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Article

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Benito Valdés

Early botanical exploration of the Maghreb*

Abstract

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The Maghreb is considered as the North African territories covered by Mauritania, Morocco, Algeria, Tunisia and Libya, an area which almost coincides with what it was named "The Barbary" by Europeans from the XVI to the XIX centuries. The period included in this paper ranges from the first botanical visit to Algiers by John Tradescant the Elder at the beginning of the XVII century to the end of the XVIII. It includes information on Tradescant, Balaam, Spotswood, Shaw, Vahl, Desfontaines, Broussonet, Durand, Jackson and Schousboe.

Key words: Tradescant, Balaam, Spotswood, Shaw, Vahl, Desfontaines, Broussonet, Durand, Jackson, Schousboe.

Introduction

The term Maghreb (Arabic for "western") is used in its widest sense to denominate the North West part of Africa that covers Mauritania, Morocco (including West Sahara), Algeria, Tunisia and Libya, an area which it is separated from tropical Africa by the Sahel. The Maghreb coincides more or less with what was named from the XVI to the XIX centuries by Europeans "The Barbary", this including all territories of N Africa west to Egypt.

The botanical exploration of this wide territory was initiated by Europeans as early as the XVII century and was initially limited to some coastal areas, sometimes only to the surroundings of some cities, due to the difficulties and often danger of penetrating inland in this territory which was practically forbidden to foreigners.

Pre-Linnaeans

John Tradescant

John Tradescant the Elder (1570-1638) was the first visitor to the Maghreb interested in plants (Fig. 1). He was not a botanist, but an excellent gardener and horticulturist. He was born

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*Extended and enriched version of the oral presentation given at the XVI OPTIMA Meeting, Athens (Greece), 2th-5th October 2019.

in Holland (Pulteney 1790: 176; Johnson 1829: 98) in 1570. He began his professional career in 1609 as gardener to Robert Cecil, first Earl of Salisbury, to keep his gardens at Hatfield first and later at Salisbury House. He was gardener of Sir Edward Wotton at Canterbury during 1614 and 1615, before employed by George Villiers, Duke of Buckingham at New Hall, Essex, in 1625, and in 1636 appointed by King Charles the First as keeper of his garden, a post he maintained till his death (Ray 1994: 689). In 1625 he also created his own garden in Lambeth, which was maintained by his son, John Tradescant the Younger.

Tradescant travelled to several European countries, interested not only to obtain new cultivated and wild plants destined to the gardens for which he was responsible and for his own, but also to collect objects of Natural History and miscellaneous rarities to form in Lambeth a Natural History Cabinet, "The Ark", (Pulteney 1790: 176-177) which is now part of the Ashmolean Museum of Oxford University.

In 1620 Tradescant joined a fleet sent by England against Algerian pirates (Johnson 1829: 98) and this gave him the opportunity to stay in Algiers for some time. It seems that Tradescant studied the plants growing in the city and its surroundings, because Parkinson, when referring to *Gladiolus* says that "Iohn Tradescant assured me, that hee saw many acres of ground in Barbary spread over with them" (Parkinson 1629: 190). It is said that Tradescant took back to England from Algeria samples of Gladiolus, wild pomegranate (it was probably naturalized, as *Punica granatum* L. is not native to N. Africa) and the Persian Lilac (*Syringa persica* L.). Tradescant prepared a Catalogue of the plants growing in his garden, which although printed was not formally published. The content of the single copy of this Catalogue was reproduced by Gunther (1922: 334-345); it includes more than 700 species and cultivars, plus separate lists of cultivars of apples, pearls, plums, cherries, apricots, "nectorious", pitches and vines. Nothing indicates that he collected any herbarium material but cuttings and seeds. Amongst the plants listed in the printed "Catalogus" of Tradescant garden, one species bears the name "Trifolium barbaricum stellat. Tradesc." (Gunther 1922: 342), which suggests that Tradescant knew *Trifolium stellatum* C. Bauh. (Bauhin 1620: 143; 1623: 329) from whom Linnaeus (1753: 769) took the specific epithet of *Trifolium stellatum* L., and that Tradescant wanted to differentiate from it the plant grown in his garden from seeds collected in Barbary, in this case in Algeria, which contradicts the statement of Pulteney that "he [Tradescant] is said to have brought the *Trifolium stellatum* L. from the island of Formentera" (Pulteney 1790: 176). His friend John Parkinson mentions him several times in Paradisi in sole (Parkinson 1629) and Theatrum botanicum (Parkinson 1640).

Alexander Balaam

The earliest notice of any botanical exploration in Morocco is by Alexander Balaam, a British trader who was established in Tangier (Zanoni 1675: 12; Ball 1877: 282) during the British occupation of the city, which extended from 1661 to 1684 (Martínez Ruíz 2005: 1045-1053). Not much is known about Balaam. Giacomo Zanoni, director of the Botanical Garden of Bologna, said that Balaam had provided seeds and plants from different origins to the Duke Gaston d'Orleans and that after the death of the Duke, Balaam moved to Tangier from where he sent him, that is, Zanoni, seeds and plants (Zanoni 1675: 12). Balaam also sent plant material to other botanists, at least to Morison (see, for example Morison 1680: 157, 583), who was then the first Professor of Botany and Director of the Botanic Garden of Oxford University.

Zanoni described some new species based on plants grown in the Botanical Garden of Bologna from seeds received from Balaam. This is the case, for instance, of Acetosa dentata di Tanger Zanoni (Zanoni 1675: 14, fig. 5) which was magnificently depicted (Fig. 2) and was accepted by Linnaeus as a distinct species: *Rumex tingitanus* L. (Linnaeus 1759: 991), a synonym of the previously described *R. roseus* L. (Linnaeus 1753: 337).

Morison also described some new species based on plants grown in the University of Oxford Botanic Garden from seeds collected in Tangier by Balaam, which were later recognized by Linnaeus, such as Lathyrus Tingitanus siliquis Orobi, flore amplo ruberrimo (Morison 1680, 2: 55; *Lathyrus tingitanus* L.) or Carduus humilis Tingitanus coeruleus, magno strobilo, tenuius laciniatus (Morison 1699, 3: 158; *Cynara humilis* L.).

Robert Spotswood

Much more important was the botanical contribution by Robert Spotswood (Spotteswoode 1637-1680), a surgeon who, like Balaam, lived in Tangier during the British occupation. He collected plants and seeds that he sent to Balaam and to Morison (Cosson 1881: 7). In 1673 Spotswood prepared a catalogue of the plants of Tangier, which he sent to Dr. Love Morley. Morley communicated it to the Royal Society of London, in whose Philosophical Transactions it was published in 1696 (Spotswood 1696) (Fig. 3). A short version was subsequently published in 1809 as a long footnote in vol. 4 of the Abridged Philosophical Transactions (Spotswood 1809).

This catalogue lists over 600 species arranged more or less alphabetically by its abbreviated name. Without descriptions or references to previous authors, it is difficult sometimes to identify the species, although the identification can be often worked out. For instance, he named two species of *Convolvulus*: Major and Minor (Spotswood 1696: 241). It is possible to assume that “Major” refers to *Calystegia sepium* (L.) R. Br., and “Minor” to *Convolvulus tricolor* L., particularly because Spotswood sent Morison seeds of a *Convolvulus* which was grown by Morison in the Botanic Garden of Oxford, who included it amongst its “Convolvuli minores” with the name “[Convolvulus] Peregrinus caeruleus, folio oblongo, flore peramoeno, triplici colore insignito, nobis” (Morison, 1680: 17), a name which was given by Linnaeus (1753: 158) as synonym of *Convolvulus tricolor* L., changing “triplici colore” to “tricolor” for the specific epithet; Linnaeus also took from Morison the reference to the native place: “Mauritania”, given by the former as “Mauritania Tingitana”. Indeed, the references given by Linnaeus in Species Plantarum to Mauritania were indirectly taken from Spotswood or Balaam or both, as, for instance, for *Lathyrus tingitanus* L.

Thomas Shaw

The most interesting pre-Linnaean explorer of the Maghreb is Thomas Shaw (1694-1751), a British cleric and traveler, chaplain to the British factory in Algiers between 1720 and 1733 (Todd 1791: 83-84). During his stay in Algiers he made a series of expeditions to Syria, Palestine, Arabia, Egypt, Tunisia and Algeria (Seccombe 1909: 1384), and made detailed observations on geography, climatology, geology, archeology, paleontology, zoology, botany, etc. of the different countries he visited. Back to England, he published his observations in a book, Travels or Observations relating to parts of Barbary and Levant (Shaw 1738), which was translated to German, Dutch and French (Seccombe 1909: 1385).

The second part of this book, with the title "A collection of such papers to serve to illustrate the foregoign observations", with a separate pagination, is divided into 15 chapters, the second of which has the title "Specimen Phytographiae Africanae &c., or a Catalogue of some of the rarer plants of Barbary, Egypt and Arabia" (Shaw 1738: 37-47). It includes 632 plant species arranged alphabetically. Shaw was familiar with botanical literature, and gave polynomial names of previous authors to most of these species. But more than 100 species were new to him. He gave names to these new species, adding a diagnosis and sometimes a good illustration for c. 50 of them.

The problem with Shaw's Catalogue is that the origin of the species is indicated very exceptionally[1]; and although he indicates sometimes the common name given by the "Arabs"[2], this cannot be understood as that he collected the plant in Arabia, as "Arab" is a term that can be applied to peoples of North Africa, not only from Arabian Peninsula. Neither the word "Arabica" included in some polynomial names can be taken as being original of Arabia. This has given rise to some mistakes. By instance, Linnaeus, who recognized and gave binomial names to several species diagnosed and drawn by Shaw, named Anthemis arabica n. 58 of Shaw's Catalogue: "Asteriscus annuus triacanthophorus" [Crassas Arabibus dictum.] (Fig. 4) and added as the area of origin "Habitat in Arabia" (Linnaeus 1753: 896). It is clear that *Cladanthus arabicus* (L.) Cass., the accepted name for *Anthemis arabica* L., does not occurs in Arabia as it is a W Mediterranean endemic.

Some of Shaw's new species from the Maghreb were given binomial names by later authors. For instance, Linnaeus (1753) gave the name *Centaurea acaulis* to "Jacea acaulos lutea, Erucae folio, squamarum ciliis candidis" (Shaw 1738: 42, n. 342), and *Teucrium mauritanum* (accepted name *T. pseudochamaepitys* L.) to "Teucrio Delphinij folio, non ramosum" (Shaw 1738: 46, n. 575).

However, Linnaeus failed to recognize and name other quite characteristic species which are very well represented by Shaw, such as "Cypressus fructo quadrivalvi, foliis Equiseti instar articulate" Shaw (1738: 40, n. 188) (Fig. 5), which had to wait until Vahl (1791, 2: 96) to be named *Thuja articulata* (accepted name: *Tetraclinis articulata* (Vahl) Mast.), and "Bursa Pastoris hirsuta, Erucae flore, stilo prominente" Shaw (1738: 38, n. 91), named *Psychine stilosa* by Desfontaines (1798, 2: 69).

But the identity of some Shaw's species is still to be resolved. For instance, "Chrysosplenii foliis Planta aquatica, flore flavo, pentapetalo" Shaw (1738: 39, n. 149). The figure which represents this species in the Catalogue (Fig. 6) is clearly a *Sibthorpia* species, and so was recognized by Linnaeus, who named it *Sibthorpia africana* with only the phrase-name Sibthorpia [africana] foliis orbiculatis integris crenatis, pedunculis solitariis. Gen. nov. 1099 and Shaw's name as a synonym, adding "Habitat in Africa" (Linnaeus 1753: 631). The phrase-name is in fact the name given by Linnaeus to this species under n. 1099 in Nova Plantarum Genera (Linnaeus 1751) where only the name of Shaw is added as a synonym, and the indication "Habitat in Africa". Shaw (1738) gave no indication on where this plant was collected, and Linnaeus supposed that it was native of

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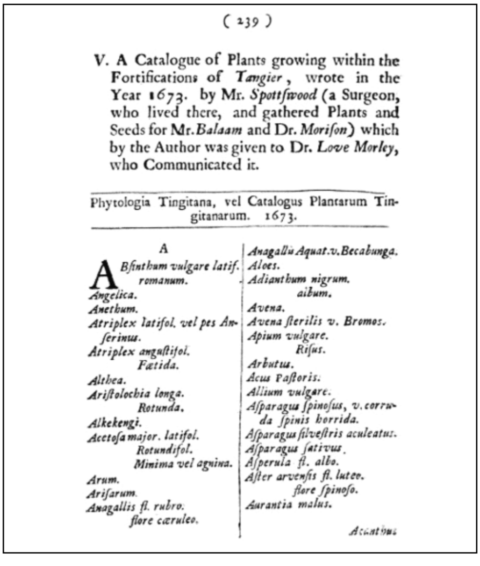
[1] "*In Arabia invenit*" for n. 391; " … *quae in Africa coluntur*" for n. 410; "*quam copiose inveni super ripas Fluminis Salfi, inter montis Al Bee-ban dictos*" for n. 482; "*copiose crescit per totam Africam*" for n. 570.

[2] By instance, "Crassas arabibus dictum" for n. 58; "Doom Arabum" for n. 143; "Arabibus Guntufs dicitus" for n. 138; "Seedra Arabum" for n. 632.

Fig. 1. John Tradescant the Elder. Engraving by Václar Holler (1607-1677).

Fig. 2. Acetosa dentata di Tanger Zanoni (1675, Istoria botanica: 12, fig.5) (*Rumex tingitanus* L.).



(239)

V. A Catalogue of Plants growing within the Fortifications of *Tangier*, wrote in the Year 1673. by Mr. *Spottſwood* (a Surgeon, who lived there, and gathered Plants and Seeds for Mr. *Balaam* and Dr. *Moriſon*) which by the Author was given to Dr. *Love Morley*, who Communicated it.

Phytologia Tingitana, vel Catalogus Plantarum Tingitanarum. 1673.

A

ABſinthum vulgare latif.
romanum.
Angelica.
Anethum.
Atriplex latifol. vel pes Anſerinus.
Atriplex anguſtifol.
Fœtida.
Althea.
Ariſtolochia longa.
Rotunda.
Alkekengi.
Acetoſa major. latifol.
Rotundifol.
Minima vel agnina.
Arum.
Ariſarum.
Anagallis fl. rubro.
flore cæruleo.
Anagallis Aquat. v. Becabunga.
Aloes.
Adianthum nigrum.
album.
Avena.
Avena ſterilis v. Bromos.
Apium vulgare.
Riſus.
Arbutus.
Acus Paſtoris.
Allium vulgare.
Aſparagus ſpinoſus, v. corruda ſpinis horrida.
Aſparagus ſilveſtris aculeatus.
Aſparagus ſativus.
Aſperula fl. albo.
Aſter arvenſis fl. luteo.
flore ſpinoſo.
Aurantia malus.

Acanthus

Fig. 3. Philosophical Transactions of the Royal Society 19: 239 (1693).

Fig. 4. Asteriscus annuus trianthophorus Shaw (1738, Specimen Phytographiae Africanae: 38, n. 58) (*Cladanthus arabicus* (L.) Cass.).

Africa. But this plant has never been collected again in N Africa. In his treatment for Flora Iberica, Rico (2009: 436) considers *Sibthorpia africana* L. as an endemic of the Balearic Islands, with *S. balearica* Knoche as a synonym, adding the following observation: “The epithet africana and the loco-typical indication are based in a possible error, as the only species of the genus that lives in Africa in a natural state is *S. europaea*”. This may be true, as in Africa *S. europaea* only occurs in high mountains of the tropics, as indicated by Rico (2009: 435). But when Knoche described *S. balearica* he stated that “Grâce à l’obligeance de M. le Dr. Stapf, j’ai pu voir, à Kew, la plante de Shaw. M. Stapf a appelé mon attention sur les différences qui existent entre cette plante et les plantes des îles Baléares … Les graines de la plante de Shaw sont lises, tandis que celles de ma plante ont la surface creusée de petites fossettes. …” (Knoche 1922: 391). But there is little doubt that Shaw’s plant was collected either in N Africa or in other territories he visited during his stay in Algiers so, the problem remains to be resolved.

At his death, the plants Shaw collected along with all his other volumes of dried plants in his possession, books of Natural History, manuscripts, etc., were deposited in the University of Oxford, as this was his last wish (Todd 1791: 86).

Linnaeans

After the explorations by Thomas Shaw, and once the Linnaean binomial system of nomenclature had been adopted, the botanical exploration of the Maghreb during the XVIII century was covered by five well known botanists and a trader: Vahl and Desfontaines in Tunisia and Algeria and Broussonet, Durand and Schousboe in Morocco, to which we must add Jackson. They contributed to the knowledge of the flora of NW Africa through their rich collections and their publications, and were responsible for the description of many endemic taxa of this broad territory.

Martin Vahl

Interesting biographical data on Martin Vahl (1749-1804) are given by Smith (1819), who facilitated Vahl to study Linnaeus’ herbarium while in his property, and gave the reasons for the personal problems Vahl had had with Carl Linnaeus and Sir Joseph Banks. Vahl was born in Bergen (Norway) in 1749 (Fig. 7). In 1766, he entered the University of Copenhagen where he resided for two years with the Rev. Hans Ström, who passed on to Vahl his deep interest in zoology and botany. To go deeper into the knowledge of both subjects, Vahl moved to the University of Uppsala where he studied for four years under Carolus Linnaeus, who was by then at the zenith of his profession. In 1773, Vahl moved to Copenhagen, where he was appointed Lecturer in Botany at the Botanic Garden in 1779. Three years later, he was asked by the King of Denmark to undertake scientific travels when he visited the Netherlands, England, France, Spain, Switzerland and Tunisia. Back to Copenhagen in 1785, Vahl was appointed the Professor of Natural History at the University and editor of the Flora Danica, for which purpose he explored several little-known areas, particularly of this own country, and in 1799 and 1780 he made scientific journeys to the Netherlands and Paris. Vahl died in Copenhagen in 1804 (Smith 1819).

Vahl spent several months in northern Tunisia, where he made important plant collections. A part of his records are included in the three volumes of Symbolae Botanicae (Vahl 1790-1794). The Symbolae were devoted mainly, as the tittle and introduction infer, to go deeper into the work of Forsskål (Helsinki 1732; Yemen 1763), one of the "apostles" of Linnaeus, which took part in a Danish expedition to the Middle East (Bernardi 1979) where he collected abundant plant material and prepared a Flora Aegyptiaco-Arabica, edited post-mortem by Carsten Niebuhr (Forsskål 1775). But Vahl also made known in the Symbolae many of his own findings and described many new species, not only from Tunisia, but above all, and most particularly in the third volume or the Symbolae, American and Asian species based on material he received from his numerous correspondents. About 20 new species were described by Vahl from material he collected in Tunisia. Several of them are still used as the accepted names for Mediterranean species, such as *Anthemis punctata* Vahl, *Calendula suffruticosa* Vahl, *Scrophularia laevigata* Vahl and *Stachys arenaria* Vahl, or as the basionym of other Mediterranean taxa, such as *Senecio delphinifolius* (*Jacobaea delphinifolia* (Vahl) Pelser), *Thuja articulata* (*Tetraclinis articulata* (Vahl) Mast.), *Scabiosa rutifolia* (*Lomelosia rutifolia* (Vahl) Avino) or *Picris aculeata* (*Helminthotheca aculeata* (Vahl) Lack), to give only a few examples.

Vahl did not give precise information on the places where he had collected his plants, neither in his herbarium (Cosson 1881: 10) nor for most of the Tunisian species included in the Symbolae[3], where their origin is generally indicated by: "Habitat in Regno Tunetano", "Legi passin Tuneti", "Legi Tuneti", etc., or the most general indications "Frequents in Barbaria", "Habitat in Barbaria", or even "Legit in Mauritania", that could be interpreted as meaning that he collected plants in other parts of the Maghreb, as Algeria or Morocco. But the precise locotypic locality for Cistus lanceolatus: "circa Bizertam Barbariae" (Vahl 1791: 62) which refers to the city of Bizerta, c. 65 km NW Tunis, indicates that "Barbaria" and "Mauritania" of Vahl must refer to Tunisia.

His herbarium, formed by the plants he collected along his travels, augmented by those sent to him by his numerous correspondents, is kept in the Natural History Museum of Denmark, Copenhagen (Lanjow & Stafleu 1964: 50).

René Louiche Desfontaines

It is not true that no naturalist had visited the Maghreb before Desfontaines (Malle 1838: 1); but indeed, the first extensive and well programmed exploration of this region is due to the French botanist René Louiche Desfontaines (1750-1833). He was born in Temblay in 1750 and in 1773 went to Paris to study Medicine, regularly attending the lectures by Louis G. Lemonnier, Professor of Botany at the Jardin des Plantes. In August 1783, Desfontaines left France to undertake an exploratory travel which covered most of Tunisia and Algeria, coming back to Paris in the first months of 1786 with a rich collection

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[3] Exception are the following: *Salicornia amplexicaulis* Vahl ("prope Bardo"; Vahl, 1791: 1), *Poa littoralis* Gouan ("lacus Sipharae"; Vahl, 1791: 12), *Scabiosa rutaefolia* Vahl ("circa cap Zebibo"; Vahl, 1791: 26), *Sedum caeruleum* L. ("ad Manub"; Vahl, 1791: 51); *Cistus lanceolatus* Vahl ("circa Bizertam"; Vahl, 1791: 62), *Ranunculus millefoliatus* Vahl ("circa promontorium Cartaginis"; Vahl, 1791: 63), *Stachys circinata* L'Hér. ("montium plumbeum"; Vahl, 1791: 63), *Stachys arenaria* Vahl ("inter Cap. Blanco & Zebido ad urbem Rafs"; Vahl, 1791: 64), *Scrophularia laevigata* Vahl ("ad Zowan"; Vahl, 1791: 67), *Scrophularia mellifera* Vahl ("circa portum Farinam"; Vahl, 1791: 68), *Scorzonera resedifolia* L. ("circa promontorium Carthaginis"; Vahl, 1791: 84), *Scorzonera brevicaulis* Vahl ("ad Hammelif"; Vahl, 1791: 88), *Picris aculeata* Vahl ("ad Zowan"; Vahl, 1791: 89), *Calendula suffruticosa* Vahl ("circa Portum Farinam"; Vahl, 1791: 94), *Thuja articulata* Vahl ("circa Hamamelif, montes Plumbeos & Schibel Ifchel; Vahl, 1791: 96) and *Periploca laevigata* Aiton ("Monte Schibel Ifchel"; Vahl, 1794: 45).

of plant material and manuscripts. He was appointed that same year the Professor of Botany at the Jardin des Plantes, to substitute his former professor and friend Lemonnier, and he lectured in botany there for more than 40 years (Flourens 1838). He was also the Director of the Muséum National d'Histoire Naturelle, and one of the founders of the Institut de France.

The study of the plants collected in Algeria and Tunisia engaged Desfontaines for several years, finally publishing his most important work: Flora Atlantica (Desfontaines 1798-1799) in two volumes, which can be considered the first Flora of the Algerian-Tunisian territory. This Flora includes the description of c. 1600 species, of which c. 300 are new, arranged according the Linnaean sexual system of classification, and including a series of 260 excellent plates most of them depicted by the artists Charles Laurent Marechal and Piérre Joseph Redouté and engraved by François Noël Sellier (see, by instance, Fig. 8).

Desfontaines did not give details on his itineraries in Flora Atlantica. However, he regularly sent letters to Lemonnier (Flourens 1838: 13) and enabled Malle (1838) to make a detailed description of his travels based on those letters and Desfontaines' unpublished manuscripts.

The plants collected by Desfontaines are kept in several institutions. The main collection, including the plants from Algeria and Tunisia is conserved in the Muséum National d'Histoire Naturelle of Paris, with duplicates mainly in the Erbario Centrale, Universitá degli Studi di Firenze and also in the Institute de Botanique de l'Université de Montpellier, the Conservatoire et Jardin Botaniques, Genève, the Botanisches Museum, Berlin and the Natural History Museum, London (Lanjouw & Stafleu 1954: 159).

Pierre Marie Auguste Broussonet

After Balaam and Spotswood, the first botanist to explore Morocco was Pierre Marie Auguste Broussonet (1761-1807). He was born in Montpellier, where he graduated in Medicine. However, he had developed a strong interest in biology, mainly zoology but also in botany and agronomy. He stayed in London from 1780 to 1782 and when back in France he devoted his efforts to zoology and agriculture. Fleeing the French Revolution which he had initially joined, he arrived in Madrid in 1794, where he was well received by Casimiro Gómez Ortega and Antonio José Cavanilles. He later visited part of Portugal and other parts of Spain. In 1795, Broussonet moved to Tangier as a doctor in the service of the Consul of the United States of America, whom he had met in southern Spain, returning to France that same year. In 1795 he was named vice-consul of Mogador (today Essaouira), where he moved with his family; but in 1801 he left for the Canary islands (Ruíz Álvarez 1965: 124-143), escaping from the plague that devastated Morocco in 1799 and 1801 and which was described in detail by Jackson (1809: 269-285; 1820: 159-190). Back in France, Broussonet was appointed Director of the Jardin des Plantes in Montpellier, where he died in 1807.

In Morocco Broussonet explored the surroundings of Tangier, Mogador and other cities, such as Salé and Ksar-el-Kebir, with an incursion inland to Meknès and Fès. He collected abundant plant material and sent collections of his plants to the main botanist of that time: Willdenow in Berlin, Desfontaines in Paris, Gouan in Montpellier and Cavanilles in Madrid. Consequently, Broussonet´s plants are not only well represented in the herbarium of Montpellier, but also in the Muséum National d'Histoire Naturelle of Paris, the Real

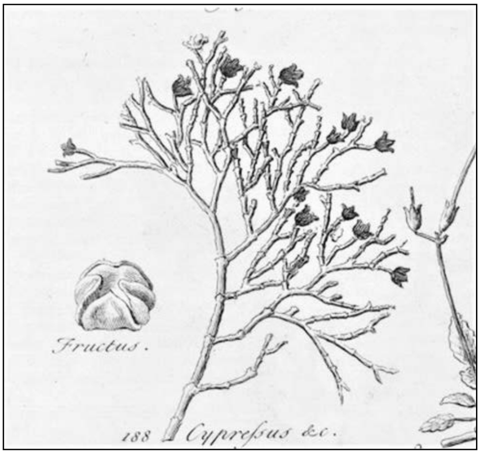

Fig. 5. Cypressus fructu quadrivalvi, foliis Equiseti instar articulatis Shaw (1728, l. c.: 40, n. 188) (*Tetraclinis articulata* (Vahl) Mast.).

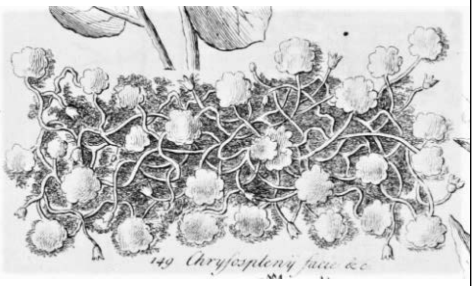

Fig. 6. Crisosplenii foliis Planta aquatica, flore flavo, pentapetalo Shaw (1738, l. c.: 39, n. 149) (*Sibthorpia africana* L.).

Fig. 7. Martin Vahl. Engraving by Ambroise Tardieu (with permision of Alamy).

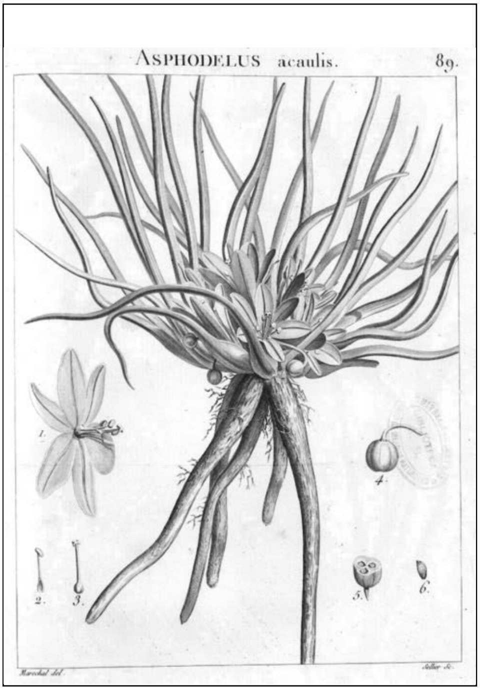

Fig. 8. *Asphodelus acaulis* Desf. (1798, Flora Atlantica 1: 302, Tab. 89; drawing by C.L. Marechal; engraving by F.N. Sellier).

Jardín Botánico, Madrid, and the Botanisches Museum of Berlin, and in some other herbaria, such as the Conservatoire et Jardin Botaniques de Genève, the Museo di storia naturale di Firenze and the Botanical Museum and Herbarium, University of Copenhagen.

Broussonet did not publish any new plant species based on the material he collected in Morocco. But he had given names to many potentially new species on the herbarium labels and some of them were later validated by other authors. This is the case, for example, of *Polygonum salicifolium* Brouss. ex Willd. (a synonym of the circummediterranean *Persicaria decipiens* (R. Br.) K.L. Willson), *Frankenia pulverulenta* Brouss. ex DC. (endemic to Morocco, but now considered as a subspecies of *Frankenia laevis* L.), *Mimosa leptophylla* Brouss. ex Lag. (a synonym of *Painteria leptophylla* (DC.) Britton & Rose, doubtfully native in Morocco), *Euphorbia pulchella* Brouss. ex Lag. & Rodr. (currently considered as a synonym of the circummediterranean *Euphorbia pithyusa* L.) and *Illecebrum mauritanicum* Brouss. ex Roemer & Schult., one of the synonyms of the cosmopolitan *Paronychia argentea* L. Besides, some authors have described new species based on plants collected by Broussonet in Morocco. For instance, Cavanilles (1801) described *Campanula afra* Cav. (currently considered a synonym of the Mediterranean *C. dichotoma* L.), *Eryngium aquifolium* Cav. (endemic to south Spain and north west Morocco), *Hyacinthus fulvus* Cav. (the basyonym of *Dipcadi fulvum* (Cav) Webb and Berth, of Morocco, south Spain and the Canary Islands), and *Celsia sinuata* Cav. (substitute synonym of the W Mediterranean *Verbascum erosum* Cav.), from plants collected by Broussonet in Salé, Tangier and Algeciras, Mogador and Tangier, respectively. But care has to be taken with the use of his material because, as indicated by Ball (1878: 283) “Broussonet seems to have been somewhat careless respecting the localities whence his specimens came, and to have sometimes intermixed those from The Canary Islands, South Morocco, Tangier and Spain”.

Abbé Phillipe Durand

Contemporary of Broussonet, and one of his friends, is the Abbé Phillipe Durand, who was appointed in 1804 Curator of plant collections at the Jardin des Plantes of Montpellier while Broussonet was the director of the gardens. He held this post until he left in 1810, mainly for misunderstandings with the young Agustin Pyramus de Candolle who had replaced Broussonet in Montpellier (Michaud 2018). Durand collected Moroccan plants, generally with Broussonet, at least in Tangier, Fès and Meknès, and according Ball (1878: 284) he was the first European to visit the Forêt de la Mamora. According Lanjouw & Stafleu (1954: 172) his plants are deposited in the Muséum National d’Histoire Naturelle, Paris, the Museo di storia naturale di Firenze, the Natural History Museum, London and the Missouri Botanical Garden.

James Gray Jackson

The Englishman James Gray Jackson was an interesting explorer and a clever and keen observer. He was not a botanist but a trader who stayed in Agadir (Santa Cruz at that time) and Essaouira (formally called Mogador) for about 16 years as “British Consul and Agent of Holland, Sweden and Denmark at Santa Cruz” as he described himself (Jackson 1820: 418). Jackson visited most coastal areas of W Morocco from Agadir, Tiznit and Tafraoute in the south to Tangier in the north, but he also visited the Rif, the Atlas, Marrakech

(Marocco), Meknès and Fès (Fig. 9). He described his travels through “west and south Barbary” on the base of a series of letters written to London to James Willis between 1792 and 1802 (Jackson 1820: 55-155). He was the first European to cross the High Atlas in a journey from Agadir to Marrakech accompanying a military detachment, along which he observed three types of vegetation from the lower areas to the summits. He published a very interesting book (Jackson 1809: 69-81) in which he briefly described a cactiform Euphorbia *(Euphorbia officinarum* L.) represented by a drawing made by himself (Fig. 10) and gave indications on how the inhabitants of arid areas of Morocco obtained its medicinal gums, and also other plants, such as the “Gum-sandarac tree” or “Arar” (*Tetraclinis articulata* (Vahl) Mast.), and truffles (*Terfezia arenaria* (Moris) Trappe, according his description)

Peder Korolf Anker Schousboe

The most important plant collector in Morocco at the end of the XVIII century was the Danish botanist Peder (Peter) Korolf Anker Schousboe (1766-1832). He was interested in algae and vascular plants. Between 1791 and 1793 he made extensive collections in south-

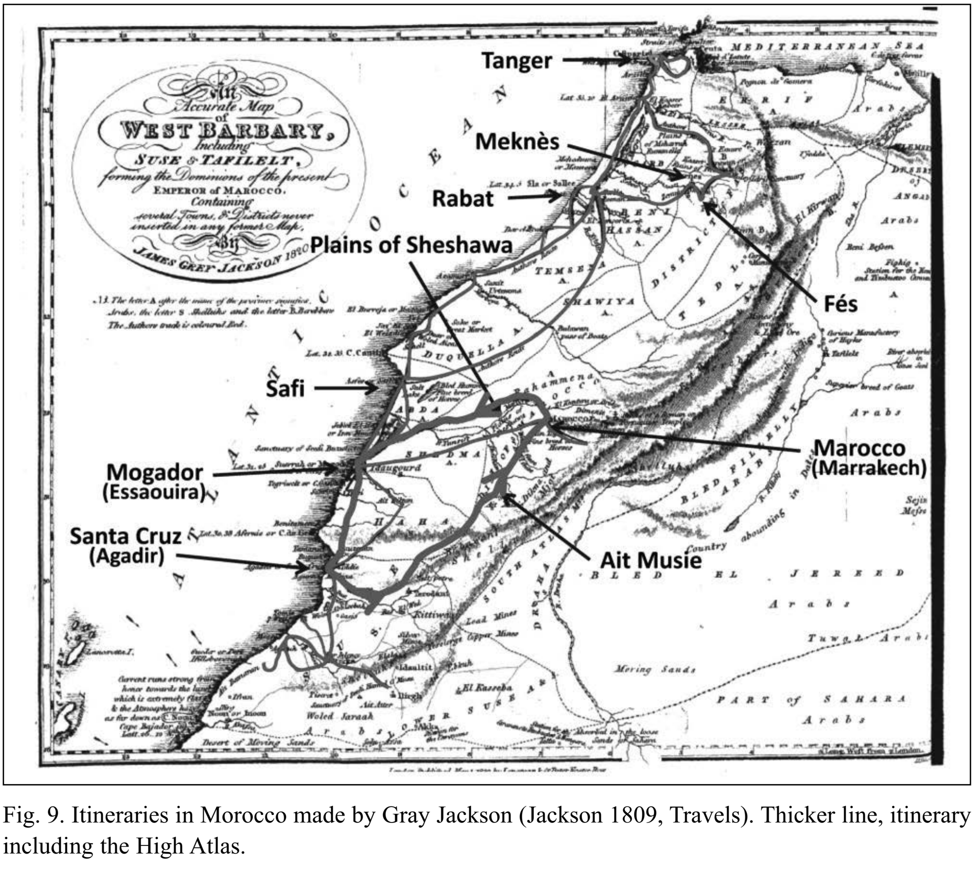

Fig. 9. Itineraries in Morocco made by Gray Jackson (Jackson 1809, Travels). Thicker line, itinerary including the High Atlas.

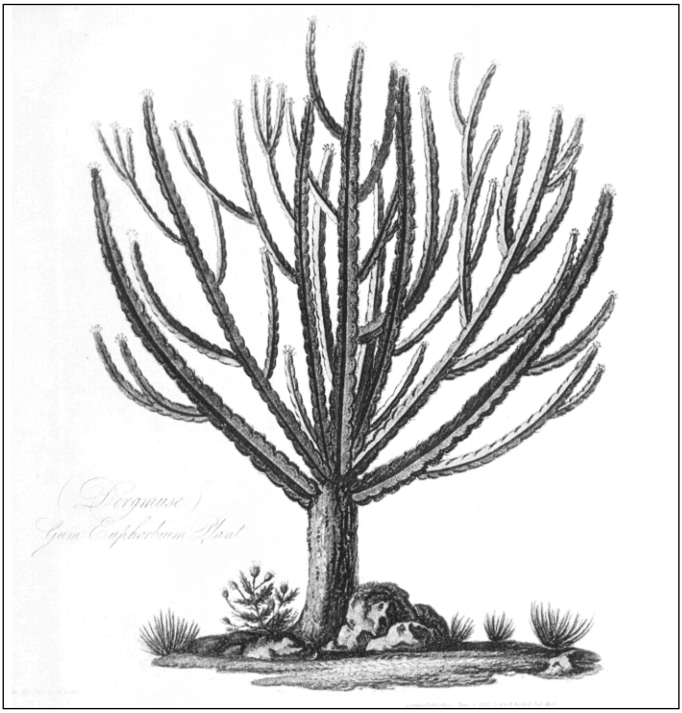

Fig. 10. Euphorbium or Dergmuse (Jackson, 1809, l. c. Plate VII) (*Euphorbia officinarum* L.).

ern Morocco in Essaouira (Mogador) and in general in the province of Haha and in the Safi area, as well as in the north in the area of Tangier. He also travelled to Marrakech, Meknès and Fès (Cosson 1881: 10-11). In 1800, he was appointed general consul of Denmark in Tangier, where he stayed until his death, greatly increasing his collections (Ball 1877: 283), particularly of algae. His main collections are deposited in the Botanical Museum and Herbarium, University of Copenhagen, with duplicates in Paris (Cosson Herbarium) and other European herbaria.

In 1800, Schousboe published the Iagttagelser over vextriget i Marokko, "first part" of which, if completed, would have been an excellent first Flora of Morocco. It was published in Danish and Latin, printed in two columns (Schousboe 1800) and translated to German one year later. It was also translated into French by E.-L. Bertherand and also printed in two columns, in Latin and French (Schousboe 1874) with additional synonyms by John Lange. This volume covers the Linnaean classes Monandria to Enneandria, with several species belonging to other classes, particularly to Singenesia, at the end. Seven excellent plates with analysis are added. In the Iagttagelser, Schousboe described 49 plant species as new. But as he had given names and added descriptive notes in the labels of many of his herbarium specimens (Cosson 1881: 11), another c. 40 Schousboe's names were validated by other authors, particularly by Ball, who revised the duplicates of Schousboe's collections sent to Kew Gardens by Cosson (Ball 1877: 283). Although some of these names are now included in the synonymy of different species, many of them are still in current use, as for instance *Salvia interrupta* Schousb. and *Bupleurum canescens* Schousb., Morocco endemics, and *Onopordum macracanthum* Schousb. a west Mediterranean endemic, or are the basionyms of other Mediterranean plants, as, for example, *Feeria angustifolia* (Schousb.) Buser, a Moroccan endemic.

Epilogue

Altogether, the collections and publications made by all these early explorers of the Maghreb, laid the foundations for all future floristic studies, and contributed to the preparation of modern Floras and checklists, of which excellent examples are the Flore Pratique du Maroc (Fennane & al. 1999, 2007, 2014) and the Index Synonymique de la Flore d'Afrique du Nord (Dobignard & Chatelain 2010-2013).

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References

Ball, J. 1877-1878: Spicilegium Florae Maroccanae. – J. Linn. Soc., Bot. **16:** 281-772.
Bauhin, C. 1620: Prodromus theatri botanici. – Francofurti.
— 1623: Pinax theatri botanici. – Basileae.
Cavanilles, A. J. 1801: De las plantas que el Ciudadano Augusto Broussonet colectó en las costas septentrionales de la África y en las islas Canarias. – Anales Ci. Nat. **3(7):** 5-78.
Bernardi, L. 1979: L'etoile polaire: Linné. – Rév. Mus., Genève (separate edition).
Cosson, E. 1881: Compendium Florae Atlanticae, **1.** – Paris.
Desfontaines, R. L. 1789-1799: Flora atlantica **1-2.** – Paris.
Dobignard, A. & Chatelain, C. 2010-2013: Index Synonymique de la Flore d'Afrique du Nord, **1-5.** – Genève.
Fennane, M., Ibn Tattou, M., Mathez, J., Ouyahya, A., El Oualidi, J. (eds) 1999: Flore Pratique du Maroc, **1.** – Rabat.
—, —, Ouyahya, A. & El Oualidi, J. (eds) 2007: Flore Pratique du Maroc, **2.** – Rabat.
—, — & El Oualidi, J. (eds) 2014: Flore Pratique du Maroc, **3.** – Rabat.
Flourens, P. 1838: Éloge Historique de R. Louiche Desfontaines. – Mém. Accad. Sci. Inst. France **16:** I-XIX.
Forsskål, P. 1775: Flora Aegyptiaco-Arabica. – Hauniae.
Gunther, R. Th. 1922: British Botanists and their gardens, based on unpublished writings by Goodyer, Tradescant and others. – Oxford.
Jackson, J. G. 1809: An account of the empire of Morocco and the district of Suse. – London.
— 1820: An account of the Timbuctoo and Housa, territories in the interior of Africa to which is added, letters descriptive of travels though west and south Barbary. – London.
Johnson, G. W. 1829: A History of English Gardening. – London.
Knoche, H. 1922: Flora Balearica, **2.** – Montpellier.

Lanjouw, J. & Stafleu F. A.1954: Index Herbariorum, 2, first Instalment A-D. – RegnumVegetabile 2.
— & Staflew, F. A. 1964: Index Herbariorum 1. The Herbaria of the World, ed. 5. – Utrecht.
Linnaeus, C. 1751: Nova Plantarum Genera (Publicae proponit Leonhard Joh. Chenon). – Upsaliae.
— 1753: Species Plantarum. – Holmiae.
— 1759: Systema Naturae, ed. 10, **2.** – Holmiae.
Malle, D.1838: Peyssonnel et Desfontaines. Voyage dans les Régences de Tunis et d'Alger**, 2**, Fragments d'un voyage dans les Régences de Tunis et d'Alger fait de 1783 a 1786 par Louiche René Desfontaines. – Paris.
Martínez Ruíz, J. I. 2005: De Tánger a Gibraltar: el estrecho en la praxis comercial e imperial británica (1661-1776). – Hispania **65(3):** 1043-1062.
Michaud, F. 2018: Le Jardin des Plantes, quelques éléments por une nouvelle écriture de l'histoire de la botanique à Montpellier. – Patrimoines Sud **8.**
Morison, R. 1680: Plantarum Historiae Universalis Oxoniensis, **2.** – Oxonii.
— 1699: Plantarum Historia Oxoniensis Universalis, **3.** – Oxonii.
Parkinson, J. 1629: Paradisi in sole paradisus Terrestris. – London.
— 1640: Theatrum botanicum. – London.
Pulteney, R. 1790: Historical and Biographical Sketches of the progress of Botany in England, **1.** – London.
Ray, D. 1994: Dictionary of British and Irish Botanists and Horticulturists. Including plants collectors, flower painters and garden designers (with the assistance of C. Ellwood). – London.
Rico, E. 2009: *Sibthorpia* L. – Pp. 434-437 in: Benedi, C., Rico, E., Güemes, J. & A. Herrero, A. (eds) Flora Iberica, **13.** – Madrid.
Ruíz Álvarez, A. 1965: Apuntes para una biografía del doctor Augusto Broussonet (1761-1807). – Anuario Est. Atlánt. **11:** 129-147.
Seccombe, T. 1909: Shaw, Thomas (1694-1751) – Pp. 384-385 in: Lee, S. (ed.), Dictionary of National Biography, **17.** – New York.
Shaw, T. 1738: Travels or Observations relating to several parts of Barbary and the Levant. – Oxford.
Schousboe, P. K. A. 1800: Iagttagelser over Vextriget i Marocco, **1.** – Kjöbenhavn.
— 1874: Observations sur le Règne Végétal au Maroc. – Paris.
Smith, J. E. 1819: Vahl [without indication of authorship] in: Ress, A. (ed.), The Cyclopedia; or, Universal Dictionary of Arts, Sciences and Literature, **16.** –London.
Spotswood, R. 1696: A catalogue of Plants growing within the Fortifications of Tanger in 1673. "Phytologia Tingitana, vel Catalogus Plantarum Tingitanarum". – Philos. Trans. Royal Soc. **19:** 239-249.
— 1809: A catalogue of Plants growing within the fortifications of Tanger in 1673. Phytologia Tingitana, vel catalogus Plantarum Tingitanarum. – Philos. Trans. Royal Soc. Abridge **4:** 85-87.
Todd, Henry [Oxoniensis] 1791: The life of Thomas Shaw, D. D. Principal of St. Edmund's Hall, Oxford. – European Mag., London Rev. **19(1):** 83-86.
Vahl, M. H. 1790-1794: Symbolae Botanicae, **1-3.** – Hauniae.
Zanoni, G. 1675: Istoria Botanica. – Bologna.

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Short note

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https://doi.org/10.7320/FlMedit31.019

Besma Dechir & Tarek Hamel

Amaryllis belladonna (*Amaryllidaceae*), a new alien to the flora of Algeria

Abstract

Dechir, B. & Hamel, T.: *Amaryllis belladonna* (*Amaryllidaceae*), a new alien to the flora of Algeria. — Fl. Medit. 31: 19-22. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Amaryllis belladonna (*Amaryllidaceae*) a new established xenophyte to Algerian flora is here reported for the first time from El Kala National Park (North-eastern of Algeria). This new report is the second record for North Africa.

Key words: geophytes, petaloid Monocots, xenophytes, North Africa.

Introduction

Among Mediterranean countries, Algeria is well-known for its diverse vegetation and high floristic richness (Battandier 1888-1890; Maire 1959; Quézel & Santa 1962-1963), with a flora balance of 3139 species corresponding to 3744 taxa. Dobignard & Chatelain (2010-2013) accounted 4449 taxa, where 3951 are identified as indigenous to North Africa. However, since the 20th century numerous important taxonomic discoveries at national or even North African scale, have been recorded (see e.g. de Bélair & Véla 2011; de Bélair & al. 2012; Véla & de Bélair 2013; Hamel & Boulemtafes 2017a, 2017b; Boulemtafes & al. 2018; Rebbas & al. 2019). Meanwhile, several xenophytes new to the Algerian flora were reported (see e.g. Véla & al. 2013; Hamel & Azzouz 2018; Touati & al. 2020; Hamel & al. 2020; Meddour & al. 2020; El Mokni & Saci 2020).

In continuation with our previous botanical research within El Kala National Park (see e.g. Dechir & al. 2019; Dechir 2019), we present here a new non-native species for Algeria.

Context of the discovery

During botanical surveys in the extreme North-eastern of Algeria, specifically within El Kala National Park, the authors encountered a population (about fifty individuals on an area of almost 100 m^2) of a little-known bulbous species that was observed growing spontaneously, for the first time. Subsequent observations were carried during the years 2016, 2017 and 2020, and photographs of the plant in its blooming period were taken. The plant was referred to genus *Amaryllis* and some specimens, from the margin of a cork oak forest (*Quercus suber* L.) in the region of El Kala (Fig. 1) were taken to laboratory for precise identification. Two of the collected blooming specimens have been displayed in the Department of Biology Herbarium at Badji Mokhtar University Annaba (Algeria).

Morphological characters of this *Amaryllis* were measured and compared to data reported in the literature for *Amaryllis* L. in North Africa (Maire 1959; El Mokni & al. 2020). The plant was identified as *Amaryllis belladonna* L. (Fig. 2).

Native habitat and distributive range

Amaryllis is a small genus of terrestrial bulbous geophytes. It comprises only two species namely *Amaryllis belladonna* L. and *A. paradisicola* Snijman (cf. El Mokni & al. 2020). Among them, *A. belladonna*, a native to the Western Cape region of South Africa (Bond & Goldblatt 1984) has been identified to be naturalized in Western Australia, California, and New Zealand where the plant is locally escaped from abandoned gardens and cut-flower crops (Duncan & al. 2016). The taxon was also reported from several Mediterranean countries (Portugal, Corse, Italy) as casual to locally naturalized alien (Huber 1998; Galasso & al. 2018; WCSP 2020). For North Africa, the plant was recently reported from Tunisia as a first record (El Mokni & al. 2020), it is here its second record as naturalized to North Africa from Algeria (Dobignard & Chatelain 2011; APD2020).

Interest of the discovery

The newly discovery of *Amaryllis belladonna* as naturalized alien in Algeria enriches the national bulbous flora and encourages further botanical investigations for an extensive inventory of the vascular flora.

Fig. 1. Locality of the site of occurrence of *Amaryllis belladonna* in Algeria.

Fig. 2. *Amaryllis belladonna*, detail of the flowe in 14-09-2020. Photo: B. Dechir.

References

APD 2020: African Plant Database (version 3.4.0). Conservatoire et Jardin botaniques. – Genève. https://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php. [Last accessed 20/06/2020].

Battandier, J. A. 1888-1890: Flore d’Algérie: Ancienne flore d’Alger transformée (Dicotyledones). – Alger.

Bond, P. & Goldblatt, P. 1984: Plants of the Cape Flora: a descriptive catalogue. – Cape Town, South Africa.

Boulemtafes, A., Hamel, T., de Bélair, G. & Véla, E. 2018: Nouvelles données sur la distribution et l’écologie de seize taxons végétaux du littoral de la péninsule de l’Edough (Nord–Est algérien). – Bull. Soc. Linn. de Prov. **69:** 59-76. https://doi.org/10.3406/htn.1992.2379

de Bélair, G. & Véla, E. 2011: Découverte de *Nymphoides peltata* (Gmel) O. Kuntze (*Menyanthaceae*) en Afrique du Nord (Algérie). – Poiretia **3:** 1-7.

—, Belouahem, F., Belouahem-Abed, D. & Véla, E. 2012: Première signalisation d’*Allium commutatum* Guss. (*Alliaceae*) sur le continent africain (Algérie). – Lagascalia **32:** 312-314.

Dechir, B. 2019: Ecologie et inventaire des plantes bulbeuses au niveau de Kroumirie Nord Est Algérien. Thèse de Doctorat des Sciences Biologiques. – Université Mohamed-Chérif Messaadia-Souk Ahras, Algérie.

—, Chouikh, A., Hamel, T., Azizi, N. N., Ganaoui, N., Grira, A., Abdiouene, A., Maazi, M. C. & Chefrour, A. 2019: Biodiversity of bulbous and tuberous geophytes from the El Kala National Park (North-Eastern Algeria): checklist, vulnerability and conservation. – Anal. Biol. **41:** 25-38. http://dx.doi.org/10.6018/analesbio.41.05

Dobignard, A. & Chatelain, C. 2010-2013: Index synonymique et bibliographique de la Flore d’Afrique du Nord, **1-5.** – Genève.

Duncan, G., Jeppe, B. & Voigt, L. 2016: The *Amaryllidaceae* of Southern Africa. – Kirstenbosch Botanical Gardens, Cape Town, South Africa.

