

Despite a current good taxonomic knowledge, taxa of the *J. phoenicea* group are difficult to identify. To distinguish the different taxa, it is necessary to combine several morphological characters according to Mazur *et al*. (2016) and we argue that it is relevant to associate geographical origin, local ecological parameters or even the habit of the plants. Our own observations across the western Mediterranean Basin show that the "turbinated" character of young cones is not always met and their size at maturity seems variable and rarely exceeds 12mm (to 14mm in the litterature). Thus, the number of seeds per cone remains the best criterion but requires several counts per population because is variable, in particular in the western Mediterranean where we exceptionally observed cones containing up to 9 seeds in *J. turbinata* (Corsica and SE France, D. Pavon pers. obs.). In addition, genetic distances between populations of the same taxon are sometimes important because of isolation and very old local persistence (Mazur *et al*. 2010; Dzialuk *et al*. 2011) even though the three taxa of the group remain very close (Lebreton & Pérez de Paz 2001; Adams *et al*. 2010).

The overlapping morphological characters, the vicariance of geographical areas and the genetic proximity encourages us to adopt a taxonomic treatment at the subspecies level (subsp.) for the three taxa of the group despite the actual "splitter" approach (Adams 2014; Mazur *et a*l. 2016; Romo *et al*. 2019).

Juniperus phoenicea L. subsp. ***phoenicea*** [1753, Species Plantarum, 2: 1040]

Lectotype: designed by Christensen *in* Strid & Kit Tan (eds.) (1997), *Flora Hellenica*, 1: 13 ("Herb. Burser XXV: 61, UPS)".

Note: choosen lectotype was collected by Burser at "Monspelii in littore" (S France), where subsp. *phoenicea* does not exist, replaced by the subsp. *turbinata*. In the Montpellier area, subsp. *phoenicea* is only present inland, far from the coast. This problem deserves to be fixed.

Biogeographic type: W Medit.

Chorology: from south Spain to NW Italy, Mallorca (Balearic Islands) and Sardinia.

Juniperus phoenicea L. subsp. ***turbinata*** (Guss.) Nyman [1881, Consp. Fl. Eur., 676]

var. ***turbinata***

Basionyme: *Juniperus turbinata* Gussone [1844, Fl. Sicula Syn., 2: 634] "In arenosis vel rupestribus maritimis, Montallegre (Gussone); Secciara (Gasparrini)" (Sicily, Italy)

Lectotype: designed by Ferrer-Gallego *et al*. (2017) "Gussone's specimen at NAP (NAP_2: the lectotype is the larger fragment, on the left of the sheet)".

≡ *Sabina turbinata* (Guss.) Antoine [1857, Die Cupressineen-Gattungen: Arceuthos, Juniperus und Sabina, 41, planche 56]

≡ *Juniperus phoenicea* L. var. *turbinata* (Guss.) Parl. [1867, Flora Italiana, vol. 4, p. 91]

≡ *Juniperus phoenicea* L. subsp. *turbinata* (Guss.) Arcangeli [1882, Comp. Fl. Ital., 637]

= *Juniperus oophora* Kunze [1846, Flora, 40: 637] "in pineto proper la Bonanza regni Sevillani" (Doñana, Spain)

= *Juniperus phoenicea* L. f. *megalocarpa* Maire [1941, Bull. Soc. Hist. Nat. Afrique Nord, 32(7): 224] "Dunes de Mogador" (Essaouira, Morocco)

= *Juniperus phoenicea* L. subsp. *eumediterranea* Lebreton & Thivend [1981, Naturalia Monspel., Sér. Bot., 47: 8] "Capo Caccia, Alghero, Sardinia" (Valsecchi in Herbier Rouy, Lyon)

= *Juniperus phoenicea* L. var. *macrocarpa* St.-Lag. [1889, in Cariot, Étude Fl., éd. 8, 2: 762]

= *Juniperus lycia* var. *tarraconensis* Sennen [1936, Diagn. Nouv.: 272] "Plage la Sabinosa, Tarragona" (Catalunya, Spain)

= ? *Juniperus lycia* L. (*nom. ambig*.)

