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Re-evaluation and typification of *Foeniculum piperitum* (Apiaceae), an underknown medicinal plant and crop wild relative

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Abstract

Foeniculum piperitum was described as *Anethum piperitum* based on plants collected in Sicily, Italy. Currently it is treated either as a synonym of *Foeniculum vulgare*, or as one of two subspecies within that taxon. Here we show that *F. vulgare* and *F. piperitum* are two different, sometimes co-occurring, taxa and that given clear morphological and ecological separation, they should be treated as distinct species. *Anethum piperitum* is typified. Owing to misapplication of names and wrong synonymizations, the ecology and chorology of *F. vulgare* and *F. piperitum* have to be better defined.

Keywords: Mediterranean flora, morphology, nomenclature, taxonomy, Umbelliferae

Introduction

Until the recent description of *Foeniculum sanguineum* Triano & A. Pujadas (in Pujadas-Salvà *et al.* 2015) from Spain, the genus *Foeniculum* Miller (1754) had been considered monospecific and containing a single species, *F. vulgare* Miller (1754), for over a century (Jiménez-Mejías & Vargas 2015). *Foeniculum vulgare* occurs spontaneously in a wide area between the Mediterranean region and southwestern Asia, and is both cultivated and naturalized on practically all continents except Antarctica (Pimenov 2017). It is an important plant used for food and medicine (Jansen 1981, Geraci *et al.* 2018, Pasta *et al.* 2020), and is a crop wild relative (Heywood & Zohary 1995).

Within *F. vulgare*, two wild infraspecific taxa are recognized: *F. vulgare* subsp. *vulgare* and *F. vulgare* subsp. *piperitum* (Ucria) Béguinot (1907: 447) (Pignatti *et al.* 2017–2019). The latter was described for the first time by Cupani (1696) from Sicily and given the polynomial “*Foeniculum Asininum folijs crispis sive Millefolij gravè olens. publicè Finocchiu d’Asinu, o sarvaggiu fitenti*”. In his work, Cupani clearly distinguished “*Foeniculum Asininum*” from the taxon now recognized as *F. vulgare*, which was also present in Sicily, and for which he used the polynomial “*Foeniculum vulgare, Italicum .semine oblongo, gustu acuto C. B. P.*” from Bauhin (1623: 147). It was only a century later that Ucria (1793) transferred Cupani’s pre-Linnaean polynomial into the Linnaean system, describing the new species *Anethum piperitum* Ucria (1793: 250) with explicit reference to the earlier polynomial and an illustration published posthumously by Cupani (1713).

All the major nineteenth-century botanists who dealt with the genus in Italy recognized Cupani’s taxon a distinct species, whether in the genus *Anethum* Linnaeus (1753: 263) (Bertoloni 1819: 21), or transferring it to the related genera *Meum* Miller (1754) (Gussone 1827: 345) or *Foeniculum* (Presl 1826: XXVI; Tenore 1829: 291; Bertoloni 1837: 342; Gussone 1842–1843: 323) (note that Gussone, in all his publications, corrects “piperitum” in “piperatum”, probably according to a more correct Latin adjective). Outside of Italy, it was also widely accepted as a species distinct from *F. vulgare* (e.g., as *Meum piperitum* by Sprengel 1820: 435; as *Foeniculum piperitum* by De Candolle 1830: 142). Although this was not universal, for instance Sprengel (1825: 891) treated *Anethum piperitum* together with *A. segetum* Linnaeus (1771: 219) (currently recognized as a distinct species in the monotypic genus *Ridolfia*) as synonyms of *Meum foeniculum* Sprengel (1820: 483).

In the 20th century a broader delimitation of species led Fiori & Paoletti (1900–1902) and Fiori (1925–1929) to treat *F. piperitum* as one of the varieties of *F. vulgare*. Thellung (1925) and then Tutin (1968) took up Coutinho's (1913) treatment of *F. vulgare* constituting a single species with two subspecies, one of which was corresponded to Cupani's taxon (i.e., *F. piperitum*). Recent Italian floras and checklists (Pignatti 1982, Bartolucci *et al.* 2018, Pignatti *et al.* 2017–2019) have maintained this infraspecific treatment while other European authors have recognized only a single entity within *F. vulgare* (Jansen 1981, Aedo 2003, Hand 2011).

Here we briefly describe *Foeniculum vulgare* subsp. *piperitum* (also according to our field experience), highlighting the distinctive characters with respect to *Foeniculum vulgare* subsp. *vulgare* and the opportunity to consider the two taxa as two different species, finally proceeding to the typification of *Anethum piperitum* Ucria.