El Mokni, R., Pasta, S. & Pacifico, D. 2020: *Amaryllis belladonna* L. *(Amaryllidaceae; Amaryllidoideae)*, first record as naturalised geophyte in Tunisia and North Africa. –Hacquetia **19:** 331-336. https://doi.org/10.2478/hacq-2020-0011

— & Saci, A. 2020: *Opuntia dejecta* Salm-Dyck – Pp. 310-311 in: Raab-Straube, E. von & Raus, Th. (ed.), Euro+Med-Checklist Notulae, 12 [Notulae ad floram euro-mediterraneam pertinentes No. 41]. – Willdenowia **50:** 305-341. https://doi.org/10.3372/wi.50.50214

Galasso, G., Conti, F., Peruzzi, L., Ardenghi, N.M.G., Banfi, E., Celesti-Grapow, L., Albano, A., Alessandrini, A., Bacchetta, G., Ballelli, S., Bandini Mazzanti, M., Barberis, G., Bernardo, L., Blasi, C., Bouvet, D., Bovio, M., Cecchi, L., Del Guacchio, E., Domina, G., Fascetti, S., Gallo, L., Gubellini, L., Guiggi, A., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R.R., Medagli, P., Passalacqua, N.G., Peccenini, S., Pennesi, R., Pierini, B., Podda, L., Poldini, L., Prosser, F., Raimondo, F.M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R.P., Wilhalm, T. & Bartolucci, F. 2018: An updated checklist of the vascular flora alien to Italy. – Pl. Biosyst. **152:** 556-592. https://doi.org/10.1080/11263504.2018.1441197

Hamel, T. & Boulemtafes, A. 2017a: Découverte d’une endémique tyrrhénienne *Soleirolia soleirolii* (*Urticaceae*) en Algérie (Afrique du Nord). – Fl. Medit. **27:** 185-193. https://doi.org/10.7320/FlMedit27.185

— & — 2017b: Nouvelle station de *Sixalix farinosa* (Coss.) Greuter et Burdet dans la péninsule de l’Edough (Nord-Est algérien). – Bull. Soc. Linn. Prov. **68:** 1-9.

— & Azzouz, Z. 2018: Découverte de *Gamochaeta antillana* (*Asteraceae*) en Numidie orientale (El Tarf-Algérie). – Fl. Medit. **28:** 155-164. https://doi.org/10.7320/FlMedit28.155

—, Bellili, A. M., Boutabia, L. & Telailia, S. 2020: L'arctothèque souci (*Arctotheca calendula*): une nouvelle espèce exotique pour la flore algérienne. – Fl. Medit. **30:** 137-142. https://doi.org/10.7320/FlMedit30.137

Huber, H. 1998: Flowering Plants, Monocotyledons. – Berlin.

Maire, R. 1959: Flore d'Afrique du Nord, **6.** – Paris.

Meddour, R., Sahar, O. & Fried, G. 2020: A preliminary checklist of the alien flora of Algeria (North Africa): taxonomy, traits and invasiveness potential. – Bot. Lett. **3:** 1-18. https://doi.org/10.1080/23818107.2020.1802775

Quézel, P. & Santa, S. 1962-1963: Nouvelle flore d'Algérie et des régions désertiques méridionales, **1-2.** – Paris.

Rebbas, K., Véla, E., Bougaham, A.F., Belharrat, A., de Bélair, G. & Prelli, R. 2019: Découverte de *Christella dentata* (*Thelypteridaceae*) en Algérie. – Fl. Medit. **29:** 55-66. https://doi.org/10.7320/FlMedit29.055

Touati, L., Hamel, T. & Meddad-Hamza, A. 2020: Sur la présence d'*Atriplex canescens (Amaranthaceae)* en Algérie: écologie, taxonomie et biogéographie. – Fl. Medit. **30:** 33-38. https://doi.org/10.7320/FlMedit30.033

Véla, E. & de Bélair, G. 2013: Découverte de *Galium verrucosum* subsp. *halophilum* (Ponzo) Lambinon (Rubiaceae) en Afrique du Nord (Algérie). – Lagascalia **33:** 350-353.

—, Rebbas, K., Meddour, R. & de Bélair, G. 2013: Note sur quelques xénophytes nouveaux pour l'Algérie (et la Tunisie). – Addenda **5:** 372-376.

WCSP (World Checklist of Selected Plant Families) 2020: Facilitated by the Royal Botanic Gardens, Kew. – http://wcsp.science.kew.org/ [Last Accessed 30/07/2020].

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Article

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M. L. Gargano, E. Di Gristina, G. Domina & G. Venturella

Trees and shrubs in the city of Bari (Italy)

Abstract

Gargano, M. L., Di Gristina, E., Domina, G. & Venturella G.: Trees and shrubs in the city of Bari (Italy). — Fl. Medit. 31: 23-30. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The authors recorded in the city of Bari 221 specific and infraspecific taxa, used as onramentals, belonging to 126 genera of 64 families with a prevalence of exotic species over native ones. The study is preparatory to the redevelopment of urban green areas concerning the recent Municipal Regulation on green spaces in the city. The flora investigated is rich in elements native to Italy. Anyway, the most common species are commonly used as ornamental also in the other regions of Italy. *Argania spinosa*, *Ceiba speciosa*, *Cyperus papyrus*, *Euphorbia ingens*, *Ficus rubiginosa*, and *Jacaranda mimosifolia* are species less commonly used and noteworthy, because at their climatic limit.

Key words: street trees, shrubs, green cities, sustainability, Apulia.

Introduction

In the last years, several authors published comprehensive inventories of the urban flora and vegetation in European and extra-European cities (Chocholoušková & Pyšek 2003; Celesti-Grapow & al. 2013, Östberg & al. 2018; Muzafar & al. 2018; Domina & al. 2019; Çoban & al. 2020).

Other studies consider city trees as a significant component of the urban landscape, with multiple ecological roles and socio-economic functions (Caneva & al. 2020).

Cities host a variety of trees and shrubs that are mainly planted solely for street beautification without rational reasoning about their future growth, ecological needs, and maintenance.

Age and species of trees, space requirements, soil type, root asphyxiation, inadequate pruning, automobile damage, pollution levels, and the socioeconomic level of a neighborhood are the primary factors that potentially become the reasons why street tree and shrub problems occur (Kadir & Othman 2012).

In the city of Bari, we recently started a census of the trees and shrubs that characterize the urban environment.

The study area

Bari is located on the Adriatic coast of Apulia on a plane of about 115 km^2, the so-named ”Conca di Bari” (41°07′31″N 16°52′00″E), which is delimited by the Adriatic Sea and the Carbonate Mountains (Murge). Bari falls within the “Apulian Lowlands Section” of the “Alupian-Hybleam Foreland Province” as defined by Blasi & al. (2014, 2018).

The area of the city of Bari has been constantly inhabited since prehistoric times but the main development of the city was carried out in the 40 years after the end of the Second World War (Borri & al. 1980). The settlement of the city is almost flat with a difference in elevation from the sea level to 100 m a.s.l. The territory of the Conca di Bari is crossed by “lame”, ancient fossil rivers and stream beds, which descend from the Murge to the Adriatic Sea. In the city of Bari actually there are only two artificial surface watercourses: the Lamasinata canal at the north-western edge of the investigated area and the Japigia canal at the south-east. The population of Bari is about 313,000 (Istat 2020).

According to Passarella & al. (2020), the bioclimate of Bari is “Dry subhumid Mediterranean”. The climate is characterized by minimum temperatures that rarely fall below 0°C during winter and quite frequent summer maximum temperatures between 38 and 40°C. The average temperature of January and February is 4.9 and 4.8°C, respectively. There is high air humidity (71.3% on average) both in winter and in summer thanks to the sea breezes. The lithological substrate is carbonatic and the most common types of soil are: Xerorthent, Xerochrepts and Lithic Rhodoxaralfs (De Pascalis & De Pascalis 2010). The area considered in this study extends over 61.4 km^2 and includes the city centre and the former suburban agricultural areas, and is bounded by the Adriatic sea and by the Bari ring road, the state road no.16 (Fig. 1).

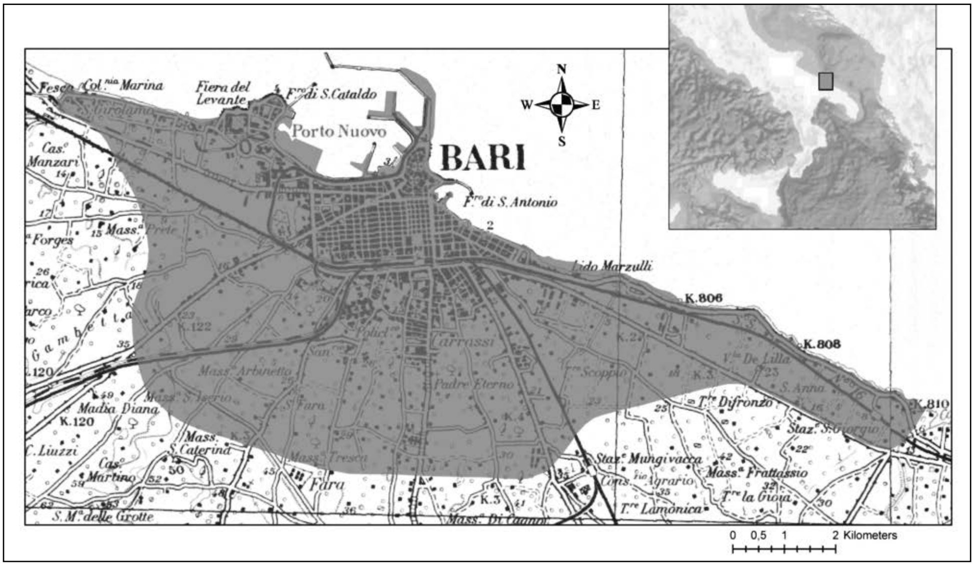

Fig. 1. The study area including the city center of Bari.

Materials and methods

In 2019, we carried out periodic observations on the presence of trees and shrubs along the streets of the city of Bari, including public and private gardens. The taxa have been identified based on their main morphological characters. In some cases, reference was made to specific contributions [e.g. Speciale & Domina (2016) for *Strelitzia* and Gargano (2018) for *Tamarix*]. The scientific names refer to Bartolucci & al. (2018) and Galasso & al. (2018) for taxa that grow spontaneous in Italy and to Graf (1980) and "The plant List" (2021) for taxa that are only cultivated.

Results

The census of trees and shrubs in the city of Bari revealed the presence of 221 taxa included in 147 genera belonging to 73 families. The list of recorded taxa is reported in the Electronic Supplementary File (ESF1). The families with a larger number of taxa are *Rosaceae* (14), *Fabaceae* (13taxa), *Arecaceae* (12), *Pinaceae* (12), *Asparagaceae* (11), *Cupressaceae* (11), and *Oleaceae* (10). The largest number of taxa is found in the genera *Pinus* L. (6), *Prunus* L. (6), *Cupressus* L. (5), *Quercus* L. (5), *Ficus* L. (4), and *Tilia* L. (4).

The most common biological forms are scapose phanerophytes (107 taxa, 48.2%) and bushy phanerophytes (68, 30.6%), followed by nanophanerophytes (19, 8.5%) (Fig. 2a).

The exotic component clearly predominates over the native species. The subtropical features of the cultivated flora is highlighted in the spectrum of Fig. 2b. This figure shows that the predominant chorotype is Asiatic (52 taxa, 23.4%) followed by South American (22 taxa, 9.9%), and North American (15 taxa, 6.7%). The Steno-Mediterranean component is represented by 15 taxa (6.7%). The flora investigated is rich in elements native to the Italian territory such as: *Anthyllis barba-jovis* L., *Carpinus orientalis* Mill., *Celtis australis* L., *Ceratonia siliqua* L., *Chamaerops humilis* L., *Cornus sanguinea* L., *Corylus avellana* L., *Euphorbia dendroides* L., *Fraxinus excelsior* L., *F. ornus* L., *Ilex aquifolium*

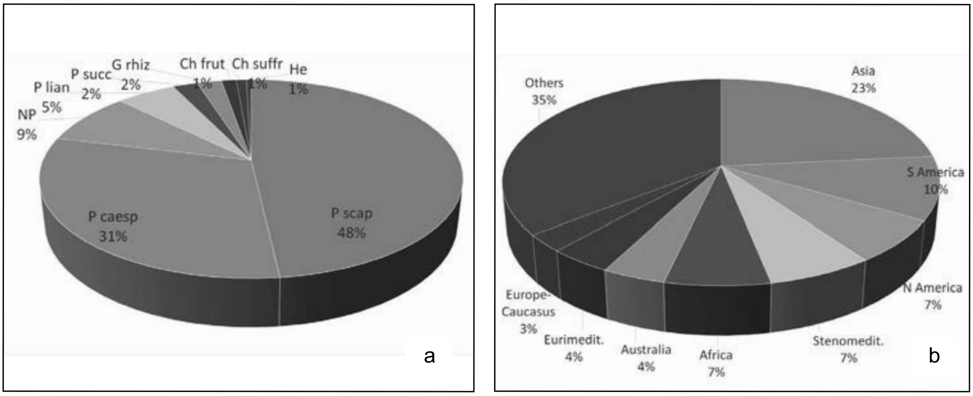

Fig. 2. a) Biological and b) chorological spectra of the investigated flora.

L., *Myrtus communis* L., *Ostrya carpinifolia* Scop., *Pistacia lentiscus* L., *P. terebinthus* L., *Prunus mahaleb* L., *P. webbii* (Spach) Vierh., *Pyrus spinosa* Forssk., *Quercus cerris* L., *Q. ilex* L., *Q. pubescens* Willd., *Rhamnus alaternus* L., *Salvia rosmarinus* Spenn., *Spartium junceum* L., *Teucrium fruticans* L., *Ulmus canescens* Melville, *U. minor* Mill., *Viburnum tinus* L., *Vitex agnus-castus* L. etc. Although most of the individuals observed come from commercial channels, it is possible that some, especially among the large trees, come from the multiplication of local native plants.

As expected, the species commonly used as ornamental in the other regions of Italy prevail, such as *Aloe arborescens* Mill., *A. vera* (L.) Bunn., *Cedrus atlantica* (Endl.) Carrière, *C. deodara* (D. Don) G. Don, *Cestrum parqui* L'Her., *Pittosporum tobira* (Thunb.) W.T. Aiton, *Platycladus orientalis* (L.) Franco, *Pyracantha coccinea* M. Roem., *Salix babylonica* L., *Schinus molle* L., *Strelitzia reginae* Banks, *Viburnum lucidum* Mill., *Washingtonia filifera* (André) de Bary, *Yucca gigantea* Lem., etc. (Figs. 3a, 3b, 4).

Fig. 3. a) Row of *Cupressus sempervirens* in Parco Don Tonino Bello; b) traffic divider with pine trees in Viale Ghandi.

Fig. 4. Partial view of the recreational Parco 2 Giugno.

Fig. 5. *Argania spinosa* cultivated within the Department of Agricultural and Environmental Science of the University.

Less common species, noteworthy, because to the limit of their use for the climate of the locality are: *Argania spinosa* (L.) Skeels (Fig. 5), *Ceiba speciosa* (A. St.-Hil.) Ravenna, *Cyperus papyrus* L., *Euphorbia ingens* E. Mayer, *Ficus rubiginosa* Desf., *Jacaranda mimosifolia* D. Don, etc. These reports testify the acclimatization to South Italy of species native under warmer climates.

Discussion

With a resolution of the Municipal Council of 25 May 2020, the Municipal Regulation of Urban Green Areas of the City of Bari was approved. The regulations contain a non-exhaustive list of recommended species for use in green areas of the city.

The census here provided is preparatory to the improvement of the management of urban green by the municipal administration and the creation of paths within the urban perimeter characterized by native species.

Trees and shrubs in cities play a key role in mitigating climate change and are responsible for 80% of greenhouse gas emissions and 50% of total waste production. Cities are also a source of wasted energy, food, and water. The cities of the future must focus on resource efficiency, resilience, circularity, inclusiveness, and sustainability. The application of good green practices is the real bet for the future in cities. But a change of mentality is needed among citizens so that they understand that planting trees in the city is not just a matter of aesthetics and decoration but also concerns the quality of life and the air they breathe.

References

Bartolucci, F., Peruzzi, L., Galasso, G., Albano, A., Alessandrini, A., Ardenghi, N. M. G., Astuti, G., Bacchetta, G., Ballelli, S., Banfi, E., Barberis, G., Bernardo, L., Bouvet, D., Bovio, M., Cecchi, L., Di Pietro, R., Domina, G., Fascetti, S., Fenu, G., Festi, F., Foggi, B., Gallo, L., Gottschlich, G., Gubellini, L., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R. P., Wilhalm, T. & Conti, F. 2018: An updated checklist of the vascular flora native to Italy. – Pl. Biosyst. **152(2):** 179-303. https://doi.org/10.1080/11263504.2017.1419996

Blasi, C., Capotorti, G., Copiz, R. & Mollo, B. 2018: A first revision of the Italian Ecoregion map. – Pl. Biosyst. **152:** 1201-1204. https://doi.org/10.1080/11263504.2018.1492996

—, —, —, Guida, D., Mollo, B., Smiraglia, D. & Zavattero, L. 2014: Classification and mapping of the ecoregions of Italy. – Pl. Biosyst. **148:**1255-1345. https://doi.org/10.1080/11263504.2014.985756

—, —, Marchese, M., Marta, M., Bologna, M. A., Bombi, P., Bonaiuto, M., Bonnes, M., Carrus, G. & Cifelli, F. 2008: Interdisciplinary research for the proposal of the Urban Biosphere Reserve of Rome Municipality. – Pl. Biosyst. **142:** 305-312. https://doi.org/10.1080/11263500802150571

Borri, D., Cucciolla, A., Morelli, D., Pastore, P., Tetrignani, M., Ruggiero Petrignani, M. 1980: Questione urbana e sviluppo edilizio, il caso di Bari. – Bari

Caneva, G., Bartoli, F., Zappitelli, I. & Savo, V. 2020: Street trees in italian cities: story, biodiversity and integration within the urban environment. – Rend. Lincei Sci. Fis. Nat. **31:** 411-417.

Celesti-Grapow, L., Capotorti, G., Del Vico, E., Lattanzi, E., Tilia, A. & Blasi, C. 2013: The vascular flora of Rome. – Pl. Biosyst. **147:** 1059-1087. https://doi.org/10.1080/11263504.2013.862315

Chocholoušková, Z. & Pyšek, P. 2003: Changes in composition and structure of urban flora over 120 years: a case study of the city of Plzeň. – Flora **198(5):** 366-376. https://doi.org/10.1078/0367-2530-00109

Çoban, S., Yener, S.D. & Bayraktar, S. 2020: Woody plant composition and diversity of urban green spaces in Istanbul, Turkey. – Pl. Biosyst. **155:** 83-91. https://doi.org/10.1080/11263504.2020.1727980

De Pascalis, A. & De Pascalis, F. 2010: Piano operativo Triennale 201-2012, Potenziamento dell'impianot di depurazione di bitonto, Studio d'Impatto ambientale. – Bari. https://www.cittametropolitana.ba.it/provinciaba/allegati/2564/All.%20C1%20Quadro%20di%20riferimento%20am bientale.pdf

Domina, G., Di Gristina, E., Scafidi, F., Calvo, R., Venturella, G., Gargano, M. L. 2019: The urban vascular flora of Palermo (Sicily, Italy). – Pl. Biosyst. **154:** 627-634. https://doi.org/10.1080/11263504.2019.1651787

Galasso, G., Conti, F., Peruzzi, L., Ardenghi, N. M. G., Banfi, E., Celesti-Grapow, L., Albano, A., Alessandrini, A., Bacchetta, G., Ballelli, S., Bandini Mazzanti, M., Barberis, G., Bernardo, L., Blasi, C., Bouvet, D., Bovio, M., Cecchi, L., Del Guacchio, E., Domina, G., Fascetti, S., Gallo, L., Gubellini, L., Guiggi, A., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Podda, L., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R. P., Wilhalm, T. & Bartolucci, F. 2018: An updated checklist of the vascular flora alien to Italy. – Pl. Biosyst. **152:** 556-592. https://doi.org/10.1080/11263504.2018.1441197

Gargano, M. L. 2018: The genus *Tamarix* (*Tamaricaceae*) in Apulia (southern Italy). – Fl Medit. **28:** 137-143. https://doi.org/10.7320/FlMedit28.137

Graf, A. B. 1980. Tropica. Color Cyclopedia of Exotic Plants and Trees, 2° ed. – New York.

Istat. 2020: Atlante statistico dei comuni, edizione 2020. – http://asc.istat.it [Last accessed 30/12/2020].

Kadir, M. A. A. & Othman, N. 2012: Towards a Better Tomorrow: Street Trees and Their Values in Urban Areas. – Proc. Soc. Behav. Sci. **35:** 267-274. https://doi.org/10.1016/j.sbspro.2012.02.088

Muzafar, I., Khuroo, A.A., Mehraj, G., Hamid, M., Rashid, I., Malik, A. H. 2018: Floristic diversity along the roadsides of an urban biodiversity hotspot in Indian Himalayas. – Pl. Biosyst. **153:** 222-230. https://doi.org/10.1080/11263504.2018.1461700

Östberg, J., Wiström, B. & Randrup, T. B. 2018: The state and use of municipal tree inventories in Swedish municipalities – results from a national survey. – Urban Ecosyst. **21:** 467-477. https://doi.org/10.1007/s11252-018-0732-3

Passarella, G., Bruno, D., Lay-Ekuakille, A., Maggi, S., Masciale, R. & Zaccaria, D. 2020: Spatial and temporal classification of coastal regions using bioclimatic indices in a Mediterranean environment. – Sci. Total Environ. **700:** 134415. https://doi.org/10.1016/j.scitotenv.2019.134415

Speciale, M. & Domina, G. 2016: On the real identity of the *Strelitzia* cultivated in Sicily's historic gardens. – Webbia **71:** 209-211. https://doi.org/10.1080/00837792.2016.1191180

The Plant List 2021: Version 1.1. – http://www.theplantlist.org/ [Last accessed 30/12/2020].

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Short note

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Ridha El Mokni & Frederic Debruille

Two new *Suaeda* (*Chenopodiaceae/Amaranthaceae*, *Suaedoideae*) records from the Tunisian coastal areas with a key to species identification

Abstract

El Mokni, R. & Debruille, F.: Two new *Suaeda* (*Chenopodiaceae/Amaranthaceae*, *Suaedoideae*) records from the Tunisian coastal areas with a key to species identification. — Fl. Medit. 31: 31-36. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Two species of *Suaeda*, *S. aegyptiaca* (sect. *Salsina*) and *S. splendens* (sect. *Schoberia*) are here reported for the first time from Tunisia. Descriptions for their distinguishing morphological characters, as well as ecological and chorological data are given. An analytical key to species of *Suaeda* belonging to *Suaedeae* tribe and occurring in Tunisia is also provided.

Key words: *Caryophyllales*, North Africa, New records, chorology.

Introduction

Suaeda Scop. (*Chenopodiaceae*/*Amaranthaceae*) comprises c. 100 species with the cosmopolitan distribution (Schenk & Ferren 2001). Its species are not easy to identify because the distinctive characters are few and high variable, particularly in vegetative parts, such as leaf shape, size, color and branching pattern of the stem within the same species (Bassett & Crompton 1978; Freitag & al. 2001; Schütze & al. 2003). Thus, identification is usually based on reproductive characters. According to Le Floc'h & al. (2010), Dobignard & Chatelain (2010) and Uotila (2011+), only 4 species of *Suaeda* occur in Tunisia, whereas 6 and 7 species occur in Lybia and Morocco, respectively (APD 2021). More recently, *Suaeda spicata* (Willd.) Moq. was added to the Tunisian flora (in Sukhorukov & al. 2019).

In the course of floristic surveys along coastal areas and saline wetlands for two decades (see e.g. Iamonico & El Mokni 2016, 2017, 2018 Sukhorukov & al. 2018, 2019; El Mokni & Iamonico 2019) two unusual species of *Suaeda* were recorded. *Suaeda aegyptiaca* and *S. splendens* are here recognized as two species new to the flora of Tunisia.

Material & Methods

The research is based on periodic field surveys during the last two decades in many saline wetlands of coastal areas going with analysis of relevant literature. Material of collected individuals was considered for features examination. Systematics and nomenclature of *Suaeda* follow Schenk & Ferren (2001) and Sukhorukov & al. (2019). For the morphological description and the characterization of the species see Pottier-Alapetite (1979: 60-63), Boulos (1999: 111-116) and Jafri & Rateeb (1978: 58-68).

Results

Suaeda aegyptiaca (Hasselq.) Zohary
≡ *Chenopodium aegyptiacum* Hasselq.
≡ *Schanginia aegyptiaca* (Hasselq.) Aellen

Morphology: (Fig. B). Annual, up to 70 cm in height; **stems** erect or ascending, the lower often spreading, terminating in bracteate, shorter or longer spike-like inflorescences; **leaves** (long: 10–17 mm, wide: 1–3 mm), succulent, with obtuse apex, the lower linear or oblong, the upper narrow obovate to clavate, obtuse, at base attenuate into a short petiole; bracts subclavate to clavate, arcuate, spreading, the lower much longer, the upper as long as or even shorter than floral and fruit clusters; bracteoles 0,8-1 mm long, narrow ovate, trullate or triangular, acute or acuminate, the margins lacerate to toothed; **flowers** fig-shaped, 2–2.5 × 2.5 mm, gathered by 5–30 in axillary glomeruli, inserted on very short axillary branches; **perianth** with very succulent tepals, fused for ½ – ⅓, in the lowermost 1 mm forming a compact cone, higher up widened into a bowl-like structure, tepal-lobes incurved, green with hyaline margins, somewhat cucullate; **stamens** 5, the thread-like filaments inserted on an epitepalous rim; anthers 0.6–0.7 × 0.5 mm, divided for c. ½ ; **ovary** semi-inferior, in its lower, ovule-bearing part fused with the perianth, its upper part forming a ca. 1 mm long column or slender cone; stigmas (2–)3(–4), 0.7–1.2(–1.5) mm long, with long papillae, inserted in the centre of the collar-like ovary apex; fruiting perianth somewhat enlarged, up to 3 mm long, fig-shaped, often partly or completely spongy; **seed** slightly flattened, vertical, black 0.9–1.2 × 0.75–1 mm shining, smooth to delicately sculptured.

Habitat in Tunisia: margins of salt wetlands and marshes in the south east at sea-level.

Elevation: 0–5 m a.s.l.

Distribution in Tunisia: we found three populations at Medenine region (SE-Tunisia). The first was discovered since 2001 at “Oued El Fedje” comprising many scattered individuals to small subpopulations on the banks of the saline stream. The second was discovered in 2015 in Djerba (Houmet-Souk). The third one was discovered in 2016 in the margins of the “Gulf of Boughrara” on the left bank before the bridge leading to Djerba from Zarzis.

Chorology: *Suaeda aegyptiaca* has a large distribution area from eastern North Africa to the Near East, Arabian Peninsula, Jordan, Syria, Lebanon, Qatar and the United Arab

Emirates (Freitag 2001; APD 2021). Its main occurrence is from northern Libya eastwards to Iraq, the southern half of Iran, southern Afghanistan, to Pakistani Baluchistan, and southwards to the Arabian Peninsula, Yemen and the Dhofar region of Oman (see e.g. Freitag 2001; Uotila 2011+; Mosti & al. 2012; Sukhorukov & al. 2016). Within Africa, it occurs also in southwards of Sudan, southeastern Ethiopia and Egypt including the Sinai (Crivellaro & Schweingruber 2013: 224; APD 2021). The plant was known also from Cyprus (Crivellaro & Schweingruber 2013: 224) and appeared in parts of southern Australia where it may has naturalized (ALA 2021).

Record: Tunisia, Medenine, Djerba, 30.09.2015, Debruille (Photographed specimens from Debruille's collection are consultable online at: https://www.orchid-nord.com/Flore-Djerba/Suaeda%20aegyptiaca/Suaeda%20aegyptiaca.html).

Suaeda splendens (Pourr.) Gren. & Godr.
≡ *Salsola splendens* Pourr.

Morphology: Annual, up to 50 cm high, reddish to glaucous and glabrous; **stems** erect or spreading-diffuse and branched from the base; **leaves** alternate, 5–15 (–20) × 0.5–1.5 mm close together, linear to semicylindrical with hyaline margins and provided at the apex with a bristle of 0.5–1.5 mm (Fig. D) quickly deciduous; **inflorescence** in a dense spike-like panicle at the tips of fertile branches; **flowers** gathered by (3–)5–8 in axillary glomeruli, the lateral ones often female, the central bisexual in the leaf axils and provided with sharp bracteoles less than or equal to the length of the flowers; **perianth** 2.5–3 mm in diameter with 5 scarious tepals, connate at the base; **stamens** 5 exert; **ovary** pear-shaped, style with 3 free stigmas; fruiting perianth accrescent enclosing the fruit; **seed** lenticular, horizontal or vertical, black 1–1.5 × 0.8–1 mm, glossy, smooth.

Habitat in Tunisia: coastal salt wetlands in the centre east.

Elevation: 10–15 m a.s.l.

Distribution in Tunisia: we found many populations at Monastir town (CE-Tunisia) comprising numerous juvenile individuals which occupy an area of about few hectares. At the current state of knowledge, we consider *Suaeda splendens* as a native species for Tunisia.

Chorology: Southern Europe (except Balearic Islands, Cyprus and Sicily), Subtropical Africa (North Africa), Asia Minor (Turkey) and Eastern Mediterranean (Lebanon, Palestine).

Specimina visa (new records): Tunisia, Monastir, Monastir-surroundings, 05.10.2019, *El Mokni s.n.* (Herb. Univ. Monastir!).

Fig. 1. Coastal species of *Suaeda* in Tunisia: A) *S. maritima*; B) *S. aegyptiaca*; C) *S. mollis*; D) *S. splendens*; E-F) *S. spicata*; G-H) *S. vera* s.lat. (Photos B. by F. Debruille and A, C-H by R. El Mokni).

Key to species of the genus *Suaeda* in Tunisia (new records in bold)

1. Upper part of the ovary swollen and spongy, the lower fused to the periant at maturity ....***S. aegyptiaca***
– Ovary thin-walled, not spongy, enveloped by the perianth at maturity but not fused to it.....2
2. Annual herbs...3
– Subshrubs or shrubs..5
3. Leaves with short caducous apical bristle; seeds shiny and smooth ....***S. splendens***
– Leaves without apical bristle; seeds ornamented...4
4. Perianth segments thickened, with a vertical keel on the back or, more rarely, with a small transverse wing of less than 1 mm ....*S. spicata*
– Perianth segments 0.8 mm long, deltoid; bracteoles 0.5 mm long, deltoid-ovate; leaves almost flat, acute or subacute...*S. maritima*
5. Stigmas flat, lobed or disc-shaped; leaves 5–18 × (0.8–)1–2.5 mm, semi-cylindrical, usually shortly apiculate ....*S. vera*
– Stigmas filiform or linear; leaves different 6
6. Leaves 2–6(–8) × 5 mm, crowded on the stems, flat above, rounded beneath......*S. pruinosa*
– Leaves 20(–30) × 1–4 mm, spaced on the stems, obovate-oblong to subglobose, terete.. ....*S. fruticosa*

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References

ALA (Atlas of Living Australia) 2021: *Suaeda aegyptiaca* (Hasselq.) Zohary. – Australia: Open access to Australia's biodiversity data. –https://id.biodiversity.org.au/node/apni/2900741 [Last accessed 23/01/2021].

APD (African Plant Database) 2021: *Suaeda aegyptiaca* (Hasselq.) Zohary and *S. splendens* (Pourr.) Gren. & Godr. – Genève; Pretoria. – http://www.ville-ge.ch/musinfo/bd/cjb/africa/details.php?langue=an&id=195224 [Last accessed 23/01/2021].

Bassett, I. J. & Crompton, C. W. 1978: The genus *Suaeda* (*Chenopodiaceae*) in Canada. – Canad. J. Bot. **56:** 581-591.

Boulos, L. 1999: Flora of Egypt, **1.** – Cairo.

Crivellaro, A, Schweingruber, F. H. 2013: Atlas of wood, bark and pith anatomy of Eastern Mediterranean trees and shrubs. With a special focus on Cyprus. – Berlin, Heidelberg.

Dobignard, A. & Chatelain, C. 2011 : Index synonymique de la flore d'Afrique du Nord. –Conserv. Jard.Bot. Ville de Genève. hors-série **2:** 52.

El Mokni, R. & Iamonico, D. 2019: *Bassia scoparia* (*Amaranthaceae* s. l.) and *Sesuvium portulacastrum* (*Aizoaceae*), two new naturalized aliens to the Tunisian flora. – Fl. Medit. **29:** 191-196. https://doi.org/10.7320/FlMedit29.191

Freitag, H. 2001: *Suaeda*. – Pp. 104-126 in: Ali, S. I. & Qaiser, M. (eds), Flora of Pakistan, **204.** – Karach and St. Louis.

—, Hedge, I. C., Jafri, S. M. H., Heinririch, G., Omer, S. & Uotila, P. 2001: *Chenopodiaceae* – Pp. 1-213 in: Ali, S. I. & Qaiser, M. (eds), Flora of Pakistan, **204.** – Karach and St. Louis.

Iamonico, D. & El Mokni, R. 2016: *Patellifolia procumbens* (C. Sm.) A. J. Scott., Ford-Lloyd et J.T. Williams. In: Raab-Straube, E., von Raus, T. (eds), Euro+Med–Checklist Notulae 6. – Willdenowia **46 (3):** 423-442. https://doi.org/10.3372/wi.46.46310.

— & — 2017: *Amaranthus palmeri* (*Amaranthaceae*) in Tunisia, a second record for the continental African flora and nomenclatural notes on *A. sonoriensis* nom. nov. pro *A. palmeri* var. *glomeratus*. – Bothalia **47:** a2100. https://doi.org/10.4102/abc.v47i1.2100.

— & — 2018: *Amaranthus tunetanus* (*Amaranthaceae*), a new species from Tunisia and a diagnostic key to the North African taxa in subgen. *Albersia*. – South African J. Bot. **114:** 78-83.

Jafri, S. M. H. & Rateeb, F. B. 1978: *Suaeda* – Pp. 58-68 in: Jafri, S. M. H. & El-Gadi, A. (eds), Flora of Libya, **58.** –Tripoli.

Le Floc'h, E., Boulos, L. & Véla, E. 2010 : Flore de Tunisie. Catalogue synonymique commenté. – Tunis.

Mosti, S., Raffaelli, M. & Tardelli, M. 2012: Contribution to the Flora of Central-Southern Dhofar (Sultanate of Oman). – Webbia **67(1):** 65-91. https://doi.org/10.1080/00837792.2012.10670909.

Schenk, H. J. & Ferren, W. R. 2001: On the sectional nomenclature of *Suaeda* (*Chenopodiaceae*). – Taxon **50(3):** 857-873. https://doi.org/10.2307/1223715

Schütze, P., Freitag, H. & Weising, K. 2003: An integrated molecular and morphological study of the subfamily *Suaedoideae* Ulbr. (*Chenopodiaceae*). – Pl. Syst. Evol. **239:** 257-286. https://doi.org/10.1007/s00606-003-0013-2

Sukhorukov, A. P., Kushunina, M., El Mokni, R., Goñalons, L. S., El Aouni, M. H. & Daniel, T. F. 2018: Chorological and Taxonomic Notes on African Plants, 3. – Bot. Lett. **165(2):** 228-240. https://doi.org/10.1080/23818107.2018.1465467.

—, —, —, Ardenghi, N. M. G., Verloove, F., Uotila, P., Baider, C., Bruyns, P. V. & Klak, C. 2019: Chorological and taxonomic notes on African plants, 4: *Caryophyllales*. – Bot. Lett. **166(4):** 401-416. https://doi.org/10.1080/23818107.2019.1652848.

—, Aellen, P., Edmondson, J. R. & Townsend, C. C. 2016: 95. *Chenopodiaceae*. – Pp. 164-255 in Ghazanfar, S. A., Edmondson, J. R. (eds), Flora of Iraq: *Elatinaceae* to *Sphenocleaceae*, **5(1).** – Kew.

Uotila, P. 2011+ [continuously updated]: *Chenopodiaceae* (pro parte majore). In: Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. – http://ww2.bgbm.org/EuroPlusMed/PTaxonDetail.asp?NameId=7721137&PTRefFk=7300000 [Last accessed 22/11/2020].

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Article

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Biological traits, habitat preferences and endemism in the flora of Peloponnisos, Greece

Abstract

Mermygkas, D., Zikos, A. & Constantinidis, Th.: Biological traits, habitat preferences and endemism in the flora of Peloponnisos, Greece. — Fl. Medit. 31: 37-52. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The Peloponnisos, the southernmost part of the Greek mainland, comprises 3,007 autochthonous spermatophytes (species and subspecies), including 4 Greek endemic genera. To compare biological traits within its flora, 4 main chorological categories were distinguished: widespread taxa, Greek endemics, range restricted taxa and local endemics. In the total flora, therophytes (34.8%) predominate, followed by hemicryptophytes (34.3%). A significant drop in the percentage of therophytes is noted among range restricted or local endemic taxa, with 11.6% and 1.3%, respectively. Diaspores are predominately seeds or single-seeded fruits, a trend even more pronounced in the range restricted and local endemic flora. Fleshy fruits are rare, with dry fruits being the norm in all categories. Annual seed production does not exhibit any significant variation among the widespread taxa and those having a restricted distribution. A preliminary investigation of dispersal syndromes showed that within genera specialized to particular dispersal modes the percentage of endemicity may vary considerably. Most Peloponnesian endemics inhabit rocky, calcareous habitats and cliffs. Dry, phryganic formations are also rich in endemics, followed by the grasslands at the lowland or subalpine areas. Ruderal and aquatic habitats have an insignificant contribution to endemism.

Key words: chorology, diaspore, dispersal, life forms, Mediterranean area.

Introduction

The range size of species and their distribution patterns on earth may vary considerably (Lamoreux & al. 2006). Endemism, as a term, refers to living organisms that have small ranges. It is usually a concept of spatial scale: endemic taxa are restricted to a defined geographic area or habitat (Gaston 2003; Hobohm 2014). Endemism is often associated with the political boundaries of countries or territories (e.g., islands, mountains) and when used in such a way, it is geographically defined.

Many endemic vascular plants have small populations and a limited geographical range. They face increased risk of area and/or population reduction and therefore, are inherently vulnerable to extinction. Very often, they are the targets of conservation efforts (Gaston

1998; Trigas & al. 2012; Keppel & al. 2018). Driving forces that shape endemism are certainly of importance, as they may be used in various models that predict endemism and/or decide on conservation priorities. Biological traits appear to have a major role in the ecological and evolutionary processes that diversify plant groups (Melendo & al. 2003; Balmford & Cowling 2006). The comparison of biological traits and ecological characteristics between local and widespread species could shed light on the driving forces that shape endemism and contribute to a better understanding of possible threats. This approach may also facilitate the application of appropriate conservation measures (Murray & al. 2002; Lavergne & al. 2004; Farnsworth 2007). Despite that acknowledgement, research on the plant traits that may contribute to a narrow spatial distribution remains limited (Bevill & Louda 1999; Casazza & al. 2005; Keppel & al. 2018). Currently, functional traits databases are emerging as an important tool for ecological studies. They can also be put in use for the identification of the relationships between plant characteristics and their relevant distribution patterns (Melendo & al. 2003; Díaz & al. 2016; Tavşanoğlu & Pausas 2018).

The Mediterranean Basin is one of the world's most important centers for plant diversity, due to its varied bioclimate, habitat heterogeneity and geologic history. Although representing only 1.6% of the Earth's surface, it hosts c. 10% of the world's higher plants (Médail & Quezél 1997). Southern and Central Greece has been identified as an important biodiversity hotspot within the Mediterranean basin (Médail & Quezél 1997, 1999). The region of Peloponnisos (Pe), at the southernmost part of the Greek mainland, hosts the highest number of endemic species and subspecies in Greece (Dimopoulos & al. 2013, 2016). Therefore, this region was selected as a model to investigate certain biological traits, particularly those related to dispersal and/or area occupation, life form and habitats within groups of different chorological characteristics.

The targets of this study include: a) the correlation of biological and habitat parameters within widespread and local plant taxa and b) a preliminary interpretation of our results as traits that are related to or promote endemism. To achieve the targets, the following steps have been taken: a) the floristic update of the vascular flora of Peloponnisos and the circumscription of different chorological groups that enable comparisons; b) the registration and identification of selected biological parameters that may reveal trait differences between widespread and local plants; c) the assignment of biological and habitat data to each species and subspecies.

Materials and methods

Study area

The study area includes the phytogeographical region of Peloponnisos (Pe) as defined in Strid & Tan (1997). It comprises Peloponnisos itself, i.e., the southernmost part of the Greek mainland, and several islands mostly to the east (Saronikos and Argolikos Gulfs islands) and to the south (Elafonisos, Kithira, Antikithira, Sapienza, Schiza). Two islets to the east (Velopoula and Falkonera) are remote and not included in the study area. The Corinth Canal, constructed in 1893, crosses the 6 km land belt that once formed the connection of Peloponnisos with adjacent Sterea Ellas and transformed the region into an artificial island. With a total surface area of approximately 22,140 km^2 (including surrounding islands), Peloponnisos is certainly larger than Kriti (8,336 km^2) and comparable in size to Sicily (25,711km^2), the largest Mediterranean Island. Its highest elevation on Mt. Taigetos reaches 2,407 m (Fig. 1). Geologically, Peloponnisos is diverse with limestone, flysch and various sediment structures being the most important rock types. Annual precipitation varies from 400 to 1,700 mm, and the mean annual temperature ranges from 18.6°C in the warmest parts to 7.5°C on the highest peaks (see Trigas & al. 2012).

Flora and chorological categories

A number of literature and herbarium records were used to synthesize the total flora of Peloponnisos. As basic sources, Dimopoulos & al. (2013, 2016) were used to construct a floristic matrix that was later enriched by some recent bibliographic references. Important comments and additions to the flora of Peloponnisos are found in Strid & Tan (2017), Kalpoutzakis & al. (2019) and several contributions appearing in Phytologia Balcanica (Vladimirov & al. 2017a, 2017b, 2018a, 2018b, 2019) and Willdenowia (Raab-Straube & Raus 2017a, 2017b, 2018, 2019a, 2019b) journals. Most of the Greek endemic plants found in Peloponnisos are included in Tan & Iatrou (2001). Information from recent field work, particularly in the central parts of Peloponnisos, and the floristic databases maintained in ATH (c. 75,000 records) and ATHU (c. 33,000 records) were also used. As current investigation intends to reveal trends among widespread and local native taxa all records

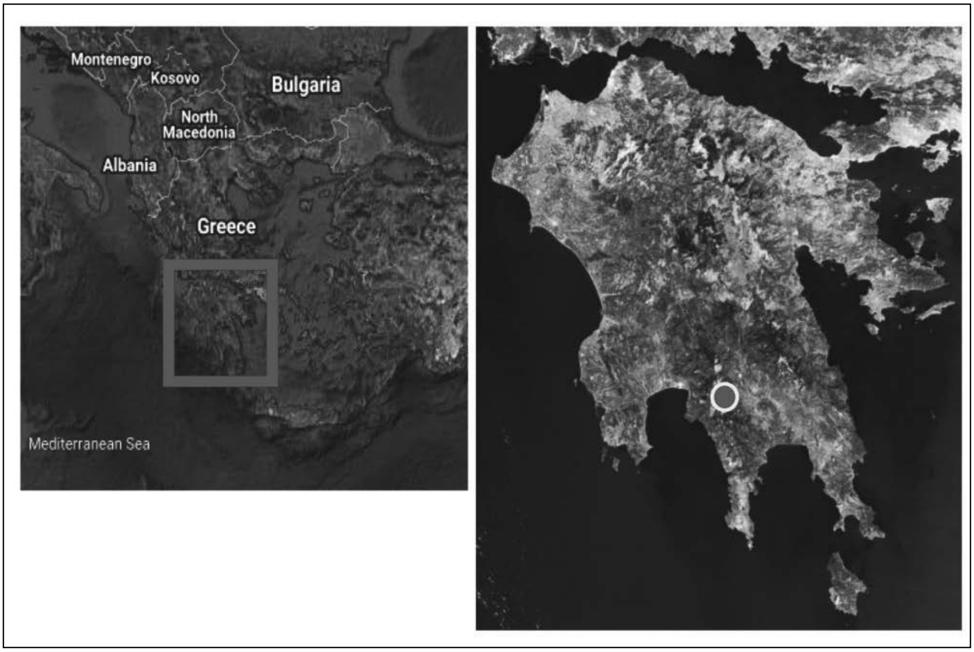

Fig. 1. Peloponnisos (red square) covers the southernmost part of the Greek mainland. The highest peak of the region is on Mt. Taigetos (red dot; 2,407 m) (topographic background from Google Earth, google.com).

of alien, casuals and cultivated species were excluded from further analyses. Likewise, pteridophytes were not considered as they present different biological traits compared to spermatophytes.

We distinguish four main chorological categories: a) widespread taxa, i.e., plants that are distributed well beyond the political borders of Greece, b) Greek endemic taxa, i.e., species or subspecies confined within the political borders of Greece, c) range restricted taxa, i.e., taxa having an area of occurrence not exceeding a linear distance of 500 km irrespective of political borders and d) local endemics, i.e., taxa with a very narrow distribution, generally not exceeding a 50 km radius. The main matrix records the distribution of the above chorological categories in the total flora of Peloponnisos, the latter considered either with or without the surrounding islands.

Traits examined

Life-forms categories: The life-forms are according to the life-form system of Raunkiaer (1934) with subsequent extensions and amendments by Ellenberg & Mueller-Dobois (1967). As revealed during the process of our work, the hydrophytes and helophytes categories had a negligible contribution to endemism; therefore, they were both merged into the aquatic plant category. Life form abbreviations follow Dimopoulos & al. (2013) and make use of P for Phanerophytes, C for Chamaephytes, H for Hemicryptophytes, G for (non-aquatic) Geophytes, T for Therophytes and A for Aquatics. In cases that a taxon presents more than a single life form, the one of the mature plant (or best developed form) in Peloponnisos has been taken into consideration. If necessary, two life-forms per taxon were considered in our analyses.

Fruit type, type of diaspore and annual seed production: Fruits were classified as dry or fleshy, depending on whether a succulent layer of miscellaneous origin covers the seed/seed aggregate when ripe, or not. Fruits with a succulent hypanthium are considered fleshy. In the case of gymnosperms (no fruit present) the hard female cones of *Pinus*, *Abies* and *Cupressus* are considered dry, while the female cones of *Taxus*, *Juniperus* and *Ephedra* are considered fleshy. The diaspore may be a seed (or single seeded fruit such as an achene or a caryopsis) or a fruit (single or aggregated). Annual seed production refers to the average seed production per individual plant, per year (Tavşanoğlu & Pausas 2018). This can be estimated by knowing the number of ovaries per flower and the average number of flowers per plant, i.e., ignoring pollination or reproductive success. Four categories are recognized: no production (particularly in cases of vegetative propagation), few seeds (≤ 50), several seeds (50-500) and many seeds (> 500). For some taxa with a difficult estimation of annual seed production their herbarium specimens were consulted and in rare cases, some taxa were assigned to two categories and subject to separate analyses.

Pollination and dispersal modes: Pollination systems may be one or more for any given species. Following Faegri & Pijl (2016), taxa have been assigned to 4 main categories, i.e., anemogamous, entomogamous, autogamous or hydrogamous. For many plant taxa of Peloponnisos detailed knowledge on pollination syndromes is lacking. Flower morphology and the general instructions provided by Stebbins (1970) have been used to deduce main pollination syndrome.

Individual dispersal syndromes are those recognized by Tavşanoğlu & Pausas (2018) for the Mediterranean region. Literature records and access to BROT 2.0 (Tavşanoğlu &

Pausas 2018) and SID 7.1 (Royal Botanic Gardens Kew 2020) databases has been used for information extraction. In several cases, main dispersal mode for each taxon was decided by examining herbarium specimens in ATH and ATHU. Guidelines provided by Pijl (1982) and Bonn & al. (2000) were used for the assessment. Nine main dispersal syndromes are recognized: autochory (G), anemochory (W), hydrochory (H), ballistichory (B), myrmecochory (M), endozoochory (N), epizoochory (E), hoarding by animals (O), and zoochory (Z) for dispersal mediated by animals in an unknown way. Attributing a main dispersal mode to the whole Peloponnisos flora (more than 3,000 taxa) left several unresolved cases that currently do not permit handling of the dataset as a whole. However, pollination and dispersal modes have been used in particular taxonomic groups to trace tendencies among endemic and widespread taxa categories.

Habitats: Two different approaches were used: a) habitat preference for each taxon according to Dimopoulos & al. (2013). The categories have as follows: freshwater aquatic habitats (A); cliffs, rock faces and walls (C); temperate and Mediterranean grasslands (G); above treeline vegetation on high mountains (H); marine and coastal habitats influenced by salt (M); xeric Mediterranean phrygana and grasslands (P); agricultural and ruderal habitats (R); woodland and scrub (W). When a taxon is found in more than one habitats, different analyses took into consideration its predominant habitat, or its more than one recorded habitats. b) Habitat preference according to the European EUNIS habitat types at various levels (downloaded from: https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification). In this latter approach important information had to be retrieved from the literature and also, from specimen labels maintained in ATH and ATHU herbaria and databases. Still, some gaps in knowledge do not permit a direct analysis of the whole set of results, at present.

Results

Peloponnisos comprises 3,007 autochthonous spermatophyte taxa (species and subspecies, see Electronic Supplementary file 1), which constitute almost half of the Greek flora. This number does not include aliens or cultivated plants escaped from man-made habitats and pteridophytes that differ from spermatophytes in important biological aspects. We recorded 475 taxa as Greek endemics, including 4 Greek endemic genera: *Hymenonema* (see Liveri & al. 2018), *Laserocarpum* (Spalik & al. 2019), *Thamnosciadium* and *Phitosia* (Fig. 2). The latter, *Phitosia*, is the only genus exclusively endemic to Peloponnisos and distributed on two mountains to the south: Taigetos and Parnonas (Kamari & al. 2010). The number of range restricted taxa present in the flora of Peloponnisos is 518, higher by 43 taxa from the number of Greek endemics. The number of local endemics is also notable: 77 taxa have a very narrow distribution that does not exceed a linear distance of c. 50 km.

The richest families in Greek endemic, range restricted, and local endemic taxa of the Peloponnesian flora are somewhat irregularly distributed among the total flora. In decreasing order, high numbers are found in *Asteraceae* (83, 92 and 14 taxa, respectively), *Caryophyllaceae* (55, 62, 6), *Lamiaceae* (39, 42, 6), *Brassicaceae* (23, 26, 3) and *Rubiaceae* (22, 23, 3). *Asteraceae* and *Caryophyllaceae* have the highest number of taxa

Fig. 2. Three endemic genera in the flora of Peloponnisos: A, *Hymenonema* with *H. laconicum* Boiss. & Heldr.; B, *Thamnosciadium* with *Th. junceum* (Sm.) Hartvig, monotypic; C, *Phitosia* with *Ph. crocifolia* (Boiss. & Heldr.) Kamari & Greuter, monotypic.

in all categories and are among the most species-rich families of the Greek flora. *Poaceae*, the second richest family of the Greek flora, presents rather low numbers of Greek endemic, range restricted and local endemic taxa (11, 13, 1, respectively).