Incl.: var. *occidentalis* Lebreton & Pérez de Paz (*nom. inval*.)

Incl.: var. *orientalis* Lebreton & Pérez de Paz (*nom. inval*.)

Biogeographic type: Medit.

Chorology: from Portugal and Morocco Atlantic coasts to eastern Mediterranean and Middle-East, and in large Mediterranean islands.

var. ***galbulis-mollibus*** Ball

Basionyme: *J. phoenicea* L. var. *galbulis mollibus* Ball [1878, *Spicilegium Florae Maroccanae*, Journ. linn. Soc. (Bot.), 16(94): 671] "Tasseremout. In convalle Aït Messan usque 1500m" (Forteresse Tasghimout et near Djebel Toubka, Marrakech, Morocco)

Type: not designated.

= chimiovar. *montana* Lebreton & Pérez de Paz (*nom. inval*.)

Biogeographic type: SW Medit.?

Chorology: Northern African mountains (exact range to be delineated).

Juniperus phoenicea L. subsp. ***canariensis*** (Guyot) D. Pavon, E. Véla & F. Médail comb. nov.

Basionyme: *Juniperus canariensis* Guyot *in* Mathou & Guyot [1942, Trav. Lab. Forest. Toulouse, Tome 1, volume 3, article 20: 7-8]

Lectotype: designated by Farjon (2005: 337) (E. Bourgeau, Plantae Canariensis nº 439/ *Juniperus phoenicea* Linn. / ins. Gomera: Barranco de Hermigua / April 1846. / Kew 000075180).

≡ *J. phoenicea* L. subsp. *canariensis* (Guyot) Romo *et al*. [2019, Phytotaxa, 406(1): 64-70], nom. inval. (cf. art. 36.1a of the 2018 International Code of Nomenclature / see International Plant Name Index: https://www.ipni.org/).

= *J. canariensis* Knight [1850, Syn. Conif.: 13] (*nomen nudum*)

Biogeographic type: Macaron.

Chorology: Canary Islands (Grán Canaria, Tenerife, La Gomera, La Palma, El Hierro) and Madeira (Madeira island and Porto Santo island).

According to this concept, the north-western populations of subsp. *turbinata* could have been introgressed by subsp. *phoenicea* which would explain the difficulty of detection and identification in this region (this is not the opinion of Adams *et al*. 2013). In addition, the "chemovar. *montana*" deserves individualization in our opinion because it has all the characteristics of a "good ecotype" (chemical and ecological signatures) and can be treated in the taxonomic rank of variety. The only name currently available appears to be var. *galbulis-mollibus* Ball (= var. *mollis* Maire & Weiller). A map makes it possible to visualize the topotypes of the main taxa described in this group of red junipers (Figure 4).

At "Bou Hedma National Park" in central Tunisia *(© D. Pavon).*

Threatened population in "El-Kouf National Park", Cyrenaica, Lybia *(© E. Véla).*

We propose below an identification key to distinguish the infraspecific taxa of *J. phoenicea*. For its realization we used the keys proposed by Lebreton & Pérez de Paz (2001) and Romo *et al*. (2019) by amending them with morphological, ecological and geographic data from the literature consulted as well as by personal observations.

1. Mature cones 5-9(10) mm and with (3) 7-10(13) seeds; pollen of male cones dispersed in late winter and spring (Feb-March); scaled leaves obtuse to subacute; young branchlet rather short, not or slightly bent and with regular obtuse