Materials and methods

The work is based on morphological and ecological field observations, carried out in Sicily over the last 5 years, first separately then together by both authors, and on the comparative study of literature data, appropriately cited in the text. Herbarium investigations were also carried out, mainly functional to typification and to have a preliminary idea of the distribution of the two taxa: PAL has been consulted personally, other herbaria such as B, CAT, FI, MW and P, have been consulted online (acronyms of herbaria according to Thiers 2021). The nomenclature of morphological characters is in accordance with Kljuykov *et al.* (2004).

Results

Description of *Foeniculum piperitum* (vs. *F. vulgare*).—An erect perennial herb, up to **1.5 (vs. 2.5) m high**; all parts glabrous, **sharp-smelling (vs. sweet-smelling)**, especially after crushing. The stem divides dichotomically after the first 2–4 nodes forming two elongated, symmetrical, slender and supple fertile branches that lean on other branches or on nearby plants to support each other, determining a **very different habitus from that of *F. vulgare*** in which, in the dichotomies, a sterile branch prevails which determines a more robust and taller plant (Fig. 1A–B). Leaves (Fig. 1C–D) alternate, decompose, sheathed; sheath glabrous, with white-membranaceous margin, forming an open cylinder, at base embracing the stem, **2–3 (vs. 4–8) cm long**, covering usually less (vs. more) than half of the petiole; blade triangular in outline, divided into **short (<5 mm) (vs. long, >5 mm), rigid (vs. flaccid) lobes**. Flowers in compound umbels, on a 3–5 cm long peduncles, with **3–7 (–9) (vs. 10–25) rays** each one supporting an umbel of 5–10 flowers; bracts and bracteoles absent. Umbels in turn in **lax (vs. congested) compound inflorescences** (Fig. 1 E–F). Each flower with 5 yellow petals, sometimes reddish along the midrib, with involute apex.

Ecology of *F. piperitum* (vs. *F. vulgare*).—During our field work in Sicily, in numerous cases we have been able to see *F. piperitum* and *F. vulgare* growing in mixed populations: typically along the roadsides, both main and secondary ones, therefore in disturbed habitats where the two species behave as pioneers. In these cases we have not seen evidence of hybridization, and the two taxa remained quite distinct. Outside of these anthropogenic disturbed habitats, it seems that *F. piperitum* prefers less calcareous substrata, for example clays; in general the two species have different preferences, so much so that *F. piperitum* has been selected as a characteristic species of the phytosociological order *Hyparrhenietalia hirtae* Rivas-Martínez 1978 (Brullo *et al.* 2010) and diagnostic species of the alliance *Bromo-Oryzopsis miliceae* O. Bolòs 1970 (Biondi & Blasi 2015) (however the suspicion of misidentifications in these phytosociological works is still possible: see below in the following headings).

Chromosome numbers.—According to available data from literature, both *F. piperitum* (Löve 1980) and *F. vulgare* (Löve 1984, Lentini *et al.* 1990) have the same chromosome number ($2n=22$). Koul *et al.* (1996), studying plants from northern India, confirm the same number for both taxa, but note that total chromatin length and chiasmata frequency are different in the two taxa. Probably further investigations are needed, also considering the problems deriving from cultivation and spread of the taxa around the world, and the possible misapplication of names.

Traditional uses and misapplication of names.—*Foeniculum vulgare* “s.l.” (sic!) is one of the most commonly harvested Sicilian native wild food plants (Geraci *et al.* 2018, Pasta *et al.* 2020), so no surprise if it is well known by everyone collecting plants in Sicily: Danilo Dolci, a famous sociologist, in a book firstly published in 1963 (Dolci 2008) reports an interview to a seller of wild plants in the poor Sicily of the Fifties of the last Century, which testifies to the widespread ability of the common people to distinguish the sought-after and appreciated *F. vulgare* (also used for