An analysis of the life form categories reveals some noteworthy results (Fig. 3). In the widespread flora, the therophyte category predominates with 989 taxa being annuals or chiefly annuals (39.7%), followed by the hemicryptophytes (31.4%, 781 taxa) and the geophytes (13.1 %, 326 taxa). The lowermost percentage (1.7%) is attributed to the aquatic plants, with 42 taxa. In the endemic and range restricted categories, the percentages change remarkably, compared to the widespread taxa. Here, the percentage of therophytes drops to 10.8% (for the range restricted category) and the percentage of hemicryptophytes rises to 54.6%. Geophytes remain, correspondingly, almost unaltered (14.5% in the range restricted category). The chamaephyte percentage increases by 3 times (18.4%) and the aquatic plants nullify. Changes become even more dramatic among the local endemics with only one therophyte (1.3%), 46 hemicryptophytes (59.8%), 18 chamaephytes (23.4%) and 10 geophytes (13.0%). Two taxa are phanerophytes (2.6%).

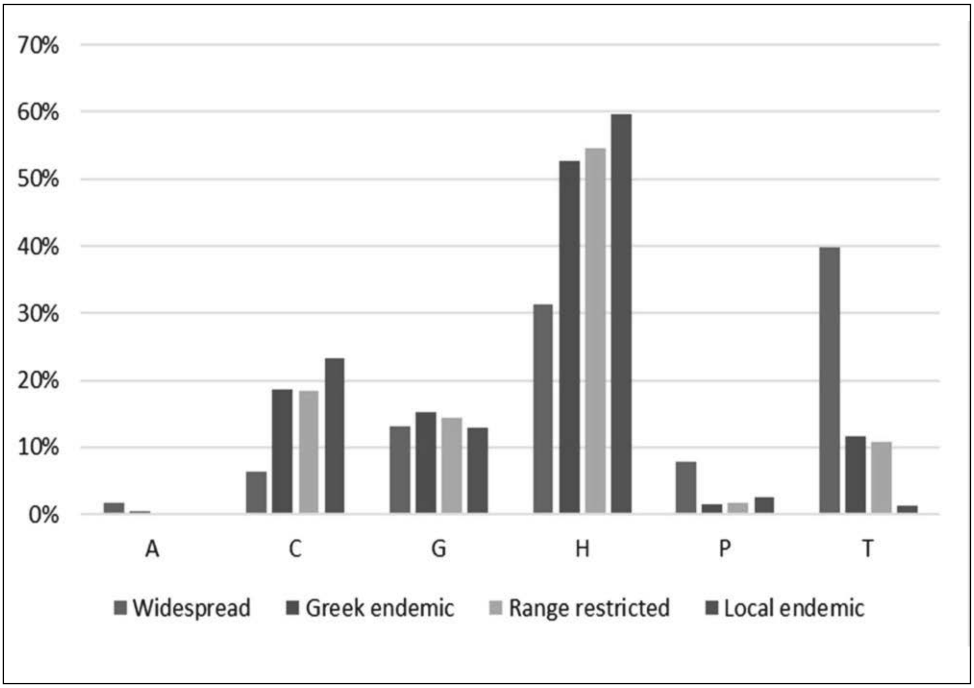

Fig. 3. Percentage of life form groups in each of the four chorological categories of the Peloponnisos flora. The abbreviations mean aquatic plants (A), chamaephytes (C), geophytes (G), hemicryptophytes (H), phanerophytes (P), and therophytes (T). Therophytes predominate in the widespread taxa (39.7%) but their percentage diminishes in the Greek endemic (11.6%), range restricted (10.8%), and especially local endemic (1.3%) categories, where the dominant life form are the hemicryptophytes (52.7%, 54.5% and 59.7% respectively).

The fruit type is an important character and may affect dispersal modes and distances. In the flora of Peloponnisos, the fleshy fruit type is rare, accounting for 6.2% among the widespread taxa, 1.3% among the Greek endemics and 1.2% among the range restricted taxa. Within local endemics, the percentage is remarkably similar to that of the Greek endemics and the range restricted taxa, and remains stable to 1.3%. As a consequence of the above, the dry fruit types are widespread in all life form categories and certainly dominant within the endemic, range restricted and local endemic categories.

The diaspore categories were examined somewhat complementary to the fruit type and the number of annual seed production. The two categories, i.e., a seed or a dry/monospermous fruit vs. a single or an aggregate fruit (polyspermous, as a rule) were evaluated in all chorological categories. The seed characterizes 1671 taxa of the widespread flora (67.6%) and the fruit 802 (32.4%). These percentages shift towards the seed category in the Greek endemic (83.5%), range restricted (84.9%), and local endemic (84.4%) chorological groups (Fig. 4). That means that the seed diaspore is approximately 5 times more common than the fruit among the chorologically restricted taxa vs. 2 times more common than the fruit among the widespread taxa.

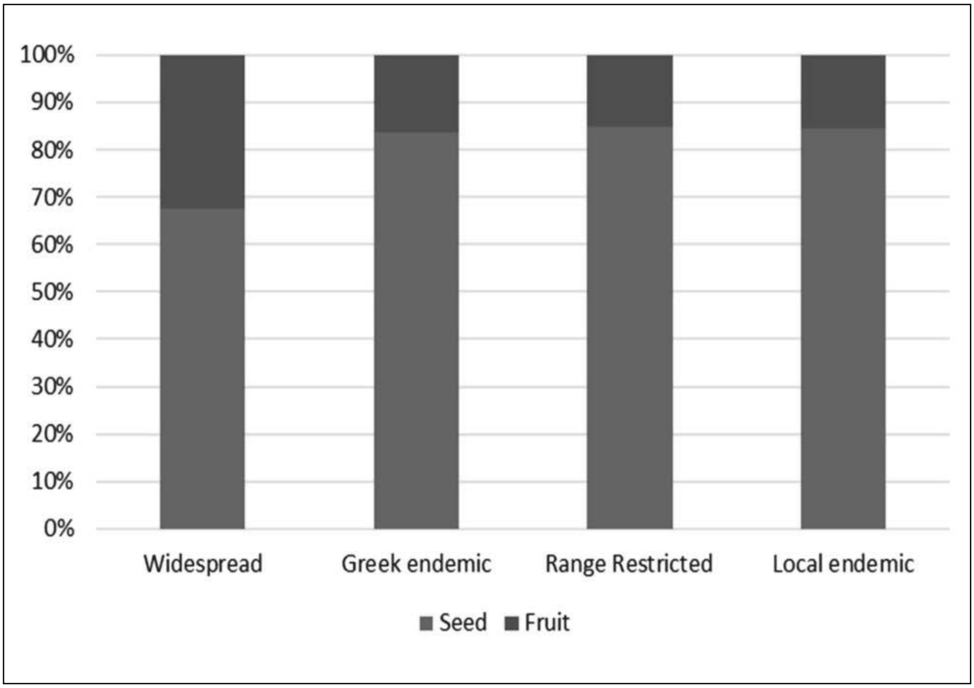

Fig. 4. The seed is the most common diaspore in the flora of Peloponnisos. The percentage of taxa developing and releasing a seed-type diaspore is 67.6% among the widespread taxa and between 83.5 to 84.9% in the Greek endemic, range restricted and local endemic categories.

Annual seed production was evaluated for practically all the taxa of Peloponnisos, yet we are aware that this parameter may, at least partly, be influenced by climate oscillations, soil fertility and plant development, during any period of years. Our estimations show that annual seed production percentages do not vary much among the widespread and the restricted taxa. The widespread taxa produce few (16.0%), a medium quantity (65.9%) and many (18.1%) seeds. Within the taxa of limited distribution the percentages are 18.0%-24.7% for the few seed category, 59.7%-62.1% for the medium quantity and 15.6%-19.9% for the many seed category.

Pollination and dispersal modes have been used rather selectively, in a few analyses at present. Information on plants dispersal modes for the flora of Peloponnisos is scarce and presumably not always trustworthy. Some preliminary experiments with *Biarum* sp. (a geophyte) and *Centaurea sonchifolia* L. (a hemicryptophyte) in cultivation indicate the presence of two dispersal modes in each taxon (a dual dispersal pattern, diplochory, e.g., autochory and myrmecochory, autochory and hydrochory, see Vander Wall & Longland (2004). In the case of *C. sonchifolia* the presence of a fruit appendage (a pappus, indicative of anemochory) is counteracted by the fruit mass. These heavy fruits present autochory rather than anemochory but other secondary dispersal mechanisms are also possible (Der Weduwen & Ruxton 2019). Likewise, we observed autochory and possible myrmecochory in *Biarum*. In this latter case, the estimation of seed dispersal distances (see Vittoz & Engler 2007) as revealed by the emergence of new seedlings over a period of three years varies from 8 to 190 cm.

In order to correlate chorology with a particular dispersal mode we have selected myrmecochory in three unrelated genera that possess an elaiosome in their seed (see Gorb & Gorb 2003): *Crocus, Euphorbia* and *Viola.* Numbers of taxa and distribution of chorological categories appear to be random, with *Crocus* and *Viola* (but not *Euphorbia*) comprising several Greek or local endemics (Fig. 5).

Habitats in relation to the four chorological categories appear in Fig. 6. Grasslands, ruderal habitats and phrygana comprise the highest numbers of widespread taxa in the flora of Peloponnisos. In the Greek endemic and range restricted categories the cliffs, grasslands and phrygana habitats harbour most of the endemics, with the ruderal habitats contributing in lower numbers. Among local endemics, the highest number of taxa is found in cliff habitats, with phrygana and above treeline habitats on mountains contributing with smaller taxa numbers. Interestingly, aquatic habitats have a zero number of local endemics, while ruderal habitats have a small contribution, both among the range restricted and the local endemics but not among taxa of the widespread category, where their contribution is considerable. Fig. 6 depicts the percentages of habitat contributions to the four chorological

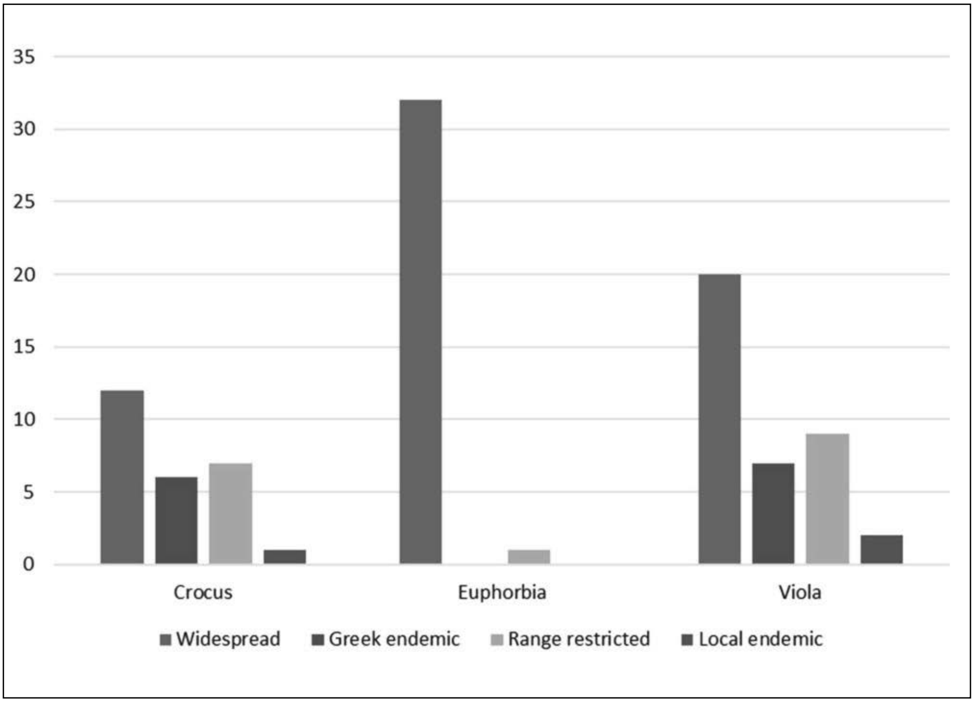

Fig. 5. The numbers of widespread, Greek endemic, range restricted, and local endemic taxa in three random entomophilous and myrmecochorous genera of Peloponnisos (*Crocus*, *Euphorbia*, *Viola*) vary considerably.

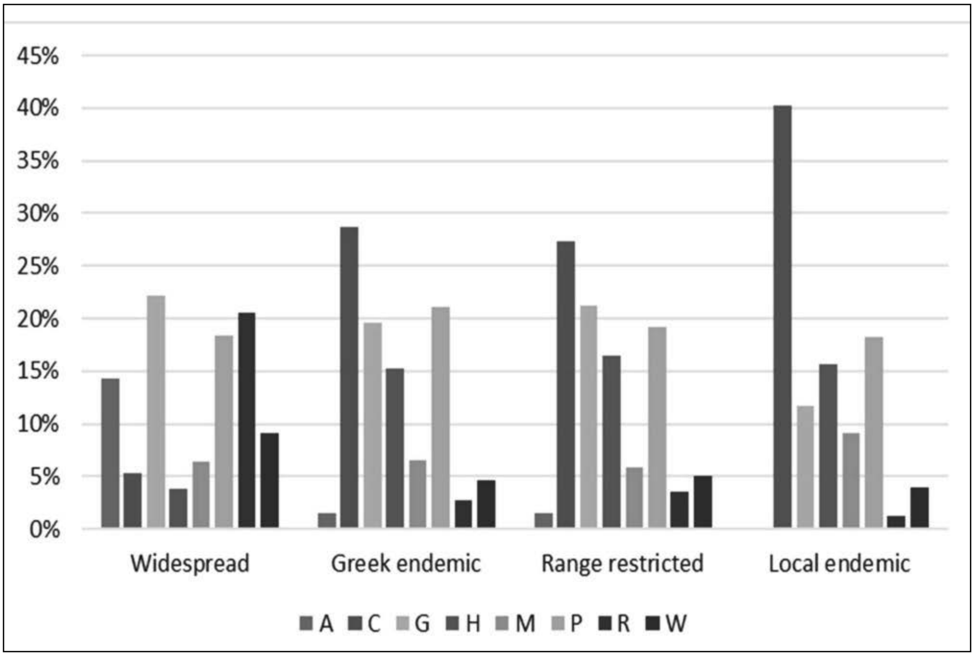

Fig. 6. Shifts in habitats appear in this comparative presentation for members of the four chorological categories. Notice the significant percentage changes in aquatic (A, 0.0% to 14.3%), cliffs and rocks (C, 5.3% to 40.3%) and ruderal (R, 1.3% to 20.6%) habitats as opposite to the relative stability of the coastal (M, 6.3% to 9.1%) and phrygana (P, 18.2% to 21.1%) habitats. For the abbreviations see also under Habitats in Materials and Methods.

categories. Note the shifts of the cliff and rock habitat (small contribution in the widespread, large or very large in the remaining chorological categories) and the aquatic habitat, as indicated above. In contrast, the phrygana and the coastal habitats have a rather stable contribution in all four groups.

Discussion and conclusions

Endemism and the factors that drive particular plant species to exhibit narrow distribution areas have been studied using various approaches. Environmental factors (e.g., altitude, geological substrate, rainfall, anthropogenic disturbance) have been usually analyzed to comprehend the ecological behavior and the present-day distribution patterns of endemic plants in the Mediterranean (Casazza & al. 2005; Trigas & al. 2013; Tomović & al. 2014; Fois & al. 2017). The necessity to understand biological and ecological factors that interfere with the distribution and maintenance of endemic plant taxa is currently even more pronounced since many of them are threatened and in need of conservation actions.

The endemic spermatophyte flora of Peloponnisos has been estimated here at three different levels: the Greek endemic flora (border-dependent) accounts for 15.8% of the total, the range restricted flora (border-independent) accounts for 17.2%, and the very localized endemic flora for 2.6%. Given the dynamic nature of the alien flora and its dissociation with endemism, all its Peloponnesian members have been excluded from analyses. An evaluation and comparison of life form patterns among the three endemic plant categories versus the widespread flora reveals a significant deviation from the norm: therophytes in all endemic chorological categories contribute to the life form spectra significantly less than the expected c. 25-50% found in the Mediterranean region. Local endemics exhibit the lowermost percentage. Low levels of annual taxa contribution to the endemicity assemblage has also been observed in the whole Greek flora (Dimopoulos & al. 2013) and in other Mediterranean countries as well (Amich & al. 2004; Giménez & al. 2004). Interpretations of this low percentage take into account the habitat preferences and the rainfall gradient of habitats where endemic taxa predominate: rocky environments and cliffs present a low percentage of therophytes but a high number of endemics (Panitsa & Kontopanou 2017; this study). Presumably, the weak root system of therophytes does not enable them withstand wind blowdowns and/or reach available water resources under the extreme conditions prevailing on cliffs (see Georghiou & Delipetrou 2010). An increased percentage of endemic plants at the above-treeline habitats on high mountains is correlated with increased precipitation levels and lower selection pressures to adopt an annual life form. In the south of Spain, therophytes, as opposite to hemicryptophytes, exhibit an inverse altitudinal distribution pattern: their rate tends to decrease as altitude increases. They present a clear positive correlation with the thermomediterranean belt and a negative correlation with the oromediterranean belt (Giménez & al. 2004). An investigation in Israel points to an optimum between 200 and 500 mm average mean annual rainfall for therophytes (Danin & Orshan 1990). For the same reasons (i.e., rocky habitat specialization, above treeline areas colonization with high precipitation, robust root system), the percentage of hemicryptophytes and chamaephytes among Mediterranean endemic plants is generally high (see also Vuksanović & al. 2016 for a study in Montenegro).

As a rule, plants of Peloponnisos do not produce fleshy fruits and this is even more pronounced in its endemic flora. Fleshy fruits are correlated to frugivory, i.e., fruit consumption by birds and mammals, which later on act as the major vertebrate seed dispersers in most terrestrial habitats (endozoochory). The very low percentage of fleshy fruit production among the endemic plants of Peloponnisos (1.2-1.3% versus 6.2% among the widespread category) may be an indication of low evolutionary mutualisms between endozoochorous plants and seed dispersers. The frugivorous animals that do exist in Peloponnisos may contribute in a general, unspecialized manner to fruit dispersal and endemic plants are less adapted to such a syndrome. This combines well with the main diaspore unit, which is the seed (or dry monospermous fruit), not the fruit, among the endemic categories. Furthermore, fleshy fruits are mostly produced in families of woody plants; families that are primarily herbaceous produce capsular or other kinds of dry fruits (Fleming & Kress 2011). Phanerophytes that exhibit fleshy fruits are rare among each chorological group of the endemics, with only a few taxa, 2 to 9, belonging to this life form category. Moreover, it appears that the Mediterranean fruit-bearing plants did not evolve any particular mutualistic behavior to benefit from animal dispersers. According to Herrera (1995), with respect to birds, variation in fruiting phenology, fruit shape, nutritional composition of fruits, and structural fruit characteristics in Mediterranean plants are more closely tied to phylogeny or to the abiotic environment than to the current disperser/dispersal prerequisites. Such a lack of disperser/dispersal specificity is apparently maintained among the endemic plants of Peloponnisos.

A comparison of annual seed production did not reveal any noteworthy differences among widespread taxa and any of the chorologically restricted groups, at the scale level examined. Number of seeds produced, per plant per year, can perhaps affect population size, particularly in annual plants that spend considerable time as dormant propagules in edaphic seedbanks. Seed mass, on the other hand, may have a critical role in dispersal distances and population expansion. Our collected data on seed mass is preliminary and does not allow comparison between widespread and local taxa, at present. Nevertheless, experiments by Lavergne & al. (2003) in southern France conducted across 13 pairs of rock endemic species and widespread congeners failed to show any statistically significant difference in seed mass between the two groups.

Pollination and particularly dispersal modes have been the most challenging biological traits we examined in this study. Soon after realizing the low number of studies on dispersal traits in Greek plants, we came across a number of parameters we had to assess in the field and in the laboratory and often combine, in order to decide on dispersal strategies. As we currently understand and despite maintaining the basic dispersal categories of Tavşanoğlu & Pausas (2018), things appear to be more complicate in nature. Hintze & al. (2013) developed the D^3, the Dispersal and Diaspore Database (to which we had no access), to quantify rather than qualify the adaptation to dispersal modes for any given taxon. Our first approaches using simple morphological characters of seed (shown in Fig. 5) or fruit (anemochory vs. barychory vs. zoochory in *Apiaceae*, not shown) failed to reveal differences among widespread and local taxa in their dispersal modes. Still, we feel that more than one parameters have to be added to simple histograms like the one of Fig. 5, before deciding about their usefulness in revealing traits. For example, the addition of seed mass would be a critical and decisive character for Fig. 5, in case that data were available for all the Peloponnesian members of the three genera. Interestingly, Gabrielová & al. (2013) found differences between Critically Endangered taxa (CR - many highly threatened species are local endemics in Greece) and common species in their mode of dispersal, in the Czech Republic. According to their results, epizoochory and hydrochory dispersal modes had a significantly higher proportion, while endozoochory and hemerochory a lower proportion, in the CR species, when compared to common species.

Finally, different habitats have been analyzed in relation to different chorological categories and important traits have been observed in this study. Most plants in the endemic categories grow on cliffs and rocky slopes, ravines and walls. For local endemics, the percentage of taxa behaving as cliff dwellers reaches 40.3%. Apart from the shift in life forms, which is partly correlated with rocky habitats, the endemic taxa clearly prefer habitats with a higher percentage of bedrock and block cover and grow on significantly steeper slopes than their widespread congeners. Cliffs and rocky places in the Mediterranean generally have a lower cover of herbaceous and woody species, a smaller number of coexisting species, and a significantly lower vegetation canopy height than habitats of widespread species (Thomson & al. 2005; observations in the western Mediterranean). The cliffs and rocks environment is also related to plant competition, which may be less intense in rocky habitats, and a refugium role, present in many rock systems and cliffs in Greece and the Mediterranean (e.g., Kypriotakis & Tzanoudakis 2001). Important parameters of the chasmophytic Greek flora are presented by Panitsa & Kontopanou (2017). The second important habitat, phrygana and xeric land, has an almost similar proportion among widespread taxa and the three categories of endemic taxa. The third most important habitat, high-mountain vegetation, is related to the isolation found on the above treeline areas on high mountains and its contribution is significant in the endemic categories. The way elevation gradient shapes endemism in Kriti Island, just south of Peloponnisos, is presented by Trigas & al. (2013).

The most important conclusions of this study focused on biological traits, habitat preferences and endemism in the flora of Peloponnisos are the following: a) groups of narrow distributed taxa have different life form spectra compared to widespread taxa or the total flora. Hemicryptophytes and chamaephytes prevail among endemics, whereas therophytes contribute with low percentages; b) fleshy fruits are very rare among the endemic categories and contribute to an even lower percentage as plant diaspores, compared to widespread taxa; c) annual seed production is rather similar, among widespread and narrowly distributed taxa; d) dispersal modes are complicate and need further study. Several different parameters should be evaluated and analyzed, before safe conclusions regarding widespread and local taxa are reached; e) habitat shifts are observed among endemics and local endemics, compared to widespread taxa. More than 40% of the local endemic flora behaves as rock and cliff dwellers, a fact that stresses the importance of these habitats as conservation targets.

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References

Amich, F., Bernardos, S., Aguiar, C., Fernández-Diez, J. & Crespí, A. 2004: Taxonomic composition and ecological characteristics of the endemic flora of the lower Duero Basin (Iberian Peninsula). – Acta Bot. Gall. **151(4):** 341-352. https://doi.org/10.1080/12538078.2004.10515439

Balmford, A. & Cowling, R. M. 2006: Fusion or failure? The future of conservation biology. – Conserv. Biol. **20(3):** 692-695. https://doi.org/10.1111/j.1523-1739.2006.00434.x

Bevill, R. L. & Louda, S.M. 1999: Comparisons of related rare and common species in the study of plant rarity. – Conserv. Biol. **13(3):** 493-498. https://doi.org/10.1046/j.1523-1739.1999.97369.x

Bonn, S., Poschlod, P. & Tackenberg, O. 2000: Diasporus – a database for diaspore dispersal-concept and applications in case studies for risk assessment. – Z. Ökol. Umweltschutz **9:** 85-97.

Casazza, G., Barberis, G. & Minuto, L. 2005: Ecological characteristics and rarity of endemic plants of the Italian Maritime Alps. – Biol. Conserv. **123(3):** 361-367.

Danin, A. & Orshan, G. 1990: The distribution of Raunkiaer life forms in Israel in relation to the environment. – J. Veg. Sci. **1:** 41-48. https://doi.org/10.1016/j.biocon.2004.12.005

Der Weduwen, D. & Ruxton, G. D. 2019: Secondary dispersal mechanisms of winged seeds: a review. – Biol. Rev. **94(5):** 1-9. https://doi.org/10.1111/brv.12537

Díaz, S., Kattge, J., Johannes Cornelissen, H. C. J., Wright, I. J., Lavorel, S., Dray, S., Reu, B., Kleyer, M., Wirth, C., Prentice, I. C., Garnier, E., Bönisch, G., Westoby, M., Poorter, H., Reich, P. B., Moles, A. T., Dickie, J., Gillison, A. N., Zanne, A. E., Chave, J., Wright, S. J., Seremet'ev, S. N., Jactel, H., Baraloto C., Cerabolini, B., Pierce, S., Shipley, B., Kirkup, D., Casanoves, F., Joswig, J. S., Günther, A., Falczuk, V., Rüger, N., Mahecha, M. D. & Gorné, L. D. 2016: The global spectrum of plant form and function. – Nature **529:** 167-171. https://doi.org/10.1038/nature16489

Dimopoulos, P., Raus, Th., Bergmeier, E., Constantinidis, Th., Iatrou, G., Kokkini, S., Strid, A. & Tzanoudakis, D. 2013: Vascular plants of Greece: an annotated checklist. – Englera **31.**

—, —, —, —, —, —, — & — 2016: Vascular plants of Greece: an annotated checklist. Supplement. – Willdenowia **46:** 301-347.

Ellenberg, H. & Mueller-Dombois, D. 1967: A key to Raunkiar plant life forms with revised subdivisions. – Ber. Geob. Inst. ETH Rübel, Zürich **37:** 56-73.

Faegri, K. & Pijl van der, L. 2016: Principles of pollination ecology. – Oxford.

Farnsworth, E. J. 2007: Plant life history traits of rare versus frequent plant taxa of sandplains: implications for research and management trials. – Biol. Conserv. **136(1):** 44-52. https://doi.org/10.1016/j.biocon.2006.10.045

Fleming, T. H. & Kress, W. J. 2011: A brief history of fruits and frugivores. – Acta Oecol. **37:** 521-530. https://doi.org/10.1016/j.actao.2011.01.016

Fois, M., Fenu, G., Cañadas, E. M. & Bacchetta, G. 2017: Disentangling the influence of environmental and anthropogenic factors on the distribution of endemic vascular plants in Sardinia. – PLoS ONE **12(8):** e0182539. https://doi.org/10.1371/journal.pone.0182539

Gabrielová, J., Münzbergová, Z., Tackenberg, O. & Chrtek, J. 2013: Can we distinguish plant species that are rare and endangered from other plants using their biological traits? – Folia Geobot. **48:** 449-466. https://doi.org/10.1007/s12224-012-9145-x

Gaston, K. J. 1998: Rarity as double jeopardy. – Nature **394:** 229-230. https://doi.org/10.1038/28288

— 2003: The structure and dynamics of geographic ranges. – New York.

Georghiou, K. & Delipetrou, P. 2010: Patterns and traits of the endemic plants of Greece. – Bot. J. Linn. Soc. **162(2):** 130-153. https://doi.org/10.1111/j.1095-8339.2010.01025.x

Giménez, E., Melendo, M., Valle, F., Gómez-Mercado F. & Cano, E. 2004: Endemic flora biodiversity in the south of the Iberian Peninsula: altitudinal distribution, life forms and dispersal modes. – Biodivers. Conserv. **13:** 2641-2660. https://doi.org/10.1007/s10531-004-2140-7

Gorb, E. & Gorb, S. (eds) 2003: Seed dispersal by ants in a deciduous forest ecosystem – Dordrecht.

Herrera, C. M. 1995: Plant-vertebrate seed dispersal systems in the Mediterranean - ecological, evolutionary, and historical determinants. – Ann. Rev. Ecol. Syst. **26:** 705-727. https://doi.org/10.1146/annurev.es.26.110195.003421

Hintze, C., Heydelb, F., Hoppe, C., Cunzea, S., König, A. & Tackenberg, O. 2013: D^3: The dispersal and diaspore database – baseline data and statistics on seed dispersal. – Perspect. Pl. Ecol. Evol. Syst. **15:** 180-192. https://doi.org/10.1016/j.ppees.2013.02.001

Hobohm, C. (ed.) 2014: Endemism in vascular plants. – Dordrecht, Heidelberg, New York & London.

Kalpoutzakis, E., Constantinidis, Th., Trigas, P. 2019: Chorological additions for some noteworthy taxa of the Greek flora. – Bot. Chron. **22:** 233-249.

Kamari, G., Kyriakopoulos, C. & Kofinas, C. 2010: New finding of *Phitosia crocifolia* (*Compositae*) in E Peloponnisos. – Fl. Medit. **20:** 235-238.

Keppel, G., Ottaviani, G., Harrison, S. Wardell-Johnson, G. W., Marcantonio M. & Mucina, L. 2018: Towards an eco-evolutionary understanding of endemism hotspots and refugia. – Ann. Bot. **122(6):** 927-934. https://doi.org/10.1093/aob/mcy173

Kypriotakis, Z. & Tzanoudakis, D. 2001: Contribution to the study of the Greek insular flora: the chasmophytic flora of Crete. – Bocconea **13:** 495-503.

Lamoreux, J. F., Morrison, J. C., Ricketts, T. H., Olson, D. M., Dinerstein, E., McKnight, M. W. & Shugart, H. H. 2006. Global tests of biodiversity concordance and the importance of endemism. – Nature **440:** 212-14. https://doi.org/10.1038/nature04291

Lavergne, S., Garnier, E. & Debussche, M. 2003: Do rock endemic and widespread plant species differ under the leaf-height-seed plant ecology strategy scheme? – Ecol. Lett. **6:** 398-404. https://doi.org/10.1046/j.1461-0248.2003.00456.x

—, Thompson, J. D., Garnier, E. & Debussche, M. 2004: The biology and ecology of narrow endemic and widespread plants: a comparative study of trait variation in 20 congeneric pairs. – Oikos **107(3):** 505-518. https://doi.org/10.1111/j.0030-1299.2004.13423.x

Liveri, E., Bareka, P. & Kamari, G. 2018: Taxonomic study on the Greek endemic genus *Hymenonema* (*Asteraceae*: *Cichorieae*), using morphological and karyological traits. – Willdenowia **48:** 5-21. https://doi.org/10.3372/wi.48.48101

Médail, F. & Quezél, P. 1997: Hot-spots analysis for conservation of plant biodiversity in the Mediterranean Basin. – Ann. Missouri Bot. Gard. **84(1):** 112-127. https://doi.org/10.2307/2399957

— & — 1999: Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. – Conserv. Biol. **13(6):** 1510-1513. https://doi.org/10.1046/j.1523-1739.1999.98467.x

Melendo, M., Giménez, E., Cano, E., Gómez-Mercado, F. & Valle, F. 2003: The endemic flora in the south of the Iberian Peninsula: taxonomic composition, biological spectrum, pollination, reproductive mode and dispersal. – Flora **198:** 260-276. https://doi.org/10.1078/0367-2530-00099

Murray, B. P., Thrall, P. H., Gill, A. M. & Nicotra, A. B. 2002: How plant life-history and ecological traits relate to species rarity and commonness at varying spatial scales. – Austral. Ecol. **27(3):** 291-310. https://doi.org/10.1046/j.1442-9993.2002.01181.x

Panitsa, M. & Kontopanou, A. 2017: Diversity of chasmophytes in the vascular flora of Greece: floristic analysis and phytogeographical patterns. – Bot. Serb. **41(2):** 199-211.

Pijl van der, L. 1982: Principles of dispersal in higher plants. – Berlin & Heidelberg.

Raab-Straube E. von & Raus Th. (eds) 2017a: Euro Med-Checklist Notulae, 7 – Willdenowia **47(1):** 89-96.

— & — (eds) 2017b: Euro Med-Checklist Notulae, 8. – Willdenowia **47(3):** 293-309.

— & — (eds) 2018: Euro Med-Checklist Notulae, 9. – Willdenowia **48(2):** 195-220.

— & — (eds) 2019a: Euro Med-Checklist Notulae, 10. – Willdenowia **49(1):** 95-115.

— & — (eds) 2019b: Euro Med-Checklist Notulae, 11. – Willdenowia **49(3):** 421-445.

Raunkiaer, C. 1934: The life forms of plants and statistical plant geography. – Oxford.

Royal Botanic Gardens Kew. (2020) Seed Information Database (SID). Version 7.1. Available from: http://data.kew.org/sid/ (February 2020)

Spalik, K., Wojewódzka, A., Constantinidis, Th., Downie, S. R., Gierek, M. & Banasiak, Ł. 2019: *Laserocarpum*, a new genus of *Apiaceae* endemic to Greece. – Acta Soc. Bot. Pol. **88(3):** 3635. https://doi.org/10.5586/asbp.3635

Stebbins, G. L. 1970: Adaptive radiation of reproductive characteristics in angiosperms, I: pollination mechanisms. – Ann. Rev. Ecol. Syst. **1(1):** 307-326. https://doi.org/10.1146/annurev.es.01.110170.001515

Strid, A. & Tan, K. (eds) 1997: Flora hellenica, **1.** – Konigstein

— & — 2017: Recent progress in plant taxonomy and floristic studies in Greece. – Bot. Serbica **41(2):** 123-152.

Tan, K. & Iatrou, G. 2001: Endemic plants of Greece - the Peloponnese. – Copenhagen.

Tavşanoğlu, C. & Pausas, J. 2018: A functional trait database for Mediterranean Basin plants. – Sci. Data **5:** 180135. https://doi.org/10.1038/sdata.2018.135

Thomson, J. D., Lavergne, S., Affre, L., Gaudeu, M., & Debussche1, M. 2005: Ecological differentiation of Mediterranean endemic plants. – Taxon **54(4):** 967-976. https://doi.org/10.2307/25065481

Tomović, G., Niketić, M., Lakušić, D., Ranđelović, V. & Stevanović, V. 2014: Balkan endemic plants in Central Serbia and Kosovo regions: distribution patterns, ecological characteristics, and centres of diversity. – Bot. J. Linn. Soc. **176:** 73-202. https://doi.org/10.1111/boj.12197

Trigas, P., Panitsa, M. & Tsiftsis, S. 2013: Elevational gradient of vascular plant species richness and endemism in Crete – the effect of post-isolation mountain uplift on a continental island system. – PLoS ONE **8:** e59425. https://doi.org/10.1371/journal.pone.0059425

—, Tsiftsis, S., Tsiripidis, I. & Iatrou, G. 2012: Distribution patterns and conservation perspectives of the endemic flora of Peloponnese (Greece). – Folia Geobot. **47(4):** 421-439. https://doi.org/10.1007/s12224-012-9130-4

Vander Wall, S. & Longland, W. S. 2004: Diplochory: are two seed dispersers better than one? – Trends Ecol. Evol. **19(3):** 155-161. https://doi.org/10.1016/j.tree.2003.12.004

Vittoz, P. & Engler, R. 2007: Seed dispersal distances: a typology based on dispersal modes and plant traits. – Bot. Helv. **117:** 109-124. https://doi.org/10.1007/s00035-007-0797-8

Vladimirov, V., Aybeke, M., Matevski, V. & Tan, K. (comps.) 2017a: New floristic records in the Balkans: 34. – Phytol. Balcan. **23(3):** 413-444.

—, Aybeke, M. & Tan, K. (comps.) 2017b: New floristic records in the Balkans: 32. – Phytol. Balcan. **23(1):** 119-146.

—, — & — (comps.) 2018a: New floristic records in the Balkans: 35. – Phytol. Balcan. **24(1):** 155-174.

—, — & — (comps.) 2018b: New floristic records in the Balkans: 36. – Phytol. Balcan. **24(2):** 263-292.

—, — & — (comps.) 2019: New floristic records in the Balkans: 40. – Phytol. Balcan. **25(3):** 295-335.

Vuksanović, S., Tomović, G., Niketić, M. & Stevanović, V. 2016: Balkan endemic vascular plants of Montenegro – critical inventory with chorological and life-form analyses. – Willdenowia **46:** 387-397. https://doi.org/10.3372/wi.46.46307

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Short note

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Erwin Bergmeier & Stefan Meyer

Lactuca aculeata (*Asteraceae*), a crop wild relative new to Europe

Abstract

Bergmeier, E. & Meyer, S.: *Lactuca aculeata* (*Asteraceae*), a crop wild relative new to Europe. — Fl. Medit. 31: 53-58. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The wild lettuce, *Lactuca aculeata*, a close relative of the widespread *L. serriola* and the cultivated lettuce *L. sativa*, has been found on the islands of Limnos and Lesbos (North Aegean region, Greece). The new records are the westernmost of this East Mediterranean taxon and represent the first ones for the Aegean and Europe. Along with locality data, we provide information on habitat preferences and co-occurring species.

Key words: Aegean, crop wild relative, Greece, floristics, stubble fields.

Introduction

Lactuca aculeata Boiss. & Kotschy (*Asteraceae*) belongs to a group of species taxonomically most closely related to the cultivated lettuce *L. sativa* L. (Zohary 1991). The distribution of *L. aculeata* as far as known so far includes parts of northern, central, southern and chiefly eastern Turkey (Güzel, pers. comm.) and the Near East (Syria, North Israel, northern Iraq, north-western Iran). Cohen & Liston (1986) and Zohary (1991) presented distribution maps of the scattered records.

L. aculeata is similar to the widespread *L. serriola* L. but differs in its stem which is aculeate throughout (instead of being prickly only at base) and in its leaves which are setulose on both surfaces above and beneath. Cohen & Liston (1986) provide an instructive detailed drawing of the plant, and diagnostic photos can be found on the Online Flora of Israel website (Danin & Fragman-Sapir 2016+).

The present paper informs about our new records of *L. aculeata* on the North Aegean islands of Limnos and Lesbos, west of the known distribution range. The morphology, habitat and species composition of the new populations are also defined.

Material and methods

This study is a by-product of the Terra Lemnia project, which aims to conserve and promote sustainable, traditional agro-pastoral practices on the island of Limnos (https://terra-lemnia.net/en/). Autumnal vegetation sampling on the island of Limnos (North Aegean, Greece) and, less extensively, on Lesbos (East Aegean) provided evidence of a number of new members of the local floras. The field surveys took place in mid-October 2019 and repeatedly from around the turn of September till November 2020. We studied the vegetation by plot-wise sampling of late-seasonal vegetation in favourable condition and collected representative plants for further examination. Among others, we collected a total of nine relevés with *L. aculeata*, five on Limnos and four on Lesbos. Plant specimens collected by Erwin Bergmeier are currently stored in the author's private herbarium (herb. EB) and those of Stefan Meyer will be incorporated in the herbarium collections of the National and Kapodistrian University of Athens (ATHU).

Results and discussion

Lactuca aculeata was found in small numbers in various sites in the central and chiefly eastern parts of Limnos, and scattered on Lesbos in the south near the Gulf of Kalloni. The plants found are robust overwintering biennials, or spring-germinating annuals, erect up to 170 cm (Fig. 1). The whitish stem is variously densely aculeate throughout up to the synflorescence. The stem-leaves are obovate-oblong, usually shorter and broader than in *L. serriola*, glaucous, rigid, spinous-ciliate on both sides; mostly unlobed, entire or denticulate, they resemble *L. serriola* f. *integrifolia* (S.F. Gray) S.D. Prince & R.N. Carter, unlike the lobed or pinnatifid leaves as in the common *L. serriola* f. *serriola*. The lower leaves are cordate-semiamplexicaul at base with auricles; the mid-rib is strongly spinose-setose. As in *L. serriola*, the stem-leaves are often held vertically. The synflorescence is a more or less elongate pyramidal panicle, with appressed auricled bracts. The involucre in the examined plants is 8-12 mm long, its bracts are glabrous and usually violet-tinged. Flowers are pale yellow (only late flowering seen). Ripe achenes are compressed, ribbed, 3.5-4.5 mm, with several pale bristles near apex, abruptly contracted into a pale beak 3-4 mm, and with pappus of simple white hairs to 7 mm.

Specimens and observations

Limnos, between Kalliopi and Keros Beach, 39°54.5'N 25°20.5'E, 10 m. Edge of stubble. 2019-10-16, *Bergmeier 19-464* (herb. EB).

Limnos, between Ag. Dimitrios and Atsiki, 39°54.512'N 25°10.736'E and 39°54.516'N 25°10.703'E, 65 m. Edge of vineyard. 2020-09-27, *Bergmeier 20-48* (EB).

Limnos, 2.5 km south of Atsiki, 39°56.155'N 25°14.124'E, 30 m. Fallow field. 2020-09-27, *Bergmeier 20-60* (EB).

Limnos, east of Kalliopi, 39°54.671'N 25°19.790'E, 10 m. Field edge and road verge. 2020-10-01, *Bergmeier 20-139* (EB). Further nearby in 39°54.704'N 25°19.847'E, 10 m, and 39°54.757'N 25°19.842'E, 12 m; 1-year fallows; 2020-10-01, Bergmeier & Meyer, obs.

Limnos, Kondias, 39°52.313'N 25°09.070'E, 12 m. 1-year fallow. 2020-10-02, Bergmeier & Meyer, obs.

Limnos, near Kondias, 39°51.988'N 25°09.345'E, 1 m. Stubble (barley) field. 2020-10-02, Bergmeier & Meyer, obs.

Lesbos, appr. 1.7 km E of Polichnitos, 39°4.708'N 26°12.129'E, 65 m. Stubble field. 2020-10-09, Meyer, obs.

Lesbos, appr. 1.6 km SW of Skamioudi, 39°7.239'N 26°11.233'E, 1 m. Stubble field. 2020-10-09, Meyer, obs.

Fig. 1. *Lactuca aculeata*, from upper left to lower right. Habit; lower part of synflorescence; upper part of stem with cauline leaves; branch of synflorescence with flower head. Photos: 1-3: U. Bergmeier, 27-09-2020 and 1-10-2020; 4: S. Meyer, 9-10-2020.

Lesbos, appr. 1.45 km SW of Skamioudi, 39°7.215'N 26°11.361'E, 5 m. Stubble field. 2020-11-27, Meyer, obs.

Lesbos, appr. 1.45 km SW of Skamioudi, 39°7.149'N 26°11.679'E, 7 m. Stubble field. 2020-11-27, Meyer, obs.

Habitat and vegetation

We found *Lactuca aculeata* on lowland field edges (cereals, vineyards), one- to two-year arable fallows, and mostly on stubble. The soils were deep, chiefly sandy or gravelly alluvial. Habitats other than arable include farm road verges and open sandy slopes disturbed by livestock and rabbits. Similar synanthropic habitat conditions, yet moreover semi-natural rocky environments, have been reported from north-eastern Israel (Zohary 1991: 32). Common plant species co-occurring with *L. aculeata* found in three or more relevés on Limnos and Lesvos include *Carthamus dentatus* (Forssk.) Vahl, *Centaurea solstitialis* L., *Chondrilla juncea* L., *Chrozophora tinctoria* (L.) A. Juss., *Cichorium intybus* L., *Cynodon dactylon* (L.) Pers., *Daucus carota* L., *Dittrichia graveolens* (L.) Greuter, *Dittrichia viscosa* (L.) Greuter, *Helminthotheca echioides* (L.) Holub, *Polygonum arenarium* Waldst. & Kit., *Sorghum halepense* (L.) Pers., *Sonchus asper* (L.) Hill, and *Verbascum sinuatum* L. *Lactuca serriola* is more widespread on the islands but co-occurs with *L. aculeata* in a few sites, with sporadic intermediate forms suggesting that the two species are (partly) interfertile (as also observed by Zohary 1991 and Lebeda & al. 2012). Beharav & al. (2010) and Lebeda & al. (2012) reported that *L. aculeata* is also fully interfertile with cultivated lettuce.

The species composition of relevés with *L. aculeata* found on the two Aegean islands suggests that it is a constituent of zoo-anthropogenic open herblands in dry heavily disturbed ruderal sites. It may be assessed as a sporadical constituent of the vegetation of stubble fields rich in summer-annual herbs of the *Atriplicion* Passarge 1978 (*Sisymbrietea*), but it occurs in xerophytic ruderal communities of biennial and short-lived perennial plants too (closest is the alliance *Inulo viscosae-Agropyrion repentis* Biondi & Allegrezza 1996; *Artemisietea vulgaris*) (for nomenclature and definition of phytosociological syntaxa see Mucina & al. 2016).

Concluding remarks

Beharav & al. (2010) and Lebeda & al. (2012) found little morphological variation in *L. aculeata* populations in north-eastern Israel (see also Danin & Fragman-Sapir 2016+), and specimens collected in the Aegean islands of Limnos and Lesbos fall into the morphological range defined there as well as in the Flora of Turkey (Jeffrey 1975) and in Boissier's original description in the Flora Orientalis (Boissier 1875). In particular, the cauline leaves appear to be more uniform in shape among most plants of *L. aculeata* than among those of *L. serriola*, which is otherwise the most similar species in terms of habit, growth form, phenology and habitat.

L. aculeata is the third species of the genus *Lactuca* L. found on Limnos (Panitsa & al. 2003; Baliousis & al. 2014; a dot in the *L. viminea* map by Strid 2016 might be erroneous and possibly refers to *L. saligna*) and the fifth on Lesbos (Strid 2016). It is unlikely to be a recent introduction, first because *L. aculeata* occurs on two different islands, second because it is more or less widespread on both islands though uncommon and, third, although restricted to anthropogenic habitats, it is fully established and should be regarded as a native species. It was probably overlooked by previous botanical observers, owing to its overall similarity to *L. serriola* and its seemingly trivial habitat. It should be looked for in western Turkey, from where it is not yet known (Güzel, pers. comm.).

L. aculeata is uncommon on the islands and the number of plants observed in any one reference plot (local population size) is small, rarely exceeding twenty individual plants in a locality. Nevertheless, due to its invariably synanthropic habitat (arable and fallows) it does not for the time being seem to be vulnerable on Limnos and Lesbos, provided the non-intensive agriculture including long stubble phases and rotational fallow is retained.

L. aculeata is a significant constituent of the Greek and European flora, not least because it is a wild close relative to cultivated lettuce, *L. sativa*. As our records of the former species from Limnos and Lesbos represent the westernmost known occurrences, these populations may turn out to be of interest for lettuce breeding.

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References

Baliousis, E. 2014: Recent data from the island of Limnos (NE Aegean, Greece): New alien invasive species affecting the agricultural economy of the island. – Edinburgh J. Bot. **71:** 275-285. https://doi.org/10.1017/S0960428614000110

Beharav, A., Ben-David, R., Doležalová, I. & Lebeda, A. 2010: Eco-geographical distribution of *Lactuca aculeata* natural populations in northeastern Israel. – Genet. Resour. Crop Evol. **57:** 679-686. https://doi.org/10.1007/s10722-009-9503-6

Boissier, E. 1875: Lactuca. Pp. 809–810 in: Flora Orientalis, **3**. – Genève, Basel, Leiden.

Cohen, O. & Liston, A. 1986: Plants new to Israel: *Lactuca aculeata*. – Rotem **21:** 72-78. [Hebrew with English summary]

Danin, A. & Fragman-Sapir, O. 2016+: *Flora of Israel Online.* https://flora.org.il/en/plants/ [Last accessed 10/01/2021]

Jeffrey, C. 1975: *Lactuca* L. – Pp. 776–782 in Davis, P. H., Matthews, V. A., Kupicha, F. K. & Parris, B. S. (eds), Flora of Turkey, **5.** – Edinburgh.

Lebeda, A., Kitner, M., Křístková, E., Doležalová, I. & Beharav, A. 2012: Genetic polymorphism in *Lactuca aculeata* populations and occurrence of natural putative hybrids between *L. aculeata* and *L. serriola.* – Biochem. Syst. Ecol. **42:** 113-123. https://doi.org/10.1016/j.bse.2012.02.008

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J.-P., Raus, T., , Čarni, A., Šumberová, K., Willner, W., Dengler, J., Gavilán García, R., Chytrý, M., Hájek, M., Di Pietro, R., Iakushenko D., Pallas, J., Daniëls, F. J. A., Bergmeier, E., Santos Guerra, A., Ermakov, N., Valachovič, M., Schaminée, J. H. J., Lysenko, T., Didukh, Y.P., Pignatti, S., Rodwell, J.S., Capelo, J., Weber, H.E., Solomeshch, A., Dimopoulos, P., Aguiar, C., Hennekens, S. M. & Tichý, L. 2016: Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. – Appl. Veg. Sci. **19 (Suppl. 1):** 3-264. https://doi.org/10.1111/avsc.12257

Panitsa, M., Snogerup, B., Snogerup, S., & Tzanoudakis, D. 2003: Floristic investigation of Lemnos island (NE Aegean area, Greece). – Willdenowia **33:** 79-105. https://doi.org/10.3372/wi.33.33108

Strid, A. 2016: Atlas of the Aegean Flora. Part 1: Text & Plates. Part 2: Maps. – Englera **33(1):** 1-700, **33(2):** 1-878.

Zohary, D. 1991: The wild genetic resources of cultivated lettuce (*Lactuca sativa* L.). – Euphytica **53:** 31-35. https://doi.org/10.1007/BF00032029

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Article

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The correlation between plant endemism and biogeographic factors – a case study from Leqinat Mt., Kosovo

Abstract

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A significant contribution to the proper ecosystem functioning and services is provided by the vascular plant species richness. Therefore, understanding the environmental, and in particular, biogeographical predictors of vascular plant richness – and richness with endemism, can accordingly support conservation efforts of biodiversity as well as ecosystem services at a proper scale. This study used field survey data, as well as herbarium materials and literature sources to explore the relation between plant endemism and natural habitats in a particular region of a National Park in “Bjeshkët e Nemuna” (Kosovo). A number of environmental factors were recorded for this study, with particular focus on the natural habitats of 65 Balkan endemic plant taxa in the Mt. Leqinat, in a narrow area (6 km^2) but yet exceedingly rich floristic diversity. A correlation between habitat diversity and richness with endemic plant taxa was confirmed. In total, 20 EUNIS habitat types were recorded with endemic plant taxa, where (E4.4) - Calcareous alpine grasslands proved to be the richest in terms of endemics they harbor. Total floristic diversity in relation to altitude, reaches the highest values in the range between 1.800 to 2.000 m. a.s.l. As a measure proposed to further improve conservation management within this area of the National Park is to better control human activities, and therefore establish a balance between strict protection and the sustainable use of natural resources.