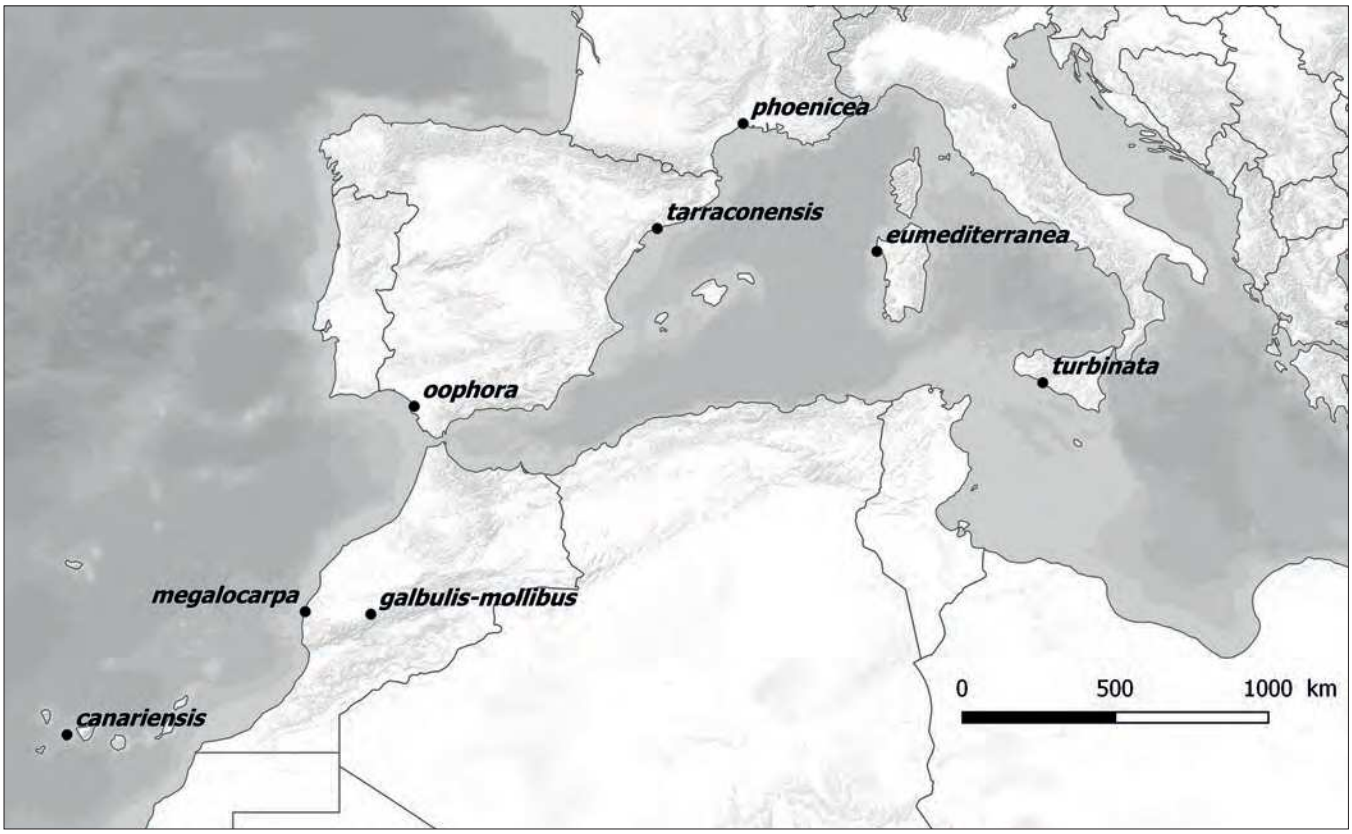


Figure 4 – Map of the main topotypes.

apex; shrubby habit generally low (± 2m high) and dense (beware of old individuals with sparse habit, very frequent in cliffs); rocky scrubland, ridges and limestone cliffs (especially in dolomitic limestones) ; leaves without prodelphinidin; west Mediterranean taxa .... subsp. ***phoenicea***

1'. Mature cones (7) 8-12(14) mm and with 3-7(9) seeds; pollen dispersed in autumn (Oct-Nov); scaly leaves markedly acute to acuminate; young branchlet with truncated apexes, frequently elongated and curved downwards; potentially tree habit, sometimes high (up to 8-12m) and sparse (beware of small individuals, more or less prostrate and dense because of anemomorphosis, very common or even predominant in coastal areas exposed to sea spray as well as in overgrazed continental areas); leaves with prodelphinidin 2

2. Mature cones with 3(4) seeds; scaly leaves with rather hard and thorny tips; branchlet bark brown; macaronesian taxa .... subsp. ***canariensis***