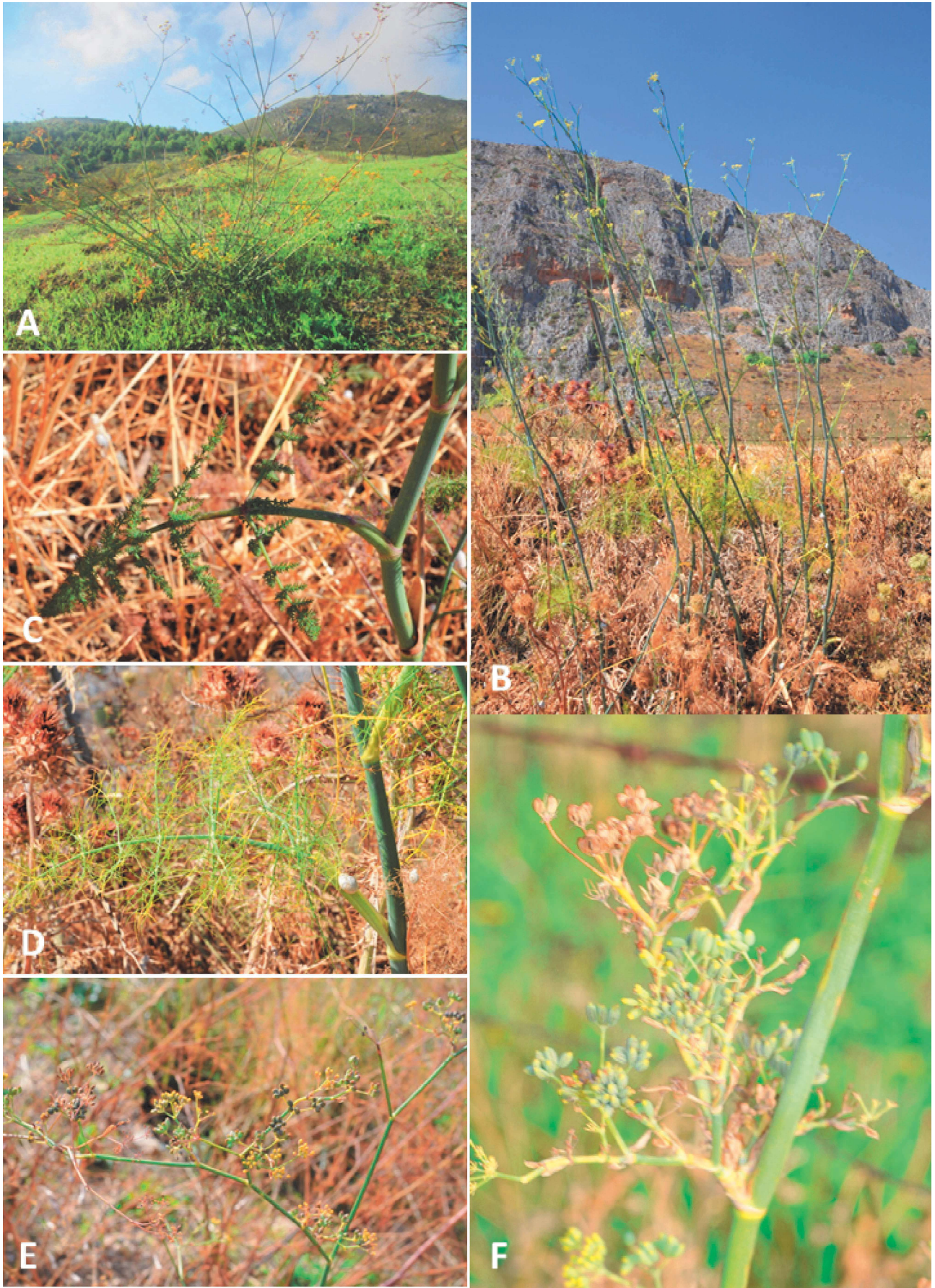


FIGURE 1. *Foeniculum piperitum* (A, C, E) compared to *F. vulgare* (B, D, F) for some characters: habit (A, B), leaf (C, D), infructescence (E, F).

a famous traditional dish, “pasta with sardines”, defined as one of the few pre-Columbian Sicilian dishes by Pignatti 1982: 518) from *F. piperitum*, already defined bad-smelling by Cupani (1696). The extreme diversity in the smell, corresponding to two very different chemical profiles, has recently been confirmed by a specific phytochemical study to which we refer (Ilardi *et al.* 2021).

A possible cause of confusion in recent decades has been to consider all the “wild fennel” as *F. piperitum*, reserving the name *F. vulgare* for the cultivated one. A similar approach seems evident in Heywood & Zohary (1995): “Wild forms of fennel (subsp. *piperitum* (Ucria) Coutinho) are widely distributed especially in Mediterranean parts of Europe”. This has led to the misrepresentation of *F. piperitum*, since both *F. piperitum* and *F. vulgare* have wild populations, whereas food use seems to be exclusive to *F. vulgare*: recent examples of this type of error can be found in the works of D’Antuono *et al.* (2017) and Biscotti *et al.* (2018), who seem to describe culinary uses of *F. vulgare* attributing them to *F. piperitum*.