Key words: balkans, biogeography, biodiversity conservation.

Introduction

High mountainous regions of the Balkan Peninsula constitute a well-known, and perhaps one of the richest centers of plant diversity and endemism of Europe, representing an area of the continent with more than 6500 vascular plant taxa (Tomović & al. 2014), out of whom, more than 2700 are endemic ones (Stevanović & al. 2005; Amidžić & al. 2013), whereas about 400 of them are treated as local endemics (Horvat & al. 1974; Rexhepi 1994, 2007; Stevanović & al. 2007; Tomović & al. 2014). However, these figures must necessarily be higher in reality, because Greece alone (along with its islands) counts 1278 endemic plant taxa (Dimopoulos & al. 2013). In the western part of Balkans, the Dinaric

Mts. – as a high mountain system are particularly distinguished with remarkable diverse flora (Horvat & al. 1974, Redžić 2011). These mountains span from Slovenia in the North to the Northern Albania in the South, while the Albanian Alps (Albanian: Alpet Shqiptare/Montenegrin: Prokletije) represent the southernmost part of the Dinarides. Their unshared floristic richness is believed to have come as a consequence of long-term isolation and high (average) altitudes. Based on this, the relation between the floristic diversity and the consequent number of endemic and relict plant taxa – along with a diversity of ecological parameters has been the subject of previous studies (Mersinllari & al. 2008; Millaku & al. 2008; Shuka & al. 2008; Rakaj 2009; Frajman & al. 2014; Vukojičić & al. 2014; Caković & al. 2017; Shuka & al. 2020). Apart from this, the flora of the Alps has also been continuously studied, both in terms of species general distribution, their numbers and abundances (Rexhepi 1982, 1986, 1997; Amidžić & Krivošej 1998; Amidžić & al. 2013; Berisha & al. 2020) and in terms of species conservation and posed threats (Stevanović 1999; Millaku ed. 2013; Vuksanović & al. 2016; Millaku & al. 2017; Shuka & al. 2020; Kuzmanović & al. 2021).

Based on available literature references, herbarium specimens deposited in the Herbarium of the Faculty of Mathematics and Natural Sciences of the University of Prishtina as well as collected data from our field surveys conducted from 2009 until 2019 – a total of 1648 plant taxa are recorded in the Albanian Alps of Kosovo. Kosovo is believed to harbor some ~ 3000 plant taxa in total (Millaku ed. 2013; Tomović & al. 2014) either though yet there are no exact figures, so Albanian Alps make ~ 55% of the entire country's flora.

Since the Albanian Alps in Kosovo include a relatively wide geographical area, in our current study we have been focused on a narrower, yet floristically very rich area, that of the Leqinat Mt. massif. In the Leqinat area alone, an area encompassing forest and grasslands of 6 km^2 – we have data on the presence of a total of 873 plant taxa, and out of them 65 being Balkan endemics (7.4 % - Annex I). From the Red Book of Vascular flora of Kosovo (Millaku ed. 2013), 27 plant taxa from Leqinat Mt. were assessed to belong any of IUCN conservation categories (lower risk = NT, LC, or threatened VU, EN, CR) in the country level. Of these, 19 are endemic plants that belong to different IUCN conservation categories: EN = 3, VU = 1, NT = 6 and LC = 9 (Electronic Supplementary File 1 table 1). This further reinforces the conclusion that this area is of particular importance in terms of diversity and floristic composition of Kosovo. In Kosovo, it is estimated that there are 360 Balkan endemic plant taxa (Rexhepi 2000; Tomović & al. 2014), and Leqinat Mt. make 18% of the entire endemic plant taxa, and it belongs to the richest region of Kosovo, based on the calculated conservation importance on a map 20×20 km grid square (Berisha & al. 2020). However, so far the influential biogeographical features of this particular area have never been properly analyzed, to be able to explain the reasons for such a remarkable floristic richness. Thus, the aims of the present study are: (**i**) to determine the correlation between habitat diversity and endemic plant taxa richness, (**ii**) to determine the correlation between altitude (m a.s.l.) and the plant taxa richness, and (**iii**) to determine the correlation between the mountain isolation, exposition and their plant taxa diversity. We believe that these data of this particular region of the National Park "Bjeshkët e Nemuna" will prove to be a very valuable tool for proper conservation actions and planning, as well for further comprehensive studies.

Material and methods

The data set

A total area of 6 km² was included in the present study (Fig. 1). This region of the Mt. Leqinat has a well known native flora, that was recorded and continuously updated and revised from 1987 until 2019 – with many detailed floristic and vegetation studies (Lakušić 1968; Rexhepi 1994; Amidžić 1998; Millaku 1999, 2001). These data include both literature data, newly documented records of plant taxa – accompanied by voucher specimens supporting their presence. A crucial point on these data-sets is represented by the number of endemic plant taxa. Endemicity of plant taxa was merged into one level, by uniting Balkan endemics with local endemics. The proportion of the number of endemics to the overall number of plant taxa is also an important measure of endemism. Based on available existing data, herbarium materials, and our field data, we analyzed also floristic gradient and richness over the altitude on the studied mountain.

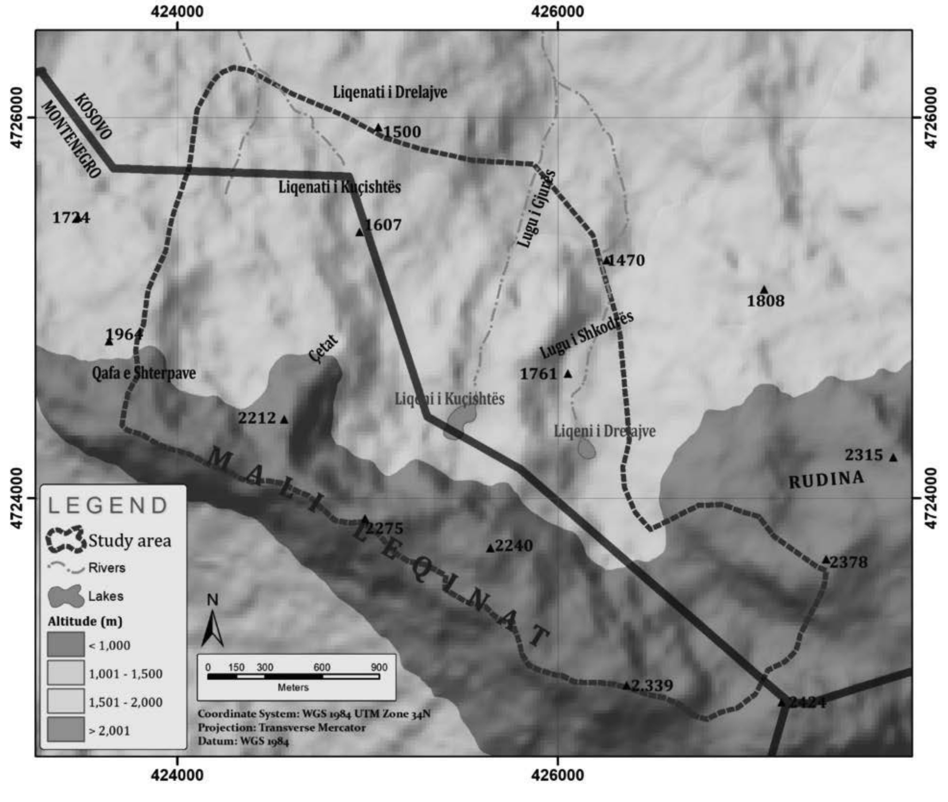

Fig. 1. The geographical location of the studied area.

Study area

The Leqinat Mt area is located in the Albanian Alps of Kosovo, which is a chain of Mountains between Kosovo, Albania and Montenegro. The study area has a surface of 6 km² and is distinguished by a mountainous relief, situated in the border area between two countries: Kosovo in the east and Montenegro in the west. In hydrographic terms, this area belongs to Lumbardhi i Pejës River basin, whose waters flows towards the Adriatic Sea.

In geological and tectonic terms, the Leqinat Mt. area belongs to the Durmitor Area - Bjeshkët e Nemuna (Pruthi 1986). It is composed mainly of dolomitic red limestones with cephalopods of middle Triassic age. Slopes have a gradient of about 40° towards the east (E) and northeast (NE). At the higher part and the top of the Mt. (2275 m a.s.l.), the limestones and dolomites predominante the substrate. Naturally, as a result of alteration processes, influenced by temperature amplitudes, mountain calcareous and acidic screes, as well as inland cliffs are found. The relief is mountainous, with hypsometry of the terrain having values of 1300 m a.s.l. up to the top of the Mountain reaching 2275 m a.s.l. The terrain is covered with steep mountain ridges and valleys, which are believed that have been created by the geological activity of high gradient rivers, Pleistocene glaciation and weathering. The most popular valleys are Lugu i Shkodrës and Lugu i Gjuricës, while in the upper part there are two alpine glacial lakes: Kuqishtë Lake (1850 m a.s.l.) and Drelaj Lake (1795 m a.s.l.).

The mountainous terrain features area with slopes with significant inclination. The average slope inclination of the whole study area is 27°. Slopes with an inclination between 20-40° are dominant ones. At the foot of Mt. Leqinat, the slope inclination is over 40°, while the lowest slopes are at the bottom of the cirques, where the cirque (glacial) lakes are located. The study area has mainly northern and northeastern aspect.

The area has a typical mountainous climate, with an average annual air temperature between 4-6 °C and an average annual rainfall of 1200-1400 mm, with snow lasting until late spring – May (Map of Rains and Air Temperature 1983). Despite of these mountainous climatic conditions, the hydrographic features of the study area are predetermined by the lithological settings (limestone dominated), resulting a poor surface drainage network. During the Pleistocene age, when glaciers had an impact on the Balkan Peninsula, glacial lakes were created, the most distinguished ones being lakes of Kuqishtë and Drelaj (Fig. 2).

Correlation of plant diversity and endemism with bio-geographical variables

Independent variables tested as potential predictors of species diversity with concern to 65 analyzed Balkan endemic plant taxa were: habitat diversity (H_D), maximum elevation (E, m), and the total number of habitats (T_H) (ESF1 Table 2). In plant ecology studies, the calculation and interpretation of habitat diversity appears a demanding issue (Kohn & Walsh 1994; Triantis & al. 2006; Sfenthourakis & Triantis 2009; Zhang & al. 2015). As a measure of habitat diversity herein we used the number of natural habitats (classified according to EUNIS 2007) where the taxa were present, using also some presumably important environmental features for plants, such as physiography, slope, substrate composition, aspect as well as vegetation type. In order to achieve this calculation for each endemic taxa, we utilized data from topographic and geological maps, data from herbarium vouchers, satellite imagery as well as extensive field recordings and verified data concerning all of the above mentioned factors. In order to explore the relationships between the endemics H_D, E and T_H, the related statistical estimations were carried out using R Studio (R Core Team 2020).

Fig. 2. Few examples of different natural habitats in the studied area on Leqinati Mt. Top left: dry calcareous grasslands nearby the forest edge. Top right: a landscape just above the Kuqishtë Lake, depicting screes, large slopes of stone walls as well as scattered *Picea abies* (L.) H. Karst. and *Pinus peuce* Griseb. trees. Bottom left: Drelaj Lake, bushes and forests nearby. Bottom right: grasslands, subalpine deciduous scrubs and *P. peuce* forests.

Results

Species richness

Based on our field surveys, herbarium materials available as well as based on extensive literature sources, we confirm that the Mt. as a whole contains 873 plant taxa. Depending on these data, we were able to analyze the floristic richness over the altitude of the Mt., where we have particularly depicted the highest parts of the Mt., having the larger proportion of floristic richness (Fig. 3) – with the altitude between 1800 up to 2000 m. a.s.l., being the richest part, where more than 700 plant taxa occur. We do not provide here the species list, as they can be found on other floristic publications, as mentioned earlier here, it was not our intention to do a floristic inventory, rather than to survey the endemic taxa and their relation to the natural, diverse habitats.

Habitat diversity and endemic plants

The study area includes a variety of natural habitats, very rugged and diverse landscapes, making it particularly interesting and valuable on national and regional scales (Fig.

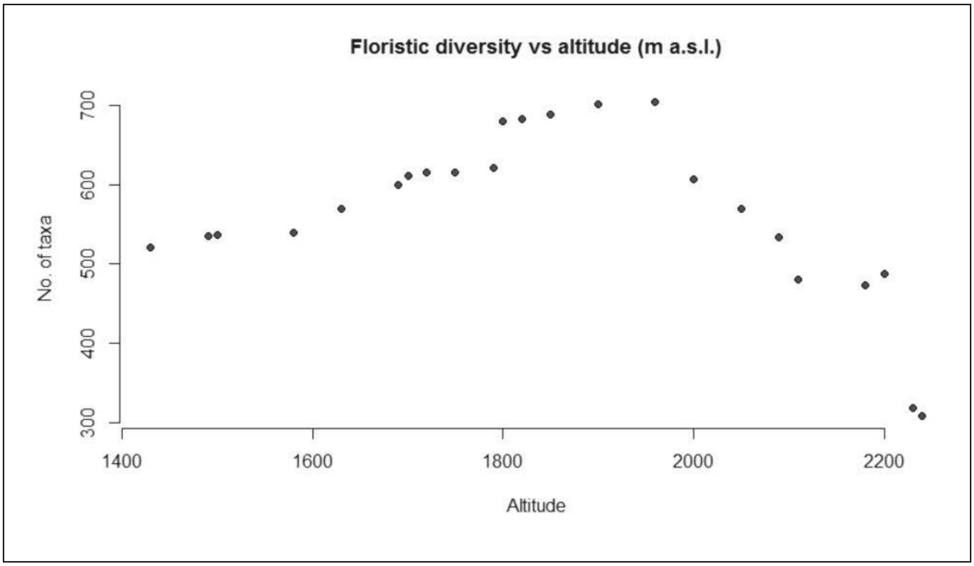

Fig. 3. The graphical plot depicting the relation between overall floristic diversity over the altitude of the Mt. Leqinat (1400 m – 2300 m. a.s.l.).

2). Concerning the natural habitat types (classified according to EUNIS) that harbor endemic taxa, we were able to distinguish 20 of them (Table 1), with the alpine calcareous grasslands (E4.4) and the calcareous screes (H2.6) being the richest ones, sheltering alone 35 out of 65 recorded endemic taxa. The average habitat diversity for all endemic plant species ranges between values 2 and 2.5, according to the performed analysis (Fig. 4 – Habitat diversity). Whereas, if we look conversely at taxa and the number of EUNIS habitat types they were affiliated with, they predominantly belonged to 1 or 2 EUNIS habitats, rarely being recorded into 3 or more habitats (Fig. 4 – Type of Habitat).

Predictors of endemic richness

A distinct colinearity among the independent factors used for predicting endemic taxa richness was observed, especially with habitat diversity. Nonetheless, since habitat diversity represents the linear function of the given area, it always displayed higher correlation coefficients with endemic taxa richness. It was observed, that with the increase of habitat diversity (inclination rate, altitude, bedrock composition, geology, etc.), the richness on its floristic composition as well as on its endemic richness grew proportionally. Based on Herbarium samples examination (e.g. Herbarium voucher of endemic plant – *Aquilegia blecicii* Podobnik– Fig. 5), it was noticeable that the Northern and North-Eastern slopes of the Mt were richer in endemics, compared to other expositions. In addition to this, even though the value of altitude for calculation reasons was united with other factors as the Habitat Diversity (HD), again, if we separate it as a single factor concerning the richness with endemic plants, it was observed that we have a particular altitude scale between 1800 to 2200 m a.s.l., where the number of endemic plants is notably higher (Fig. 4 – Altitude gradient).

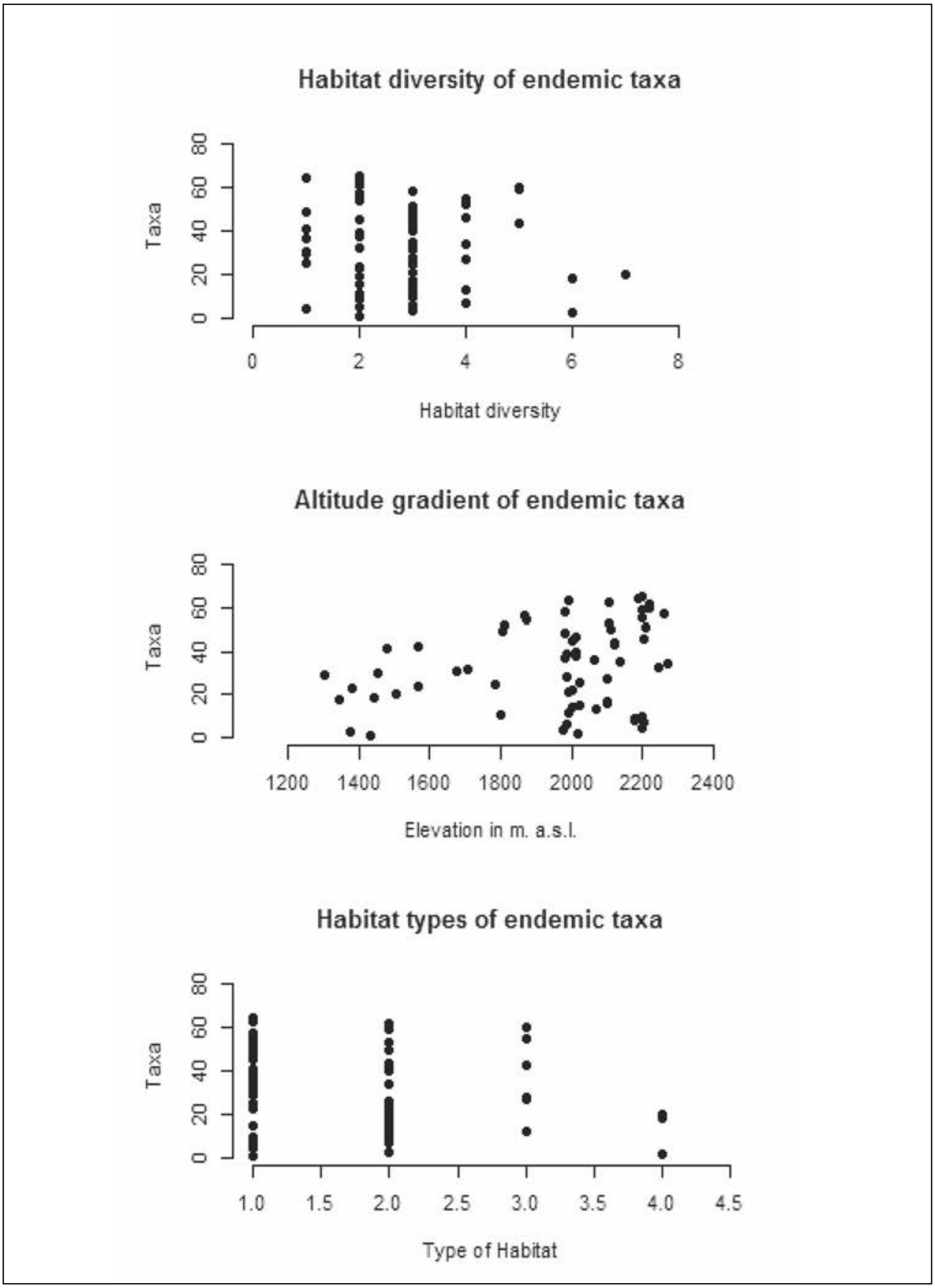

Fig. 4. Three plotted graphs of endemic plant taxa versus their Habitat Diversity (HD) value (first, from up-down), endemic plant taxa versus the altitude in m. a.s.l., as a separated factor from HD (second, from up-down) and the endemic taxa versus the EUNIS habitat types occupied (third, from up-down).

Table 1. EUNIS Habitat types and their corresponding endemic plant taxa they contain in numbers.

Endemic taxa	EUNIS code	Habitat description
24	E4.4	Calcareous alpine and subalpine grasslands
11	H2.6	Calcareous and ultra-basic screes of warm exposures
10	E4.39	Oro-Moesian acidophilous grassland
9	E4.5	Alpine and subalpine enriched grassland
9	F2.3	Subalpine deciduous scrub
8	E1.2	Perennial calcareous grassland and basic steppes
7	H3.2	Basic and ultra-basic inland cliffs
5	F2.2	Evergreen alpine and subalpine heath and scrub
5	H2.4	Temperate-montane calcareous and ultra-basic screes
4	E1.92	Perennial open siliceous grassland
4	E5.4	Moist or wet tall-herb and fern fringes and meadows
3	H3.1	Acid siliceous inland cliffs
2	E4.31	Alpic *Nardus stricta* swards and related communities
2	F3.2	Submediterranean deciduous thickets and brushes
2	G3.1	Coniferious - *Abies* and *Picea* woodland
1	D2.2	Poor fens and soft-water spring mires
1	D4.1	Rich fens, including eutrophic tall-herb fens and calcareous flushes
1	D4.2	Basic mountain flushes and streamsides, with a rich arctic-montane flora
1	F2.1	Subarctic and alpine dwarf willow scrub
1	G4.6	Mixed *Abies* - *Picea* - *Fagus* woodland

Discussion

The results of this study put a special emphasis on the important role that habitat diversity plays in shaping endemic taxa richness. This type of notable correlation between habitat diversity and plant taxa richness in general, and endemics in particular, has already been reported by different authors (e.g., Hobohm 2000; Guilhaumon & al. 2008; Alsterberg & al. 2017; Vladimirov & al. 2020), although varying estimation approaches to habitat diversity were used. The diversity of natural habitats, due to their heterogenity in topography and geology, among other factors, promotes plant species richness – and that in particular, of those plant species that have a tendency to thrive only in certain, rather isolated or narrow natural habitats, as is the case with endemic plants taxa (Hannus & Numers 2008; Sfenthourakis & Triantis 2009; Stein & al. 2014). The number of endemic plant taxa, as expected from the nature of the studied area, is significantly high for the national and regional scale, taking into account the total intensive study area of only 6 km^2. Nevertheless, at a local scale, elevation, habitat diversity and isolation can still predict richness with endemic plant taxa – with elevation as a dimension calculated within the habitat diversity value.

It should be noted that the area of Leqinat Mt., within the “Bjeshkët e Nemuna” National Park represents one of the most distinctive and richest areas in terms of floristic diversity. In this area, there are 27 plant taxa which are estimated to belong any of the IUCN conservation categories in Kosovo (Millaku ed. 2013), either lower risk (NT, LC) or threatened (VU, EN, CR) ones. With this detailed information we are now offering, we verify the presence of 65 Balkan endemic plant taxa, which further distinguishes the importance of this natural area. Out of these 65 endemics, 3 are IUCN-internationally (Farjon 2017) categorized plant taxa at lower risk of endangerment (*Pinus peuce* Griseb. (NT), *Aquilegia blecicii* A. Podob. (DD) and *Geum bulgaricum* Pančić (LC)).

Aside from purely theoretical importance and study attraction, endemicity studies and their general evaluation plays a decisive role in the development of comprehensive, rather practical, conservation strategies (Bonn & al. 2002). Moreover, plant diversity and diversity with endemic in particular, represent one of the best available predictors of diversity and richness of other living taxa as well (Brunbjerg & al. 2018) and has already been used as such tool in the designation of biodiversity hotspots (Médail & Quézel 1999). In addition, a useful approach in this regard has led to the use of species–area relationship (Duarte & al. 2008).

Conclusions

The presented results show that endemicity richness studies, habitat diversity factor, along with natural habitat types, can easily serve as environmental predictors of vascular plant richness and can aid the conservation management of protected areas. Local endemic taxa, as well as wider geographical ones, appear to be mainly affected by habitat diversity. Elevation was observed as an important factor affecting the bulk of endemic species richness. Habitat diversity yet is confirmed as the principal factor shaping endemic plant taxa richness of Leqinat Mt., and should be further examined in order to gain important insight into wider plant diversity patterns. Finally, attention should be focused on the roles of plant species composition on sustainable management effectiveness of the protected areas of Kosovo. Due to the presence of two glacial lakes in the area, the area is visited on average by many tourists during the year. Therefore, it would be highly advisable to provide them with enough notice information about the importance and values of the Leqinat Mt. area.

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References

Alsterberg, C., Roger, F., Sundbäck, K., Juhanson, J., Hulth, S., Hallin, S. & Gamfeldt, L. 2017: Habitat diversity and ecosystem multifunctionality – The importance of direct and indirect effects. – Sci. Adv. **3(2):** 1-9. http:/dx.doi.org/10.1126/sciadv.1601475

Amidžić, L. & Krivošej, Z. 1998: High-mountain flora of Nedzinat and Zuti Kamen (Prokletije Mts.). – Univ. Thought. **1(1):** 99-112.

Amidžić, L. 1998: *Pinetum mughi-Geum bulgaricum* - a new plant community of the Mountain Pine (*Pinus mugo* Turra) on Prokletije Mountain. – Univ. Thought. **4(2):** 89-97. University of Prishtina.

Amidžić, L., Panjković, B. & Perić, R. 2013: Chorological analysis of the endemic flora in the Prokletije Mountains. – Arch. Biol. Sci. **65(2):** 645-650. http:/dx.doi.org/10.2298/ABS1302645A

Berisha, N., Krasniqi, E. & Millaku, F. 2020: A quantitative approach for conservation of endangered and endemic plants from Kosovo, SE Europe. – Folia Oecol. **47(1):** 52-63. http:/dx.doi.org/10.2478/foecol-2020-0007

Bonn, A., Rodriques, A. S. L. & Gaston, K. J. 2002: Threatened and endemic species: are they good indicators of patterns of biodiversity on a national scale? – Ecol. Lett. **5(1):** 733-741. http:/dx.doi.org/10.1046/j.1461-0248.2002.00376.x

Brunbjerg, A. K., Bruun H. H., Dalby L., Fløjgaard C., Frøslev T. G., Høye T. T., & Ejrnæs R. 2018: Vascular plant species richness and bioindication predict multi-taxon species richness. – Methods Ecol. Evol. **9(12):** 2372-2382. http:/dx.doi.org/10.1111/2041-210x.13087

Caković, D., Stešević, D., Schönswetter, P. & Frajman, B. 2017: Long neglected diversity in the Accursed Mountains of northern Albania: *Cerastium hekuravense* is genetically and morphologically divergent from *C. dinaricum*. – Pl. Syst. Evol. **304(1):** 57-69. http:/dx.doi.org/10.1007/s00606-017-1448-1

Dimopoulos, P., Raus, T., Bergmeier, E., Constantinidis, T., Iatrou, G., Kokkini, S., Strid, A. & Tzanoudakis, D. 2013: Vascular plants of Greece: *an annotated checklist*. – Englera. **31:** 1-372.

Duarte, M. C., Rego, F., Romeiras, M. M. & Moreira, I. 2008: Plant species richness in the Cape Verde Islands - eco-geographical determinants. – Biodivers. Conserv. **17(2):** 453-466.

EUNIS 2007: EUNIS Habitat Classification. Available at: http://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification.

Farjon, A. 2017: *Pinus peuce*. The IUCN Red List of Threatened Species 2017: e.T34193A95751594. – http:/dx.doi.org/10.2305/IUCN.UK.2017-2.RLTS.T34193A95751594.en. [Last accessed 20.12.2020]

Frajman, B., Pachschwöll, C. & Schönswetter, P. 2014: Contributions to the knowledge of the Flora of the Dinarides (Balkan Peninsula). – Phyton **54(1):** 27-46.

Guilhaumon, F., Gimenez, O., Gaston, K. J. & Mouillot, D. 2008: Taxonomic and regional uncertainty in species-area relationships and the identification of richness hotspots. – Proc. Nat. Acad. Sci. **105(40):** 15458-15463.

Hannus, J. & Numers, M. 2008: Vascular plant species richness in relation to habitat diversity and island area in the Finnish Archipelago. – J. Biogeogr. **35(1):** 1077-1086.

Hobohm, C. 2000: Plant species diversity and endemism on islands and archipelagos, with special reference to the Macaronesian Islands. – Flora. **195(1):** 9-24. http:/dx.doi.org/10.1016/s0367-2530(17)30943-x

Horvat, I., Glavač, V. & Ellenberg, H. 1974: Vegetation Südosteuropas. – Stuttgart.

Kohn, D. D. & Walsh, D. M. 1994: Plant species richness – the effect of island size and habitat diversity. – J. Ecol. **82:** 367-377.

Kuzmanović, N., Lakušić, D., Frajman, B., Stevanoski, I., Conti, F., & Schönswetter, P. 2021: Long neglected diversity in the Accursed Mountains (Western Balkan Peninsula): *Ranunculus bertisceus* is a genetically and morphologically divergent new species. – Bot. J. Linn. Soc. http:/dx.doi.org/10.1093/botlinnean/boab001

Lakušić, R. 1968: Mountain vegetation of the South-Eastern Dinarides. – Glasnik **1:** 9-75.

Map of Rains and Air Temperature. 1983: Jaroslav Cerni Institute for Hydroeconomy. – Belgrade.

Médail, F. & Quézel, P. 1999: Biodiversity hotspots in the Mediterranean Basin: setting global conservation priorities. – Conserv. Biol. **131(1):** 1510-1513.

Mersinllari, M., Xhulaj, M., Shuka, L. & Kashta, L. 2008. Data on rare plant species in the area of Albanian Alps. – Nat. Sci. Bul. (UT). **5:** 179-189.

Millaku, F. 1999: Subalpine and alpine flora of the Albanian Alps of Kosovo. PhD Thesis. FNSM – University of Prishtina, Kosovo.

— 2001: Endemic plants in flora of Albanian Alps. – Res. Kosovo Acad. Sci. Arts **9(1):** 79-87.
— (ed.), Rexhepi, F., Krasniqi, E., Pajazitaj, Q., Mala, Xh. & Berisha, N. 2013: The Red book of vascular flora of the Republic of Kosovo. – Prishtina.
—, Krasniqi, E., Berisha, N. & Rexhepi, F. 2017: Conservation assessment of the endemic plants from Kosovo. – Hacquetia **16(1):** 35-47. https://doi.org/10.1515/hacq-2016-0024
—, Rexhepi, F. & Krasniqi, E. 2008: The importance of Liqenat as a refugial place in the aspects of flora and vegetation. – Pp. 344 in: International Conference on Biological and Environmental Sciences. –Tirana.
Pruthi, V. 1986: Cotemporary research methodology of the regional geological structre of SAP Kosovo with special view on metallogeny and forecast of mineral raw materials. – Doctoral disertation - PhD. University of Prishtina.
R Core Team 2020: R: A language and environment for statistical computing. R Foundation for Statistical Computing. – Vienna. https://www.R-project.org/.
Rakaj, M. 2009: Floristic and chorological news from north Albania. – Bot. Serb. **33(2):** 177-183.
Redžić, S. 2011: Phytogeographic and syntaxonomic diversity of high mountain vegetation in Dinaric Alps (Western Balkan, SE Europe). – J. Mt. Sci. **8:** 767-786.
Rexhepi, F. 1982: Balkan endemics in the high-mountian flora of Kosovo. – Sci. Res. Bull. FNS Prishtina **8:** 211-219.
— 1986: High mountain flora of Kosovo. – Prishtina.
— 1997: Mediterranean, Submediterranean and Il-lyric floristic elements in the flora of Kosovo. – Bocconea **5(2):** 451-456.
— 2000: Endemic plants of Kosovo. – Prishtina.
— 2007: The Vegetation of Kosovo, **1.** – Prishtina.
Sfenthourakis, S. & Triantis, K. A. 2009: Habitat diversity, ecological requirements of species and the Small Island Effect. – Divers. Distrib. **15:** 131-140. https://doi.org/10.1111/j.1472-4642.2008.00526.x
Shuka, D., Tan, K., Hallaçi, B. & Shuka, L. 2020: Additions to the flora of North Albania. – Phytol. Balcan. **26(3):** 517-522.
Shuka, L., Kashta, L. & Xhulaj, M. 2008: Evaluation of potential transboundary important plant areas of North Albania. – Nat. Monteneg. **7(3)**: 425-439.
Stein, A., Gerstner, K. & Kreft, H. 2014: Environmental heterogeneity as a universal driver of species richness across taxa, biomes and spatial scales. – Ecol. Lett. **17(7):** 866-880.
Stevanović, V. (ed.) 1999: Red data Book of Serbian Flora 1 – extinct and extremely endangered taxa. – Belgrade.
—, Tan, K. & Petrova, A. 2005: Size, distribution and phytogeographical position of the Balkan endemic flora. – P. 66 in: XVII International Botanical Congress, 17-23 July 2005, Abstract book. –Vienna.
—, — & — 2007: Mapping the endemic flora of the Balkans - a progress report. – Bocconea **21:** 131-137.
Tomović, G., Niketić, M., Lakušić, D., Ranđelović, V. & Stevanović, V. 2014: Balkan endemic plants in Central Serbia and Kosovo regions: distribution patterns, ecological characteristics, and centres of diversity. – Bot. J. Linn. Soc. **176(2):** 173-202. https://doi.org/10.1111/boj.12197
Triantis, K. A., Vardinoyannis, K., Tsolaki, E. P., Botsaris, I., Lika, K. & Mylonas, M. 2006: Re-approaching the small island effect. – J. Biogeogr. **33:** 914-923. https://doi.org/10.1111/j.1365-2699.2006.01464.x
Vladimirov, V., Bancheva, S., Delcheva, K., Vassilev, K. & Pedashenko, H. 2020: Contribution to the knowledge of habitat and vascular plant diversity of Alibotush Reserve, Slavyanka Mountain (Bulgaria). – Fl. Medit. **30:** 19-32. http:/dx.doi.org/10.7320/flmedit30.019
Vukojičić, S., Jakovljević, K., Matevski, V., Randjelović, V., Niketić, M. & Lakušić, D. 2014: Distribution, diversity and conservation of Boreo-Montane plant species in the central part of

the Balkan Peninsula and the southern part of the Pannonian Plain. – Folia Geobot. **49:** 487-505. http:/dx.doi.org/10.1007/s12224-014-9192-6

Vuksanović, S., Tomović, G., Niketić, M., & Stevanović, V. 2016: Balkan endemic vascular plants of Montenegro - critical inventory with chorological and life form analyses. – Willdenowia. **46(3):** 387. http:/dx.doi.org/10.3372/wi.46.46307

Zhang, Y., Wang, R., Kaplan, D. & Liu, J. 2015: Which components of plant diversity are most correlated with ecosystem properties? A case study in a restored wetland in northern China. – Ecol. Indic. **49:** 228-236. https://doi.org/10.1016/j.ecolind.2014.10.001

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Article

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R. Hand, C. S. Christodoulou, A. Kyratzis, G. Chrysostomou & E. M. McLoughlin

***Rostraria hadjikyriakou* (*Poaceae*), a new gypsophilous and endemic species from Cyprus**

Abstract

Hand, R., Christodoulou, C. S., Kyratzis, A., Chrysostomou, G. & McLoughlin, E. M.: *Rostraria hadjikyriakou* (*Poaceae*), a new gypsophilous and endemic species from Cyprus. — Fl. Medit. 31: 71-82. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Rostraria hadjikyriakou (*Poaceae*) is described as new to science. This gypsophilous taxon occurs in three disjunct sites in the eastern half of Cyprus. From a morphological point of view there are similarities to the polymorphic and widespread *R. cristata*. However, it differs by a number of discontinuous characters from this species as well as all other members of the genus. Provisionally, it can be classified as “Vulnerable”.

Key words: gypsum, *Koeleriinae*, micro-endemism, Mediterranean islands.

Introduction

The genera *Koeleria* Pers. and *Rostraria* Trin. are closely related to each other and to *Trisetum* Pers. (Saarela & al. 2017). The same authors summarise the systematic history of these genera, which are part of the subtribe *Koeleriinae* Asch. & Graebn. Thus, various authors have considered *Rostraria* to be an annual derivative of the perennial *Koeleria*, differing also in longer awns. This position has already been adopted by the last and only monograph of the group (Domin 1907). In the 20th century most authors argued in favour of a generic status of *Rostraria* (initially often sub *Lophochloa* Rchb.). In all recent phylogenetic studies, sampled species of *Koeleria* and *Rostraria* resp. have consistently been resolved as closely related within the *Koeleriinae* clade (Saarela & al. 2017). Phylogenetic results are still contradictory as regards various genetic markers. Saarela & al. (2017) summarised them as follows: “Clarification of generic circumscription of species of *Rostraria* awaits better taxon sampling of the genus and taxonomic decisions for the whole clade.”.

The absolute number of taxa is still controversial. The only monograph of the genus nowadays separated as *Rostraria* was published more than 100 years ago (Domin 1907) and is outdated. Henderson & Schäfer (2003) mention “about ten species”. Clayton & al. (2020) accept 13 species, of which most occur in the Euro-Mediterranean region.

However, there are at least two taxa, *R. clarkeana* (Domin) Holub described from Kashmir and *R. trachyantha* (Phil.) Soreng from S America, restricted to areas outside this presumable centre of diversification. Phylogeny of the latter seems to be in need for clarification (see results by Persson & Rydin 2016). Details about morphology, distribution and other aspects can be found in the database by Clayton & al. (2020) and need not to be listed here.

Concerning Cyprus, the current checklist of the country comprises five species (Hand & al. 2021). Apart from the common and polymorphic *R. cristata* (L.) Tzvelev, *R. smyrnacea* (Trin.) H. Scholz can be found scattered, however island-wide. *R. amblyantha* (Boiss.) Holub, *R. obtusiflora* (Boiss.) Holub and *R. hispida* (Savi) Doğan are rarer, and the latter has not been confirmed in recent decades. The spectrum of taxa has not changed since Bor (in Meikle 1985). In his treatment, all taxa are described in great detail (sub *Lophochloa*). A modified version of the determination key for the species occurring in Cyprus can be found online (Hand & al. 2021).

On 5 April 2018, Georgios N. Hadjikyriakou found a *Rostraria* population SW of Mandres Ammochostou, at the S foothills of the Pentadaktylos range in Cyprus. He and, subsequently, the authors of this contribution failed to identify it with any species of the genus, including the numerous infraspecific taxa of *R. cristata* (see Domin 1907), to which it seems systematically close. Further examination as well as intensive field studies, which also led to additional records in other parts of Cyprus, strongly suggest that these plants represent a taxon new to science.

Material and methods

Results are based on all-year round studies of all known populations in the field, on the *Rostraria* gatherings conserved in the herbaria B and CYP as well as in the private herbarium of G. Hadjikyriakou (herb. GeoHad), and plants of the new taxon grown at the Agricultural Research Institute (ARI) at Athalassa, Cyprus.

Taxonomy and nomenclature of taxa occurring in Cyprus follow Hand & al. (2021). Geographical coordinates refer to the UTM 36N zone.

Results

Rostraria hadjikyriakou Christodoulou & Hand, **spec. nova**

Holotypus: Cyprus, Division 7 (sensu Meikle 1985), Ypsarovounos forest, c. 2.5 km southwest of Mandres Ammochostou, on somewhat vertical or steep, almost bare and soft gypsum faces of few square metres, with flattish patches on or at their base, alt. c. 280 m, 5.4.2018, *G. Hadjikyriakou 7600* (CYP; isotypes ARI, B, G, PAL, STU, herb. GeoHad).

Diagnosis: *Rostraria hadjikyriakou* differs from other *Rostraria* taxa, namely the group with unequal glumes by culms never extending beyond the leaf sheaths and by spikelets which do not disarticulate. Furthermore, compared to morphologically similar species, it differs from *R. hispida* by, e.g., only 2 fertile florets per spikelet (not 3–4) and by the spikelets which are not longer than 2.5 mm (not 4–5 mm). It differs from *R. rohlfsii* by, e.g., panicles not longer than 2 cm (not 3–10 cm) and also by shorter spikelets (not 2.0–5.5 cm). From the highly variable *R. cristata* it differs inter alia by only 2 fertile florets per spikelet (not 3 and more), by ligules not longer than 0.6 mm (not 1–3 mm) and by very short spikelets, which are never longer than 2.5 mm (only very rarely shorter than 3 mm in *R. cristata*).

Annual, 2–5 cm tall. **Culms** usually 1–2, rarely with up to 2 additional fertile or sterile branches, arising from basal or upper nodes, erect, never extending beyond the sheath top, glabrous, green to purplish, shining. **Leaf-blades** lanceolate or linear-acuminate, flat, somewhat rigid, 10–30 × 0.8–2.3 mm, covered on both surfaces with sparse or dense, long or short, spreading or ascending hairs, usually those of the upper surface longer than those of the lower, scabrid on the margins; **sheaths** striate, clasping the culms and parts of the panicle, the uppermost inflated, margins widely membranous, indumentum externally as in leaf-blades; **ligule** c. 0.4–0.6 mm long, membranous, truncate, usually lacerate. **Panicle** very dense, ellipsoid or oblong, sometimes ovoid, rounded or obtuse at the apex, 0.8–2.0(–2.6) × 0.2–0.8 cm, light green, changing into light brown after anthesis; **spikelets** (2.0–)2.2–2.5 mm long excluding the awns, laterally compressed, wedge-shaped; **florets** 5, the lower 2 always bisexual, the upper 3 sterile, reduced to empty lemmas; **pedicels** 0–0.5 mm; **axis** glabrous; **rachilla** not disarticulating above the glumes and below the florets, glabrous; **glumes** unequal, carinate, the lower 1-nerved, scabrid at the back of the nerve, oblong, 1.2–1.8 × 0.2–0.3 mm, subulate, acute to acuminate, narrowly membranous, the upper glabrous, ovate, 3-nerved, longer than the lower floret, (2.0–)2.3–2.5 × 0.9–1.1 mm, acute, margins broadly membranous; **lemmas** of the 2 bisexual florets keeled, 5-nerved, somewhat prominent, with dense, spreading or ascending, stiff hairs, margins broadly membranous on the upper part, bifid at the tip, awned in the sinus, each leg of which is acute, restricted chiefly within the membranous margins width; lowest lemma 1.8–2.0(–2.2) × 1.0 mm; upper lemmas smaller 1.3–1.5 × 0.8-1.0 mm; **awn** simple, straight, not articulated, (1.0–)2.5–3.5 mm long, scabrid, green to purplish; **palea** conspicuously shorter and narrower than the lemma, linear, 0.8–1.0 mm long as a whole, 2-nerved, ciliate on the nerves, the nerves excurrent at the tip into two short aristulae; the 3 **empty lemmas** shortly hairy or subglabrous, 1.0–1.5 mm long, the lowest one bifid, mucronate or with a usually short, 0.3–0.5(–2.3) mm long awn in the sinus, the other 2 cuculate, obtuse or rounded, not awned, all 3 forming an obovate structure, c. 1.5 mm long, rounded on top. **Ovary** without a hairy apical appendage. **Anthers** 3, ellipsoid to oblong, (0.3–)0.4–0.6 mm long. **Caryopsis** 1.5–1.7 × 0.6 mm, oblong, compressed, rounded at both ends, brown.

Illustrations: Fig. 1–3; see also photo documentation in Hand & al. (2021).

Phenology: Flowering March–April.

Etymology: The new species is dedicated to Georgios N. Hadjikyriakou (Trachoni Lemesou) on the occasion of his 75th birthday (* 18.8.1946) who not only discovered

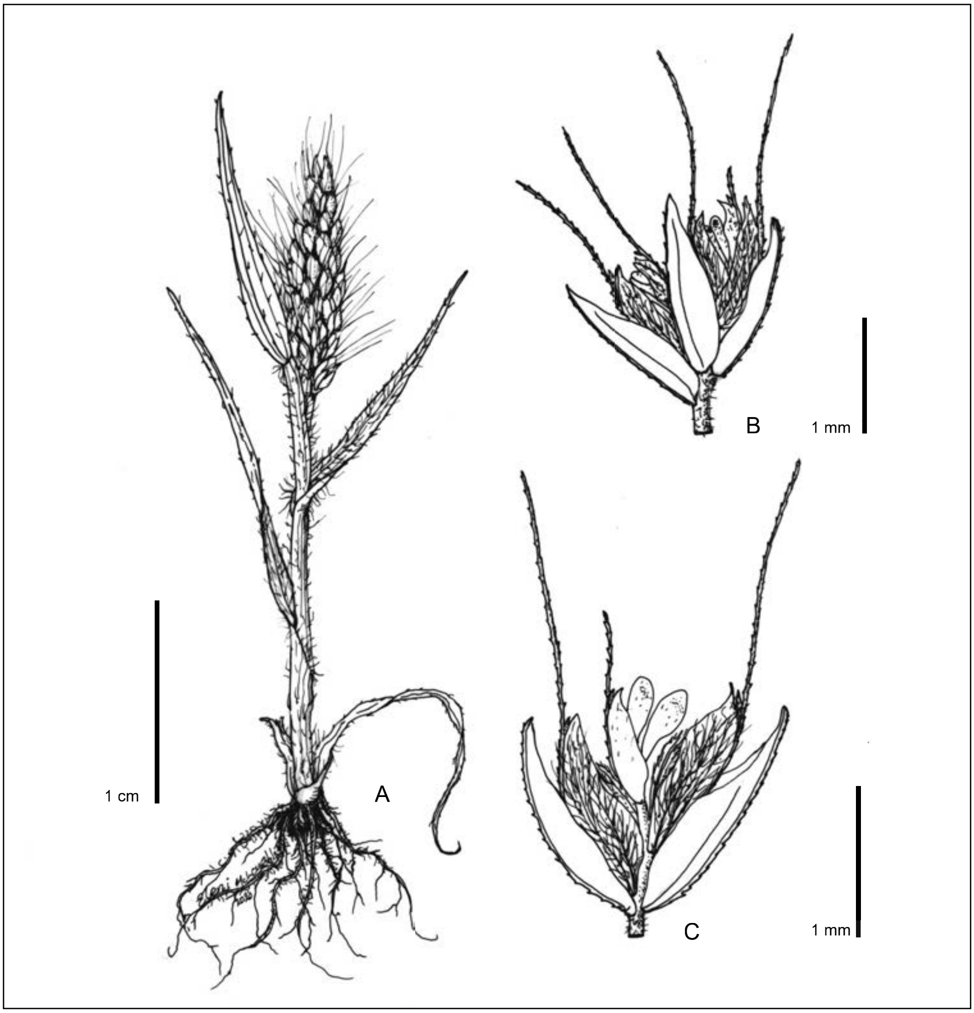

Fig. 1. *Rostraria hadjikyriakou*: A) habit; B) Two spikelets; C) spikelet with spread flower components; based on the specimen Agios Iakovos, Ypsarovounos, alt. 277 m, 4.4.2019, *R. Hand 9271 & G. Hadjikyriakou* (CYP). – Drawings: E. M. McLoughlin.

the plant in the field but also provided us with his detailed results of his studies and accompanied us in various excursions to the gypsum sites of Cyprus. His Greek family name is already in genitive form and is here apposed to the generic name as an indeclinable epithet.

Specimens seen (all known gatherings of *R. hadjikyriakou* and selected specimens of three morphologically similar *Rostraria* taxa used for comparison, phytogeographical divisions in Cyprus sensu Meikle 1985):

Fig. 2. *Rostraria hadjikyriakou*, fruiting plants in typical micro-habitat, Cyprus, Ypsarovounos, 14 April 2018. – Photo: C. S. Christodoulou.

Fig. 3. *Rostraria hadjikyriakou*, habit, Cyprus, Ypsarovounos, 14 April 2018. – Photo: C. S. Christodoulou.

R. hadjikyriakou

Cyprus: Division 3, Between Tochni and Kalavasos c. 1.6 km to the south, alt. 125 m, 30.5.2020, *G. Chrysostomou* (B, CYP 6586); ibid., on undisturbed gypsum outcrops with very sparse phrygana, 18.6.2020, *C.S. Christodoulou, G. Chrysostomou & K. Iosif* (B, CYP 6587). – Division 7, Ypsarovounos forest, c. 2.5 km southwest of Mandres Ammochostou, alt. c. 280 m, 8.8.2018, *G. Hadjikyriakou 7625* (herb. GeoHad); ibid., 9.9.2018, *G. Hadjikyriakou 7631* (herb. GeoHad); Agios Iakovos, Ypsarovounos, central part, open gypsum slopes, but only on small banks with fine, soft material, not on hard gypsum rocks, alt. 277 m, 19.6.2018, *R. Hand 9029 & G. Hadjikyriakou* (B); ibid., 4.4.2019, *R. Hand 9271 & G. Hadjikyriakou* (CYP). – Division 8, 2 km southeast of Agios Symeon, Karpasia peninsula, alt. c. 70–90 m, 28.4.2018, *G. Hadjikyriakou 7613* (herb. GeoHad).

R. cristata

Cyprus: Division 1, Pafos, near the lighthouse, rocky beach, alt. c. 3 m, 1.4.1998, *R. Hand 2045* (B). – Division 2, Agios Ioannis, SW slope of mountain SE of the village, phrygana on abandoned vineyards, alt. c. 800 m, 4.5.1999, *R. Hand 3070* (B). – Division 3, Kofinou, alt. c. 250 m, 20.4.1998, *G. Hadjikyriakou 3152* (herb. GeoHad); east of Akrotiri Salt Lake, alt. 0 m, 9.4.1999, *G. Hadjikyriakou 4278* (herb. GeoHad); Zakaki–Akrotiri Salt Lake, alt. 0 m, 9.4.1999, *G. Hadjikyriakou 4285* (herb. GeoHad); Mazotos, Akro Petounta, W of cape and W of bifurcation of tracks, sandy margins by track along rocky plateau, alt. 10 m, 30.3.2019, *R. Hand 9241* (CYP). – Division 4, South Larnaka Salt Lake, alt. c. 0 m, 12.4.1999, *G. Hadjikyriakou 4333* (herb. GeoHad); ibid., 12.4.1999, *G. Hadjikyriakou 4334* (herb. GeoHad); Ormideia, alt. 30 m, 17.4.1999, *G. Hadjikyriakou 4388* (herb. GeoHad); Perivolia, c. 600 m W of lighthouse, S of Archiepiskopou Makariou III, sandy beach, alt. 2 m, 31.3.2019, *R. Hand 9250* (CYP). – Division 8, Moni Apostolou Andrea, c. 800 m W Kastros, at coastal track, rocky and sandy beach, alt. c. 5 m, 29.4.2005, *R. Hand 4750 & G. Hadjikyriakou* (B).

R. hispida

Greece: ins. Kos (Dodekanes), östl. Marmari bei den Salinen im Salzrasen, 26.4.1990, *H. Scholz* (B).

Italy: Palermo, in argillosis hyeme inundatis, s. d., ex. herb. R. Gross (B).

Tunisia: Salzsteppe am Meer zwischen Enfidaville u. Sebkrat, 16.4.1968, Assa Djiriba [eligible] *& H. Scholz* (B).

R. rohlfsii

Libya: Fezzan, Wadi esc Sciati, Brak: campi coltivati a E del paese fra la strada e l'altipiano, 28.2.1978, *C. Ricceri & C. H. Steinberg*, conf. H. Scholz (B); Fezzan, Sebha, ruderal an bewässerten Gräben der Stadt, 8.4.1970, *H. Scholz* (B); Tripolitanien, Tripolis, in der Stadt, 3.4.1970, *H. Scholz* (B).