2'. Mature cones with 4-7(9) seeds; scaly leaves without hard and thorny tips; branchlet bark reddish; circum-mediterranean taxa ..... subsp. ***turbinata***

a. Low altitude and island taxon; high-level of prodelphinidin (6-9mg/g) .... var. ***turbinata***

a'. Mountain steppic taxon; low-level of prodelphinidin (4-5mg/g) .... var. ***galbulis-mollibus***

Conclusion and perspectives

The taxonomic and chorological knowledges of *J. phoenicea* subsp. *turbinata* have improved significantly since the 1980s, in particular thanks to the remarkable work of Philippe Lebreton and his collaborators. It is curious that most botanists have ignored this research during such a long time. Despite this, it is still necessary to intensify the field surveys in order to improve distribution maps. We have to focus on problematic areas where the two Mediterranean taxa coexist at short distances (Andalusia, Balearic Islands, Catalonia, Provence, Sardinia) or where the presence of one or the other of the two subspecies is not confirmed but need to be sought (coast of the province of Alicante and mainland Spain for subsp. *turbinata*; northern Morocco and Algeria for subsp. *phoenicea*).

At "Dana National Reserve", Jordan *(© F. Médail).*

Currently, *J. phoenicea* subsp. *turbinata* is either a rare taxon or a formerly common taxon now in sharp decline, the populations of which deserve special attention.

Thanks to a better understanding of its taxonomic delimitation we can now propose many study perspectives for this taxon:

- Update and refine its chorology, population dynamics and conservation status in many countries;
- Reassess the global IUCN status, which currently appears underestimated due to its significant declin and threats;
- Refine and multiply specific work on the impact of fires on populations;
- Improve knowledge on biologic interactions in different biogeographical and ecological contexts;
- Develop conservation and restoration programs for populations and habitats in threatened or degraded sites.

Finally, several personal pictures illustrate *J. phoenicea* subsp. turbinata in various landscape, ecological and geographical contexts, from the Atlantic coast of Portugal to Jordan.