On the other hand, the tendency of the main national and European floras to merge the two taxa has led in the most recent works to refer to “*F. vulgare* s.l.” (see for example some recent ethnobotanical papers, Geraci *et al.* 2018, and Pasta *et al.* 2020), losing an important part of information: the traditional uses of the two taxa are not in fact the same (see for example Ilardi & Raimondo 1992, Lentini & Venza 2007, Certa 2020).

With regard to the existing confusion, which has led to erroneous determinations (we just mention the issue of the importance of taxonomy for the other sciences, see e.g. Kholia & Fraser-Jenkins 2011), we report in Table 1 some examples which also testify to the need to revise the chorology of the two species.

TABLE 1. Some herbarium specimens exemplifying the current confusion about *Foeniculum piperitum*.

Specimen (herbarium code and id number)	Locality	Current identification	Corrected identification
CAT 58139 http://www.hortusbotanicuscatinensis.it/herbarium/foto/05/058139.jpg	Fiumara Troina (Bronte, Sicily, Italy)	<i>Foeniculum piperitum</i>	<i>Foeniculum vulgare</i>
CAT 006839 http://www.hortusbotanicuscatinensis.it/herbarium/foto/06/006839.jpg	Lentini (Lago), Sicily, Italy	<i>Foeniculum piperitum</i>	Not a <i>Foeniculum</i> (<i>Ridolfia segetum</i> ?)
P02600841 https://science.mnhn.fr/institution/mnhn/collection/p/item/P02600841	Chemin de Tartres (en face le Falcaria), Champiery Sur Marne (Seine (France))	<i>Foeniculum piperitum</i>	Not a <i>Foeniculum</i> (<i>Ridolfia segetum</i> ?)
P00687224 http://coldb.mnhn.fr/catalognumber/mnhn/p/p04348640	butte du Château à St-Agnès (Alpes-Maritimes) (France)	<i>Foeniculum piperitum</i>	<i>Foeniculum vulgare</i>
P04348640 http://coldb.mnhn.fr/catalognumber/mnhn/p/p04348640	Alep (Syria)	<i>Foeniculum piperitum</i>	Not a <i>Foeniculum</i> (<i>Ridolfia segetum</i> ?)

The subspecific rank.—The subspecies concept (generally applied in a questionable or inconsistent way in plant taxonomy) (cf. Hamilton & Reichard 1992, Mallet 2013, Pignatti *et al.* 2017–2019, 1: XXVI) should provide (as now consolidated in the zoological field) a geographical separation that does not exist in our case; alternatively, it is possible to focus on an ecological separation which in our case seems to exist but which, where it fails, does not seem to affect the genetic separation between the two taxa that do not appear to hybridize. We therefore believe, given the clear morphological and ecological separation between the two taxa, that they cannot be considered as two subspecies but should be treated as two distinct species.

Typification of *Foeniculum piperitum*.—The taxon under study was described in 1793 as *Anethum piperitum* in a publication (Ucria 1793) well known in botanical literature (numerous other taxa were in fact described there, e.g. *Allium siculum*, *Ambrosinia maculata*, *Crataegus laciniata*, *Nepeta apuleji*, *Rhamnus tripartita*, *Scabiosa dichotoma*, *Zostera nodosa*). A few years later, the exact same work was republished (Ucria 1796) in a prestigious German journal, *Archiv für die Botanik*, so that erroneously some sources (e.g. Hand 2011) report this as the place of publication.

The protologue is very meagre (“foliis bipinnatis, foliolis crispis, fructibus subrotundis”), and this may have influenced the tendency (in those who do not know the plants in the field) to consider the taxon not well distinguished from *F. vulgare*. No herbarium samples are mentioned, but only the Cupani’s iconographic work (“Cup. Pamph.”) (Cupani 1713), which is the only original material for typification in the absence of herbarium samples (Ucria’s herbarium having been probably destroyed, see Mazzola *et al.* 1997). As for the typification of the name *Ambrosinia maculata* Ucria (Troia *et al.* 2018), for the lectotype we refer to the copy of the Panphyton Siculum kept at the Palermo Regional Library, which was recently reproduced (Pastena *et al.* 2003). Considering that the lectotype is an illustration (and not a real specimen), and that it shows only the leaves, we selected also as epitype a herbarium specimen collected in Sicily and showing the typical traits of *Anethum piperitum*.