Algeria: Oase Oued Said an d. Sebka v. Timimoun, stark versandet, Nähe d. Faggara, 27.2.1978, *Schmidt*, det. H. Scholz (B); El Goleà, in hortis, 4.1904, *L. Chevallier* (B); Metlili, El Goleà, in cultis, 6.-13.3.1899, *L. Chevallier* (B).

Tunisia: gouvern. de Mededine, île de Jerba, Houmt Souk (côte nord), terrain rudéral…, 7.4.1999, *J. Lambinon 99/Tu/24 & J. Margot* (B).

Distribution and ecology

R. hadjikyriakou was first located at Ypsarovounos forest (ýpsaros = gypsum + vounón = mountain), in the vicinity of Mandres, Agios Iakovos and Platani villages (main occurrence at 572184 E 3909366 N). More specifically it was located 2.5 km SW of Mandres Ammochostou (c. 2000 plants) and at Kakotris gypsum hill (c. 20 plants), 1 km S of the same village (division 7, sensu Meikle 1985). Further investigations were carried out in division 8 but the new species was found only 2 km E of Agios Symeon village (Karpasia peninsula), about 45 km E of the type locality. In an area of about one hectare (co-ordinates 612203 E 3926980 N) with scattered spots which possess the ecological requirements (see below) 20–30 plants were found growing here and there in groups of 2–5. Finally, in May 2020 the species was discovered 2.2 km SW of Tochni village (500–1000 plants; coordinates 592022 E 3846652 N), growing on undisturbed gypsum outcrops along with other typical gypsophiles (see Fig. 4).

A search, without any success, has also been performed in various other gypsum areas of Cyprus by G. Hadjikyriakou and the authors in a very promising region situated between the villages Bogazi and Gastria, about 15 km E of the type locality (co-ordinates 597964 E 3911280 N and 590366 E 3911944 N) as well as the poor in gypsophiles, westernmost part of gypsum formations in Pafos district.

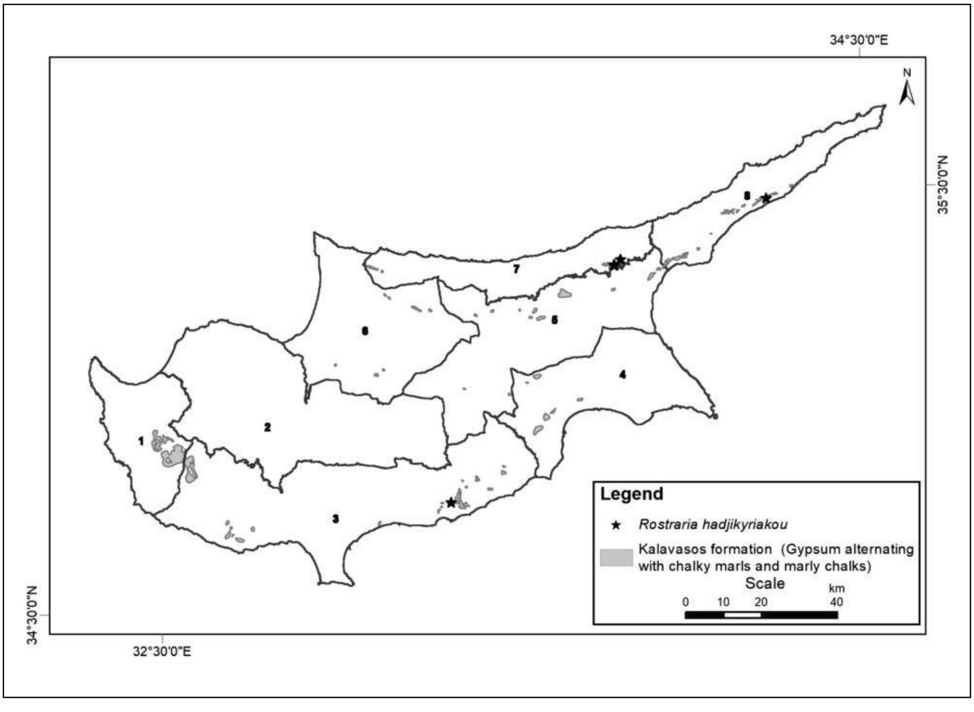

Fig. 4. *Rostraria hadjikyriakou*, distribution in Cyprus; phytogeographical divisions sensu Meikle 1977, 1985. – Map design: K. Papasavvas.

During the search it has been observed that *R. hadjikyriakou* usually grows on spots with somewhat vertical or steep, almost bare and soft gypsum faces of few square metres, with flattish patches on or at their base, generally with a low cover of vegetation consisting mostly of therophytes. Hardish gypsum substrate is clearly avoided and is considered a limiting factor (see also Escudero & al. 2015). The type locality is a compact gypsum outcrop of about 5 km^2 with an altitude ranging between 230–300 m a.s.l., whereas the localities at Agios Symeon (between 70–90 m a.s.l.) and Tochni (110–130 m a.s.l.) consist of smaller and more fragmented gypsum outcrops. All areas in division 7 are dissected by small streams, and are characterised by steep to even slopes, cliffs and scattered, small flattish areas, whereas in division 3 (Tochni) the site is relatively flat with small, even slopes. Geologically they fall within Kalavasos formation (Upper Miocene), which is composed of gypsum alternating with chalky marls and marly chalks (Geological Survey Department 1995).

Derived from measurements at nearby meteorological stations, precipitation rates of about 400–515 mm per year seem probable, if one considers the special topographical situations (Department of Meteorology 2019).

The habitats colonised belong generally to Gypsum steppes “habitat type 1520” (sensu Annex I of the EU Directive 92/43/EEC), the protection of which is of priority. Trees growing in the vicinity of the known localities are *Ceratonia siliqua* L., *Cupressus sempervirens* L., *Pinus brutia* Ten. and *Pistacia lentiscus* L., but *R. hadjikyriakou* avoids shade of trees and shrubs. It most often flourishes on bare gypsum slopes and flattish areas or large openings; sometimes it can be found in the shade of dwarf shrubs. Typical accompanying species are *Allium cupani* subsp. *cyprium* Meikle, *Brachypodium distachyon* (L.) P. Beauv., *Bromus rubens* L., *Bupleurum sintenisii* Huter, *Centaurium pulchellum* (Sw.) Druce, *Chaenorrhinum rubrifolium* (DC.) Fourr., *Cheilanthes acrostica* (Balb.) Tod., *Crepis foetida* L., *Crupina crupinastrum* (Moris) Vis., *Erodium crassifolium* L’Hér., *Filago eriosphaera* (Boiss. & Heldr.) Chrtek & Holub, *Fumana thymifolia* (L.) Verl., *Minuartia picta* (Sm.) Bornm., *Onobrychis venosa* (Desf.) Desv., *Plantago afra* L., *Psilurus incurvus* (Gouan) Schinz & Thell., *Sedum eriocarpum* subsp. *porphyreum* (Kotschy) ‘t Hart, *Teucrium micropodioides* Rouy, *Thymbra capitata* (L.) Cav., *Valantia hispida* L. (with high frequency) and *Vulpia ciliata* Dumort. The gypsophilous taxa *Campanula fastigiata* Schult., *Gypsophila linerarifolia* (Fisch. & C. A. Mey.) Boiss. and *Teucrium salaminium* Hadjik. & Hand as well as the gypsocline species *Herniaria hemistemon* J. Gay were also found in close vicinity. At least at the type locality, in a few spots *R. cristata* has been observed growing syntopically with *R. hadjikyriakou*, but there were no indications of intermediacy or interbreeding. However, the latter colonises only gypsum substrate. Hence, it is the second Cypriot gypsophilous endemic, after *T. salaminium*, which was discovered and described from the same type locality.

Field observations showed that, in contrast to other taxa of its genus, in *R. hadjikyriakou* infructescences do not disarticulate nor shed spikelets and remain on the culms up to six months or even more. Spikelets persist during the whole Mediterranean summer until the first autumn rains start. Repeatedly, we found groups of plants which have germinated and grown up from the remains of a mother plant. Such a strategy may be successful in minimising transfer of diaspores to less appropriate micro-habitats within the gypsum coenoses.

Conservation

R. hadjikyriakou seems to be a rare endemic of Cyprus and according to the IUCN Red List Categories and Criteria (Version 3.1; IUCN Standards and Petitions Subcommittee (2014) it can provisionally be characterised as VU (Vulnerable): D2. This means that the area of occupancy is less than 20 km^2 and the number of locations are less than five, concretely three. Potential threats are grazing, quarrying of gypsum, road construction, agriculture and forestry operations. There are two main subpopulations, the largest one is found at Ypsarovounos, which is State Forest Land and the second and smaller one at Tochni area. At both locations, the species is part of the priority habitat Gypsum steppes (1520*).

Seeds from the Ypsarovounos region (leg. G. Hadjikyriakou, 2018) are stored under the accession number ARI02418 in the Agricultural Research Institute (Athalassa).

Discussion

Material of the new taxon has been compared to all known *Rostraria* species. The cultivation of plants under standardised conditions revealed that all relevant morphological characters observed in the field and in herbarium material are constant and not influenced by ecological factors. Plants showed only a slightly more vigorous growth. *R. hadjikyriakou* belongs to the group of species which possess unequal glumes. However, it displays a unique combination of characters which has not been documented for any other *Rostraria* taxon. Its culms are always enclosed in the subtending leaf sheaths. After anthesis the infructescences do not disarticulate and persist for various months whereas in other *Rostraria* taxa a quick disarticulation can be observed. Furthermore, spikelets of *R. hadjikyriakou* always develop two fertile florets as opposed to three and more in the congeneric taxa. From a morphological point of view, three taxa from this group show certain affinities and were included in a closer comparison. Differences to *R. hispida* and *R. rohlfsii* have been summarised in the diagnosis. Details in comparison are outlined in Table 1. The widespread and very polymorphic *R. cristata* has many similarities to *R. hadjikyriakou* but differs by various characters (see also diagnosis and Tab. 1). In Cyprus as well as in the vast majority of regions elsewhere in the Mediterranean, *R. cristata* develops spikelets longer than 3 mm, often considerably so, whereas *R. hadjikyriakou* is characterised by more delicate spikelets not longer than 2.5 mm. However, two infraspecific taxa of the former with exceptionally small spikelets demand a closer look. Both of which have been described by Domin (1907): *Koeleria phleoides* var. *azorensis* from the Azores islands and *K. phleoides* var. *nitens* from S Italy. In both, exceptionally small spikelets (minimum length c. 2 mm) have been documented. The latter variety differs not only in the general characters unique for *R. hadjikyriakou*, but also in (sub)glabrous, whitish spikelets and the lax, lobate panicle. The former variety is said to have three flowers of which – according to the illustration by Domin (1907) – only the lowest one is shortly awned. Among other characters described, the golden-coloured panicles may be mentioned. Henderson & Schäfer (2003) revised original material of this taxon. They concluded that in this and other material from the Azores “variation is neither distinct nor consistent enough to warrant varietal status”.

Table 1. Main differences of *Rostraria hadjikyriakou* in comparison with selected *Rostraria* taxa, diagnostic characters in bold and shades of grey; main sources: Domin (1907); Clayton & al. (2020), supplemented by own measurements and data from Meikle (1985) and Henderson & Schäfer (2003).

	R. hadjikyriakou	*R. cristata*	*R. hispida*	*R. rohlfsii*
culm length (cm)	2–5	(2–)5–45(–70)	5–30	15–30(–35)
culm, relation to sheath	**always included in subtending sheath**	extending sheath	extending sheath	extending sheath
ligule length (mm)	0.4–0.6	1–3	0.5–0.9	0.5–1
leaf-blade upper surface	pilose to pubescent	glabrous to pubescent	pilose	pubescent
panicle length (cm)	0.8–2.0	(0.5–)1–15(–20)	1–6	3–10
number of fertile florets per spikelet	2	3–8(–13)	3–4	2–4
spikelet length (mm)	(2.0–)2.2–2.5	(2–)3–7(–8)	4–5	4–5.5
disarticulation of spikelet	**not breaking up at maturity, no disarticulation below each fertile floret**	breaking up at maturity, disarticulating below each fertile floret	breaking up at maturity, disarticulating below each fertile floret	breaking up at maturity, disarticulating below each fertile floret
lower glume length (mm)	1.2–1.8	(1.5–)2–3(–4)	2–5	3–3.5
upper glume (mm)	(2.0–)2.3–2.5	(2–)3–4(–5.5)	3–4	4–5
fertile lemma length (mm)	1.3–2.0(–2.2)	(1.5–)3–4(–5)	3–4	3–4
lemma awn length (mm)	1.0-3.5	0–3	3–5	1–3
lemma awn position	apically (in the sinus)	apically (in the sinus) or subapically	subapically	dorsally
anther length (mm)	0.3–0.6	(0.2–)0.3–0.6	0.7–1	0.5–0.7

R. cristata, also the lectotype of the genus, is a taxon with different ploidy levels and discordant placements in phylogenetic trees. It, or at least some of its cytotypes, may have a putative hybrid origin, which needs clarification (Saarela & al. 2017). Generally, phylogenetic studies in all known *Rostraria* species plus various samplings from widespread and variable taxa such as *R. cristata* and the new species from Cyprus would be useful to disentangle the systematics of the genus.

Gypsum ecosystems have been in the focus of nature conservation because of their priority status given by the EU directive. In Cyprus, there have been some intensive studies and monitoring activities within the last 15 years. Therefore, the discovery of a new gypsum endemic comes as a surprise. However, it should be kept in mind that all gypsum specific taxa of the island have been discovered only after the finalisation of the project “Flora of Cyprus” (Meikle 1977, 1985): *Campanula fastigiata* (Hand 2009), *Gypsophila linearifolia* (Hand 2006), *Herniaria hemistemon* (Hand 2006) and the endemic *Teucrium salaminium* (Hadjikyriakou & Hand 2011). It is difficult to explain why all of them escaped the attention of previous generations of field-botanists in Cyprus. The newly described taxon *R. hadjikyriakou* is another addition to the list of obligate gypsum substrate colonisers. The disjunctions within its distribution range are typical for all mentioned taxa. The currently known distribution pattern also confirms that the obligate gypsicolous taxa are restricted to the S and E of the island where precipitation is lower compared to the W part. *R. hadjikyriakou* extends the list of taxa that hopefully will boost protection strategies for gypsum ecosystems in Cyprus.

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References

Bor, N. L. 1985: 28. *Lophochloa* Reichb. Pp. 1766-1770 in: Meikle, R. D. (ed.), Flora of Cyprus, **2.** – Kew.

Clayton, W. D., Vorontsova, M. S., Harman, K. T. & Williamson, H. 2020: GrassBase – The Online World Grass Flora. – http://www.kew.org/data/grasses-db.html [Last accessed 21.7.2020]

Department of Meteorology 2019: Station 572, Kalavasos, Climatological data 1989–2018. Lefkosia.

Domin, K. 1907: Monographie der Gattung *Koeleria*. – Biblioth. Bot. **65.**

Escudero, A., Palacio, S., Maestre, F. T. & Luzuriaga, A. L. 2015: Plant life on gypsum: a review of its multiple facets. – Biol. Rev. Cambridge Philos. Soc. **90:** 1-18. https://doi.org/10.1111/brv.12092

Geological Survey Department 1995: Geological map of Cyprus. Revised Edition. – Lefkosia.

Hadjikyriakou, G. & Hand, R. 2011: *Teucrium salaminium* (*Lamiaceae*, *Teucrium* sect. *Polium*), a new species from Cyprus. – Candollea **66:** 341-351. https://doi.org/10.15553/c2011v662a11

Hand, R. (ed.) 2006: Supplementary notes to the flora of Cyprus V. – Willdenowia **36:** 761-809. https://doi.org/10.3372/wi.36.36211

— (ed.) 2009: Supplementary notes to the flora of Cyprus VI. – Willdenowia **39:** 301-325. https://doi.org/10.3372/wi.39.39209

—, Hadjikyriakou, G. N. & Christodoulou, C. S. (eds) 2021 (continuously updated): Flora of Cyprus – a dynamic checklist. – http://www.flora-of-cyprus.eu/ [Last accessed 10.5.2021]

Henderson, S. & Schäfer, H. 2003: Synopsis of the genus *Rostraria* (*Poaceae*) in the Azores. – Bot. J. Linn. Soc. **141:** 125-131. https://doi.org/10.1046/j.1095-8339.2003.00114.x

IUCN Standards and Petitions Subcommittee 2014: Guidelines for Using the IUCN Red List Categories and Criteria. Version 11. Prepared by the Standards and Petitions Subcommittee. – http://www.iucnredlist.org/documents/RedListGuidelines.pdf [Last accessed 21.7.2020].

Meikle, R. D. 1977, 1985: Flora of Cyprus, **1-2.** – Kew.

Persson, N. L. & Rydin, C. 2016: Phylogenetic relationships of the '*Briza* complex' to other members of the subfamily *Pooideae* (*Poaceae*). – Pl. Ecol. Evol. **149:** 216-227. http://dx.doi.org/10.5091/plecevo.2016.1194

Saarela, J. M., Bull, R. D., Paradis, M. J., Ebata, S. N., Peterson, P. M., Soreng, R. J. & Paszko, B. 2017: Molecular phylogenies of cool-season grasses in the subtribes *Agrostidinae*, *Anthoxanthinae*, *Aveninae*, *Brizinae*, *Calothecinae*, *Koeleriinae* and *Phalaridinae* (*Poaceae*, *Pooideae*, *Poeae*, *Poeae* chloroplast group 1). – PhytoKeys **87:** 1-139. https://doi.org/10.3897/phytokeys.87.12774

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Short note

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Ridha El Mokni & Filip Verloove

First appointment of the invasive *Cyperus eragrostis* (*Cyperaceae*) as an established species in Tunisia

Abstract

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The South American weed *Cyperus eragrostis* Lam. (*Cyperaceae*) is reported for the first time in the wild from Tunisia, North Africa. A brief description of the species is given and it is illustrated in its Tunisian habitat. Its actual distribution is presented and discriminatory characteristics as compared to *C. flavescens*, a native species with which it has been confused for some time, are commented.

Key words: alien plant; *Commelinids*; Monocots; North Africa; *Poales*.

Introduction

Cyperus eragrostis Lam. (*Cyperaceae*) is one of the earliest known alien *Cyperus* species in the European flora. It was initially introduced as a gardening plant in the middle of the 19th century. Its invasion history and distribution were summarized by Petřík (2003) and Verloove (2006). At present, *C. eragrostis* occurs in many countries in South, West and Central Europe and partly also in the Balkan Peninsula (Verloove 2014; Verloove & al. 2014; Stoyanov & Barzov 2018).

In continental North Africa, the genus *Cyperus* is represented by 22 and 15 species in Algeria and Morocco respectively but only by 11 species in Tunisia where *C. eragrostis* has not been recorded so far (Carine & al. 2006; Jiménez-Mejías & Luceño 2011; Bouldjedri & al. 2011; Khabbach & al. 2020; APD 2021).

As part of the ongoing study on the Tunisian Monocots s. lat. (see e.g. El Mokni 2018a, 2018b; El Mokni & Domina 2018a, 2018b; El Mokni & Verloove 2017, 2019a, 2019b; El Mokni & Hadj Khalifa 2020), field surveys revealed a naturalized population of *C. eragrostis*, thus representing its first record in Tunisia. Given the species' invasive attributes, this likely will be the precursor of a wider naturalization in the area. Therefore, morphological notes, data on its habitat, as well as its actual distribution are here presented.

Material and methods

In the summer (July-August) of 2016, during botanical field surveys along and around some ponds and streams within Kroumiria region (NW of Tunisia), an unknown species of *Cyperus* was collected at El Houamdia near the village of Bouhertma (Fernana). Initially, it was erroneously identified as an unusually tall specimen of *C. flavescens* L., a native species that may be found in such habitats and that looks similar. Subsequently, after detailed examination of the glumes, it was correctly identified as *C. eragrostis*, a non-native species not previously recorded in Tunisia. Further field surveys were carried out in the summers of 2017, 2018 and 2020 in the same area and these have confirmed the persistence of *C. eragrostis* in Tunisia. Locally, it behaves like a naturalized species. A revision of herbarium specimens (in the personal herbarium of R. El Mokni) has confirmed this assumption, demonstrating that the oldest record of this species in Tunisia from this same locality dates back already to 2008.

GPS coordinates and altitude for sites are derived from Google Earth® (projected coordinate system WGS84).

The general distribution of *Cyperus eragrostis* has been summarized mainly according to the following works: Flora Europaea (DeFilipps 1980: 286), Flora d'Italia (Pignatti 1982: 696), Petřík (2003), Verloove (2006), Dakskobler & Vreš (2009), Verloove (2014), Stoyanov & Barzov (2018), the Euro+Med PlantBase (2021) and the African Plant Database (APD, 2021). Voucher herbarium specimens from El Houamdia (Bouhertma; Fernana) are preserved in the personal herbarium of R. El Mokni at the Faculty of Pharmacy of Monastir (Herb. Univ. Monastir, not listed in Index Herbariorum) and others were deposited in the herbarium of Meise Botanic Garden, Belgium (BR).

Taxonomic notes

Cyperus eragrostis and *C. flavescens* are morphologically similar and have been confused in Tunisia. Both have a simple or seldom compound 3–6 (–10)-rayed umbel, with ± globose spikes, 1–3 cm in diameter; densely clustered spikelets, close together in slightly furnished heads, oblong, distinctly flattened, 5–20 × 2–3 mm, 10–30-flowered; glumes navicular, distichous, imbricate, oval-obtuse scales. However, *C. eragrostis* is essentially distinguished by its glume characters: these are medially 2-keeled, laterally greenish, off-white to light-brown, with one inconspicuous white vein and a conspicuously isodiametric-reticulate surface; the species moreover is a coarse perennial and its styles are 3-fid. *C. flavescens*, in turn, is a slender annual, rarely exceeding 30 cm with fibrous root. Its glumes are golden yellow, its nutlet surface has transverse, whitish undulations and indistinct longitudinally elongate cells. Its stigmas are always 2-fid.

Distribution in the native and invaded area

Cyperus eragrostis is native to South America. Bryson & al. (1996: 507–508) report the species from Argentina, Bolivia, Brazil, Chile, Peru (cf. also Brako & Zarucchi 1993: 393), Surinam, Uruguay, Juan Fernández Islands and Easter Island (former Isla de Pascua) and

Fig. 1. Morphological characters of *Cyperus eragrostis* in Northwestern Tunisia. A: Plant in its habitat on the banks of Bouhertma river. Culms are obtusely trigonous; B. Inflorescence with several umbels composed of 5–10 rays. Each ray bears densely crowded, compressed spikelets. All photographs were taken by R. El Mokni in Fernana (NW of Tunisia), 30 July 2018.

Mexico (Tucker 1994). In North America the species was introduced into many states (see e.g. Bryson & al. 1996; Kartesz & Meacham 1999). Adventive occurrences are recorded for Tahiti and Cape Land (Kükenthal 1935–1936), New Zealand (Healy & Edgar 1980: 186; Johnson & Brooke 1989: 96), Queensland in Australia (Sharpe, 1986 sec. Clement & Foster, 1994), Canary Islands, Azores and Madeira (Coste 1906; Hohenester & Welß 1993: 311). Egorova (2000: 10) recently reported it from the W Caucasus. See also Verloove (2014) for more details.

In Europe, *C. eragrostis* is included in many handbooks and encyclopedias on gardening and house plants (Grounds 1979: 190; Walters & al. 1984: 115) and at present the nursery trade probably indeed represents the species' main vector of introduction and dispersal. The earliest recorded occurrence in Europe is from Hamburg (1854), although even older reports exist for the 1840s (Nyman 1889). Further early records are known from Northern Spain (since 1857), Western England (1876), Portugal (1877), Belgium (1896), the Netherlands (1913), Switzerland and Hungary (1914), Montenegro (1915) and Northwestern Italy (1934) (see e.g. Walters & al. 1984; Petřík 2003). Actually, in Italy the species occurs in almost all the administrative regions (Domina & al. 2018; Galasso & al. 2018).

In continental North Africa, the exact mode of introduction of *C. eragrostis* is unknown. The species apparently is a relatively recent introduction, only known from a few localities in Morocco (Carine & al. 2006; Khabbach & al. 2020) and Algeria (Bouldjedri & al. 2011).

Occurrence in Tunisia

Cyperus eragrostis is first recorded from Tunisia in the present paper. The species is found since 2008 in the Kroumiria region (NW of Tunisia) where it is growing along the main stream across El Houamdia (Coordinates 36°40'37" N, 08°44'47" E, alt. 225 m a.s.l., Bouhertma; Fernana) in the summer season. At present, the species is well established and is part of the summer floristic vegetation of tributaries within the dam of Bouhertma in the region. Main co-occurring species are: *Dittrichia viscosa* (L.) Greuter subsp. *viscosa*, *Heliotropium supinum* L., *Mentha pulegium* L., *M. suaveolens* Ehrh. subsp. *suaveolens*, *Potamogeton natans* L., *Xanthium spinosum* L., *X. strumarium* L., etc.

References

APD (African Plant Database) 2021: *Cyperus eragrostis* Lam. – http://www.ville-ge.ch/musinfo/bd/cjb/africa/details.php?langue=an&id=37598 [Last accessed 14/01/2021].

Bouldjedri, M., De Belair, G., Mayacha, B., Muller, S. D. 2011: Menaces et conservation des zones humides d'Afrique du Nord: le cas du site Ramsar de Beni-Belaid (NE algérien). – C. R. Biol. **334:** 557-772.

Brako, L. & Zarucchi, J. L. 1993: Catalogue of the flowering plants and gymnosperms of Peru. – St. Louis.

Bryson, C. T., MacDonald, J. R., Carter, R. & Jones, S. D. 1996: Noteworthy *Carex*, *Cyperus*, *Eleocharis*, *Kyllinga*, and *Oxycaryum* (*Cyperaceae*) from Alabama, Georgia, Louisiana, Mississippi, North Carolina, Tennessee, and Texas (USA). – Sida **17/2:** 501-518.

Carine, M. A., Rumsey, F. J, Ait-Lafkih, M., Rejdali, M., Rutherford, R. W. & Jury, S. L. 2006: New plant collections from the north morocco checklist area. – Lagascalia **26**: 196-218.

Clement, E. J. & Foster, M. C., 1994: Alien Plants of the British Isles. A Provisional Catalogue of Vascular Plants (excluding grasses). – London.

Coste, H. J. 1906: Flore descriptive et illustrée de la France, de la Corse et des contrées limitrophes, **3.** – Paris.

Dakskobler, I., Vreš, B. 2009: *Cyperus eragrostis* Lam. – a new adventitious species in the flora of Slovenia. – Hacquetia **8:** 79-90.

DeFilipps, R. A. 1980: *Cyperus* L. – Pp. 284-288 in: Tutin, T. G., Heywood, V. H., Burges, N. A., Moore, D. M., Valentine, D. H., Walters, S. M. & Webb, D. A. (eds), Flora Europaea, **5.** – Cambridge.

Domina, G., Galasso, G., Bartolucci, F. & Guarino, R. 2018: Ellenberg Indicator Values for the vascular flora alien to Italy. – Fl. Medit. **28:** 53-61. http://doi.org/10.7320/FlMedit28.053

Egorova, T. V. 2000: *Cyperus eragrostis* Lam. (*Cyperaceae*): novyi vid dlya flory Kavkaza. – Novosti Sist. Vyssh. Rast. **32:** 7-11.

Euro+Med PlantBase 2021: *Cyperus eragrostis* Lam. Euro+Med PlantBase – the information resource for Euro-Mediterranean plant diversity. –http://www.europlusmed.org/cdm_dataportal/taxon/2978213a-f05f-4589-afcf-df74604301b2 [Last accessed 16/01/2021].

El Mokni, R. 2018a: *Tradescantia fluminensis* Vell. in: Raab–Straube, E. von., Raus, T. (eds), Euro+Med–Cheklist notulae 9. – Willdenowia **48(2):** 199-200. https://doi.org/10.3372/wi.48.48203

— 2018b: *Tradescantia pallida* (Rose) D. R. Hunt. in: Raab–Straube, E. von., Raus, T. (eds), Euro+Med–Cheklist notulae 9. – Willdenowia **48(2):** 200. https://doi.org/10.3372/wi.48.48203

— & Domina, G. 2018a: *Spirodela polyrhiza* (L.) Schleid. in: Raab–Straube, E. von., Raus, T. (eds), Euro+Med–Cheklist notulae 9. – Willdenowia **48(2):** 198. https://doi.org/10.3372/wi.48.48203

— & Domina, G., 2018b: *Wolffia arrhiza* (L.) Wimm. in: Raab–Straube, E. von., Raus, T. (eds), Euro+Med–Cheklist notulae 9. – Willdenowia **48(2):** 197-198. https://doi.org/10.3372/wi.48.48203

— & Hadj Khalifa, K. 2020: More new geophytes for Tunisian and North African alien flora. Fl. Medit. 30: 185-196. https://doi.org/10.7320/FlMedit30.185

— & Verloove, F. 2017: *Ehrharta calycina* Sm. in: Raab–Straube, E. von., Raus, T. (eds), Euro+Med–Cheklist notulae 8. – Willdenowia **47(3):** 299. https://doi.org/10.3372/wi.47.47311

— & — 2019a: New records, distribution and taxonomic notes for non-native vascular flora of Tunisia – I. *Poaceae*. – Fl. Medit. **29:** 45-53. https://doi.org/10.7320/FlMedit29.045

— & — 2019b: *Cyperus alternifolius* subsp. *flabelliformis* Kük. (*Cyperaceae*). in: Raab-Straube, E. von & Raus, Th. (eds), Euro+Med-Checklist Notulae, 11 [Notulae ad floram euro-mediterraneam pertinentes No. 40]. Pp. 430–431. – Willdenowia **49:** 421-445. https://doi.org/10.3372/wi.49.49312

Galasso, G, Conti, F., Peruzzi, L., Ardenghi, N. M. G., Banfi, E., Celesti-Grapow, L., Albano, A., Alessandrini, A., Bacchetta, G., Ballelli, S., Bandini Mazzanti, M., Barberis, G., Bernardo, L., Blasi, C., Bouvet, D., Bovio, M., Cecchi, L., Del Guacchio, E., Domina, G., Fascetti, S., Gallo, L., Gubellini, L., Guiggi, A., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R.R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennei, R., Pierini, B., Podda, L., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R. P., Wilhalm, T. & Bartolucci, F. 2018: An updated checklist of the vascular flora alien to Italy. – Pl. Biosyst. **152:** 556-592. http://doi.org/10.1080/11263504.2018.1441197

Grounds, R. 1979: Ornamental grasses. – London.

Healy, A. J. & Edgar, E. 1980: Flora of New Zealand, **3.** – Wellington.

Hohenester, A. & Welß, W. 1993: Exkursionsflora für die Kanarischen Inseln: mit Ausblicken auf ganz Makaronesien'. – Stuttgart.

Jiménez-Mejías, P. & Luceño, M. 2011: *Cyperaceae* in: Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. *Cyperus eragrostis* Lam. http://ww2.bgbm.org/euroPlusMed/PTaxonDetail.asp?UUID=2978213A-F05F-4589-AFCF-DF74604301B2 [Last accessed 14/01/2021].

Johnson, P. N. & Brooke, P. 1989: Wetland plants in New Zealand. – Wellington.

Kartesz, J. T. & Meacham, C. A. 1999: Synthesis of the North American Flora. Version 1.0'. – Berkeley.

Khabbach, A., Libiad, M. & Ennabili A. 2020: An updated checklist of the wetland vascular flora from Morocco. – Moroccan J. Biol. **17:** 1-35

Kükenthal, G. 1935–1936: *Cyperaceae-Scirpoideae-Cypereae* in: Engler, A. & Diel, L. (eds) – Das Pflanzenreich **IV/20** (Heft 101)**:** 1-671.

Nyman, C. F. 1889: Conspectus florae Europaeae. Supplementum II. Pars prima, Örebro.

Petřík, P. 2003: *Cyperus eragrostis* – a new alien species for the Czech flora and the history of its invasion of Europe. – Preslia **75:** 17-28.

Pignatti, S. 1982: Flora d'Italia, **3.** – Bologna.

Sharpe, P. R. 1986: Keys to *Cyperaceae*, *Restionaceae* & *Juncaceae* of Queensland. – Bot. Bull. Brisbane **5:** 1-47.

Stoyanov, S. & Barzov, Z., 2018: *Cyperus eragrostis* – an addition to the Bulgarian alien flora. – Phytol. Balcan. **24(2):** 239-242.

Tucker, G. C. 1994: Revision of the Mexican species of *Cyperus* (*Cyperaceae*). – Syst. Bot. Monogr. **43:** 1-213.

Verloove, F. 2006: *Cyperus eragrostis* (*Cyperaceae*): historiek en huidige status in België. – Dumortiera **89:** 7-11.

— 2014: A conspectus of *Cyperus* s.l. (*Cyperaceae*) in Europe (incl. Azores, Madeira and Canary Islands), with emphasis on non-native naturalized species. – Webbia **69(2):** 179-223.

—, Laguna Lumbreras, E. & Ferrer Gallego, P. P. 2014: Some potentially weedy *Cyperaceae* new to Spain. – Fl. Medit. **24:** 197-205. http://doi.org/10.7320/FlMedit24.197

Walters, S. M., Brady, A., Brickell, C. D., Cullen, J., Green, P. S., Lewis, J., Matthews, V. A., Webb D. A., Yeo, P. F. & Alexander, J. C. M. 1984: The European garden flora, Monocotyledons (*Juncaceae* to *Orchidaceae*), **2.** – Cambridge.

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Article

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B. Grigorov, N. Velev, A. Assenov, M. Nazarov, M. Gramatikov, B. Genova & K. Vassilev

Grassland habitats on the territory of Dragoman Municipality (Western Bulgaria)

Abstract

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This study aims at mapping and investigating the grassland habitats, defined by Directive 92/43/EEC, on the territory of Dragoman Municipality, Bulgaria. The municipality is located in the western part of the country and is characterized by semi-mountainous terrains and temperate climate. During the fieldwork in 2019 and 2020, 212 relevés were collected, following the Braun-Blanquet approach. Additionally, grassland habitats were checked up at 1340 field points. Grassland habitats covered 89.57 km² or 27.6% of the whole municipality's territory. Six grassland habitat types were differentiated: *Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi* (6110), Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites) (6210), Eastern sub-Mediterranean dry grasslands (62A0), *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*) (6410), Hydrophilous tall herb fringe communities of plains and the montane to alpine levels (6430) and Lowland hay meadows (6510). The most widespread were the xeric grasslands presented within habitats 6210 and 62A0. Traditionally, they are managed as pastures. Habitat 6210 is found on silicate and calcareous substrates, whereas habitat 62A0 is limited to calcareous substrates only. Mesic grasslands were presented by habitat 6510. It is distributed mainly in the Dragoman lowlands and along rivers. Habitats 6410 and 6430 are locally found and cover 0.07 km² and 0.001 km², respectively. The condition, structure and threats for each habitat type are taken into consideration also.

Key words: mapping, natural conservation, NATURA 2000 network.

Introduction

Semi-natural grasslands can be considered among the most species rich habitats particularly in Europe (Wilson & al. 2012; Roleček & al. 2014; Turtureanu & al. 2014; Dengler & al. 2016). A good basis for preserving this natural treasure and setting proper habitat conservation objectives is the adoption of Council Directive 92/42/EEC, due to its promotion of biodiversity protection (Council Directive 92/43/EEC). In this regard, habitat protection is also an important issue, as Fahring (2003) pointed at in his study on the effects of habitat fragmentation.

Republic of Bulgaria, as being a part of the European Union, follows the EU legislation. The ecological network NATURA 2000 is being developed in Bulgaria since 2002. Nowadays, it includes 234 sites declared under the Habitat Directive and covers ca. 30.3% of the country's territory. Habitat studies in Bulgaria are still being carried out by the minute and the vegetation investigations are at the very basis of them.

Some 40% of the territory of Dragoman municipality falls within two Sites of Community Interest: Dragoman (BG0000322) and Western Balkan Range and Forebalkan (BG0001040). Studies on vegetation and habitats in the municipality are still fragmentary and lack completeness. Grassland vegetation on the municipality's territory has been investigated partly by Velev & al. (2011a, 2011b), Vassilev (2012) and Vassilev & al. (2012). It is classified within *Molinio-Arrhenatheretea* and *Festuco-Brometea* classes. Wetland vegetation of the Dragoman Marsh has been studied by Apostolova & al. (2001), Traykov & Tosheva (2015) and Vassilev & al. (2019). Grassland management regimes are reflected in the study of Velev & Vassilev (2014). The condition of grassland ecosystems outside the NATURA 2000 network is assessed in the work of Sopotlieva & al. (2018).

Western Bulgarian Mountains are characterized by highly diversified grasslands containing many rare and endemic species (Horvat & al. 1974; Knapp 1979). At the same time, the semi-mountainous character of the territory combined with its ecological diversity define it as an interesting item for investigating. Furthermore, especially the local flora is rich in endemic and rare species such as *Edraianthus serbicus* Petrovič, *Jurinea tzar-ferdinandii* Davidov, *Astragalus wilmottianus* Stoj, *Tulipa urumoffii* Hayek, *Salix rosmarinifolia* L., etc (Vassilev 2012). The scientific interest in the investigation and mapping of grassland habitats in Dragoman Municipality is related to its proximity to the capital city of Sofia. The latter fact inevitably leads to an intensive anthropogenic impact on habitats and vegetation and especially to plant species and habitat loss. Intensively managed grasslands are mainly found around settlements and are typically ruderalized by overexploitation, while less accessible ones often are subjected to abandonment (Nikolov 2010; Vassilev & al. 2011; Velev & Vassilev 2014). Nowadays many abandoned pastures are to be observed all across the country. Abandonment affects biodiversity, ecology and syntaxonomy of grasslands (Velev & Apostolova 2008; Meshinev & al. 2009; Házi & al. 2011; Vassilev & al. 2011).

The investigation of habitats at a national level is a dynamic process and the current study is intended to contribute to this knowledge. Likewise, grassland habitats within the municipality's area are not completely investigated so far. The main effort is focused on investigating of distribution and condition of grassland habitats, as defined by Habitat Directive, on the whole territory of Dragoman municipality. It is also trying to refine some issues regarding NATURA 2000 habitat mapping like the territorial extent of some habitat polygons and species misinterpretation.

The aim of this study is a complete investigation and mapping of grassland habitats according to Directive 92/43/EEC on the territory of Dragoman Municipality.

Materials and Methods

Geographical position of the study area – Dragoman Municipality is located in the western part of the country, it covers about 324 km² and is characterized by a prevalent semi-mountainous relief. It includes the mountains of Chepun, Mala Planina and Viskyar, as well as the valleys of Sofia and Burel. The highest peak within the municipality's territory is Petrovski Krust (1205 m) in Chepun Mt.

Lythology – The area is underlain by carbonate and non-carbonate sediments and magmatic rocks, represented mainly by the following rock types: limestones, dolomites, sandstones, siltstones, marls and hornblende andesites, trachyandesites, andesitobasalts in extrusive, explosive and subvolcanic facies. Sedimentary rocks are accounting for more than 80% of the area, while magmatics are covering less than 10%.

Soils – Soil types include predominantly rendzinas, leached and podzolized cinnamonic forest soils. The first soil type is typical for the northern and eastern parts of the investigated territory, while the other soil types are characterized by a mosaic distribution in the other parts of the area.

Climate and hydrology of the area – According to the climatic zoning of Bulgaria, Dragoman municipality falls in the Temperate climate zone. It is characterized by warm summers and cold winters (Velev 2010). The climate can also be identified as humid throughout the most parts of Dragoman Municipality with the exception of the southwestern section where the climate is moist subhumid. The main river arteries are Nishava and Gaberska. Other important rivers are Ezhovitsa, Letnishka, Shiroki dol, Kalugeritsa and Skakavets to the north and Kambelevska, Chekinska, Dervent and Sharabanitsa to the south. An important note is that the eastern section of Dragoman Municipality lacks surface runoff due to the karst rocks that are presented there, leading to a prevalence of the underground outflow where the waters emerge in the southern slopes of Mala Planina. The water richness is also accompanied by the presence of the Dragoman Marsh, located in the central part of the municipality. The marsh itself represents a karst water body and an important wetland zone in Bulgaria.

Fieldwork and mapping of habitats

The habitat and vegetation samplings were conducted in 2019 and 2020 field working seasons following Braun-Blanquet approach (1965). All relevés were plotted in homogenous areas of grassland communities and were assigned to a habitat type according to Directive 92/43/EEC. The whole territory was studied thoroughly and during the field trips 1340 field verification points were collected, which were taken from any representative part of the mapped polygons and are categorized to any habitat type (Fig. 1). The acquired data was applied in order to build the habitat map of the area.

The nomenclature of vascular plants followed Delipavlov and Cheshmedzhiev (2003), whereas the high rank syntaxa were harmonized with Mucina & al. (2016).

The habitat types' determination was accomplished according to the Interpretation Manual of European Union Habitats (2013) and Kavrakova & al. (2009) The application of the ArcGIS 10.1 software helped for the cartographic analysis. Spatial data from Forestry Management Plans and habitat mapping of NATURA 2000 in Bulgaria were also used. Habitat types were determined according to Directive 92/43/EEC (Interpretation Manual of European Union Habitats 2007; Kavrakova & al. 2009). 'Habitat directive

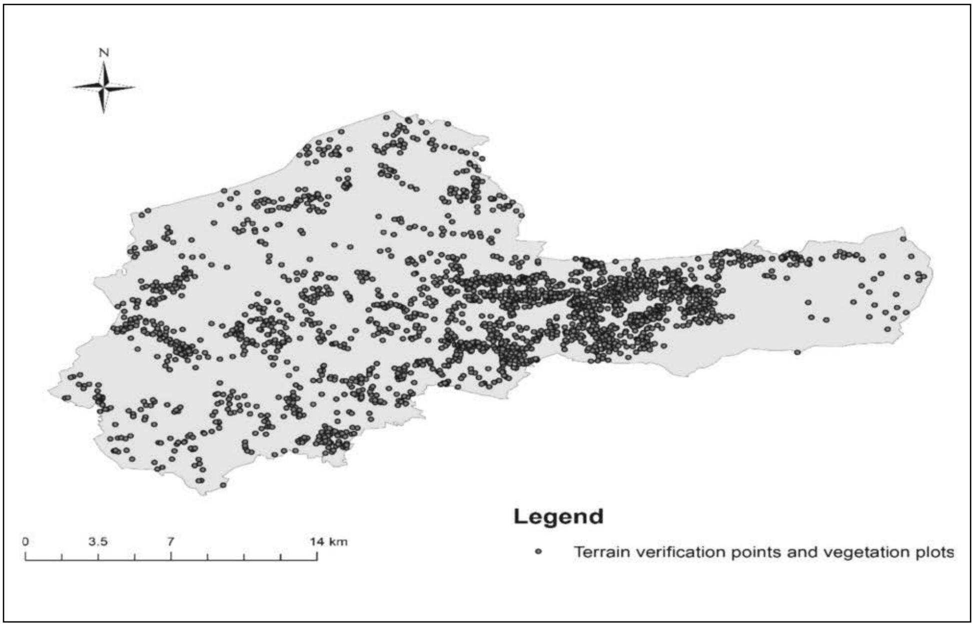

Fig. 1. Vegetation plots and validation points in Dragoman Municipality.

code' is abbreviated as 'HDC' throughout the text below. Mapping was done using ArcGIS 10.1 software (ESRI 2011). Spatial data was collected in the field using the GPS devise Juno BS by Trimble and was later laid over the most recent orthophoto images available. The habitat map was created by the application of the "Intersect" tool by combining the layers, containing forestry data from Forestry Management Plans, as well as data about agricultural areas and habitat data from the habitat mapping of NATURA 2000 in Bulgaria. Later, the "Cut polygon" tool was used in order to modify polygon area. Polygons were outlined manually by using features collected in the field as well as the orthophoto images. Mapping was done in scale 1:5000.

Results & Discussion

Habitat diversity

They cover 89.57 km^2 or 27.6% of the whole territory of Dragoman municipality (Fig. 2). Six habitat types were identified, as following: *Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi* (6110), Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites) (6210), Eastern sub-mediteranean dry grasslands (62A0), *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*) (6410), Hydrophilous tall herb fringe communities of plains and the montane to alpine levels (6430), and Lowland hay meadows (6510).

6110 *Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*

Abiotic characteristic: This habitat can be found as a part of a mosaic (7 mosaic polygons) with habitat types 40A0 and 62A0 within the territory of Dragoman Municipality between 600 and 1000 m a.s.l. Terrains are flat or with a slope inclination up to 60-70°. These mosaics are located in the eastern part of the area, to the northwest and southeast of the villages of Golemo Malovo, Malo Malovo and Vasilovtsi. They cover a total area of 0.15 km^2. The bedrock types are limestones and dolomites. Intensive heating occurs during the summer and the season also leads to prolonged droughts.

Vegetation structure: Very species-poor phytocoenosis with open horizontal structure with total cover 35-60%. Cover of lichens and bryophytes is up to 10%. Herb layer is formed by *Achillea ageratifolia* (Sm.) Boiss. *Sedum album* L., *S. hispanicum* L., *Alyssum minus* (L.) Rothm., *Saxifraga tridactylites* L.*, Arenaria serpylifolia* L.*, Minuartia hybrida* (Vill.) Schischk.*, Globularia aphyllantes* Crantz*, Poa badensis* Willd.*, Hyacenthella leucophaea* (K.Koch) Schur.*, Draba lasiocarpa* Rochel.*, Sempervivum marmoreum* Griseb.*, Jovibarba heuffelii* Schott., etc. In the species composition are also found some endemic plants such as *Edraianthus serbicus Astragalus wilmottianus.* The most frequent lichens and mosses are *Cladonia furfuracea* Vain., *Ceratodon purpureus* (Hedw.) Brid., *Syntrichia ruralis* (Hedw.) F. Weber & D. Mohr., *Ditrichium flexicaule* (Schwägr.) Hampe. Shrubland species, such as *Corothamnus procumbens* (Willd.) C. Presl and *Syringa vulgaris* L. also occur in the territory.

From syntaxonomical point of view this vegetation is transitional between classes *Festuco-Brometea* (all. *Saturejion montanae*) and *Sedo-Scleranthetea* (all. *Alysso alyssoidis-Sedion*).

6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)

Abiotic characteristic: The habitat is widespread, accounting for an area of 53.53 km^2 and is presented by 2033 polygons. It is equally distributed in range 600 to 1000 m a.s.l. Stands cover slopes with different exposition with rough microreleif. Terrains are flat or slightly inclined (up to 20°). Soils are shallow to moderately deep. The bedrock types are consisting mainly of limestones, dolomites and sandstones. It is used mainly for haymaking and as pastures.

Vegetation structure: Species-rich phytocoenoses with semi-open to closed horizontal structure and a projected coverage 85-100%. The coverage of mosses and lichens is 5-15%. Plant communities are rich in species with a prevalence of tussock-forming grasses, such as *Chrysopogon gryllus* (L.) Trin.*, Festuca dalmatica* (Hack.) K. Richt.*, F. pseudodalmatica* Krajina*, F. valesiaca* Gaudin.*, Dichantium ischaemum* (L.) Roberty*, Stipa capillata* L.*, Poa angustifolia* L. This habitat includes communities of alliances *Festucion valesiacae*, *Chrysopogono-Danthionion* and *Brachypodion pinnati* which are investigated in region by Vassilev (2012) and Vassilev & al. (2012). Xero-mesophilic communities of the alliance *Chrysopogono-Danthonion* that are typical for deep, humid soils and on western and northern slopes have a transitional species compound with communities of the alliance *Cynosurion cristati* of *Molinio-Arrhenatheretea class*. Many xero-mesophilic species are common such as *Briza media* L., *Agrostis capillaris* L., *Cynosurus cristatus* L., *Betonica officinalis* L., *Filipendula vulgaris* Moench.*, Trifolium repens* L., *T. montanum* L., *Leucanthemum vulgare* Lam. Communities of the alliance *Brachypodion pinnati* occur on limestone bedrock and are rich in calciphilous species, such as *Brachypodium pinnatum* (L.) P. Beauv*, Anthyllis vulneraria* L., *Polygala major* Jacq*., Trifolium alpestre* L., *T.ochroleucon* Huds. These vegetation types are used for haymaking and as pastures. Xerophilic communities are classified in the alliance *Festucion valesiacae*. Species with higher cover and abundance are *Festuca dalmatica* (Hack.) K.Richt.*, F. valesiaca* Gaudin.*, Dichantium ischaemum* (L.) Roberty*, Chrysopogon gryllus* (L.) Trin.*, Stipa capillata* L. *, Poa angustifolia* L., *Dorycnium herbaceum* Vill.*, Medicago falcata* L.*, Coronilla varia* L.

62A0 Eastern sub-Mediteranean dry grasslands

Abiotic characteristic: The habitat type is presented by 303 polygons and covers 31.88 km^2. Stands are found predominantly on eastern and southern facing-slopes of Chepun Mt., Viskyar Mt. and Mala Planina Mt. within the range of 600-1000 m a.s.l. Terrains are flat to moderately inclined up to 45-50°. The bedrock type is of carbonate and dolomite rocks. Soils are shallow to deep, dry with rough microreleif and calcareous outcrops. The habitat type is sometimes used as a pasture land.

Vegetation structure: Communities have semi-open to closed horizontal structure with a projective coverage between 65-95%. Mosses and lichens cover 10-35%. In the species composition subdominants are *Stipa eriocaulis* Borbás*, Festuca dalmatica* (Hack.) K. Richt.*, Dichantium ischaemum* (L.) Roberty*, Artemisia alba* Turra*, Satureja montana* subsp. *kitaibelii* Wierzb. ex Heuff.*, Potentilla cinerea* Vill. Some polygons have a more heterogeneous structure and they lack a dominant species. Species composition is rich of calcareous species such as *Euphorbia niciciana* Borbás*, Agropyron cristatum* (L.) Gaertn.*, Melica ciliata* L.*, Carex humilis* Leyss.*, Teucrium montanum* L.*, T. polium* L.*, Sideritis montana* L.*, Asperula purpurea* (L.) Ehrend.*, Anthyllis vulneraria* L.*, A. montana* L., *Leontodon crispus* Vill. It is also rich of species with a conservation importance such as *Himantoglossum jankae* Somlyay, Kreutz & Óvári*, Hypericum rumeliacum* Boiss.*, Astragalus wilmottianus, Achillea clypeolata* Sibth.*, Jurinea tsar-ferdinandii, Tulipa urumoffii, Tragopogon balcanicus* Velen.*, Edraianthus serbicus, Chamaecytisus jankae* (Velen.) Rothm, etc. From syntaxonomical point of view this vegetation belongs to alliance *Saturejon montanae* of class *Festuco-Brometea*. Syntaxonomical diversity of this alliance on the territory of municipality is investigated by Vassilev (2012) and Vassilev & al. (2012).

Together with habitat types 40A0, 6110 and 6210 it is also forming 1 mosaic polygon, which covers an area of 1.74 km^2.