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Appendix *(Annexe)*

Table 1 – Phytosociological groups

		Short description – Characteristic species – Notes
Class **Quercetea ilicis** Braun-Blanq. *in* Braun-Blanq. *et al*. 1952		
Forest or pre-forest groups		
Ord. ***Pinetalia halepensis*** Biondi *et al*. *in* Biondi *et al*. 2014	All. ***Pistacio lentisci-Pinion halepensis*** Biondi *et al*. *in* Biondi *et al*. 2014	Shrub to small tree communities of the NW Mediterranean (from the Spanish Levant to the Adriatic), on coastal limestone rocks with shallow soils, in the semi-arid to sub-humid mesomediterranean bioclimatic belt. *Erica multiflora*, *Juniperus phoenicea* subsp. *turbinata*, *Lotus hirsutus*, *Pinus halepensis*, *Pistacia lentiscus*, *Rhamnus alaternus*, *Rosmarinus officinalis, Smilax aspera*.
Ord. ***Pistacio lentisci-Rhamnetalia alaterni*** Rivas-Martínez 1975	All. ***Juniperion turbinatae*** Rivas-Martínez 1975 *corr*. 1987	Shrub to small tree circum-Mediterranean communities dominated by junipers and developed on fixed sand, most often coastal but sometimes in continental locations (fossil dunes). *Cistus halimifolius*, *Corema album*, *Ephedra distachya* and *E. fragilis*, *Helichrysum spp*., *Juniperus oxycedrus* subsp. *macrocarpa*, *Juniperus phoenicea* subsp. *turbinata*, *Lotus creticus*, *Matthiola sinuata*, *Phillyrea angustifolia*, *Pinus pinea*. Currently, many phytosociological groups with the subsp. *turbinata* but concerning rocky substrates (slopes and coastal cliffs) are included in this alliance. We think on the contrary that they should be included in the *Oleo-Ceratonion siliquae*.
	All. ***Ericion arboreae*** Rivas-Martínez (1975) 1987	Shrub to small tree circum-Mediterranean communities on acid substrates, in thermomediterranean to supramediterranean bioclimatic belts. *Arbutus unedo*, *Cistus spp*., *Erica arborea*, *Lavandula stoechas*, *Quercus ilex* sensu lato, *Q. suber* Some authors currently link communities of this juniper on siliceous rock to the alliance of *Juniperion turbinatae* in a specific association (*Erico arboreae-Juniperetum turbinatae*)
	All. ***Asparago albi-Rhamnio oleoidis*** Rivas-Martínez 1975	Shrub to small tree Ibero-Maghrebian communities in semi-arid to sub-humid thermomediterranean bioclimatic belt. *Aristolochia baetica*, *Asparagus aphyllus*, *Bupleurum gibraltaricum*, *Ceratonia siliqua*, *Chamaerops humilis*, *Juniperus phoenicea* subsp. *turbinata*, *Osyris quadripartita*, *Pistacia lentiscus*, *Quercus coccifera*, *Rhamnus oleoides* This alliance could be included in the *Oleo-Ceratonion siliquae*.
	All. ***Oleo sylvestris-Ceratonion siliquae*** Braun-Blanq. *ex* Guin. & Drouineau 1944	Shrub to small tree circum-Mediterranean communities on rocky substrates in semi-arid to sub-humid thermomediterranean and mesomediterranean belt. *Arisarum vulgare, Ceratonia siliqua, Chamaerops humilis*, *Clematis cirrhosa, Euphorbia dendroides*, *Juniperus phoenicea* subsp. *turbinata*, *Myrtus communis*, *Olea europaea* subsp. *sylvestris*, *Periploca angustifolia*, *Pinus brutia*, *Pinus halepensis*, *Pistacia lentiscus*, *Prasium majus*, *Rosmarinus officinalis* Some authors currently link thermomediterranean juniper communities on limestone rock to the alliance of *Juniperion turbinatae*. We consider that the latter is specific to sandy substrates.
	All. ***Rhamno graeca-Ceratonion siliquae*** Barbero & Quézel *in* Asensi *et al*. 2007	Shrub to small tree eastern Mediterranean communities of semi-arid to sub-humid thermomediterranean bioclimatic belt and on various substrates. *Ephedra foeminea*, *Juniperus phoenicea* subsp. *turbinata*, *Pistacia terebinthus* subsp. *palaestina*, *Quercus calliprinos*, *Rhamnus spp*. Could be included in the alliance *Oleo-Ceratonion siliquae*.
	All. ***Aro cyrenaici-Rhamnion libyci*** Brullo & Furnani 1994	Shrub to small tree communities of Cyrenaica on rocky substrates, in the arid thermomediterranean bioclimatic belt. *Arbutus pavarii*, *Arum cyrenaicum*, *Cyclamen rohlfianum*, *Juniperus phoenicea* subsp. *turbinata*, *Olea europaea* subsp. *sylvestris*, *Periploca angustifolia*, *Rhus tripartita.* This alliance only seems to constitute a geographic and arid variant of *Oleo-Ceratonion siliquae*.