T. 117

1299



FIGURE 2. Lectotype of *Anethum piperitum* Ucria (Cupani 1713, vol. 1: t. 117) (reproduced from Pastena *et al.* 2003).

For the correct specific name under *Foeniculum*, we followed POWO (2020). We remind that *F. vulgare* Mill. has been already typified by Jansen (1981: 25).

Foeniculum piperitum (Ucria) C.Presl, Fl. Sicul. (Presl) 1: p. xxvi. 1826

≡ *Anethum piperitum* Ucria in Nuov. Racc. Opusc. Aut. Sicil. vi. (Pl. Linn. Op. Addend. & Secund. Linn.Syst.) 250. 1793.

≡ *Meum piperitum* (Ucria) Schult., Syst. Veg., ed. 15 bis [Roemer & Schultes] 6: 435. 1820.

≡ *Foeniculum vulgare* subsp. *piperitum* (Ucria) Bég. in Ann. Mus. Civ. St. Nat. Genova, Ser. 3, 3: 447. 1907 (≡ *Foeniculum vulgare* subsp. *piperitum* (Ucria) Cout., Fl. Portugal: 450. 1913).

Ind. loc.: Non indicated explicitly [by implication, described from Sicily]—**Lectotype (designated here)** (Fig. 2): [illustration] “foeniculum Asinum folis crispis sive Millefolij gravé olens” in Cupani (1713), Panphyt. Sicul. 1: t. 117. 1713—**Epitype (designated here)**: ITALY. Sicily, southern slopes of the limestone massif of Rocca Busambra, 37° 50' 51.60" N; 13° 21' 20.75" E, ca. 700 m elevation, 24 Oct 2020, Troia & Ilardi s.n. (PAL 109712!).

Conclusions

Foeniculum vulgare and *F. piperitum* are clearly different, not only from the morphological and ecological point of view (as shown above), but also on the basis of recent and targeted phytochemical investigations (Ilardi *et al.* 2021); in this regard, unfortunately many previous phytochemical data are scarcely usable due to this uncertain separation between the two taxa. In reality, as argued above, the difference is such that we cannot fail to consider it on a specific level. As we mentioned in the introduction, *Foeniculum vulgare* s.l. is listed as “crop wild relative” (Heywood & Zohary 1995): actually, as a conclusion of our work, there are two crop wild relatives in the genus, *F. vulgare* and *F. piperitum*.

The phylogenetic relationships within the genus remain to be clarified, using molecular markers, as well as the definition of the ecology and chorology of *F. vulgare* and *F. piperitum*, due to the confusion linked to the aforementioned fusion of the two taxa. Finally, considering both the morphological and phytochemical characters, the affinity between *F. piperitum* and the recently described *F. sanguineum* must be investigated.

Authors' contribution

VI and AT designed the study, performed the field work, collected data from literature, checked herbarium specimens. AT led the writing, with significant contributions from VI.

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APPENDIX—SPECIMINA VISA (SELECTA):

Foeniculum piperitum: ITALY. Sicily: southern slopes of the limestone massif of Rocca Busambra (Corleone, Palermo, Italy) on calcareous soil (37° 50' 51.60" N; 13° 21' 20.75" E; 700 m elevation), 16 Jul 2020, *V. Ilardi* (PAL 109709); Sicily: Pantano Longarini (Pozzallo), 23 Mar 1969, *S. Brullo* (CAT 058134) <http://www.hortusbotanicuscatinensis.it/herbarium/foto/05/058134.jpg>; Sicily: Sampieri (Pozzallo), *S. Brullo*, 25 Apr 1969 (CAT 058135) <http://www.hortusbotanicuscatinensis.it/herbarium/foto/05/058135.jpg>

Foeniculum vulgare: ITALY. Sicily: southern slopes of the limestone massif of Rocca Busambra (Corleone, Palermo, Italy) on calcareous soil (37° 50' 51.60" N; 13° 21' 20.75" E; 700 m elevation), 16 Jul 2020, *V. Ilardi* (PAL 109708). GREECE: Saronic Islands, Poros, SE tip of Sphairia, stony slope along highway, 37°29'45" N, 23° 27' 50" E, 30 m elevation, 2 Sep 2010, *A. Seregin* № E-1148 (MW 0785167) <https://plant.depo.msu.ru/open/public/en/item/MW0785167>; Lakonia, Hania, 36° 38' 08" N, 22° 23' 34" E, 9 Oct 2003, *Willing R. & E. 121.659* (B 10 0148167) <http://herbarium.bgbm.org/object/B100148167>