6410 *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*)

Abiotic characteristic: This habitat type is restricted only to the most eastern part of the municipality at 800 m a.s.l. where it covers ca. 0.07 km^2. It is located to the southeast of Tsraklevtsi village. Frequently, this habitat type is in mosaic with habitat 6510 Lowland hay meadows, so they form complex vegetation. Most of this complex habitat is to be found eastwards from the eastern municipality border and falls within the SCI BG0000322 Dragoman as part of the NATURA 2000 network. The bedrock types are mainly of carbonate origin. The soils in this area are thick and clayey with a slightly acid reaction. The habitat is characterized with a variable soil moisture throughout the year. Traditionally, in springtime the soils are flooded, but they can dry out for a long period in the summer.

Vegetation structure: Species rich mesic to hygrophilous grasslands with closed horizontal structure and total cover 80-95%. Most frequent species are *Molinia caerulea* (L.) Moench, *Danthonia alpina* Vest., *Agrostis capillaris* L., *Serratula tinctoria* L., *Sanguisorba officinalis* L., *Potentilla erecta* (L.) Raeusch., *Galium verum* L., *Lotus corniculatus* L., *Gentiana pneumonanthe* L., *Hieracium umbellatum* L., *Sieglingia decumbens* (L.) Bernh., *Bistorta major* S. F. Gray., *Iris sibirica* L., *Ranunculus polyanthemos* L., *Festuca pratensis* Huds., *Anthoxanthum odoratum* L. Some tree species as *Betula pendula* Roth and *Pyrus pyraster* Burgsdorf are present also in the area by single individuals. The species composition of this habitat is characteristic with the presence of a very rare species in Bulgaria – *Salix rosmarinifolia*. It is evaluated as Critically Endangered at national level (Apostolova & Tsoneva 2009) and is included in the *Red Data Book of the Republic of Bulgaria* (Apostolova & Tsoneva 2015). *Salix rosmarinifolia* is a shrub reaching up to 0.60–1.0 m in height. The whole population of *S. rosmarinifolia* L. occupies about 100 ha, but only a small part of it falls within Dragoman Municipality. The main part of the species' population is included into the BG0000322 Dragoman protected area. The vegetation is managed as haymaking grasslands and is regularly cut every year. Sometimes cattle are released freely to pasture after cutting. This vegetation belongs to alliance *Molinion caeruleae* W. Koch 1926, order *Molinietalia caeruleae* W. Koch 1926 and class *Molinio-Arrhenatheretea* Tüxen 1937. The phytocoenoses with *S. rosmarinifolia* L. are classified as association *Junco effusi-Molinietum caeruleae* Tüxen 1954 (Hájek & al. 2006).

6430 Hydrophilous tall herb fringe communities of plains and the montane to alpine levels

Abiotic characteristic: This habitat has a limited distribution in the north of Kambelevtsi village at about 610-640 a.s.l and is covering only 0,001 km^2. It occurs in a floodplain area on rather wet and nutrient-rich soils. Typically, ground water usually decreases in dry periods in summer, but soils never dry out completely. It is located over volcanic rocks.

Vegetation structure: Species-poor communities dominated by broad-leaved tall forb *Filipendula ulmaria* (L.) Maxim., which cover 80-90%. The height of herbs is about 1-1.5 m. In the species composition are also found some hygrophyte (e.g. *Carex acutiformis* Ehrh., *Lythrum salicaria* L., *Epilobium hirsutum* L., *Mentha longifolia* (L.) Huds.) and mesic (e.g. *Festuca pratensis* Huds., *Agrostis stolonifera* L., *Deschampsia caespitosa* (L.) Beauv.) species but their cover is up to 2-3%. The maximum of vegetation development is in second half of summer period. The strong shade effect leads to low presence of bryophytes. The litter also formed separate layer and has cover about 90-95%. From syntaxonomical point of view communities of this habitat belongs to alliance *Filipendulion ulmariae* Westhoff & Den Held 1969, order *Filipendulo ulmariae-Lotetalia uliginosi* Passarge 1975 and class *Molinio-Arrhenatheretea.*

6510 Lowland hay meadows

Abiotic characteristic: This habitat type has a fragmented distribution and only within the eastern part of the municipality. It is presented by 153 polygons and occupies a total area of 3.94 km^2. The biggest areas are located in the vicinities of Malo Malovo, Vasilovtsi and Tsraklevtsi villages. Sometimes, this habitat type forms complexes with habitat 6410 *Molinia* meadows on calcareous, peaty or clayey-siltladen soils (*Molinion caeruleae*). Most often, the bedrock types are limestones, dolomitic limestones, dolomites and less shales, sandstones, siltstones and less often – boulders, pebbles and sands. The altitude spans across the range of 620–850 m a.s.l.

Vegetation structure: Species rich mesic grasslands with closed horizontal structure and total cover in the range 80–100%. It represents secondary grassland vegetation, found at the areas of former forests. These grasslands are managed as hay meadows and pastures. The most common plant species are *Arrhenatherum elatius* (L.) J. & C. Presl., *Festuca pratensis* Huds., *F. rubra* agg. L., *Alopecurus pratensis* L., *Cynosurus cristatus* L. , *Poa pratensis* L., *Convolvulus arvensis* L., *Trisetum flavescens* (L.) P. Beauv., *Crepis biennis* L., *Vicia cracca* L., *Agrostis capillaris* L., *Holcus lanatus* L. , *Anthoxanthum odoratum* L., *Lathyrus pratensis* L., *Plantago lanceolata* L. This vegetation is classified within class *Molinio-Arrhenatheretea* Tüxen 1937, order *Arrhenatheretalia elatioris* Tüxen 1931, alliances *Arrhenatherion elatioris* Luquet 1926 and *Cynosurion cristati* Tüxen 1947. Five associations belonging to this habitat type are recognized on the territory of Dragoman Municipality. Three associations present alliance *Arrhenatherion*: the mesic ones *Ranunculo repentis-Alopecuretum pratensis* (Eggler 1933) Ellmauer in Mucina & al. 1993

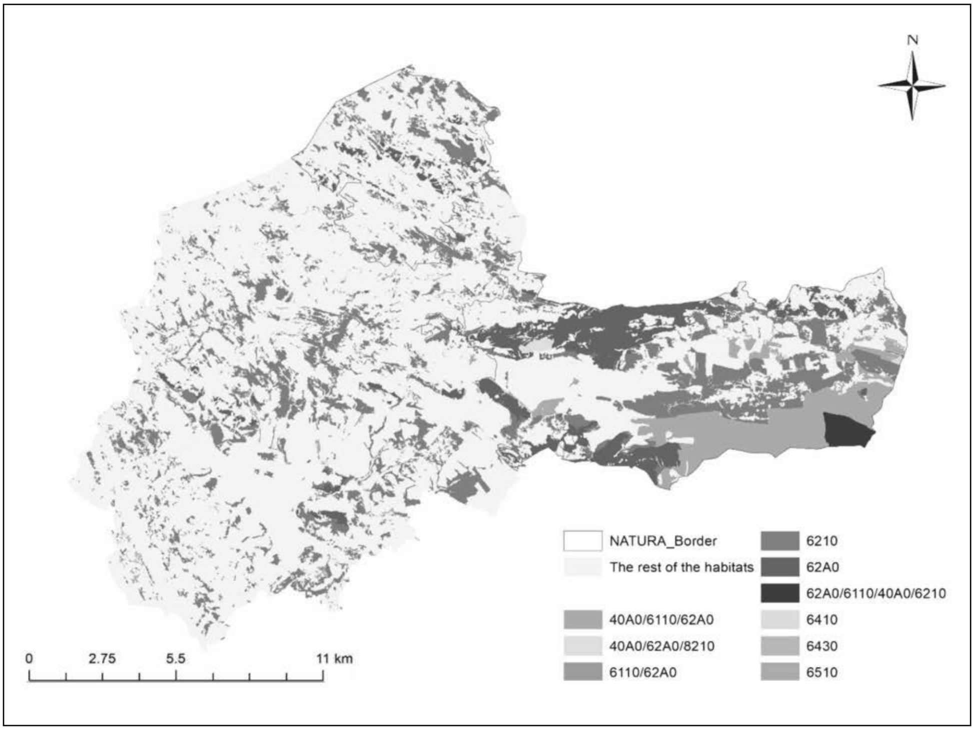

Fig. 2. Grassland habitats in Dragoman Municipality.

and *Pastinaco sativae-Arrhenatheretum elatioris* Passarge 1964, and the xero-mesic *Ranunculo bulbosi-Arrhenatheretum elatioris* Ellmauer in Mucina & al. 1993. Two associations from *Cynosurion* alliance are recorded: the mesic *Bromo racemosi-Cynosuretum cristati* Horvatić (1930) 1958 and the xero-mesic *Festuco rubrae-Agrostetum capillaris* Horvat 1951. All the associations listed were investigated by Velev & al. (2011a, 2011b) in Bulgaria, including those in the studied region.

Evaluation of habitat distribution, condition and threats

This is the first municipality in Bulgaria where all habitat types, protected by Council Directive 92/43/EEC, were investigated and mapped, using the scale of 1:5000. In this paper we are focusing on the representation of grassland habitats, while the results for forest habitat types were prepared in other manuscript (Grigorov & al. in review).

Six grassland habitats have a fragmented distribution, due to the physical characteristics of Dragoman Municipality and the prolonged anthropogenic influence. Habitat 62A0 is representing xerophyte grassland communities and can be discovered on carbonate rocks in the mountains of Mala Planina, Chepun and parts of Viskyar Mountain. Habitat 6110 has a local distribution only on eroded limestones in Mala Planina Mt. and Chepun Mt. Xero-mesophyte and xerophyte communities of habitat 6210 have an even distribution in the valleys and mountainous areas of the municipality. Mesophyte communities of habitat 6510 are found mainly on flat terrains or on slopes with up to 5-6^o inclination in the valley between Mala Planina Mt. and Chepun Mt. as well as in the higher parts of Viskyar Mt. Habitats 6430 and 6410 are locally distributed in areas with high water table. Following the official data habitat 6230 can be located only within 3 polygons. However, nowadays these areas are turned into agricultural areas.

The condition of the grassland habitats is different in the various parts of the municipality. Semi-natural grasslands and grasslands in the stage of formation, such as abandoned agricultural territories are typical for the area. The condition of those habitats that are close to the city of Dragoman and the ones that are falling within the boundaries of the NATURA 2000 sites has improved during last 7-8 years, because of the agricultural subsidies. Habitats 6210, 62A0 and 6510 are known to have been abandoned for the period after the fall of the communism between 1989 and 2010. Extensive grazing was also observed, leading to an ecological change and an appearance of shrubs (10-15%) and overgrazing plays a negative role by altering the ecological structure. Thanks to the subsidies these areas were cleared. A large proportion of the meadows are being mown each year. At the same time pastures are being grazed by sheep and cows. Moderate trampling occurs and cattle helps for the decomposition of nutrients, for example, yet when this processes happens in mid-summer, it leads to erosion and decline in the number of species. Unfortunately, habitats (mainly 6210 and 6510) in remote and depopulated areas, such as Viskyar Mt. and the border area between Bulgaria and Serbia are in a bad condition. In those areas non-grassland species such as *Rosa sp.* L.*,* *Crataegus monogyna* Jacq.*,* *Prunus spinosa* L., *Rubus spp.* L., *Quercus frainetto* Ten.*,* *Q. cerris* L.*,* *Q. daleschampii* (Ten.) A. Camus*,* *Carpinus betulus* L., *C. orientalis* Mill.*,* *Fagus sylvatica* L. and *Fraxinus ornus* L. are becoming dominant. Conservation grazing may be adopted here in order to improve their condition.

During the last 7-8 years some of the polygons that were a part of the NATURA 2000 network were turned into agricultural areas: 6210 (1.78 km^2), 6230 (0.21 km^2), 6430 (0.14 km^2) and 6510 (0.51 km^2). The abandonment of agricultural areas has led to ruderalization in the neighboring grassland polygons. Sites with a disposal of household waste and illegal landfills were found near some polygons of habitats 6210 and 6510. The invasion of *Robinia pseudoacacia* L. is occurring in polygons of habitat 6210 in parts of the slopes of Viskyar Mountain. During the last 10-15 years the exploitation of several quarries in the eastern parts of the municipality has led to the destruction of areas with habitats 6210 and 62A0.

Acknowledgments

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References

Apostolova, I., Petrova, C., Vassilev, P. 2001: Flora and vegetation of the Aldomirovsko marsh protected area. – Ann. Univ. Sofia "Kl.Ohridski" Fac. Biol. Bot. **93(2):** 115-132.

— & Tsoneva, S. 2009: *Salix rosmarinifolia* L. – P. 70 in: Petrova, A. & Vladimirov, V. (eds), Red List of Bulgarian vascular plants. – Phytol. Balcan. **15(1):** 63-94.

— & — 2015: *Salix rosmarinifolia* L. – in: Peev, D., Vladimirov, V., Petrova, A., Anchev, M., Temniskova, D., Denchev, Ts., Ganeva, A. & Gussev, Ch. (eds), Red Data Book of the Republic of Bulgaria, **1.** – Sofia.

Braun-Blanquet, J. 1965: Plant Sociology. The Study of Plant Communities. – New York & London.

Commission of the European Communities, 2013: Interpretation manual of European Union habitats-EUR 28. DG Environment Nature and Biodiversity. Brussels. Commission of the European Communities. –https://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf [Last accessed 2/3/2021]

Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. – http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm [Last accessed 2/3/2021]

Delipavlov D. & Cheshmedzhiev I. (eds). 2003: Key to the plants of Bulgaria. – Plovdiv.

Dengler, J., Biurrun, I., Apostolova, I., Baumann, E., Becker, T., Berastegi, A., Boch, S., Cancellieri, L., Dembicz, I., Didukh, Y. P., Dolnik, C., Ermakov, N., Filibeck G., Garcia-Mijangos, I., Gusso del Galdo, G., Guarino, R., Janišová, M., Jaunatre, R., Jensen, K., Jeschke, M., Kącki, Z., Kozub, Ł., Kuzemko, A. A., Löbel, S., Pedashenko, H., Polyakova, M., Ruprecht, E., Szabó, A., Vassilev, K., Velev, N. & Weiser, F. 2016: Scale-dependent plant diversity in Palaearctic grasslands: a comparative overview. – Bull. EDGG **31:** 12-26.

Fahring, L. 2003: Effects of habitat fragmentation on biodiversity. – Ann. Rev. Ecol. Evol. Syst. **34(1):** 487-515. https://doi/10.1146/annurev.ecolsys.34.011802.132419

Háyek, M., Hájková, P., Apostolova, I., Sopotlieva, D. & Velev, N. 2006: Reports 49–52. – In: Vladimirov, V., Dane, F., Nikolic, T., Stefanovic, V. & Tan, K. (eds), New floristic records in the Balkans: 2. – Phytol. Balcan. **12(2):** 286-287.

Házi, J., Bartha, S., Szentes, S., Wichmann, B. & Penksza, K. 2011: Seminatural grassland management by mowing of *Calamagrostis epigejos* in Hungary. – Pl. Biosyst. **145:** 699-707. https://doi.org/10.1080/11263504.2011.601339

Horvat, I., Glavač, V. & Ellenberg, H. 1974: Vegetation Südosteuropas. – Stuttgard.

Information system for protected areas of the ecological network NATURA 2000 in Bulgaria. – http://natura2000.moew.government.bg/ [Last accessed 3/3/2021]

Kavrakova, V., Dimova, D., Dimitrov, M., Tzonev, R., Belev, T. & Rakovska, K. (eds.) 2009: Manual for Determination of Habitats with European Importance in Bulgaria. 2° ed. –Sofia [in Bulgarian].

Knapp, R. 1979: Distribution of Grasses and Grasslands in Europe. – Pp. 111-123 in: Numata, M. (ed.) Ecology of Grasslands and Bamboolands in the World. – Jena.

McCune, B. & Mefford, M. 1999: PC-ORD. Multivariate analysis of ecological data. Version 4. – Gleneden Beach.

Meshinev, T., Apostolova, I., Petrova, A. & Georgiev, V. 2009: Grassland in North–Eastern Bulgaria – tradition and changes. – Pp. 246-255 in: Veen, P., Jefferson, R., de Smidt, J. & van der Straten, J. (eds), Grasslands in Europe of high nature value. – Zeist.

Mucina, L., Bültmann, H., Dierßen, K., Theurillat, J.-P., Raus, T., Čarni, A., Šumberová, K., Willner, W., Dengler, J., Gavilán García, R., Chytrý, M., Hájek, M., Di Pietro, R., Iakushenko, D., Pallas, J., Daniëls, F. J. A., Bergmeier, E., Santos Guerra, A., Ermakov, N., Valachovič, M., Schaminée, J. H. J., Lysenko, T., Didukh, Ya. P., Pignatti, S., Rodwell, J. S., Capelo, J., Weber, H. E., Solomeshch, A., Dimopoulos, P., Aguiar, C., Freitag, H., Hennekens, S. M. & Tichý, L. 2016: Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. – Appl. Veg. Sci. **19:** 3-264. https://doi/10.1111/avsc.12257

Nikolov, S. 2010: Effects of land abandonment and changing habitat structure on avian assemblages in upland pastures of Bulgaria. – Bird Conserv. Intern. **20:** 200-213.

Roleček, J., Čornej, I. I. & Tokarjuk, A. I. 2014: Understanding the extreme species richness of semi-dry grasslands in east-central Europe: A comparative approach. –Preslia **86:** 13-34.

Sopotlieva, D., Velev, N., Tsvetkova, N., Vassilev, V. & Apostolova, I. 2018: Ecosystem condition assessment of semi-natural grasslands outside the Natura 2000 network in Bulgaria, using vegetation data. – Tuexenia **38:** 385-404. https://doi.org/10.14471/2018.38.012.

Tichý, L. 2002: JUICE, software for vegetation classification. – J. Veg. Sci. **13:** 451-453.

Turtureanu, P. D., Palpurina, S., Becker, T., Dolnik, C., Ruprecht, E., Sutcliffe, L. M. E., Szabó, A. & Dengler, J. 2014: Scale- and taxon-dependent biodiversity patterns of dry grassland vegetation in Transylvania. – Agric. Ecosyst. Environ. **182:** 15-24. https://doi.org/10.1007/s10531-016-1093-y

Traykov, I. & Tosheva, A. 2015: Primary productivity of restored wetland – Dragoman marsh, Bulgaria. – Intern. J. Res. Stud. Biosci. (IJRSB) **3(6):** 61-66.

Tzonev, R., Dimitrov, M. & Roussakova, V. 2009: Syntaxa according to Braun-Blanquet approach in Bulgaria. – Phytol. Balcan. **15(2):** 209-233.

Vassilev, K. 2012: Grassland vegetation on limestone terrains western of Sofia. –Dissertation. Sofia.

—, Apostolova, I. & Pedashenko, H. 2012: *Festuco–Brometea* in Western Bulgaria with an emphasis on *Cirsio–Brachypodion pinnati*. – Hacquetia **11:** 227-248. https://doi.org/10.2478/v10028-012-0011-4

—, Gecheva, G., Ilieva, T. 2019: Macrophyte-based Assessment of Ecological Status of Aldomirovsko and Dragomansko Marshes, Bulgaria. – Ecol. Balkan **11(1):** 161-166.

—, Pedashenko, H., Nikolov, S. C., Apostolova, I. & Dengler, J. 2011: Effect of land abandonment on the vegetation of upland semi-natural grasslands in the Western Balkan Mts., Bulgaria. – Pl. Biosyst. **145:** 654-665. http://doi/abs/10.1080/11263504.2011.601337

—, —, Velev, N. & Apostolova, I. 2014: Grassland vegetation of Special Protection Area “Ponor”. – Acta Zool. Bulgar. **5 (suppl.):** 61-73.

—, —, Alexandrova, A., Tashev, A., Ganeva, A. Gavrilova, A. Gradevska, A., Assenov, A. Vitkova, A., Grigorov, B., Gussev, Ch., Filipova, E., Aneva, I., Knollova, I., Nikolov, I., Georgiev, G., Tinchev, G., Pachedjieva, K., Koev, K., Lyubenova, M., Dimitrov, M., Apostolova-Stoyanova, N., Velev, N., Zhelev, P., Glogov, P., Natcheva, R., Tzonev, R., Boch, S., Hennekens, S., Georgiev, S., Stoyanov, S., Karakiev, T., Kalnikova, V., Shivarov, V., Roussakova, V. & Vulchev, V. 2016: Balkan Vegetation Database: historical background, current status and future perspectives. – Phytocoenologia **46(1):** 89-95. https://doi.org/10.1127/phyto/2016/0109

Velev, S. 2010: Climate of Bulgaria. –Sofia [in Bulgarian].

— & Apostolova, I. 2008: Successional changes of *Nardus stricta* communities in the Central Balkan Range (Bulgaria). – Phytol. Balcan. **14(1):** 75-84.

— & Vassilev, K. 2014: Management regimes within syntaxa of semi-natural grasslands from West Bulgaria. – Hacquetia **13(1):** 191-204. https://doi/full/10.1111/10.2478/hacq-2014-0003

—, Apostolova, I., Fajmonová, Z. 2011a: *Cynosurus cristatus* grasslands in West Bulgaria. – Phytol. Balcan. **17(2):** 221-236.

—, —, Rozbrojová, Z. 2011b: Alliance *Arrhenatherion elatioris* in West Bulgaria. – Phytol. Balcan. **17(1):** 67-78.

Wilson, J. B., Peet, R. K., Dengler, J. & Pärtel, M. 2012: Plant species richness: the world records. – J. Vegetati. Sci. **23:** 796-802. https://doi/full/10.1111/j.1654-1103.2012.01400.x

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Article

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Dimitrios Phitos

Reinstating *Campanula nisyria* as a distinct species of Sect. *Quinqueloculares* (*Campanulaceae*)

Abstract

Phitos, D.: Reinstating *Campanula nisyria* as a distinct species of Sect. *Quinqueloculares* (*Campanulaceae*). — Fl. Medit. 31: 101-107. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The recently emerging trend to define *Campanula nisyria* as a synonym of *C. hagielia* provided the incentive for the publication of the current paper. The morphological differences of the two species, along with their different geographical distribution are supplemented by recent molecular data, which reinforce the clear distinction of the two aforementioned species.

Key words: *Campanula hagielia*, morphology, taxonomy, distribution.

Introduction

The decision to prepare this article stemmed from the examination of the available *Campanula* material, for the PhD Thesis of our collaborator Eleni Liveri (2021).

Thus, after several decades, I return to the study of the *Campanula lyrata* Lam. group, which on the Aegean islands and W Anatolia presents a unique polymorphism, the center of which is on Rhodes island and the surrounding islets. I believe that K. H. Rechinger was the first to clearly express the mentioned polymorphism in his fundamental work "Flora Aegaea – Flora der Inseln und Halbinseln des ägäischen Meeres" (1943), noting (p. 595): "Der Formenkreis der Sect. *Medium* Subsect. *Quinqueloculares* bedürfte dringend einer monographischen Bearbeitung, doch muss diese auf späteren Zeitpunkt verschoben werden". Already, in the first publication on the group of the quinquelocular *Campanula* species (Phitos 1965), we emphatically pointed out its polymorphism. Also Carlström (1987), who studied the flora of Rhodes island and the surrounding islets, mentions, in relation to this: "The quinquelocular *Campanula* species on the East Aegean islands and in W Anatolia are problematic and experimental work on the group is badly needed". In addition, Eddie & Ingrouille (1999) devote another paper to the "Polymorphism in the Aegean "five-loculed" species of the genus *Campanula* section *Quinqueloculares*".

In the process of examining the above-mentioned, collected *Campanula* material, we also turned to the recent, two-volume work by Arne Strid "Atlas of the Aegean

Flora" (2016). In that work, *Campanula nisyria* Papatsou & Phitos is mentioned as synonym of *C. hagielia* Boiss.

Taxonomy

Campanula nisyria Papatsou & Phitos in Notes Roy. Bot. Gard. Edinburgh 34: 203 (1975).
Holotype: − [GREECE, EAST AEGEAN ISLANDS]. No 446. Ins. Nisyros (Dodekanisa): in ditione pagi Emporios, in petrosis vulc., ca. 150 m, 29.5.1971, *S. Papatsou* (Herb. Phitos & Kamari in UPA!). − Fig. 1.

Campanula nisyria is a stenoendemic species that grows only on Nisyros island (East Aegean Islands).

It should be pointed out from the beginning that *C. nisyria* grows mostly on volcanic substrates. No other species of the *C. lyrata* group has been found on Nisyros island. Besides, on Rhodes island, despite the unrestrained polymorphism of the *C. lyrata* group, no individuals have been found so far, bearing the characteristic features of *C. nisyria.*

Table 1 presents the morphological differences between *Campanula nisyria* and *C. hagielia*, based also on the herbar-material, collected in the meanwhile. However, we consider useful to further comment on some characteristic features of *C. nisyria.*

As shown in Fig. 1, the most characteristic traits of *Campanula nisyria* are its robust and usually sole stem, up to 70 cm tall and the leaves in rosettes, oblong-ovate to

Table 1. The main morphological differences between *Campanula nisyria* and *C. hagielia*.

Campanula nisyria	***Campanula hagielia***
Plants long hirsute, scabrid, sometimes strigose	Plants softly hirsute or pubescent
Stem usually single, erect, up to 70 cm, rarely with 1‒2 lateral branches	Stems usually many (1–)2–3(–4), suberect, up to 60 cm, irregularly branched or stems flexuose
Basal leaves (8–)12–18(–21) cm long, oblong-lanceolate to oblong-ovate, crenate, rarely bicrenate	Basal leaves (6–)10–16(–20) cm long, cordate or ovate-cordate, serrate, lobulated-petiolate or sublyrate, crenate to bicrenate
Flowers usually 2–3 together, or sessile to subsessile, forming a spikelet-like inflorescence	Flowers usually solitary, pedicelate or subpedicelate
Corolla tube infundibular; calyx lobe ovate, clearly less than ½ of corolla tube length; appendages densely incanus-hirsute or albo-strigose	Corolla broadly cylindrical to infundibular; calyx lobe variable in form and length; appendages hirsutulous to hirsute

FLORA HELLENICA
INSULAE AEGAEAE
№ 446

Campanula nisyria Papatsou & Phitos

Ins. NISYROS (Dodekanisa): in ditione pagi Emporios, in petrosis vulc. ca I50 m.

29 . V . 197I leg.: S. Papatsou

Fig. 1. Holotype of *Campanula nisyria* (Herb. Phitos & Kamari in UPA).

oblanceolate, reaching 22 cm in length. The main stem usually bears 1-2 lateral stems. The rarely appearing forms with short stems that grow from the base of the plant, are derived from individuals, in which the main stem is missing, most likely eaten by sheep and goats; herding is one of the common practices for Nisyros residents, taking place all over the island. In this case, the common habitus of *C. nisyria* changes, however, the extensive damage on the main stem is visible.

Campanula hagielia Boiss., Fl. Orient. 3: 899 (1875).
Lectotype (designated here): − [GREECE, EAST AEGEAN ISLANDS], Rhodes: Rochers du mont Santo Elio près Salakos, 30 Mai 1870, *Bourgeau 217*, sub *Campanula lyrata* Lam. (G00748548 photo! - SIB 427802/1, image available at http://www.ville-ge.ch/musinfo/bd/cjb/chg/adetail.php?id=550546&base=img). − Fig. 2.

In the Lectotype of *Campanula hagielia* (Fig. 2) it is clear that, apart from a single main stem, at least two secondary shoots grow from its base with stemmed single flowers. Moreover in Fig. 3, the leaf form in the two rosettes, that have been collected from the *locus classicus*, must be considered to be the typical form for this species. It is also clear in this case, that the different variants in leaf form are common, due to the polymorphism (Table 1).

In addition to the above morphological differences, recent molecular data (Liveri & al. 2020) reveal that *Campanula nisyria* belongs to a well-supported clade, together with five Turkish endemics, whereas *C. lyrata* and *C. hagielia* form a different clade; both clades, though, are included in a larger one, consisting of taxa distributed in SE Aegean and Anatolia.

With the above remarks and with the hope that it has become at least clear that *Campanula nisyria* constitutes a distinguished species, this does not mean that the unusual polymorphism of *C. lyrata,* mainly on Rhodos island and the surrounding islets has been solved. In fact, further work is required, which is left to the younger colleagues, particularly in view of the writing of “Flora Hellenica”.

Besides, the author himself has repeatedly commented that the Aegean region with the multitude of islands and islets, is considered a natural laboratory for the evolution of living organisms, a result of which is also the formation of the above-mentioned polymorphism. Without doubt, this creates several difficulties in the taxonomy of the plants and especially in the polyphyletic genus *Campanula,* commonly leading to mistakes that even the author has not avoided in the past.

Acknowledgements

To our collaborator, Dr. E. Liveri, who performed her study on *Campanula* section *Quinqueloculares* with molecular methods, I express my thanks for her help. I also thank our collaborator, Dr. G. Mitsainas, who, like always, checked the English language of the manuscript.

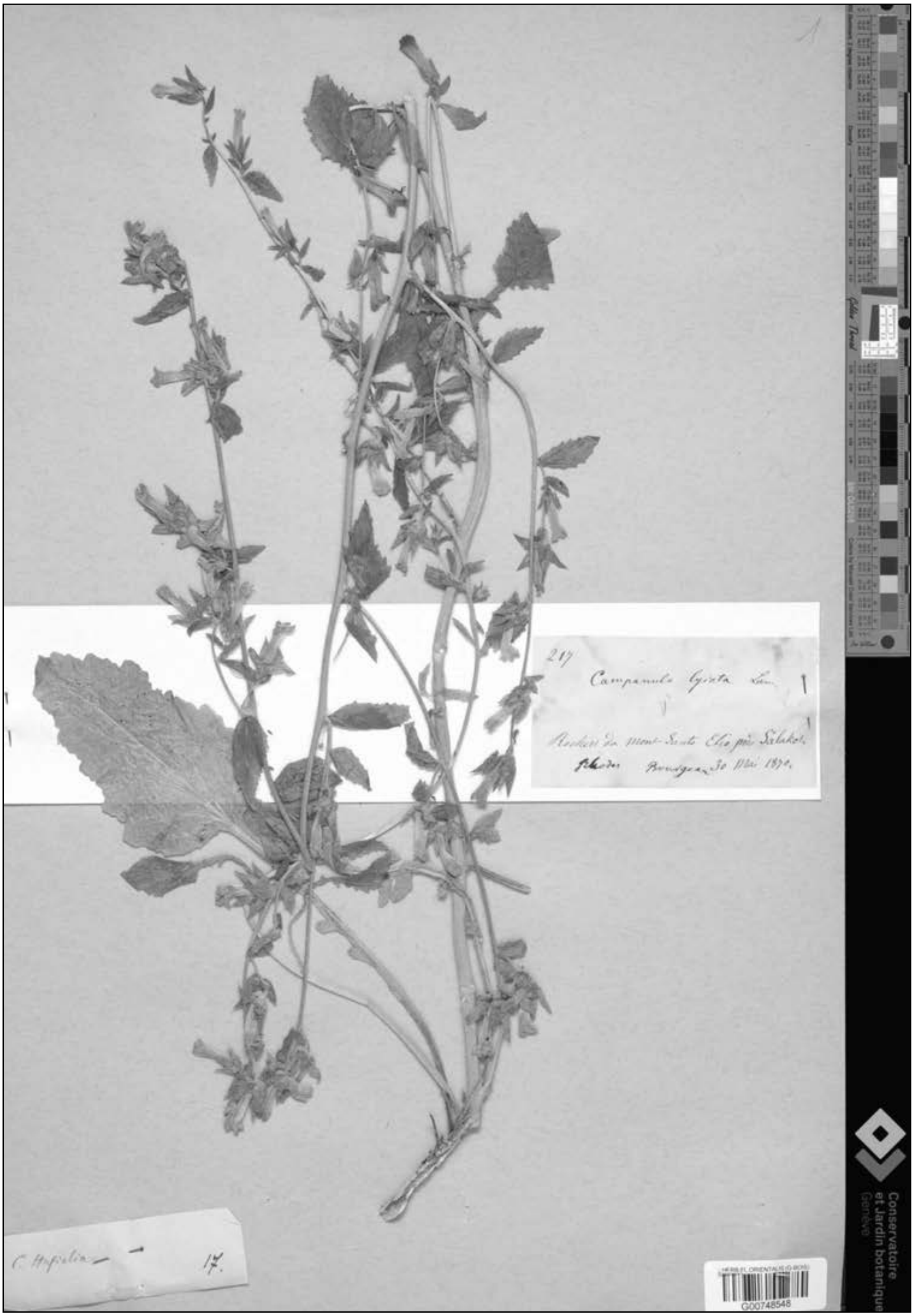
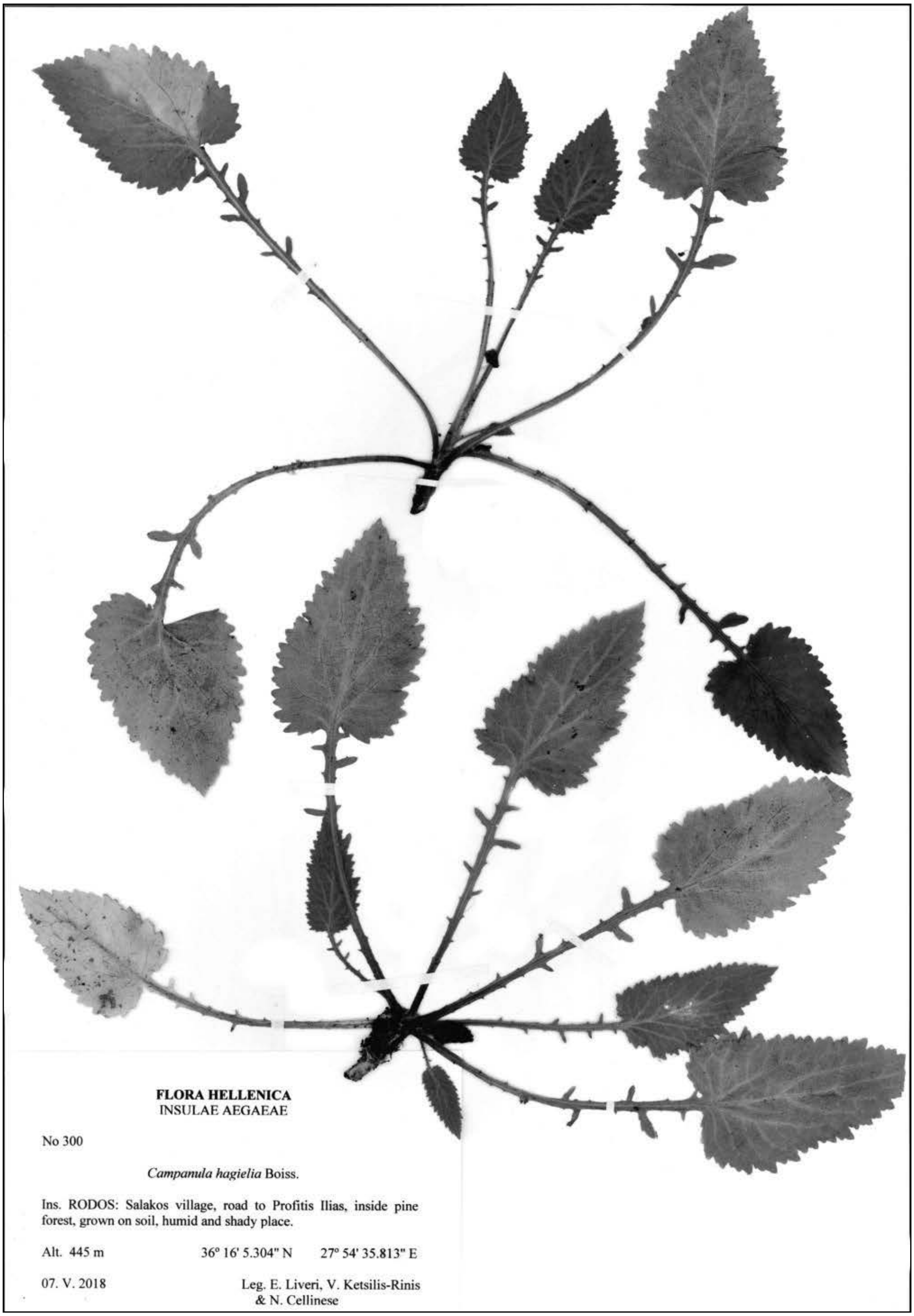


Fig. 2. Lectotype (designated here) of *Campanula hagielia* (Herb. Genève).



FLORA HELLENICA
INSULAE AEGAEAE

No 300

Campanula hagielia Boiss.

Ins. RODOS: Salakos village, road to Profitis Ilias, inside pine forest, grown on soil, humid and shady place.

Alt. 445 m 36° 16' 5.304" N 27° 54' 35.813" E

07. V. 2018 Leg. E. Liveri, V. Ketsilis-Rinis & N. Cellinese

Fig. 3. Rosettes leaves of *Campanula hagielia* from Rhodos island (*locus classicus*).

References

Carlström, A. 1987: A survey of the flora and phytogeography of Rodhos, Simi, Tilos and the Marmaris Peninsula (SE Greece, SW Turkey). – PhD Thesis, Department of Systematic Botany, University of Lund, Sweden.

Davis, P. H. (ed.) 1978: Flora of Turkey and the East Aegean Islands, **6.** – Edinburgh.

Eddie, W. M. M. & Ingrouille, W. J. 1999: Polymorphism in the Aegean “five-loculed” species of the genus *Campanula*, section *Quinqueloculares* (*Campanulaceae*). – Nordic J. Bot. **19:** 153-169. https://doi.org/10.1111/j.1756-1051.1999.tb00659.x

Liveri, E. 2021: Phylogeny and biogeography of *Campanula* L. section *Quinqueloculares* (Boiss.) Phitos (*Campanuloideae*, *Campanulaceae)*. – PhD Thesis, Department of Biology, School of Natural Sciences, University of Patras, Greece [in English with an extensive Greek summary].

—, Crowl, A. A., Mavrodiev, E., Yıldırım, H., Kamari, G. & Cellinese, N. 2020: Another piece of the puzzle, another brick in the wall: The inevitable fate of *Campanula* section *Quinqueloculares* (*Campanulaceae*: *Campanuloideae*). – Taxon **69(6):** 1239-1258. https://doi.org/10.1002/tax.12372

Papatsou, S. & Phitos, D. 1975: Two new taxa from eastern Aegean. – Notes Roy. Bot. Gard. Edinburgh **34:** 203-204.

Phitos, D. 1965: Eine neue art der Gattung *Campanula* aus der Ägäis. – Mitt. Bot. Staatssamml. München **5:** 121-124.

Strid, A. 2016: Atlas of the Aegean Flora, 1. Text & Plates. – Englera **33(1):** 1-700.

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Recent and new taxonomic acquisitions in some native genera of *Asteraceae* from southern Italy and Sicily

Abstract

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After a brief review of the recent acquisition in some native genera of family *Asteraceae* from southern Italy and Sicily, a new endemic species of *Anthemis* (sect. *Hiorthia*) is described from Sicily and named *Anthemis parlatoreana*. The locus classicus of the new taxon, falling in the NW Tyrrhenian coast of the island (Castellammare del Golfo, Trapani), coincides with that of *Ptilostemon greuteri,* another endemic very rare species of the Sicilian flora. Data on the morphology, distribution, ecology and conservation status of the new species are provided. The taxonomic relationships with the other Sicilian taxa of the same section, in particular *A. cupaniana*, are also analyzed. The simultaneous presence in the same site of other endemic plants enriches the area of the limestone reliefs of Castellammare del Golfo and all of north-western Sicily with biogeographic significance and biogenetic importance.

Key words: Italian flora, *Anthemis*, *Centaurea*, *Hieracium*, *Pilosella*, *Ptilostemon, Taraxacum.*

Introduction

In Sicily, as in the other Italian regions, the *Asteraceae* family is very rich of genera and species (see Bartolucci & al. 2018; Pignatti 2019). Some of this are very complex and still contain critical groups within them. In the Mediterranean flora, this condition occurs particularly in the genera *Anthemis*, *Centaurea*, *Hieracium* and *Taraxacum* (Greuter 2008). Several taxa belonging to these genera have recently been described or rediscovered in the flora of southern Italy and Sicily.

In this regard, for *Anthemis* can be mentioned 2 species; for *Hieracium* 7 species and 9 subspecies; for *Taraxacum* 9 species; for *Pilosella* 1 subspecies and for *Ptilostemon* 1 species.

With referring to *Anthemis*, the investigations on the vascular flora of the coastal reliefs of North West Sicily, allowed us to identify a new species in the sect. *Hiorthia* (DC.) R. Fernandes.

In this article, after a brief review of the taxa recently described or rediscovered for the southern regions of Italy and Sicily in the family *Asteraceae*, the new Sicilian species of *Anthemis,* here proposed with the name of *Anthemis parlatoreana,* is finally presented.

Review of recent acquisitions

Anthemis L.

In this genus were described:

A. messanensis Brullo [from Sicily (Brullo 1994)];
A. pignattiorum Guarino, Raimondo & Domina [from Sicily (Guarino & al. 2013)].

Centaurea L.

In this genus were described:

Centaurea poeltiana Puntillo [from Calabria (Puntillo 1996)];
C. aspromontana Brullo, Scelsi & Spampinato [from Calabria (Brullo & al. 2001)];
C. ionica Brullo [from Calabria (Brullo & al. 2001)];
C. pentadactyli Brullo, Scelsi & Spampinato [from Calabria (Brullo & al. 2001)];
C. scillae Brullo [from Calabria (Brullo & al. 2001)];
C. brulla Greuter [from Apulia and Basilicata (Greuter 2003)];
C. erycina Raimondo & Bancheva [from Sicily (Raimondo & Bancheva 2004)];
C. saccensis Raimondo, Bancheva & Ilardi [from Sicily (Raimondo & al. 2004)];
C. sarfattiana Brullo, Gangale & Uzunov [from Calabria (Brullo & al. 2004)];
C. giardinae Raimondo & Spadaro [from Sicily (Raimondo & Spadaro 2006)];
C. lacaitae Peruzzi [from Campania (Peruzzi 2008)];
C. sicana Raimondo & Spadaro [from Sicily (Raimondo & Spadaro 2008)];
C. tyrrhena C. Brullo, Brullo & Giusso [from Sicily (Brullo C. & al. 2011)];
C. calabra G. Caruso, S.A. Giardina, Raimondo & Spadaro [from Calabria (Caruso & al. 2013)];
C. aegusae Domina, Greuter & Raimondo [from Sicily (Domina & al. 2017)];
C. heywoodiana Raimondo, Spadaro & Di Grist. [from Sicily (Raimondo & al. 2020)].

Hieracium L.

In this genus were described or rediscovered:

Hieracium pignattianum Raimondo & Di Grist. [described from Sicily (Raimondo & Di Gristina 2004)];
H. madoniense Raimondo & Di Grist. [described from Sicily (Raimondo & Di Gristina 2007)];
H. pallidum subsp. *aetnense* Gottschl., Raimondo & Di Grist. [described from Sicily (Gottschlich & al. 2013)];
H. hypochoeroides subsp. *montis-scuderii* Di Grist., Gottschl., Galesi, Raimondo & Cristaudo [described from Sicily (Di Gristina & al. 2013)];
H. busambarense Caldarella, Gianguzzi & Gottschl. [described from Sicily (Caldarella & al. 2014)];
H. terraccianoi Di Grist., Gottschl. & Raimondo [described from Calabria (Di Gristina & al. 2014)];
H. barrelieri Gottschl., Raimondo, Greuter & Di Grist. [described from Campania (Gottschlich & al. 2015)];

H. hypochoeroides subsp. *peracutisquamum* Di Grist., Gottschl. & Raimondo [described from Basilicata (Di Gristina & al. 2015a)];
H. hypochoeroides subsp. *lucanicum* (Arv.-Touv.) Di Grist., Gottschl. & Raimondo [rediscovered from Campania (Di Gristina & al. 2015b)];
H. hypochoeroides subsp. *cilentanum* Di Grist., Gottschl. & Raimondo [described from Campania (Di Gristina & al. 2016a)];
H. schmidtii subsp. *nebrodense* (Tineo ex Lojac.) Di Grist., Gottschl. & Raimondo [rediscovered from Sicily (Di Gristina & al. 2016b)];
H. pollinense Zahn [rediscovered from Basilicata (Gottschlich & al. 2017a)];
H. umbrosum subsp. *abietinum* (Boiss. & Heldr.) Greuter [rediscovered from Basilicata (Gottschlich & al. 2017b)];
H. jurassicum subsp. *serrapretense* Di Grist., Gottschl. & Scafidi [described from Basilicata (Di Gristina & al. 2018)];
H. racemosum subsp. *lucanum* Di Grist., Domina, Gottschl. & Scafidi [described from Basilicata (Di Gristina & al. 2019)].

Taraxacum F. H. Wigg.

In this genus were described:
T. carthusianorum Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2008a)];
T. lilianae Aquaro, Caparelli & Peruzzi [from Basilicata (Aquaro & al. 2008b)];
T. calabricum Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2009)];
T. cescae Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2009)];
T. garbarianum Peruzzi, Aquaro, Caparelli & Raimondo [from Sicily (Peruzzi & al. 2009)];
T. kirschneri Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2009)];
T. optimae Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2009)];
T. pollinense Aquaro, Caparelli & Peruzzi [from Calabria (Aquaro & al. 2009)];
T. annalisae Carlesi & Peruzzi [from Campania (Carlesi & Peruzzi 2012)].

Pilosella Vaill.

In this genus was described only:
Pilosella hoppeana subsp. *sicula* Di Grist., Gottschl. & Raimondo [from Sicily (Di Gristina & al. 2016c].

Ptilostemon Cass.

In this genus was described only:
Ptilostemon greuteri Raimondo & Domina [from Sicily (Raimondo & Domina 2006)].

New acquisition

In *Anthemis*, to the two species mentioned above and described from Sicily, today we add a new species wwith the name of *Anthemis parlatoreana*.

Anthemis parlatoreana Raimondo, Bajona, Spadaro & Di Gristina ***sp. nov.*** (Fig. 1).

Diagnosis
Planta caespitosa perennis, *suffruticulosa, viridis-cinerea, cum scapis ramosis, prostratis-ascendentibus, pluricephalibus. Folia petiolata, laciniata; inferiores virides et gradatim cinerea. Capitula* fere 3-5, *receptaculum insigniter conicum. Squamae externae sub-triangulares, acutae, canescentes, cum marginibus brunneis, scariosis et pilosis; internae cartilagineae. Flores radii 18-22; ligula alba, cum apice denticulato; flores disci tubulosi, flavi, cum petalis acutis, curvatis ab exteriore parte; antherae intense flavae. Fructus cuneatus, granulatus in longitudinem costatus, oblique coronatus.*

Typus – Sicily: Castellammare del Golfo (Trapani), northern slopes of Pizzo Stagnone (Inici Mount), on calcareous rock, ca.400 m (a.s.l.), 10 june 2020, *Raimondo & Bajona* (holo PAL-Gr; iso PAL and FI).

Description (Figs 1-3)
Perennial plant, suffruticose, bushy, ashy-green, with branchy scapes, lying down-ascending, (20)30–60(70) cm long, hairy, with numerous capitula. Leaves green and gradually ashy, laciniate; basal leaves 7–10.5 cm long, with obtuse to acute lacinies; median leaves laciniate, 6–10 cm long; the apical leaves laciniate to entire, 1.5–2 cm long; petioles of the basal and median leaves 3–6 cm long; petioles of the cauline ones 2–3 cm long; the apical leaves sessile. Capitula (1)3–5(7); receptacle markedly conical, 1.5–1.8 cm wide at the base, high 0.7–0.8 cm. Involucral bracts outermost sub-triangular, acuminate, greyish subtomentose, brownish, scarious and sparsely hairy at the edges, 1.2–1.5 mm wide, 3 mm long; the innermost cartilaginous, lanceolate and sharp, 1 mm wide, 3.5–4.5 mm long. Ray florets (16)18–22(25), female; ligule white, with dentate apex, (12)13–14(15) mm long; disc florets tubular, golden yellow, with 6–7 mm long pointed petals, curved on the outside; anthers intense yellow. Achene cuneate, 2.5–3.0 × 1 mm long, granulated, longitudinally costate; corona obliquely truncated.

Flowering: April-June.

Etymology: The epitet of the name of the new Sicilian species commemorates one of the most famous Italian botanists of the 19th century: Filippo Parlatore (Palermo 1816–Firenze 1877).

Distribution: Plant is currently known only from the northern coastal reliefs of Castellammare del Golfo in the Trapani province (NW Sicily). It is believed that the new species is however localized in this important carbonate sector of western Sicily (Fig. 4).

Biology and Ecology (Figs 5 and 6): Chamaephyte suffruticose (Ch suff). Ligulate flowers unisexual, female and frequentely abortive.
A. parlatoreana is a robust and competitive plant. From the ecological point of view it is a very plastic species. It prefers the rocky habitat but also colonizes stony ground, rocky soils and, in general, inconsistent substrates in open places. The seeds have a high germinative power (Fig. 5b) and the plants spread the seeds widely even at medium dis-

tances, thus managing to colonize the suitable spaces below the rock environment or, in any case, close to it. *A. parlatoreana*, primarily inhabits the calcareous rocks (Figs 4a, 5b, 5c & 5e) facing to north and north-east, between 250 and 750 m (a.s.l.). It adapts to different habitats and competes well with the corresponding phytocoenoses. On the rocks, it is associated with *Allium subhirsutum* L., *Antirrhinum siculum* Miller, *Asplenium trichomanes* L., *Ballota rupestris* (Biv.) Vis., *Brassica villosa* subsp. *bivonana* (Mazzola & Raimondo) Raimondo & Mazzola, *Centaurea panormitana* subsp. *ucriae* (Lacaita) Greuter, *Ceterach officinarum* DC., *Coronilla valentina* L. (Fig. 5h), *Cymbalaria pubescens* (C. Presl) Cufod., *Dianthus rupicola* Biv. subsp. *rupicola*, *Elichrysum rupestre* subsp. *stramineum* (Guss.) C. Brullo & Brullo, *Euphorbia bivonae* Steudel*, Hyoseris radiata* L., *Iberis semperflorens* L., *Lithodora rosmarinifolia* (Ten.) Johnston, *Lomelosia cretica* (L.) Greuter & Burdet (Fig. 5g), *Matthiola incana* subsp. *rupestris* (Raf.) Nyman, *Melica minuta* L. subsp. *minuta, Micromeria fruticulosa* (Bertol.) Silić, *Ranunculus rupestris* Guss., *Seseli bocconi* Guss., *Silene fruticosa* L., *Umbilicus rupestris* (Salisb.) Dandy; further down also with *Asparagus acutifolius* L., *Chamaerops humilis* L. *Coronilla valentina* L. (Fig. 5h)*, Erica multiflora* L.*, Euphorbia dendroides* L., *Galium aetnicum* Biv.*, Malva arborea* (L.) Webb & Berthel.*, Prasium majus* L., *Ptilostemon greuteri* Raimondo & Domina (Figs 5d and 5h), *Ruta chalepensis* L.*, Teucrium flavum* L.(Fig. 5h), *Urginea maritima* (L.) Baker., and *Valantia muralis* L. In more mesophilous conditions it also associates with *Odontites bocconei* (Guss.) Walpers subsp. *bocconei*.