		Short description – Characteristic species – Notes
Pre-steppic groups		
Ord. ***Ephedro-Juniperetalia africanae*** Quézel & Barbero 1981 *ex* Quézel *et al*. 1988	All. ***Periplocion angustifoliae*** Rivas-Martínez 1975	Pre-steppic shrub to small tree communities of SW Mediterranean at low and medium altitude in coastal environments, in the arid or semi-arid thermomediterranean bioclimatic belt. *Chamaerops humilis*, *Juniperus phoenicea* subsp. *turbinata*, *Launaea spp*, *Lycium intricatum*, *Lygeum spartum*, *Macrochloa tenacissima, Maytenus senegalensis*, *Periploca angustifolia*, *Retama spp*., *Withania spp*., *Ziziphus lotus* Because of its distinctly steppic affinities we placed this alliance here whereas it is generally classified in the order of *Pistacio lentisci-Rhamnetalia alaterni*.
	All. ***Tetraclino articulatae-Pistacion atlanticae*** Rivas-Martínez *et al*. 1986	Steppic and continental communities of North Africa (and Middle-East?), in arid and semi-arid thermo- to mesomediterranean bioclimatic belt. *Artemisia herba-alba*, *Juniperus phoenicea* subsp. *turbinata*, *Pistacia atlantica*, *Rhus pentaphylla*, *Tetraclinis articulata* Because of its distinctly steppic affinities, we placed this alliance here whereas it is generally classified in the order of *Pistacio lentisci-Rhamnetalia alaterni*.
	All. ***Junipero africanae-Quercion rotundifoliae*** Quézel et Barbero 1981 *ex* Quézel *et al*. 1988 *corr*. Barbero *et al*. 1994	Shrub to small tree continental pre-steppic communities of the high plateaus and internal mountains of North Africa on rocky substrates at mesomediterranean and supramediterranean bioclimatic belt. *Bupleurum fruticescens* subsp. *spinosum*, *Buxux balearica*, *Diplotaxis harra*, *Hedysarum coronarium*, *Genista microcephala*, *Globularia alypum*, *Juniperus oxycedrus*, *Juniperus phoenicea* subsp. *turbinata*, *Macrochloa tenacissima, Pinus halepensis*, *Quercus ilex* subsp. *ballota*, *Rosmarinus spp*. This alliance could be treated in a distinct class: Ephedro-Juniperetea Barbero & Quézel 1981
	All. ***Ephedro nebrodensis-Juniperion turbinatae*** Quézel & Barbero *in* Asensi *et al*. 2007	Pre-steppic communities of the Moroccan High Atlas developed in arid and semi-arid areas with endemic elements or Macaronesian affinities. *Bupleurum dumosum*, *Coronilla ramosissima*, *Cupressus atlantica*, *Juniperus phoenicea* subsp. *turbinata*, *Retama dasycarpa*, *Rhus tripartita*, *Warionia saharae* This alliance could be treated in a distinct class: Ephedro-Juniperetea Barbero & Quézel 1981
Class **Cisto ladaniferi-Lavanduletea stoechadis** Braun-Blanq. *in* Braun-Blanq. *et al*. 1940 **(Shrub communities on acid substrate)**		
Ord. ***Lavanduletalia stoechadis*** Braun-Blanq. *in* Braun-Blanq. *et al*. 1940	All. ***Cistion ladaniferi*** Braun-Blanq. *in* Braun-Blanq. *et al*. 1940	Shrub communities dominated by *Cistus spp.* on rocky acid substrates in thermo- and mesomediterranean bioclimatic belts. *Cistus creticus*, *Cistus monspeliensis*, *Cistus salviifolius*, *Cytisus laniger*, *Erica arborea*, *Juniperus phoenicea* subsp. *turbinata* (shrub), *Helichrysum italicum*, *Lavandula stoechas*. Possible evolution to the *Oleo-Ceratonion siliquae* or *Ericion arboreae*.
Ord. ***Stauracantho genistoidis-Halimietalia commutati*** Rivas-Martínez *et al*.1990	All. ***Stauracantho genistoidis-Halimion halimifolii*** Rivas-Martínez 1979	Shrub communities of sand dunes in thermo- and mesomediterranean bioclimatic belts. *Cistus halimifolius*, *Helichrysum italicum*, *Juniperus phoenicea* subsp. *turbinata* (schrub) Possible evolution to the *Juniperion turbinatae*.
Class **Rosmarinetea officinalis** Rivas-Martínez *et al*. 2002 **(Shrub communities on limestone substrate)**		
Ord. ***Rosmarinetalia officinalis*** Braun-Blanq. *ex* Molinier 1934	All. ***Rosmarinion officinalis*** Molinier 1934	Shrub communities of the NW Mediterranean in thermo- to supramediterranean bioclimatic belts. *Cistus albidus, Coronilla juncea, Erica multiflora*, *Helichrysum stoechas*, *Juniperus phoenicea* subsp. *turbinata* (shrub), *Lotus dorycnium*, *Globularia alypum*, *Rosmarinus officinalis*, *Thymus vulgaris*. Possible evolution to the *Pistacio lentisci-Pinion halepensis*.