From the phytosociological point of view, due to its high frequency and coverage, the new species has a differential role in the phytocoenosis attributable to the *Dianthion rupicolae* Brullo & Marcenò 1979 alliance (*Asplenietalia glandulosi* Br.-Bl. & Meier 1934).

Taxonomic remarks: *Anthemis parlatoreana* is well distinct from the species of the *Anthemis* sect. *Hiorthia*. It is very close to the taxa of *Anthemis punctata* group, which in Sicily includes *A. cupaniana* Tod ex Nyman and *A. pignattiorum*. However, *A. parlatoreana* differs from these as it is a more robust and developed plant, very thermophilous, with a short vegetative stasis in mid-summer and early vegetative restart in autumn (Fig. 6a) rather than spring. Due to the ecology and the shape of the receptacle, *A. parlatoreana* is related to *A. pignattiorum* of the southern eastern coast of Sicily. However, it differs from *A. pignattiorum* by the greater length of the floral scapes, by the greater number of capitula per scape, by the greater number of ray florets, by the prominent conical receptacle and to have achenes with corona, rather than devoid of corona as in said species. Furthermore, it is related to *A. cupaniana*, from which, however, it differs by its ecology – as a more thermophilous plant – by the even longer scapes and with more capitula, as well as for the richer number of peripheral flowers of the capitula. It also differs in the markedly conical shape and the larger diameter of the receptacle, in the larger size and pubescence of the external involucral scales (Fig. 2d).

From *Anthemis cretica* subsp. *columnae* occurring in Sicily, the new species differs by its longer and with more capitula scapes, by capitula with a greater number of ray florets, and by the conical rather than subglobose receptacle.

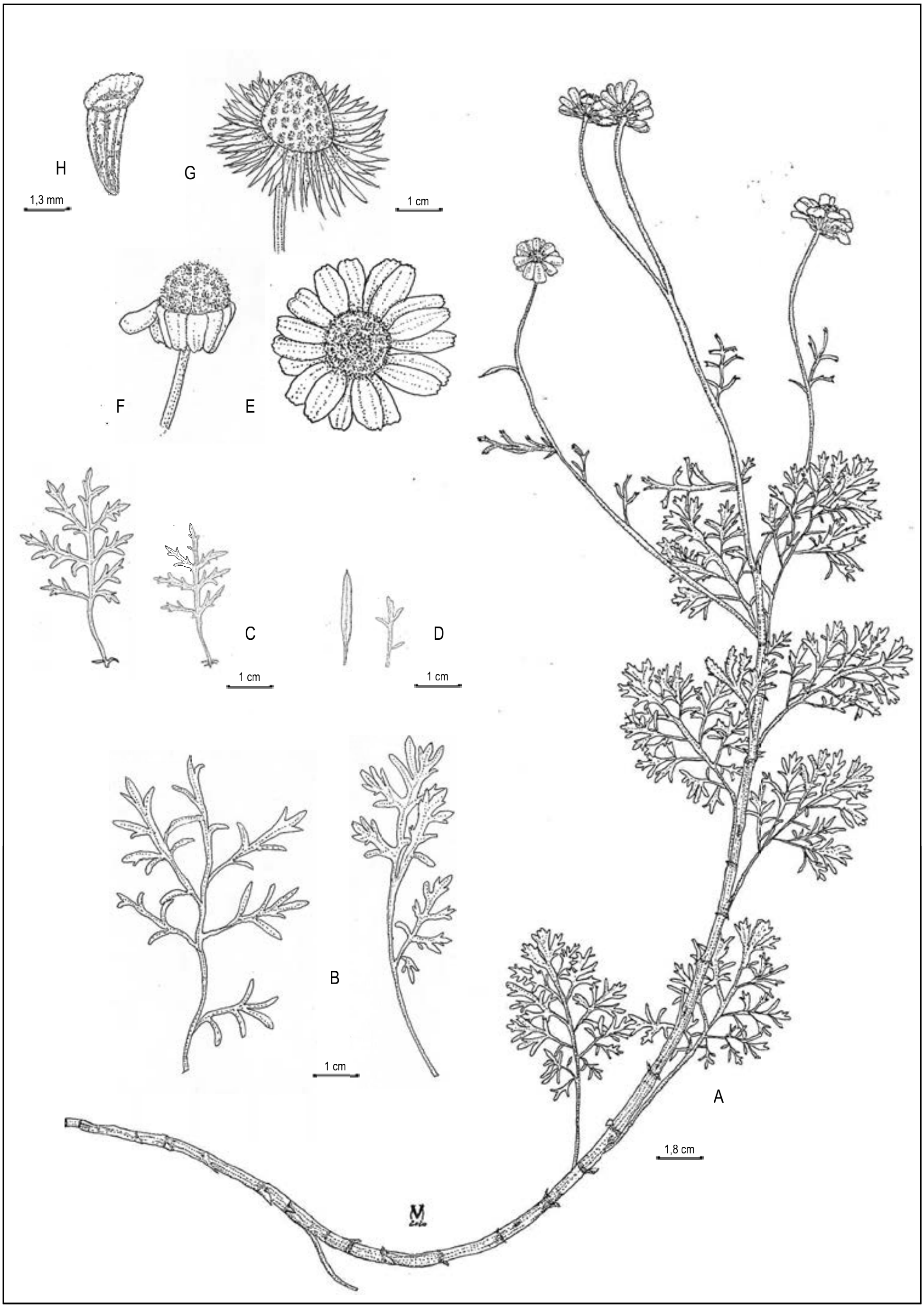

Fig. 1. Iconographic plate of *Anthemis parlatoreana*: a) plant; b) basal leaves; c) cauline leaves; d) apical leaves; d) capitulum in flower; e) post flowering capitulum; f) receptacle; g) mature achene.

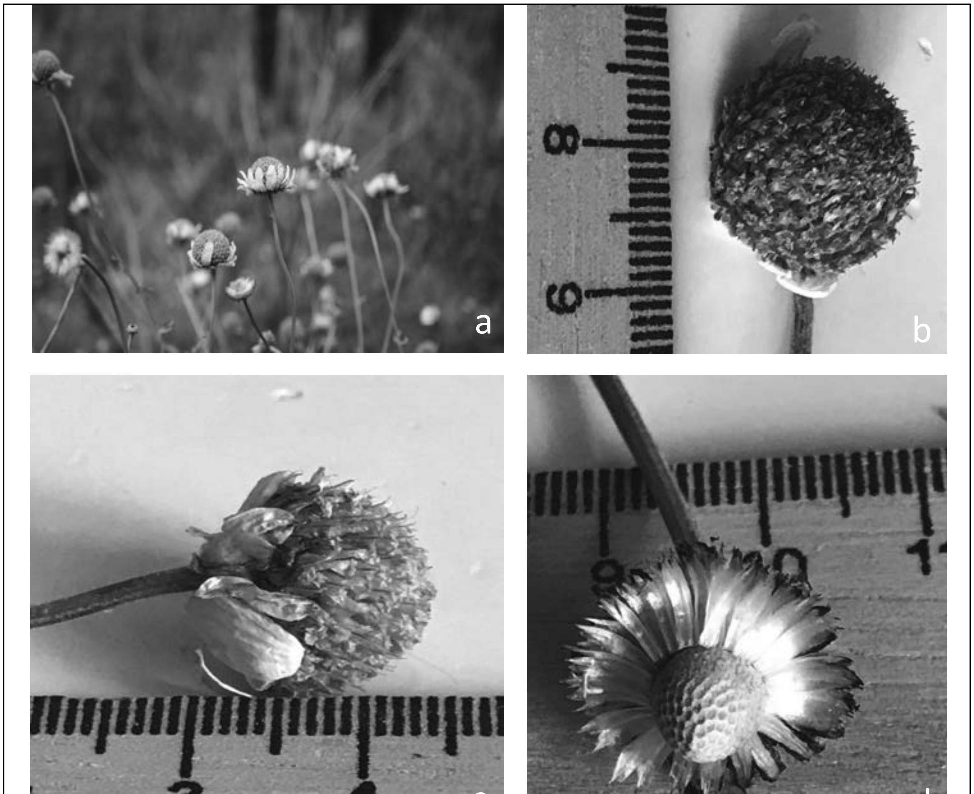

Fig. 3. Details of representative organs of the plant of *Anthemis parlatoreana*: a) mature capitula on the plant *in situ*; b-c) shape and size of the mature capitulum; d-f) shape and size of receptacle in mature capitulum; f) mixture of achenes and internal scales of the capitulum at maturity.

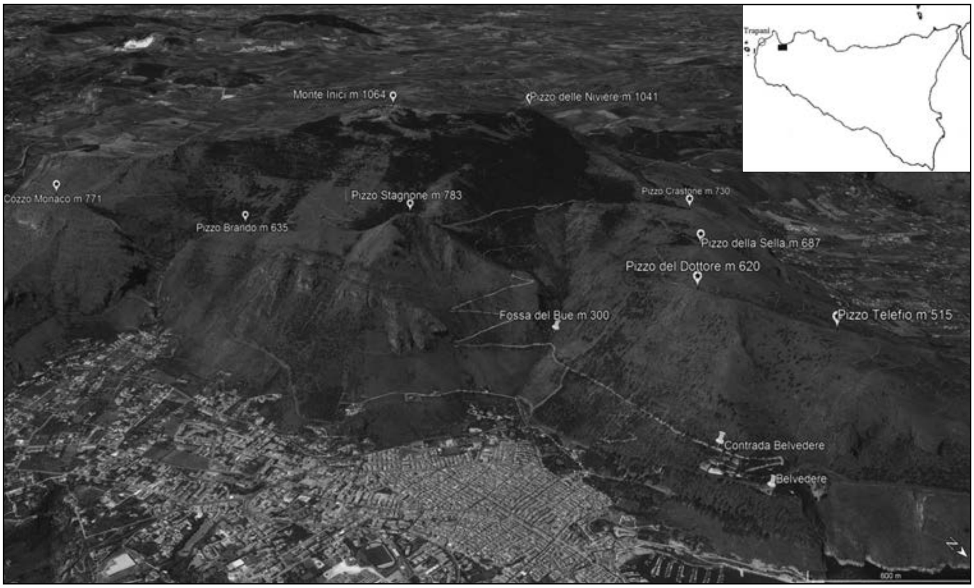

Fig. 4. Overall view of the coastal relief system of Castellammare del Golfo (Trapani) (from Google Earth).

Finally, from the others Sicilian perennial species included in the same section, the new taxon is distinguished from *A. messanensis* and from *A. ismelia* Lojac. – of the nearby coast of Palermo – in being a much more developed and competitive plant, as well as in the shape of the receptacle of the capitula, conical and not obtuse. Instead, *A. parlatoreana* is related to *A. ismelia* by the ecology and shape of the corona of the fruit. From *A. aetnensis* Schouw, it differs not only by its very different ecology, but also by its longer and with more capitula scapes, by the greater number of ray flowers and the different color of the ligules, which are totally white in the new species, while pinkish-purple, at least in the basal portion, in the Etna species (Brullo C. & Brullo 2020). With the latter, *A. parlatoreana* is related, however, to the shape of the corona of the fruit, obliquely truncated (Fig. 1H).

Conservation status: The new taxon is currently known only from one location not exceeding 300 hectares. However, its single known population consist of about 2500 mature individuals that produce many fertile seeds (Fig. 6b) and the renewal is evident and considerable. The recurrence of fires (Fig. 5a) is the main threat for the population, because the *locus classicus* is close to an inhabited center with a rapid urban development (Fig. 4). Although the plants grow preferably on rocks, the recurrent presence of fire could progressively reduce the number of mature individuals. Following the IUCN criteria (IUCN 2019), on the basis of criterion B, due to its restricted area (EOO < 100 km^2 and AOO < 10 km^2), number of location (1) and declining inferred of the quality of habitat and number of mature individuals, *Anthemis parlatoreana* can be classified as *Critically Endangered* (CR): B1ab(iii,v) + 2ab(iii,v).

Fig. 2. *Anthemis parlatoreana*: a-b) plants in full bloom; c) capitulum in full bloom; d) detail of the esternal scales of the capitulum; e-f) plants and capitula at the end of flowering.

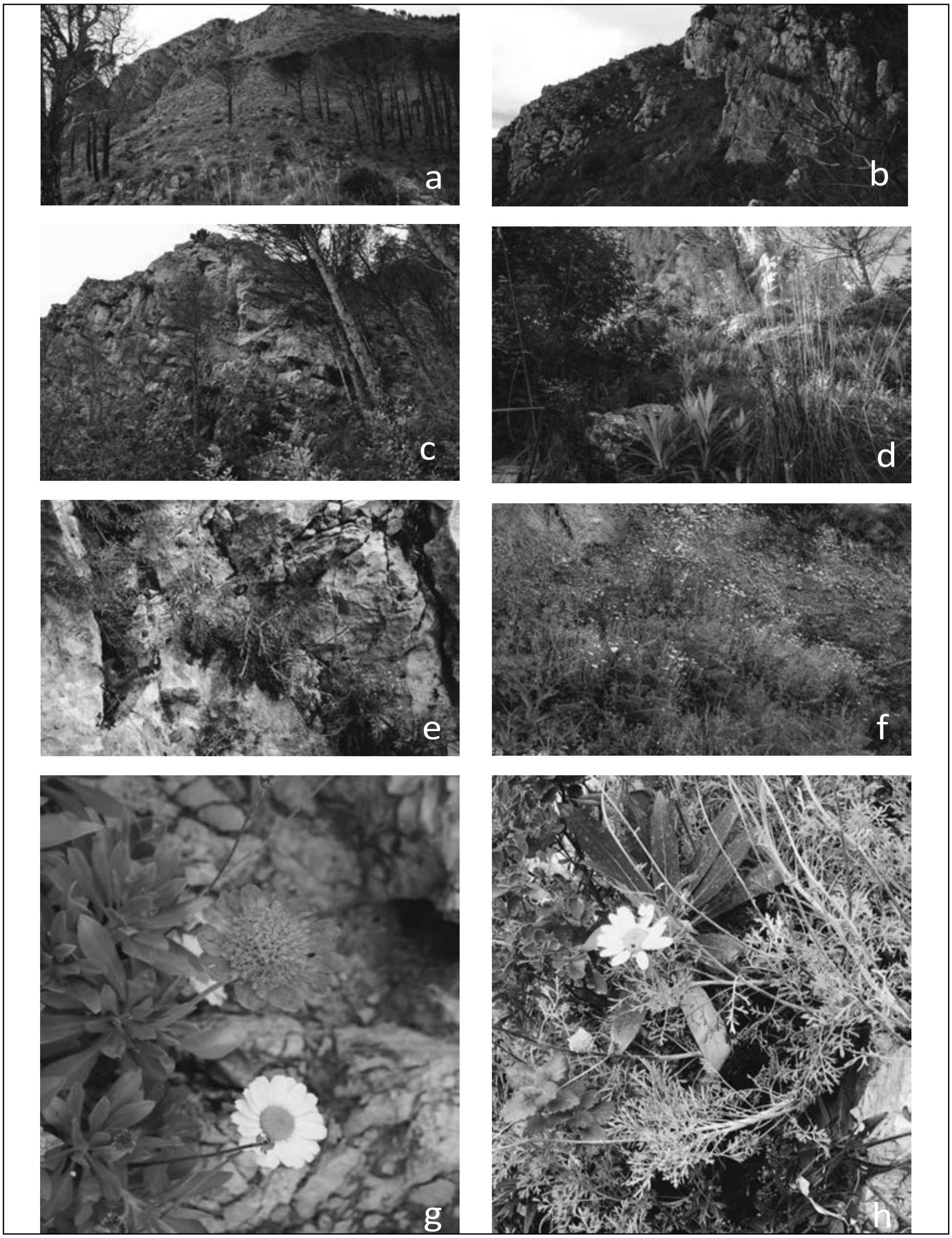

Fig. 5. *Anthemis parlatoreana*: a) habitat of on the northern summit of Pizzo Stagnone (873 m a.s.l.); b) different mesophilous habitats on limestone slopes of Pizzo Stagnone; c) termophilous rock habitats near his *locus classicus*; d) termophilous habitat on limestone debris with *Ptilostemon greuteri* and *Ampelodesmos mauritanicus*; e) chasmophytic habitus in the *locus classicus*; f) habitus of the species on detrital soil; g-h) the new species respectevely with *Lomelosia cretica* and with *P. greuteri*, *Teucrium flavum,* and *Coronilla valentina.*

Fig. 6. *Anthemis parlatoreana*: a) autumn regrowth of a head in habitat; b) germination response of *A. parlatoreana* seeds 20 days after sowing in a plant pot.

Discussion and conclusion

In southern Italy and Sicily, the *Asteraceae* family, and some of its genera in particular, has had a significant increase in specific and subspecific taxa. This increase was particularly evident in the genera *Centaurea* (16 taxa), *Hieracium* (15 taxa), *Taraxacum* (9 taxa) and *Anthemis* (3 taxa, including the new species described here for Sicily). Particulary, the Sicilian flora is enriched by another endemic species of the genus *Anthemis* (*Asteraceae*, *Anthemideae*). In detail, it is a taxon belonging to the sect. *Hiorthia* and connected to the *Anthemis punctata* group that is also present in North Africa (Oberprelier 1998) and already represented in Sicily by two other endemics localized (*A. pignattiorum*) or more widespread in the carbonate mountains of western Sicily (*A. cupaniana*). The population of the new taxon occurs in an interesting area characterized by a high level of endemism, including taxa with very local distributions and at extinction risk, as in the case of *Ptilostemon greuteri* and *Brassica villosa* subsp. *bivonana*. *Anthemis parlatoreana* is therefore added to these latter taxa. It is localized in the area that has its center on Mount Inici (1064 m a.s.l.), a coastal relief close to the town of Castellammare del Golfo (Trapani, NW-Sicily), locality previously mentioned for *A. cupaniana* (Lojacono 1903). However, unlike the other two taxa, by its biological and ecological characteristics, it is not unlikely that the presence of the new taxon goes beyond this restricted area of the Trapani province.

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References

Aquaro, G., Caparelli, K. F. & Peruzzi, L. 2008: The genus *Taraxacum* (*Asteraceae*) in Italy. I. A systematic study of *Taraxacum* sect. *Palustria*. – Phytol. Balcan. **14(1):** 61-67.

—, — & — 2009: The genus *Taraxacum* (*Asteraceae*) in Italy. II. Five new species of *Taraxacum* sect. *Erythrocarpa*. – Pp. 161-169 in: Proceedings of IV Balkan Botanical Congress, 2006. – Sofia.

Bartolucci, F., Peruzzi, L., Galasso, G., Albano, A., Alessandrini, A., Ardenghi, N. M. G., Astuti, G., Bacchetta, G., Ballelli, S., Banfi, E., Barberis, G., Bernardo, L., Bouvet, D., Bovio, M.,Cecchi, L., Di Pietro, R., Domina, G., Fascetti, S., Fenu, G., Festi, F., Foggi, B., Gallo, L.,Gottschlich, G., Gubellini, L., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L.,Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A.,Wagensommer, R. P., Wilhalm & T. Conti, F. 2018: An updated checklist of the vascular flora native to Italy. – Pl. Biosyst. **52(2):** 179-303. https://doi.org/10.1080/11263504.2017.1419996

Brullo, C. & Brullo, S. 2020: Flora endemica illustrata della Sicilia. – Reggio Calabria.

—, — & Giusso, G. 2011: Lectotipificazione e *loci classici* di alcuni endemismi della flora sicula. – Pp. 35–39 in: Peccenini, S. & Domina, G. (eds), Loci classici, taxa critici e monumenti arborei della flora d'Italia. Società Botanica Italiana. – Firenze.

Brullo, S. 1994: *Anthemis messanensis*. – Boll. Accad. Gioenia Sci. Nat. Catania, ser. 3, **27:** 404.

Brullo, S., Gangale, C. & Uzunov, D. 2004: The orophilous cushionlike vegetation of the Sila Massif. – Bot. Jahrb. Syst. **125(4):** 453-488.

—, Scelsi, F. & Spampinato, G. 2001: La Vegetazione dell'Aspromonte. Studio fitosociologico. – Reggio Calabria.

Caldarella, O., Gianguzzi, L. & Gottschlich, G. 2014: *Hieracium busambarense*, a new species of the sect. *Grovesiana* (*Asteraceae*) from Sicily (Italy). – Pl. Biosyst. **148(3):** 439-443. https://doi.org/10.1080/11263504.2013.778352

Carlesi, V. & Peruzzi, L. 2012: The genus *Taraxacum* (*Asteraceae*, *Cichorieae*) in Italy. IV. Two new species of *Taraxacum* sect. *Palustria*. – Willdenowia **42:** 191-197.

Caruso, G., Giardina, A. S., Raimondo, F. M. & Spadaro, V. 2013: A new species of *Centaurea* (*Asteraceae*) from Calabria (S Italy). – Pl. Biosyst. **147(3):** 844-848. http://dx.doi/10.1080/11263504.2013.829889

Di Gristina, E., Gottschlich, G., Galesi, R., Raimondo, F. M. & Cristaudo, A. 2013: *Hieracium hypochoeroides* subsp. *montis-scuderii* (*Asteraceae*), a new endemic subspecies from Sicily (Italy). – Fl. Medit. **23:** 49-55. http://dx.doi/10.7320/FlMedit23.049

—, — & Raimondo, F. M. 2014: *Hieracium terraccianoi* (*Asteraceae*), a new species endemic to the Pollino National Park (Southern Italy). – Phytotaxa **188(1):** 55-60. https://doi.org/10.11646/phytotaxa.188.1.8

—, — & — 2015a: *Hieracium hypochoeroides* subsp. *peracutisquamum* (*Asteraceae*), a new taxon from Basilicata, southern Italy. – Ann. Bot. Fennici **52:** 376-380. http://dx.doi.org/10.5735/085.052.0519

—, — & — 2015b: Taxonomic remarks on *Hieracium sartorianum* var. *lucanicum* (*Asteraceae*), a little known taxon of Cilento (Campania, southern Italy). – Nordic J. Bot. **33:** 465-468. http://dx.doi.org/10.1111/njb.00755

—, — & — 2016a: *Hieracium hypochoeroides* subsp. *cilentanum* (*Asteraceae*), a new taxon from S Italy. – Phytotaxa **246(3):** 192-197. https://doi.org/10.11646/phytotaxa.246.3.3

—, — & — 2016b: Rediscovery of *Hieracium nebrodense* (*Asteraceae*), a little-known endemic of Sicily (Italy). – Phytotaxa **265(1):** 59-66. https://doi.org/10.11646/phytotaxa.265.1.5

—, — & — 2016c: *Pilosella hoppeana* subsp. *sicula* Di Grist., Gottschl. & Raimondo (*Asteraceae*), a new endemic subspecies from Sicily (Italy). – Candollea **71(1):** 7-12. https://doi.org/10.15553/c2016v711a2

—, — & Scafidi, F. 2018: *Hieracium jurassicum* subsp. *serrapretense* (*Asteraceae*), a new hawkweed taxon from the Pollino National Park (southern Italy). – Phytotaxa **340(2):** 186-190. https://doi.org/10.11646/phytotaxa.340.2.8

—, Domina, G., Gottschlich, G., Maturo, F. & Scafidi, F. 2019: *Hieracium racemosum* subsp. *lucanum* (*Asteraceae*), a new hawkweed from southern Italy. – Phytotaxa **425(5):** 297-300. https://doi.org/10.11646/phytotaxa.425.5.5

Domina, G., Greuter, W. & Raimondo, F. M. 2017: A taxonomic reassessment of the *Centaurea busambarensis* complex (*Compositae*, *Cardueae*), with description of a new species from the Egadi Islands (W Sicily). – Israel J. Pl. Sci. **64(1-2):** 48-56. https://doi.org/10.1080/07929978.2016.1257146

Gottschlich, G., Raimondo, F. M. & Di Gristina, E. 2013: *Hieracium pallidum* subsp. *aetnense* (*Asteraceae*), a new subspecies from Sicily (Italy), with notes on the taxonomy of *H. pallidum* Biv. – Pl. Biosyst. **147(3):** 826-831. https://doi.org/10.1080/11263504.2013.829882

—, Scafidi, F. & Di Gristina, E. 2017a: *Hieracium pollinense* (*Asteraceae*), an endemic species to the Pollino National Park (Southern Italy) rediscovered. – Acta Bot. Croat. **76 (1):** 95-97. https://doi.org/10.1515/botcro-2016-0047

—, Domina, G. & Di Gristina, E. 2017b: *Hieracium umbrosum* subsp. *abietinum* (*Asteraceae*), a further example of amphi-Adriatic disjunction. – Pl. Biosyst. **151:** 792-794. https://doi.org/10.1080/11263504.2017.1341439

—, Raimondo, F. M., Greuter, W. & Di Gristina, E. 2015: *Hieracium barrelieri*, a new hawkweed species from S Italy, with notes on Tenore's *Hieracium murorum* var. *barrelieri* (*Asteraceae*). – Phytotaxa **208(1):** 70-74. http://dx.doi.org/10.11646/phytotaxa.208.1.7

Greuter, W. 2003: The Euro Med treatment of *Cardueae (Compositae)* — generic concepts and required new names. – Willdenowia **33(1):** 49-61.

— 2008: Med-Checklist, Dicotyledones (*Compositae*), **2.** – Palermo.

Guarino, R., Raimondo, F. M. & Domina, G. 2013: A new species of *Anthemis* sect. *Hiorthia* (*Asteraceae*) from SE Sicily. – Pl. Biosyst. **147(3):** 821-825. http://dx.doi.org/10.1080/11263504.2013.82988

IUCN 2019. Guidelines for Using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Committee. Cambridge U.K. Available from: http://www.iucnredlist.org/documents/RedListGuidelines.pdf [Last accessed 3.5.2021]

Lojacono Pojero, M. 1903: Flora Sicula, **2(1).** – Palermo.

Oberprieler, C. 1998: The systematics of *Anthemis* L. (*Compositae*, *Anthemideae*) in W and C North Africa. – Bocconea **9:** 5-328.

Peruzzi, L. 2008: *Centaurea lacaitae* Peruzzi. – Pp. 97-115 in: Masin, R., Cassanego, L. & Tietto, C. (eds), Notulae alla checklist della flora vascolare italiana 5. – Inform. Bot. Ital. **40(1).**

—, Aquaro, G., Caparelli, K. F. & Raimondo, F. M. 2009: The genus *Taraxacum* (*Asteraceae*) in Italy. III. A new species of *Taraxacum* sect. *Erythrocarpa* from Sicily. – Fl. Medit. **19:** 73-79.

Pignatti, S. 2018: Flora d'Italia, 2a ed., **3.** – Milano.

Puntillo, D. 1996: A new species of *Centaurea* sect. *Phalolepis* from Calabria (S. Italy). – Fl. Medit. **6:** 219-222.

Raimondo, F.M. & Bancheva, S. 2004: *Centaurea saccensis* (*Asteraceae*), a new species from SW-Sicily. – Bocconea **17:** 293-298.

— & Di Gristina, E. 2004: *Hieracium pignattianum* (*Asteraceae*), a new species from the Madonie Mountains (N-Sicily). – Bocconea **17:** 313-324.

— & — 2007: *Hieracium madoniense* (*Asteraceae*), a new species from Sicily. – Pl. Biosyst. **141(1):** 86-92. https://doi.org/10.1080/11263500601153982

— & Domina, G. 2006: *Ptilostemon greuteri* (*Compositae*), a new species from Sicily. – Willdenowia **36(1):** 169-175.

— & Spadaro, V. 2006: Una nuova specie di *Centaurea* (*Asteraceae*) dell'Etna (Sicilia orientale). – Naturalista Sicil., s.4, **30(4):** 371-378.

— & — 2008: A new species of *Centaurea* (*Asteraceae*) from Sicily**.** – Bot. J. Linn. Soc. **157(4):** 785-788. https://doi.org/10.1111/j.1095-8339.2008.00813.x

—, Bancheva, S. & Di Gristina, E. 2020: *Centaurea heywoodiana* (*Asteraceae*) a new species from Nebrodi Mountains (N-E Sicily). – Fl. Medit. **30:** 369-376. https://doi.org/10.7320/FlMedit30.369

—, — & Ilardi, V. 2004: *Centaurea erycina* (*Asteraceae*), a new species from NW-Sicily. – Bocconea **17:** 299-306.

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Short note

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A. Saci, Z. Boussaada, T. Hamel & G. de Bélair

Première observation d'une endémique tyrrhénienne (*Leucojum aestivum* subsp. *pulchellum*, *Amaryllidaceae*) sur le continent africain (Algérie)

Abstract

Saci, A., Boussaada, Z., Hamel, T. & de Bélair, G.: Première observation d'une endémique tyrrhénienne (*Leucojum aestivum* subsp. *pulchellum*, *Amaryllidaceae*) sur le continent africain (Algérie). — Fl. Medit. 31: 123-128. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

First observation of a Tyrrhenian endemic (*Leucojum aestivum* subsp. *pulchellum*, *Amaryllidaceae*) on the African continent (Algeria). — This work highlights a plant of proven ecological and heritage importance. It is *Leucojum aestivum* subsp. *pulchellum* (Salisb.) Briq., a very rare and localized tyrrhenian endemic taxon from western Numidia (northeastern Algeria). Given its distribution and population characteristics and threats on the only observation locality in North Africa, the taxon deserves appropriate protection measures.

Key words: tyrrhenian endemic, rarity, Numidia, threat, protection.

Introduction

Depuis une dizaine d'années, les connaissances taxonomiques sur la flore vasculaire de l'Algérie ont progressé de manière significative avec la parution de l'index synonymique et bibliographique de la flore d'Afrique du Nord (Dobignard & Chatelain 2010-2013). Nombreux taxons indigènes ont été décrits (ex. de Bélair & Véla 2011; Laribi & al. 2011; de Bélair & al. 2012; Véla & de Bélair 2013; Laribi & al. 2016; Hamel & Boulemtafes 2017a; Sekkal & al. 2017; Boulemtafes & al. 2018; Rebbas & al. 2019; Bougaham & al. 2020) et la chorologie de certaines espèces a pu être précisée (Véla & al. 2016; Babali & Bouazza 2016; Chelghoum & al. 2020; Hamel & al. 2020a).

Toutefois, plusieurs régions en Algérie, restent à ce jour mal explorées, y compris celles classées en tant que "point–chaud" (*hotspot*) de biodiversité (Véla & Benhouhou 2007), mais également certaines zones de littoral numidien, négligées, voire oubliées lors des diagnostiques récents (cf. Yahi & al. 2012; Hamel & al. 2013; Hamel & Boulemtafes 2017b; Boulemtafes & al. 2018).

Nos recherches floristiques dans le massif de Filfila (Nord-Est algérien), entreprises depuis plus de cinq années, nous ont conduits à identifier plusieurs espèces endémiques et rares, dont certaines sont méconnues (cf. Hamel & al. 2020a, 2020b; Hamel & al. inédit).

C'est dans ce contexte, que s'inscrit notre travail mettant en évidence la découverte d'une nouvelle présence sur le continent africain de *Leucojum aestivum* subsp. *pulchellum* (Salisb.) Briq. et permettant la mise à jour syntaxonomique de ce taxon très rare en Algérie.

Observation et découverte

C'est à l'occasion de l'inventaire floristique des milieux humides de la Numidie occidentale que nous avons récolté un spécimen de la Nivéole élégante (*Leucojum aestivum* subsp. *pulchellum*) en janvier 2021 au centre d'une station marécageux située dans une dépression, creusée par l'oued au centre de dunes côtières à Filfila (Fig. 1). L'essentiel de cet hydrosystème est occupé par une ripisylve à *Alnus glutinosa* (L.) Gaertn. et *Populus alba* L., avec une riche couche herbacée dominée par *Pteridium aquilinum* (L.) Kuhn), *Mentha suaeveolens* Ehrh., *Juncus bufonius* L. subsp. *bufonius*, *Helosciadium nodiflorum* (L.) W.D.J. Koch, *Rorippa nasturtium- aquaticum* (L.) Hayek, et aussi par *Veronica anagallis-aquatica* L. subsp. *anagallis-aquatica*, *Juncus acutus* L., *Persicaria decipiens* (R. Br.) K.L. Wilson, *Callitriche obtusangula* Le Gall, *Carex* cfr. *pendula* Huds., *Poa trivialis* L., *Hypericum afrum* Lam. et *Ficaria verna* Huds. Sur les portions de sol en voie de stabilisation, situées à l'interface de cette prairie humide, s'installent quelques plantes psammophiles en contact avec la subéraie (*Malcolmia malcolmioides* (Coss. & Durieu) Greuter & Burdet, *Anchusa aggregata* Lehm., *Linaria pinifolia* (Poir.) Thell., *Cynodon dactylon* (L.) Pers., *Veronica polita* Fr., *Romulea ligustica* Parl., *Lamium amplexicaule* L., *Arisarum vulgare* O. Targ. Tozz., *Polygonum aviculare* L., *Bellis annua* L., *Halimium halimifolium* L. et *Quercus suber* L.).

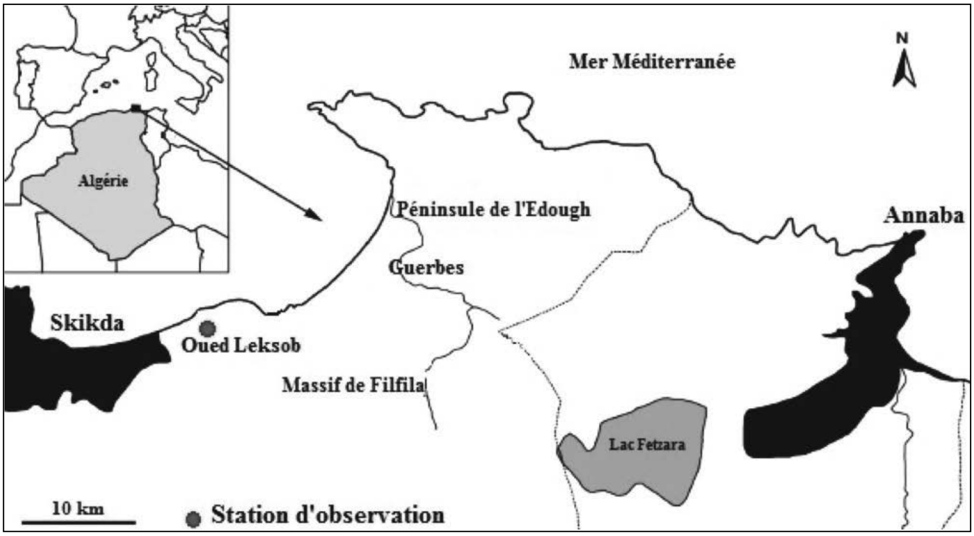

Fig. 1. Localisation de la station d'observation.

La plante observée (Fig. 2) est une Amaryllidaceae de souche endémique tyrrhénienne. Son aire de distribution s'étend depuis la Corse, Sardaigne jusqu' à les îles Baléares (Jeanmonod & Gamisans 2007; Bartolucci & al. 2018).

A ce jour, aucune signalisation n'a été faite pour le continent africain, les deux localités connues étant insulaires (cf. Jeanmonod & Gamisans 2007). Par ailleurs, Maire (1959) décrit l'espèce comme ornementale en Algérie, alors que la réalité terrain nous oblige à la considérer comme une espèce spontanée tout à fait inféodée aux milieux tourbeux de la station d'observation. Toutefois, cette découverte confirme les affinités biogéographiques de l'extrême nord-est algérien et l'île de Galite avec le bloc corso-sarde et/ou l'ensemble insulaire tyrrhénien (Pavon & Véla 2011; Hamel & Boulemtafes 2017a, 2017b; Hamel & al. 2020a). En effet, la découverte inattendue de cette espèce, très éloignée de ses stations classiques des îles tyrrhéniennes, augure de l'existence d'autres populations, qu'il convient de rechercher dans son aire potentielle. Il serait également utile de la rechercher ailleurs dans les aulnaies de la péninsule de l'Edough, où *Soleirolia soleirolii* (Req.) Dandy a été découvert par Hamel et Boulemtafes en 2017(a), il est fort probable que d'autres stations naturelles de ce taxon puissent être découvertes, dans les lacs tourbeux de Guerbès-Senhadja (ex. Garaet Ouajaa, Garaet Chaichaya, lac Sidi Freitis…) comme dans les aulnaies (ex. Demnet Attaoua, El messaousa…).

Menaces

La station de Oued Leksob est soumise à la pression plus ou moins régulière et ancestrale du pâturage ovin et caprin, mais surtout elle est dégradée sur les marges par l'agricul-

Fig. 2. a. Détail de la plante (cliché SACI Amar, le 04-01-2021); b. Photo de la plante dans son habitat (cliché HAMEL Tarek, le 11-01-2021).

ture traditionnelle et les parcelles abandonnées sont envahies par *Ricinus communis* L. et *Oxalis pes-caprae* L. Toutefois, cette région est inscrite sur le plan local d’urbanisme comme *zone naturelle à urbaniser à long terme*, ce qui fait peser sur elle une menace de destruction dans les décennies à venir.

Bilan de conservation

La dégradation irréversible déjà très avancée, et le danger imminent toujours très présent~~,~~ nous invitent à solliciter un classement urgent de protection des espèces et des écosystèmes les plus critiques de massif de Filfila. Les espaces géographiques constituées par le cordon dunaire de l’ouest de Filfila, sur une largeur environ d’un kilomètre, d’une part, et sur la partie Nord-Est depuis les plaines de Guerbès jusqu’au massif forestier à *Quercus suber* L. et *Q. canariensis* Willd. d’autre part, peuvent désormais être classes zones importantes pour les plantes (ZIP) sur la base des critères recommandées par Plantlife International (2004) et Radford & al. (2011). Une telle décision viendra compléter la prise en compte récente, en tant que ZIP, des zones voisines de Guerbès et péninsule de l’Edough d’une part et de la péninsule de Collo d’une autre part (Yahi & al. 2012; Benhouhou & al. 2018). Toutefois, la présence de ce taxon critique à Filfila sera un argument supplémentaire pour considérer cette région comme future Zone Importante pour les Plantes « ZIP » en Algérie (cf. Hamel & al. 2020a, 2020b).

Il va de soi qu’il est important de conserver le taxon en utilisant à la fois des méthodes de conservation *ex situ* et *in situ*. *Ex situ* peut consister en la collecte et conservation de graines en chambre froide, ainsi que de bulbes pour mise en culture en jardin conservatoire, les unes comme les autres pouvant ultérieurement servir à des renforts de populations dans des secteurs de présence, voire à des réintroductions dans les aulnaies de Guerbès. *In situ*, par la mise en défend de la station d’observation.

Conclusion

Cette nouvelle observation contribue à renforcer nos connaissances sur la répartition géographique d’un taxon endémique et très rare en Algérie.

Il reste à souligner que ce taxon est représenté par une seule population en Algérie et qu’il doit être proposé pour inscription sur la liste des espèces protégées dans ce pays (cf. JORA 2012).

Références

Babali, B. & Bouazza, M. 2016: Redécouverte de *Pulicaria vulgaris* subsp. *pomeliana* (Faure et Maire) E. Gamal-Eldin (*Asteraceae*) dans la région de Tlemcen (Algérie occidentale). – Bull. Soc. Linn. Prov. **67:** 45-52. https://doi.org/10.24310/abm.v43i0.4840

Bartolucci, F., Peruzzi, L., Galasso, G., Albano, A., Alessandrini, A., Ardenghi, N. M. G., Astuti, G., Bacchetta, G., Ballelli, S., Banfi, E., Barberis, G., Bernardo, L., Bouvet, D., Bovio, M., Cecchi, L., Di Pietro, R., Domina, G., Fascetti, S., Fenu, G., Festi, F., Foggi, B., Gallo, L., Gottschlich, G., Gubellini, L., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Poldini, R., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R.P., Wilhalm, T. & Conti, F, 2018: An updated checklist of the vascular flora native to Italy. – Pl. Biosyst. **152:** 179-303. https://doi.org/doi.org/10.1080/11263504.2017.1419996

Benhouhou S., Yahi N. & Véla E. 2018: Chapter 3, Algeria. – Pp. 53-60 in: Valderrábano, M., Gil, T., Heywood, V. & de Montmollin, B., Conserving wild plants in the south and east Mediterranean region. – Gland. https://doi.org/10.2305/iucn.ch.2018.21.en

Bougaham, AF., Rebbas, K. & Véla, E. 2020: Découverte d'*Epipactis microphylla* (*Orchidaceae*) au Djebel Babor (nord-est de l'Algérie), orchidée nouvelle pour l'Afrique du Nord. – Fl. Medit. **30:** 261-271. https://doi.org/10.7320/FlMedit30.261

Boulemtafes, A., Hamel, T., de Bélair, G. & Véla, E. 2018: Nouvelles données sur la distribution et l'écologie de seize taxons végétaux du littoral de la péninsule de l'Edough (Nord–Est algérien). – Bull. Soc. Linn. Provence **69:** 59-76.

Chelghoum, H., Ait Hammou, M., Miara, MD., Nemer, W. & Véla, E. 2020: Précisions sur la répartition de *Malva stenopetala (Malvaceae)* en Algérie. – Bull. Soc. Linn. Provence **71:** 229-233.

de Bélair, G., Belouahem, F., Belouahem-Abed, D. & Véla, E. 2012: Première signalisation d'*Allium commutatum* Guss. (*Alliaceae*) sur le continent africain (Algérie). – Lagascalia **32:** 312-314.

de Bélair, G. & Véla, E. 2011: Découverte de *Nymphoides peltata* (Gmel) O. Kuntze (*Menyanthaceae*) en Afrique du Nord (Algérie). – Poiretia **3:** 1-7.

Hamel, T., Seridi, R., de Bélair, G., Slimani, A. R. & Babali, B. 2013: Flore vasculaire rare et endémique de la péninsule de l'Edough (Nord-Est algérien). – Rev. Synth. Sci. Technol. **26:** 65-74.

— & Boulemtafes, A. 2017a: Découverte d'une endémique tyrrhénienne *Soleirolia soleirolii* (*Urticaceae*) en Algérie (Afrique du Nord). – Fl. Medit. **27:** 185-193. https://doi.org/10.7320/FlMedit27.185

— 2017b: Nouvelle station de *Sixalix farinosa* (Coss.) Greuter et Burdet dans la péninsule de l'Edough (Nord–Est algérien). –Bull. Soc. Linn. Provence **68:** 93-100.

—, Saci, A. & de Bélair, G. 2020a: Redécouverte d'un subendémique tyrrhénien, *Tuberaria acuminata* (Viv.) Grosser, en Numidie (Nord – Est algérien). – Bull. Soc. linn. Provence **71:** 243-248.

—, de Bélair, G., Slimani, AR., Boutabia, L. & Telailia, S. 2020b: Nouvelle station de *Pteris vittata L.* (*Pteridaceae*) en Numidie (Algérie orientale). – Act. Bot. Malacitana **45:** 1-4. https://doi.org/10.24310/abm.v45i0.5744

J.O.R.A., 2012: Décret exécutif du 18 janvier 2012, complétant la liste des espèces végétales non cultivées et protégées. – (eds) J. Off. Rép. Alg. **12-03:** 28.

Jeanmonod, D. & Gamisans, J. 2007: Flora Corsica. – Aix-en- Provence.

Laribi, M., Acherar, M., Mathez, J. & Derridj, A. 2011: Découverte de *Rhynchocorys elephas* (L.) Griseb. dans l'Akfadou (Grande Kabylie, Algérie): première mention pour l'Afrique du Nord. – J. Bot. Soc. Bot. France **53:** 31-36.

Laribi, M., Véla, E., Acherar, M., Mathez, J. & Hamchi, A. 2016: Sur la découverte de *Potentilla supina* L. en Algérie : Écologie, taxinomie, biogéographie et statut de conservation. – Rev. Ecol. (Terre et Vie) **71(3):** 266-277.

Maire, R. 1959: Flore de l'Afrique du Nord (Maroc, Algérie, Tunisie, Tripolitaine, Cyrénaïque et Sahara), **6.** – Paris.

Pavon, D. & Véla, E. 2011: Espèces nouvelles pour la Tunisie observées sur les petites îles de la côte septentrionale (archipels de la Galite et de Zembra, îlots de Bizerte). – Fl. Medit. **21:** 273-286.

Radford, E.A., Catullo, G., Montmollin, B., 2011: Zones importantes pour les plantes en Méditerranée méridionale et orientale, sites prioritaires pour la conservation. – Gland.

Rebbas, K., Véla, E., Bougaham, A.F., Belharrat, A., de Bélair, G. & Prelli, R. 2019: Découverte de *Christella dentata* (*Thelypteridaceae*) en Algérie. – Fl. Medit. **29:** 55-66. https://doi.org/10.7320/FlMedit29.055

Sekkal, F. Z., Hadjadj-Aoul, S. & Véla, E. 2018: *Echium modestum* Ball*, Plantago benisnassenii* Romo, Peris & Stübing*, Teucrium doumerguei* Sennen: Nouveaux taxons pour la flore d'Algérie (Massif des Traras). – Rev. Ecol. (Terre et Vie). **73(1):** 41-56.

UICN. 2021: Liste rouge de l'UICN des espèces menacées. Version 2021–1. www.iucnredlist.org [Dernier accès 1.3.2021]

Véla, E. & Benhouhou, S. 2007: Évaluation d'un nouveau point chaud de biodiversité végétale dans le bassin méditerranéen (Afrique du Nord). – C. R. Biol. **330:** 589-605. https://doi.org/10.1016/j.crvi.2007.04.006

— & de Bélair, G. 2013: Découverte de *Galium verrucosum* subsp. *halophilum* (Ponzo) Lambinon (*Rubiaceae*) en Afrique du Nord (Algérie). – Lagascalia **33:** 350-353.

—, —, Rosato, M. & Rosselló, J. 2016: Taxonomic remarks on *Scilla anthericoides* Poir. (*Asparagaceae*, *Scilloideae*), a neglected species from Algeria. – Phytotaxa **288(2):** 154-160. https://doi.org/10.11646/phytotaxa.288.2.5

Yahi, N., Véla, E., >Benhouhou, S., de Bélair, G. & Gharzouli, R. 2012: Identifying Important Plants Areas (Key Biodiversity Areas for Plants) in northern Algeria. – J. Threat. Taxa **4:** 2453-2765. https://doi.org/10.11609/jott.o2998.2753-65

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Short note

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V. Vladimirov, S. Bancheva & M. Delcheva

Pilosella lactucella (*Asteraceae*), first record for the Bulgarian flora

Abstract

Vladimirov, V., Bancheva, S. & Delcheva, M.: *Pilosella lactucella* (*Asteraceae*), first record for the Bulgarian flora. — Fl. Medit. 31: 129-133. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Pilosella lactucella has been recorded for the first time for the Bulgarian flora. It grows in damp to wet subalpine meadows in the Rila Mts, at ca. 2250 m. A single population of about a thousand specimens has been observed, occupying an area of less than 0.5 ha. The recorded site is the south-easternmost locality of the species in Europe and is rather isolated. The ploidy level was estimated by flow cytometry and the species is a diploid. If the IUCN categories and criteria are applied at national level, the species would qualify for a Critically Endangered taxon under criterion B.

Key words: C-value, *Hieracium* s.l., new records, ploidy level, *Pilosella*, Rila Mts.

Introduction

During field work to study the alpine plant diversity in the Rila Mts, SW Bulgaria, a species of the taxonomically intricate vascular plant genus *Pilosella* Hill. (*Asteraceae*) was recorded for the first time in the Bulgarian flora – *P. lactucella*. The aim of the present paper is to report the species as a new record for the Bulgarian flora and to provide some data about the population size, ploidy level and its conservation significance.

Material and methods

Field work was carried out in summer of 2020 in the Rila Mts. Herbarium material and live plants were collected for further studies. The morphological description of the species is based on the Bulgarian material and compared with relevant literature, e.g. Zahn (1923) and Sell & West (1976). Data about the population size and habitats were noted in the field. Genome size and ploidy level of the species were estimated by a flow cytometer CyFlow SL Green (PARTEC, Germany), following the methodology described in Szeląg & Vladimirov (2019). *Pisum sativum* 'Kleine Rheinländerin' (1C = 4.38 pg, Greilhuber & al. 2007) was used as an internal standard. The conservation significance of the species was evaluated using the IUCN categories, criteria and guidelines (IUCN 2012a, b; IUCN Standards and Petitions Subcommittee 2019).

Results and discussion

Pilosella lactucella (Wallr.) P. D. Sell & C. West (1967: 314) [syn.: *Hieracium lactucella* Wallr. (1822: 408)].

Herbaceous perennial. Stolons usually 1–3(4), long, slender. Stems ca. 15–25(30) cm, erect, with sparse, 5–7 mm, simple eglandular hairs and 0.2–1.2 mm glandular hairs, and very sparse stellate hairs. Rosette leaves 4–6, 20–90 × 3–10 mm, lanceolate to linear-lanceolate, ±acute, with a few, 4–5 mm, simple eglandular hairs usually on the margins and midrib below, glaucous; cauline leaves 0–1. Flowering stems with a few scales below the capitula and with moderately dense stellate and glandular hairs, and occasional, 1.0–3.5 mm, simple eglandular hairs. Capitula usually solitary, rarely 2(3). Involucral bracts 7–9 mm, linear-lanceolate, obtuse to subacute at apex, with pale margin, with scattered stellate hairs, dense, 2.0–2.5 mm, simple eglandular hairs and moderate, 1.0–1.5 mm, glandular hairs. Ligules lemon-yellow. Achenes ca. 2 mm, dark brown to blackish, with ca. 5 mm, dirty-white pappus. Flowering July, fruiting August.

The species belongs to *Pilosella* sect. *Auriculinae* (Fr.) F.W.Schultz & Sch. Bip. and is the first taxon of this section to be recorded in the Bulgarian flora. It has a distinctive morphology and clearly differs by the other *Pilosella* species in the area by the slender, long and glabrous to subglabrous stolons, the glabrous or nearly so and glaucous leaves, and the presence of mostly one, rarely 2–3 capitula.

Distribution. – Bulgaria, Rila Mts, small river valley SW of Kalin reservoir above Pastra village, Rila Municipality, 42.171133°N, 23.242451°E, damp to wet meadows, ca. 2250 m, 22.07.2020, coll. V. Vladimirov, S. Bancheva & M. Delcheva (SOM).

The native distribution area of the species comprises larger parts of Europe, ranging from Spain to the west to European Russia to the east and to Scandinavia to the north. So far the species has not been recorded in most of South-East Europe (Bräutigam & Greuter 2007-2009). In the Balkan Peninsula, *P. lactucella* has been reported from Croatia, Montenegro, Serbia and Slovenia (Bräutigam & Greuter 2007-2009). In fact, *P. lactucella* was reported for Bulgaria by Zahn (1925: 1235, sub *Hieracium auricula* Lam.) for damp places without mentioning of exact localities. In the next editions of Flora of Bulgaria, the species was reported as a possibly occurring in the country species, which, however, has never been confirmed (Georgiev 1933, 1948; Stojanov & al. 1967: 1183).

Habitat and population. – In the Rila Mts, *P. lactucella* grows in damp to wet meadows at slopes with small inclination (1–5°) facing to the east (Fig. 1). The projective vegetation cover is ca. 90%. Some 50 accompanying vascular plant species were noted of which most common were: *Agrostis canina* L., *Alchemilla glabra* Neygenf., *Bistorta vivipara* (L.) Delarbre, *Carex canescens* L., *C. echinata* Murray, *C. fuliginosa* Schkuhr, *C. nigra* (L.) Reichard, *Cerastium cerastoides* (L.) Britton, *C. fontanum* Baumg., *Crocus veluchensis* Herb., *Dactylorhiza cordigera* (Fr.) Soó, *Deschampsia caespitosa* (L.) P. Beauv., *Eleochais palustris* (L.) R. Br., *Epilobium nutans* F. W. Schmidt, *Eriophorum latifolium* Hoppe, *E. vaginatum* L., *Festuca nigrescens* Lam., *Gentiana*

Fig. 1. *Pilosella lactucella* in the Rila Mts,Bulgaria: a) habit; b) capitulum; c) rosette leaves.

pyrenaica L., *Gymnadenia frivaldii* Griseb., *Juncus filiformis* L., *Luzula multiflora* (Ehrh.) Lej., *Myosotis sicula* Guss., *Nardus stricta* L., *Phleum alpinum* L., *Pilosella hoppeana* subsp. *testimonialis* (Peter) P. D. Sell & C. West, *P. pseudopilosella* (Ten.) Soják, *Pinguicula balcanica* Casper, *Plantago gentianoides* Sibth. & Sm., *Primula deorum* Velen., *P. farinosa* L., *Scorzoneroides autumnalis* (L.) Moench, *S. rilaensis* (Hayek) Holub, *Saxiraga stellaris* L., *Sesleria comosa* Velen., *Trifolium badium* Schreb., *T. repens* L., *Veronica serpyllifolia* L., etc. The population comprised about a thousand of flowering specimens and occupied a very small area of ca. 0.45 ha. Often the specimens grow on small elevations of the substrate which are somewhat dryer. Considering the chorotypes of the vascular plants in the habitat, some 60% of the species belong to the European, Boreal, Arctic-Alpine, European-SW Asian and Euro-Siberian chorotypes which is typical for the high-mountain wet meadows in Rila Mts.

Genome size and ploidy level. – The genome size of three specimens has been measured by flow cytometry: 1C = 1.94 pg. This agrees with previous reports (e.g. Bräutigam & Bräutigam 1996) and corresponds to a diploid level.

Conservation significance. – The population in the Rila Mts represents the south-easternmost locality of the species in Europe and is strongly isolated. The closest localities are in Serbia, e.g. in Kopaonik Mts (Mráz & Šingliarová 2009). Considering the small population size and area of the Bulgarian locality, as well as the vulnerability of the habitat (wet meadow), the species is of conservation concern in Bulgaria. If the IUCN categories and criteria are applied at national level, the species should be assigned the following national IUCN category: Critically Endangered [CR B1ab(ii,iii)+2ab(ii,iii)]. The evaluation is based on the presence of a single very isolated population and the projected decline of the area of occupancy and quality of the habitat due to climate change and anthropogenic pressure.

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References

Bräutigam, S. & Bräutigam, E. 1996: Determination of the ploidy level in the genus *Hieracium* subgenus *Pilosella* (Hill) S. F. Gray by flow cytometric DNA analysis. – Folia Geobot. Phytotax. **31:** 315-321.

— & Greuter, W. 2007-2009: *Pilosella*. – In: Greuter, W. & Raab-Straube, E. von (eds), *Compositae*. Euro+Med Plantbase – the information resource for Euro-Mediterranean plant diversity. – http://ww2.bgbm.org/EuroPlusMed/query.asp [Last accessed 10.3.2021]

Georgiev, T. 1933. *Hieracium*. – Pp. 1063-1090 in: Stojanov, N. & Stefanov, B. Flora na Balgaria. 2nd ed. – Sofia [in Bulgarian].

— 1948. *Hieracium*. – Pp. 1241-1274 in: Stojanov, N. & Stefanov, B. Flora na Balgaria. 3rd ed. – Sofia [in Bulgarian].

Greilhuber, J., Temsch, E. M. & Loureiro, J. C. M.2007. Nuclear DNA Content Measurement. – Pp. 67-101 in: Doležel, J., Greilhuber, J. & Suda, J. (eds), Flow cytometry with plant cells. – Weinheim.

IUCN. 2012a: IUCN Red List Categories and Criteria: Version 3.1. Second edition. – Gland, Cambridge.

— 2012b: Guidelines for Application of IUCN Red List Criteria at Regional and National Levels: Version 4.0. – Gland, Cambridge

IUCN Standards and Petitions Subcommittee. 2019: Guidelines for using the IUCN Red List Categories and Criteria. Version 14. Prepared by the Standards and Petitions Subcommittee. – http://www.iucnredlist.org/documents/RedListGuidelines.pdf.

Mráz, P. & Šingliarová, B. 2009: Reports 38–46. [In: Mráz, P. (ed.), Chromosome number and DNA ploidy level reports of vascular plants – 4]. – Biologia **64(6):** 1086-1088. https://doi.org/10.2478/s11756-009-0208-2

Sell, P. D. & West, C. 1967. *Pilosella* Hill. – pp. 313-314 in: Sell, P. D. (ed.), Taxonomic and nomenclatural notes on the British flora. – Watsonia **6(5):** 292-318.

Sell, P. D. & West, C. 1976: *Hieracium* L. – Pp. 358-410 in: Tutin, T. G., Heywood, V. H., Burges, N. A. & Valentine, D. H. (eds), Flora Europaea, **4.** – Cambridge.

Stojanov, N., Stefanov, B. & Kitanov, B. 1967. Flora na Balgaria, 4th ed, **2.** – Sofia [in Bulgarian].

Szelag, Z. & Vladimirov, V. 2019: The species intermediate between *Hieracium petrovae* and *H. olympicum* (*Asteraceae*): a treatment of *H. kritschimanum* and description of a new species from Greece. – Phytotaxa **402(2):** 107-113. https://doi.org/10.11646/phytotaxa.402.2.4

Wallroth, F. G. 1822. Schedulae Criticae de Plantis Florae Halensis Selectis. Corollarium novum ad C. Sprengelii Floram halensem. Accedunt generum quorundam specierumque omnium definitiones novae, excursus in stirpes difficiliores et icones V. Tom. I. Phanerogamia. – Halae.

Zahn, K. H. 1923. *Compositae – Hieracium*. – Pp. 1147-1705 in: Engler, A. (ed.), Das Pflanzenreich Regni Vegeabilis Conspectus. IV.**280**, Heft 82. – Leipzig.

— 1925: *Hieracium*. – Pp. 1225-1272 in: Stojanov, N. & Stefanov, B. Flora na Balgaria, **2.** – Sofia [in Bulgarian].

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Article

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Systematic structure and florogenetic connections of dendroflora of Tbilisi area (South Caucasus)

Abstract

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Tbilisi area is located in the central part of South Caucasus at the intersection of various floristic centres. The aim of the article is to clarify composition of dendroflora of Tbilisi area, analysis it's systematic and chorological structure and establish florogenetic connections. 166 species of trees and shrubs, which belong to 74 genera and 41 families, were recorded. The leading families by the ratio of species are: 1. *Rosaceae* – 32.6%, 2. *Salicaceae* – 7.2%, 3. *Fabaceae* – 4.8%, 4. *Sapindaceae* – 4.2%, 5. *Ulmaceae* – 3.6%, 6-7. *Cupressaceae*, *Rhamnaceae* – 3.0-3.0%. Based on composition and proportion of chorotypes, several directions of florogenetic connection are identified: (1) Boreal, (2) Mediterranean, (3) South-West Asian, (4) Euxinean and (5) Hyrcanean. Dominance of local (Caucasian) species is sharply expressed (19.3%). The composition and proportion of chorotypes points, that forming of dendroflora of Tbilisi area was going through the "struggle" of boreal and Ancient Mediterranean floristic centers. On the background of powerful competition, great number and different bioecological composition of local species emphasize originality of flora of Tbilisi area. We suppose that forming process of dendroflora of Tbilisi area was going on during a long period that not so small number of relict and endemic species speaks about.

Key words: trees, shrubs, floristic composition, chorotype, Ancient Mediterranean.

Introduction

Tbilisi area is located at the intersection of various floristic centers (Mediterranean, Boreal, South-West Asia, Turan) and represents distinctive "botanical junction" (Sakhokia 1961), which is clearly reflected in its biodiversity.

According to some researchers (Gagnidze & Davitadze 2000), the study area belongs to the Ancient Mediterranean world. In particular, these authors discuss most part of the Tbilisi area within the range of Submediterranean and the endings of the Mtkvari-Araks lowland entering in Tbilisi area belong to the South-West Asia-Turan region. Some of the researchers (Takhtadjan 1978) attribute the largest part of the Tbilisi area to the boreal world, while the endings of Mtkvari-Araks lowland consider the Ancient Mediterranean (in particular to Turan province).

Tbilisi area are characterized by both floristic and ecosystem diversities. There are distributed approximately 1650 species of vascular plants (Makashvili 1952, 1953). Forests of foothill, lower and middle mountain belts, xeromesophilous and mesoxerophilous shrubberies, shrubberies of shibliak type and steppe are the main vegetation cover. They are presented by various modifications. Besides them, plant communities of desert-semidesert, xerophytic forests, tragacanthic shrubberies, meadow-steppe, meadows, saline meadow, floodplain forest and wetlands are distributed. Also there are rocks and scree-stones communities (Lachshvili & al. 2013).

The role of trees and shrubs is especially prominent in the creation of natural landscapes (forests and shrubberies of different types) of Tbilisi area. In addition, trees and shrubs are spread in almost all ecosystems, including herbaceous ecosystems. Therefore, there is a great interest in the origins of dendroflora of Tbilisi area and its florogenetic connections.

The aim of our research was to clarify floristic composition of trees and shrubs of Tbilisi area, the systematic and chorological characterization of this dendroflora; based on their analysis establishing their florogenetic connections.

Materials and methods

Presented research is based on the article of Lachashvili & al. (2017), in which conspectus of trees and shrubs of Tbilisi area are given. There are listed 177 species of trees and shrubs (included naturalized species) and for each species are indicated distribution area and habitat in Tbilisi area in this article. Systematic structure, composition of chorotypes and florogenetic connections are not discussed.

In recent years (2017-2020) floristic composition has been clarified and supplemented; according to new taxonomic data the name and volume of individual species was revised and clarified.

Chorotypes and their general areas correspond to the methods and principles of Ivanishvili (1973), Portenier (2000a, 2000b) and Gagnidze (2004). Phytogeographic zoning of Earth by Takhtadjan (1978) is taken into consideration. Brovich (1989) and Meusel & Jager (1989) approaches and concepts are also taken into account. During the selection of chorotypes detailing was emphasized. Mono, double, triple, and in some occasions fourfold regional chorotypes are selected. The names of all those main botanic-geographic units, that the chorotype area contains, are used in the names of chorotypes. During determination of chorotype of the species and subspecies, the main attention is directed to the center of gravity of the species (subspecies) spread. In case the plant is ranked as subspecies (subsp.), the chorotype of the subspecies is given. By mentioned methodology, in the most chorotypes (where there a need and an opportunity were) lower-ranking units – chorological groups are separated. The selected chorotypes are apportioned in four major groups. They are: (1) boreal, (2) Ancient Mediterranean, (3) "connective" and (4) "widespread". Such attitude gave the opportunity to conduct more detailed analyzes (Lachashvili & al. 2020).

The boarders of the Ancient Mediterranean and Boreal regions are defined according to Takhtajan (1978). Caucasus and accordingly, Caucasus endemics are discussed in the bounds of Caucasus eco-region (Solomon & al. 2013).

Names and authors of taxa are reconciled with international databases of plants [The plant list (2021), Euro+Med (2006+), IPNI (2021), GBIF.org (2021), Tropicos.org (2021)]. Only several “narrow” species are given according to Solomon & al. (2013) and Davlianidze & al. (2018).

Description of study area

Tbilisi area (Fig. 1) is located in the central part of South Caucasus. The territory covers part of Mtkvari River basin from vil. Dzegvi to the section between Ponichala and Rustavi. Endings of large geographical units of different origin and geological age are gathered in the area of Tbilisi, which greatly conditions complexity of the relief. In particular, Tbilisi area comprises the Saguramo-Ialno (Kukheti) Ridge, the eastern part (Skhaltba Ridge) of Kvernaki Ridge, the eastern endings of the Trialeti Ridge (Satskepela and Armazi, Mskhaldidi and Lisi, Mtatsminda, Narikala, Tabori, Kojori, Teleti ridges), the extreme end of the north-west and western parts of Iori plateau (Samgori, Vaziani, Tbilisi Sea and its vicinities), the extreme north-west end of the Mtkvari-Araxi lowland – Kvemo Kartli lowland, in particular, Ponichala and Kumisi-Tsalaskuri plaines. Hypsometrical amplitude of Tbilisi area is about from 350 m a.s.l. to 1875 m a.s.l. (Maruashvili 1964; Kavrishvili 1964; Ukleba 1968, 1974; Tatashidze 2000).

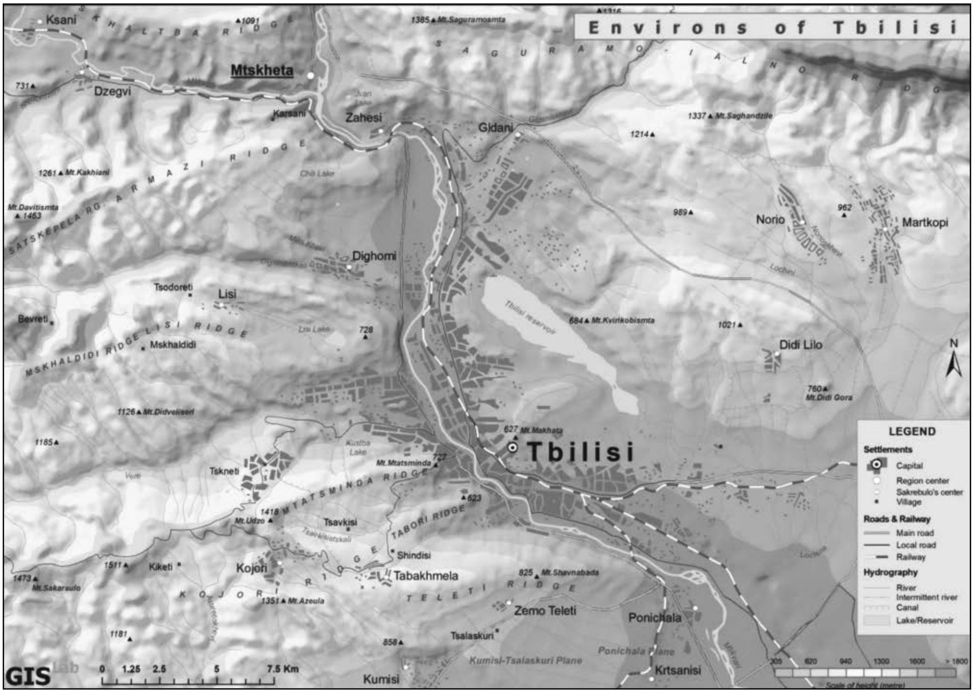

Fig. 1. Physical-geographic map of Tbilisi area.

The area of Tbilisi is characterized by a transitional climate from semi-arid to humid. Two main climate zones are expressed (Kavrishvili 1964; Ukleba 1968): (1) The climate with insufficient humidity, dry and hot summer and mild but well expressed winter, (2) moderately humid climate with moderately warm summer and moderately cold snowy winter. The first zone of the climate contains almost whole left side of the Mtkvari River, Ponichala and Kumisi-Tsalaskuri plains and the river floodplain as well. The second climate zone covers Saguramo-Ialno Ridge and the mountainous part of the right side of Mtkvari River. In the first zone annual evaporation exceeds the sum of precipitation. The average annual temperature is within 12°, while the average annual atmospheric precipitation is from 380 to 530 mm. In the most part of zone the dryness index equals to 2. In the second zone the average annual precipitation (550-780 mm) increases with elevation, while the average annual temperature decreases (from 10.8° to 7.4°). The humidity (precipitation-evaporation) ratio is 1. The highest amount of precipitation is in the crest part of the Saguramo Ridge – approximately 1000-1200 mm. A transition from semi-humid to humid climate is expressed in some parts of Tbilisi area.

Main soil types are grey-cinnamonic, cinnamonic and brown forest soils, which are presented by different modifications. On the terraces of rivers (especially along the Mtkvari River) there are alluvial soils developed. Besides them, there are rocky and scree-stony ecotypes and loamy and clayey-sandy badlands (Kavrishvili 1964; Ukleba 1968; Urushadze 1999, 2016; Tatashidze 2000).

Results

Systematical structure. – On the basis of own researches and literary data, 166 species of trees and shrubs are registered in Tbilisi area, which belong to 41 families and 74 genera.

Distribution of genera by families gives the following picture: with most of number of genera standout is *Rosaceae* – 12 genera (16.2%). By 5 genera represented *Fabaceae* (6.8%). 4 Families (*Anacardiaceae*, *Oleaceae*, *Rhamnaceae* and *Ulmaceae*) includes 3 genera each, 10 families – 2 and 25 families one genera each. Data demonstrates that most of the families (35 families) are presented by only 1-2 genera.

Number of species is distributed disproportionally in the families. 7 families standout by number of species (Table 1).

Table 1. Number of species by the leading families.

Family	Number of Species	%
1. *Rosaceae*	54	32.6
2. *Salicaceae*	12	7.2
3. *Fabaceae*	8	4.8
4. *Sapindaceae*	7	4.2
5. *Ulmaceae*	6	3.6
6. *Cupressaceae*	5	3.0
7. *Rhamnaceae*	5	3.0
Total	97	58.4%

8-12 places are shared by 5 families: *Celastraceae*, *Corylaceae*, *Fagaceae*, *Oleaceae* and *Viburnaceae***.** Any of them are presented by 4 species. 6 families (*Anacardiaceae*, *Betulaceae*, *Caprifoliaceae*, *Cornaceae*, *Tamaricaceae* and *Thymelaeaceae*) contain 3 species each, 8 families (*Araliaceae*, *Berberidaceae*, *Elaeagnaceae*, *Ericaceae*, *Grossulariaceae*, *Loranthaceae*, *Pinaceae*, *Polygonaceae*) 2 species each, and 15 family one species each.

Among 74 genera by content of species 11 genera standout (Fig. 2). 8 genera includes 3 species each and 13 genera – 2 species each. Greatest part of genera – 42 genera are presented by one species for each. So 55 genera, which make up 74.3% of whole composition of genera, are represented by only 1-2 species. Acorrdingly, floristic diversity is mostly conditioned by a great number of genera. It is noteworthy, that most of leading genera (7 genera) belong to *Rosaceae* family, that emprasizes one more time on the importance of this family in creation the dendroflora of Tbilisi area.

Composition of chorotypes (Types of geographic range). – We assign 166 species to 28 types of geographic range (chorotypes), which are united in 4 groups: boreal, Ancient Mediterranean, "conjunctive" and "widespread". Their proportions are given in Fig. 3.

Endemics. – One of the significant characteristic of any flora is endemism. High share of endemic species indicates to originality and uniqueness of flora. From 166 species of trees and shrubs spread in Tbilisi area 32 (19.3%) are endemics of Caucasus. They are: *Acantholimon lepturoides* (Jaub. & Spach) Boiss., *Acer ibericum* M. Bieb., *Alnus glutinosa* subsp. *barbata* (C. A. Mey.) Yalt., *Astracantha caucasica* (Pall.) Podlech, *Astragalus tanae*

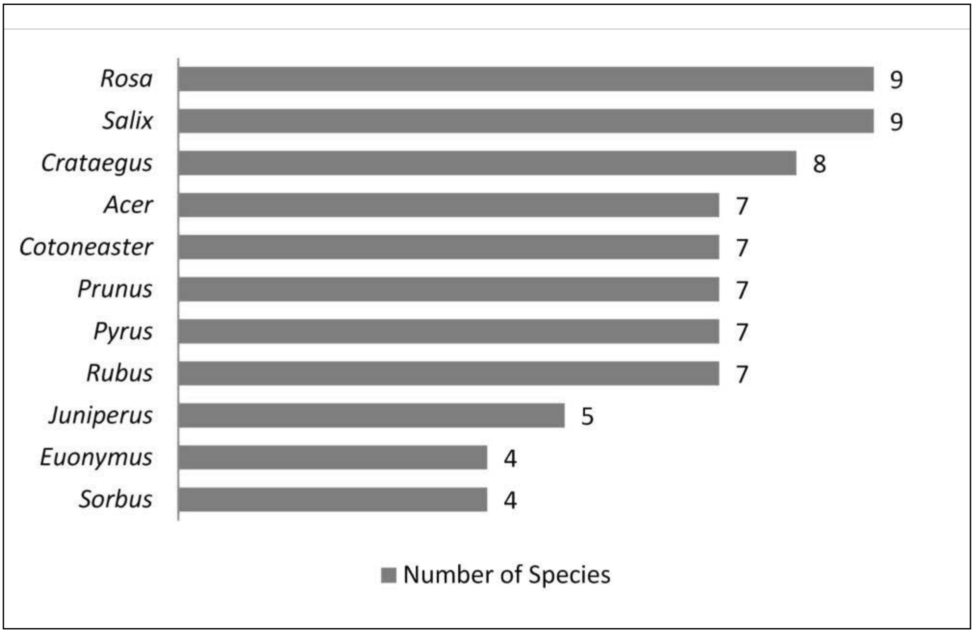

Fig. 2. Number of species by leading genera.

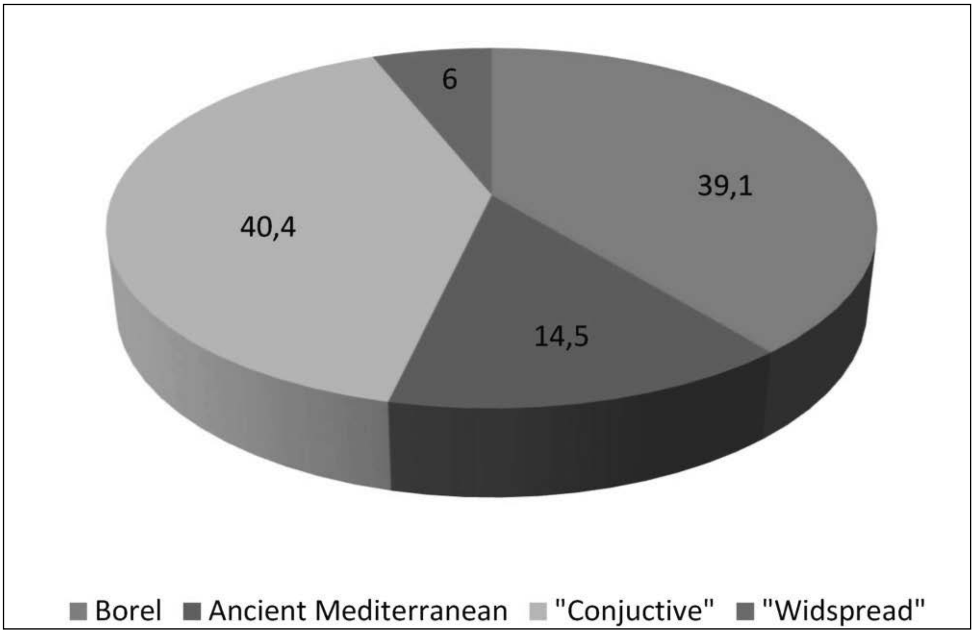

Fig. 3. Proportion (%) of boreal, Ancient Mediterranean, “conjunctive” and “widespread” chorotypes.

Sosn., *Berberis iberica* DC., *Cornus iberica* Woronow, *Corylus iberica* Kem.-Nath., *Cotoneaster meyeri* Pojark., *C. saxatilis* Pojark., *Crataegus caucasica* K. Koch, *Cytisus caucasicus* Grossh., *C. hirsutissimus* K. Koch, *Daphne axilliflora* (Keissl.) Pobed., *Daphne oleoides* subsp. *transcaucasica* (Pobed.) Halda, *Euonymus leiophloeus* Steven, *Philadelphus caucasicus* Koehne, *Picea orientalis* (L.) Peterm., *Prunus georgica* (Desf.) Eisenman, *Pyrus demetrii* Kuth., *P. fedorovii* Kuth., *P. georgica* Kuth., *P. ketzkhovelii* Kuth., *P. sachokiana* Kuth., *Rosa marschalliana* Sosn., *R. prilipkoana* Sosn., *R. transcaucasica* Manden., *Rubus caucasicus* Focke, *R. dolichocarpus* Juz., *R. ibericus* Juz., *Salix kuznetzowii* Goerz, *Sorbus caucasigena* Gatsch..

Various botanical references (by instance, Makashvili 1952; Gviniashvili 1984; Gagnidze 2005; Solomon & al. 2013; Lachashvili & Eradze 2017; Davlianidze & al. 2018) mentioned *Swida armasica* (Sanadze) Gvin. (*Telycrania armasica* Sanadze), which is local endemic of Tbilisi area. This species is not listed in international databases or is not discussed as accepted species. With that in mind, we have not included it in present article.

Relicts. – Relicts of the tertiary period deserve attention among the trees and shrubs of Tbilisi area. 13 relict species are distributed in Tbilisi area. They are: *Buxus colchica* Pojark., *Corylus iberica* Kem.-Nath., *Fagus orientalis* Lipsky, *Hedera pastuchovii* Woronow, *Ilex colchica* Pojark., *Prunus laurocerasus* L., *Quercus macranthera* Hohen., *Quercus robur* subsp. *pedunculiflora* (K. Koch) Menitsky, *Smilax excelsa* L., *Staphylea pinnata* L., *Taxus baccata* L., *Vaccinium arctostaphylos* L., *Viburnum orientale* Pall..

Discussion

Systematic structure. – Dominance of family *Rosaceae* which includes almost 1/3 of floristic composition is obvious. Such high share is completely regular, as *Rosaceae* is one of the characteristic families of the forests and, partly shrubberies. This family is always in the top ten families of nemoral, submediterranean and boreal floras (Turrill 1929; Tolmachev 1986; Chasapis & al. 2020; Vladimirov & al. 2020, etc.). Species diversity of the family *Rosaceae* considerably reduces from humid regions to the direction of semiarid and, especially arid regions (Tolmachev 1986; Lachashvili & al. 2007; Lachashvili & al. 2020). In the floristic spectrum of woody plants of Tbilisi area, diversity of this family is not expressed only in species diversity, but is represented by trees and shrubs of different bioecology which are spread in almost every ecosystem of Tbilisi area.

High location of *Salicaceae* in the floristic spectrum can be explained by diversity of species of genus *Salix*. 9 species from the 16 of the genus *Salix* common in Georgia (Davlianidze & al. 2018) are presented in the area of Tbilisi. They are spread in various moist ravines. However, distribution area for most of them in Tbilisi area is limited and their importance in creation of main landscape is small. From this side, species of genus *Populus* (*P. nigra*, *P. canescens*) are more important.

Conversely other leading families, *Fabaceae* in dendroflora of Tbilisi area is not presented by characteristic species of forests and xeromesophilous shrubberies but xerophilous and hemixerophilous shrubs (*Astracantha caucasica*, *A. microcephala*, *Astragalus tanae*, *A. cornutus*, *Caragana grandiflora*, *Colutea orientalis*). They are characterstic species of tragacanthic, hemixerophilous shrubberies of shibliak type, xerophytic forests and rocks and scree-stones communities. Distributed *Cytisus caucasicus* and C. *hirsutissimus* besides them, which are less xerophilous comparing with the rest species and should be belonged to xeromesophilous plants.

Families *Sapindaceae* and *Ulmaceae* unites mesophilous species characterised for forests. Besides them xeromesophilous species are also (*Celtis caucasica*, *C. planchoniana*, *Acer ibericum*, *Zelkova carpinifolia*). Accordingly, their high position in the floristic spectrum is relevant.

Considering that, family *Rhamnaceae* unites woody plants its being in the top ten of the floristic spectrum is regular. In Tbilisi area, this family is represented by shrubs and trees with different bioecological. Parts of them (*Paliurus spina-christi*, *Rhamnus pallasii*, *R. spathulifolia*) are components of hemixerophilous shrubberies of shibliak type and xerophytic forests, growing in the rocks and scree-stones communities too, whereas *Frangula alnus* and *Rhamnus cathartica* are distributed in the forest edges, xeromesophilous shrubberies and partially in forests.

High position of *Cupressaceae* is due to the participation of *Juniperus* species (*Juniperus communis*, *J. excelsa*, *J. foetidissima*, *J. oxycedrus*, *J. polycarpos*), a characteristic genus of xerophitic forests. These species besides xerophitic forests are spread in hemixerophilous shrubberies and in the rocks and scree-stones communities. It is noteworthy, that *J. communis* is presented by 2 subspecies: *J. communis* subsp. *hemisphaerica* and *J. communis* subsp. *oblonga*. Noted subspecies are given according to Imkhanitskaya (2003). These subspecies by some researchers (Gagnidze 2005; Shetekauri & Chelidze 2016; Davlianidze & al. 2018) until now are discussed in the independent species rank (*J. hemisphaerica* C. Presl, *J. oblonga* M. Bieb.).

Families *Celastraceae*, *Cornaceae*, *Corylaceae*, *Fagaceae Oleaceae* and *Viburnaceae*, which are presented by 4 species each mainly contains characteristic mesophilous trees and shrubs of forests and xeromesophilous shrubberies and their 8-13 position in floristic spectrum is natural. Moreover, main dominannts of forests (*Quercus petraea* subsp. *iberica*, *Q. macranthera*, *Quercus robur* subsp. *pedunculiflora*, *Fagus orientalis*, *Fraxinus excelsior*, *F. angustifolia* subsp. *oxycarpa*) belong to *Fagaceae* and *Oleaceae*.

Chorotypes (Types of geographic range). – Boreal and "conjunctive" chorotypes are represented by nearly equal number of species.

Greatest number of species belongs to so-called "conjunctive chorotypes". Their total number consists of 67 species (40.4%). In them, by capacity of species, European–Mediterranean, Euxino–Hyrcanian and Caucasian–South-West Asian chorotypes are distinguished.

Total number of boreal species are also big – 65 species (39.1%). First of all this is conditioned by wide participation of Caucasian species – Caucasian chorotype contains almost the half of boreal plants. Here we will remark that part of researchers (Gagnidze 2004; Shetekauri & Gagnidze 2000) Caucasian chorotype are considered within Ancient Mediterranean (in particular in submediterranean) region.

Comparing with "conjunctive" and boreal chorotypes, participation of Ancient Mediterranean species is small (24 species / 14.5%). Widespread species are presented by the smallest amount (10 species / 6%).

Among the chorotypes by content of species, Caucasian chorotype dominates (Table 2). It is important that 29 of Caucasian species are endemics of Caucasus and only 2 species have irradiation in South-West Asia [in particular to Anatolia (*Pyrus caucasica*) and North-East Iran (*Rhamnus spathulifolia*)]. Noteworthy that the species included in Caucasian chorotype are of different bioecology and belong to characteristic plants of various habitats. This emphasizes the highlighted role of this chorotype in creation of dendroflora of Tbilisi area.

In boreal chorotypes, after Caucasian, European–Caucasian chorotype is outstanding by its number of species. Not few number of these species points to the florogenetic connection with nemoral forests. These connections are firmed by the participation of Euro–Siberian and European species. Influence of Euxine floristic center is also expressed.

Florogenetic connection of two directions is obvious in Ancient Mediterranean species: Mediterranean and South-West Asian. It is noteworthy, that the area of species connected to the Mediterranean mostly comprises East Mediterranean. Turanian–Central Asian connections are weakly impressed as well. It is significant, that the plants, of which area spread in both directions – on the one hand, Mediterranean and, on the other hand, South-West Asia, Turan, Central Asia, have an important place.

From the side of florogenetic connections, composition and ratio of "conjunctive" chorotypes is important and interesting. These chorotypes by distributed area can be divided into several groups: chorotypes connected with Europe and Mediterranean (European–Mediterranean, Submediterranean), chorotypes connected with Europe, Mediterranean and Soth-West Asia (European–Mediterranean–South-West Asian, European–Mediterranean–South-West Asian–Central Asian), chorotypes connected with Caucasus and South-West Asia (Caucasian–South-West Asian, Caucasian–South-West Asian–Middle Asian, Caucasian–Anatolian and Caucasian–Middle Asian). Outstandingly, it is necessary to highlight the Euxino–Hyrcanian chorotype. First group emphasizes connections with

Table 2. Proportion of chorotypes in the dendroflora of Tbilisi area.

Chorotype	Number of species	%	Number of species	%
Boreal species				
Caucasian	31	18.7	65	**39.1**
European–Caucasian	10	6.0		
Eurasian steppe–Caucasian	2	1.2		
Caucasian–Euxinian	1	0.6		
European	7	4.2		
Euro–Siberian	7	4.2		
Euxinian	7	4.2		
Ancient Mediterranean species				
Mediterranean	6	3.6	24	**14.5**
Mediterranean–South-West Asian	9	5.4		
Mediterranean–South-West Asian–Turanian	1	0.6		
Mediterranean–South-West Asian–Turanian–Central Asian	1	0.6		
South-West Asian	3	1.8		
South-West Asian–Turanian	1	0.6		
South-West Asian–Turanian–Central Asian	2	1.2		
South-West Asian–Central Asian	1	0.6		
“Conjunctive” species				
Submediterranean	7	4.2	67	**40.4**
European–Mediterranean	17	10.3		
European–Mediterranean–South-West Asian	5	3		
European–Mediterranean–South-West Asian–Central Asian	1	0.6		
Euro–Siberian–Central Asian	1	0.6		
Euxino–Hyrcanian	15	9.0		
Caucasian–Hyrcanian	1	0.6		
Caucasian–South-West Asian	14	8.4		
Caucasian–South-West Asian–Middle Asian	2	1.2		
Caucasian–Anatolian	3	1.8		
Caucasian–Middle Asian	1	0.6		
Widespread species				
Palearctic	9	5.4	9	**6.0**
Holarctic	1	0.6	1	
All	166	100	166	100

Remark – “Middle Asian” means mountainous Middle Asia (Pamir-Alay, Tian Shan, etc.).

nemoral forests. Simultaneously chorotypes of first group with chorotypes of second group strengthen the Mediterranean links. Chorotypes of second group play an important role in forming connection to South-West Asia direction and make conjunctive florogenetic bridge between Europe and South-West Asia. Chorotypes of the third group are distinguished: they make a kind of circle of florogenetic connection between Caucasus and South-West Asia. Most of species, which are united in these chorotypes, are hemixerophilous and xerophilous plants of dry ecotopes. Among the “conjunctive” chorotypes the species of Euxino–Hyrcanian chorotype deserve distinguished attention. Considering the location and peculiarity of physical-geographic conditions of Tbilisi area, their non-little share is completely regular. Euxinian and Hyrcanian ties strengthen also by Caucasian–Hyrcanian (*Hedera pastuchovii*) and Caucasian–Euxinian (*Acer trautvetteri*) plants.

In correspondence with "conjunctive" chorotypes, Holarctic species *Juniperus communis* is noteworthy. As noted, in Tbilisi area it is represented by two subspecies: *Juniperus communis* subsp. *oblonga* and *Juniperus communis* subsp. *hemisphaerica*. The first subspecies of them belongs to Caucasian–South-West Asian chorotype and the second subspecies we assign to Mediterranean–Caucasian chorotype. Participation of these subspecies also increases importance of "conjunctive" chorotypes in the structure of dendroflora of Tbilisi area.

Among widespread species plants of Palearctic chorotype are the main. 9 Palearctic species are distributed in 3 groups of geographic area: Palearctic – 3 species, South Palearctic – 2, West Palearctic – 4. Palearctic species belongs to plants of different bioecology and are spread in various habitats.

Presented data indicates different directions of florogenetic connections. Principal directions among them are: European (nemoral forests), Mediterranean, South-West Asian, Euxinian, Hircanian. Relatively weak ties are to direction Siberia. The links of Central Asia, Middle Asia and Turan are much weaker. In spite of many-sided florogenetic connections and powerful competition, role of local (Caucasian) species in forming of dendroflora of Tbilisi area are very high.

Endemic species. – By distributed area among endemic species 3 groups separate out:

Endemics of Caucasus (their distribution area covers both South and North Caucasus) – 16 species (*Acer ibericum*, *Alnus glutinosa* subsp. *barbata*, *Astracantha caucasica*, *Cotoneaster meyeri*, *C.saxatilis*, *Crataegus caucasica*, *Cytisus caucasicus*, *C. hirsutissimus*, *Euonymus leiophloeus*, *Philadelphus caucasicus*, *Picea orientalis*, *Pyrus georgica*, *P. sachokiana*, *Rubus caucasicus*, *R. ibericus*, *Salix kuznetzowii*);

Endemics of South Caucasus – 15 species (*Acantholimon lepturoides*, *Prunus georgica*, *Astragalus tanae*, *Corylus iberica*, *Daphne axilliflora*, *D. oleoides* subsp. *transcaucasica*, *Pyrus demetrii*, *P. fedorovii*, *P. ketzkhovelii*, *Rosa marschalliana*, *R. prilipkoana*, *R. transcaucasica*, *Rubus dolichocarpus*, *Sorbus caucasigena*, *Cornus iberica*);

Endemics of East Caucasus (their main distribution area is in the eastern part of Caucasus) – 1 species (*Berberis iberica*).

From endemic species 2 (*Prunus georgica* and *Rosa transcaucasica*) are endemics to Georgia.

32 Caucasus endemic species by chorotypes are distributed in this way: Caucasian chorotype – 29 species, Euxinian chorotype – 2 (*Philadelphus caucasicus*, *Picea orientalis*) and Euxinian–Hyrcanian – 1 (*Alnus glutinosa* subsp. *barbata*).

For territory which localed in crossing area of different floristic centres, 19.3% of endemism should be considered as high indicator.

Florogenetic connections of dendroflora by habitats. – As it was designated, in Tbilisi area trees and shrubs are spread in almost every habitat. Tendencies of florogenetic connections revealed in the principal habitats are discussed below.

In the dendroflora of forests most of all reveals boreal roots, especially ties with nemoral forests. Ancient Mediterranean connections are weakened – these links are reflected in the participating of species of "connective" chorotypes (Euxinian–Hyrcanian, European–Mediterranean, Submediterranean).

In the dendroflora of hemixerophilous ecosistems (xerophitic forests, shrubberies of shibliak type, tragacanthic shrubberies, rocks and scree-stones communities) Ancient Mediterranean roots are expresed, whereas boreal links are weak. Boreal connections in many cases reveals in participation of plants of Caucasian and Caucasian–South-West Asian chorotypes. Participation of species linked with Europe is small. It is important, that Caucasian–South-West Asian species, in many cases, are plants of arid and semiarid regions. They, with their bioecological features and distribution area, have little in common with the boreal region. They, in our opinion, are more associated with Ancient Mediterranean ecosistems.

From the side of composition of chorotypes and florogenetic connections, between the forests and hemixerophilous ecosystems, the dendroflora of post-forest secondary xeromesophilous and mesoxerophilous shrubberies holds transitional condition. In these habitats trees and shrubs of different bioecology (hemixerophilous, mesophilous, xeromesophilous) are gathered. Consequently, species of both boreal, Ancient Mediterranean and "connective" chorotypes are widely presented. Accordingly, in the floristic composition there are reflected as boreal or Ancient Mediterranean ties. We face strong competition between these two floristic worlds, where the one side (boreal) fights for survival and the other (Ancient Mediterranean) expands its area.

An important role of "connective" species is highlighted in the dendroflora of almost every habitat.

It is also noteworthy that Caucaian species are seen in every habitat.

Received results put emphasis one more time on transitional character of flora of Tbilisi area and its originality.

Relicts. – Distributed area of relict trees and shrubs in Tbilisi area is limited. Most of the relicts are gathered on Saguramo-Ialno Ridge in moist environment and are the components of beech, elm beech-hornbeam and hornbeam forests. They are: *Hedera pastuchovii*, *Vaccinium arctostaphylos*, *Viburnum orientale*, *Corylus iberica*, *Staphylea pinnata*, *Taxus baccata*, *Ilex colchica*, *Prunus laurocerasus* and *Buxus colchica*. *Corylus iberica* and *Staphylea pinnata* are also spread on the east endings of Trialeti Ridge. *Vaccinium arctostaphylos, Viburnum orientale, Ilex colchica* and *Prunus laurocerasus* are components of Colchic forests, and *Hedera pastuchovii* is a characteristic species of Hyrcanian forests. We meet *Quecus macranthera* on the east endings of Trialeti Ridge. The relicts spread in the floodplain forests and moist ravines are: *Quercus pedunculiflora* and *Smilax excelsa*.

General Conclusion

The composition of chorotypes and ratio between them gives us opportunity to express the following point of view: geographic location of Tbilisi area in the intersection areal of various floristic centers, diversity of physical-geographic conditions and geological past gave an opportunity of spreading trees and shrubs of either boreal or South-West Asian and Mediterranean origin. On the one hand, invasion and settlement of mesophilous and on the other hand, hemixeropilous and xerophilous species was possible from various regions. Accordingly, forming of dendroflora of Tbilisi area was going through the "struggle" of boreal and Ancient Mediterranean floristic centers. Such competition in the intersection areal of various floristic centers conditioned wide assortment of “conjunctive” species. On the background of powerful competition, great number and different bioecological composition of local (Caucasian) species emphasize originality of flora of Tbilisi area. All that is stated above conditioned the complex character of dendroflora of Tbilisi area. We suppose that forming process of dendroflora of Tbilisi area was going on during a long period that not so small number of relict and endemic species speaks about.

Our expressed views based on chorotypes analysis reflect precisely transitional character of flora of Tbilisi area and are in complete concur with the view of M. Sakhokia (1961) about the fact, that Tbilisi area represent a kind of “botanical junction”.

Floristic composition indicating chorotypes for each species in table form are given below (Table 3).

Table 3. Floristic composition of Tbilisi area dendroflora.

GYMNOSPERMAE		
Cupressaceae	*Juniperus communis* L. • *J. communis* subsp. *hemisphaerica* (J. Presl & C. Presl (Hyman) (*J. hemisphaerica* C. Presl; *J. depressa* Stevels) • *J. communis* subsp. *oblonga* (M. Bieb.) Galushko (*J. oblonga* M. Bieb.; *J. communis* var. *saxatilis* Pall.)	Holarctic • Med.–Caucasian • Caucasian–S.-W. Asian (conditionally)
	Juniperus excelsa M. Bieb. (*J. isophyllos* K. Koch)	Med.–S.-W. Asian (E. Med.–S.-W. Asian)
	Juniperus foetidissima Willd.	Med. (E. Med.)
	Juniperus oxycedrus L. (*Juniperus rufescens* Link)	Med.
	Juniperus polycarpos K. Koch	S.-W. Asian
Ephedraceae	*Ephedra major* subsp. *procera* (C. A. Mey.) Bornm. (*E. procera* C. A. Mey.)	Med.–S.-W. Asian (E. Med.–S.-W. Asian)
Pinaceae	*Picea orientalis* (L.) Peterm.	Euxinian (with irradiation) (Cauc. endemic)
	Pinus sylvestris var. *hamata* Steven [*P. sylvestris* var. *hamata* Steven; *P. kochiana* K. Koch; *P. sosnowskyi* Nakai]	Caucasian–Anatolian (with Crimean irradiation)
Taxaceae	*Taxus baccata* L.	European–Med.
ANGIOSPERMAE		
DYCOTYLEDONEAE		
Anacardiaceae	*Cotinus coggygria* Scop.	Palearctic (S. Palearctic)
	Pistacia atlantica subsp. *mutica* (Fisch. & C. A. Mey.) Rech. f. (*Pistacia mutica* Fisch & C. A. Mey.)	Med.–S.-W. Asian
	Rhus coriaria L.	Med.–S.-W. Asian
Apocynaceae *(Asclepiadaceae)*	*Periploca graeca* L.	Euxino–Hyrcanian (with E. Med. irradiation)
Aquifoliaceae	*Ilex colchica* Pojark.	Euxinian (Colchic, Colchic-Lazistanian)
Araliaceae	*Hedera helix* L.	European–Med.
	Hedera pastuchovii Woronow	Caucasian–Hyrcanian (E. Caucasian–Hyrcanian)
Berberidaceae	*Berberis iberica* DC.	Caucasian (Cauc. endemic)
	Berberis vulgaris L.	European–Med.

Table 3. continued.

Betulaceae	*Alnus glutinosa* subsp. *barbata* (C. A. Mey.) Yalt. (*A. barbata* C. A. Mey.)	Euxino–Hyrcanian (Cauc. endemic)
	Betula litwinowii Doluch.	Euxino–Hyrcanian
	Betula pendula Roth	Euro–Siberian
Buxaceae	*Buxus colchica* Pojark.	Euxinian (Colchic)
Caprifoliaceae	*Lonicera caprifolium* L.	European–Med. (C. European–Med.)
	Lonicera caucasica Pall.	Caucasian–S.-W. Asian
	Lonicera iberica M. Bieb.	Caucasian–S.-W. Asian
Celastraceae	*Euonymus europaeus* L.	European–Caucasian
	Euonymus latifolius (L.) Mill.	Submed.
	Euonymus leiophloeus Steven	Caucasian (Cauc. endemic)
	Euonymus verrucosus Scop.	European–Caucasian
Cistaceae	*Fumana procumbens* (Dunal) Gren. & Godr.	European–Med. (C. European–Med.)
Cornaceae	*Cornus iberica* Woronow [*Swida iberica* (Woronow) Grossh.]	Caucasian (Cauc. endemic)
	Cornus mas L.	Submed.
	Cornus sanguinea subsp. *australis* (C. A. Mey.) Jáv. [*C. australis* C. A. Mey.; *Swida australis* (C. A. Mey.) Grossh.]	European–Caucasian (conditionally)
Corylaceae	*Carpinus betulus* L. (*C. caucasica* Grossh.)	European–Caucasian
	Carpinus orientalis Mill.	Submed. (E. Submed.)
	Corylus avellana L.	European–Caucasian
	Corylus iberica Kem.-Nath.	Caucasian (Cauc. endemic)
Elaeagnaceae	*Elaeagnus angustifolia* L.	Palearctic (S. Palearctic)
	Hippophaë rhamnoides L	European–Med.–S.-W. Asian–C. Asian
Ericaceae	*Rhododendron luteum* Sweet	Euxinian (with European irradiation)
	Vaccinium arctostaphylos L.	Euxino–Hyrcanian
Fabaceae	*Astracantha caucasica* (Pall.) Podlech	Caucasian (Cauc. endemic)
	Astracantha microcephala (Willd.) Podlech	Caucasian–S.-W. Asian (S. Caucasian–S.-W. Asian)
	Astragalus cornutus Pall.	Eurasian steppe–Caucasian (with Iranian irradiation)
	Astragalus tanae Sosn.	Caucasian (Cauc. endemic)
	Caragana grandiflora (M. Bieb.) DC.	Caucasian–S.-W. Asian
	Colutea orientalis Mill.	Med. (E. Med.; Caucasian-Crymean)
	Cytisus caucasicus Grossh. [*Chamaecytisus caucasicus* (Grossh.) Holub]	Caucasian (Cauc. endemic)
	Cytisus hirsutissimus K. Koch	Caucasian (Cauc. endemic)
Fagaceae	*Fagus orientalis* Lipsky	Euxino–Hyrcanian
	Quercus macranthera Fisch. & C. A. Mey. ex Hohen.	Caucasian–S.-W. Asian
	Quercus petraea subsp. *iberica* (M. Bieb.) Krassiln. (*Q. iberica* M. Bieb.)	Caucasian–S.-W. Asian
	Quercus robur subsp. *pedunculiflora* (K. Koch) Menitsky (*Q. pedunculiflora* K. Koch)	Med. (E. Med.)
Grossulariaceae	*Ribes alpinum* L.	European
	Ribes uva-crispa L. [*Grossularia reclinata* (L.) Mill.; *R. reclinatum* L.]	European

Table 3. continued.

Hydrangeaceae	*Philadelphus caucasicus* Koehne	Euxinian (with irradiation) (Cauc. endemic)
Loranthaceae (*Santalaceae*, *Viscaceae*)	*Arceuthobium oxycedri* (DC.) M. Bieb.	Med.–S.-W. Asian
	Viscum album L.	Palearctic (conditionally)
Malvaceae *(Tiliaceae)*	*Tilia begoniifolia* Steven	Euxino–Hyrcanian
Moraceae	*Ficus carica* L.	S.-W. Asian
Oleaceae	*Fraxinus excelsior* L.	European–Caucasian
	Fraxinus angustifolia subsp. *oxycarpa* (Willd.) Franco & Rocha Afonso (*F. oxycarpa* Willd.)	Submed. (E. Submed.) (conditionally)
	Jasminum fruticans L.	European–Med.–S.-W. Asian
	Ligustrum vulgare L.	European–Med.
Plumbaginaceae	*Acantholimon lepturoides* (Jaub. & Spach) Boiss.	Caucasian (endemic)
Polygonaceae	*Atraphaxis caucasica* (Hoffm.) Pavlov	Caucasian–M. Asian
	Atraphaxis spinosa L.	Med.–S.-W. Asian–Turanian–C. Asian (E. Med.–S.-W. Asian–Turanian–Jungaro-Kashgarian)
Ranunculaceae	*Clematis vitalba* L.	European–Med.
Rhamnaceae	*Frangula alnus* Mill.	Euro–Siberian
	Paliurus spina-christi Mill.	Med.–S.-W. Asian
	Rhamnus cathartica L.	Palearctic
	Rhamnus pallasii Fisch. & C. A. Mey.	Caucasian–S.-W. Asian
	Rhamnus spathulifolia Fisch. & C. A. Mey.	Caucasian
Rosaceae	*Amelanchier ovalis* Medic.	European–Med. (C. European–Med.)
	Cotoneaster integerrimus Medic.	European–Med.–S.-W. Asian (conditionally)
	Cotoneaster melanocarpus Fisch. ex A. Blytt.	Euro–Siberian–C. Asian
	Cotoneaster meyeri Pojark.	Caucasian (endemic)
	Cotoneaster morulus Pojark.	Caucasian–S.-W. Asian
	Cotoneaster racemiflorus (Desf.) K. Koch	Caucasian–S.-W. Asian–M. Asian
	Cotoneaster saxatilis Pojark.	Caucasian (endemic)
	Cotoneaster suavis Pojark.	S.-W. Asian–C. Asian (conditionally)
	Crataegus caucasica K. Koch	Caucasian (endemic)
	Crataegus kyrtostyla Fingerh.	European–Caucasian (condotionally)
	Crataegus meyeri Pojark.	Caucasian–S.-W. Asian
	Crataegus microphylla K. Koch	Euxino–Hyrcanian
	Crataegus orientalis M. Bieb.	Med. (E. Med.)
	Crataegus pentagyna Willd.	Euxino–Hyrcanian
	Crataegus pontica K. Koch [*C. azarolus* var. *pontica* (K. Koh) K. I. Chr.]	S.-W. Asian
	Crateagus pseudoheterophylla Pojark.	Caucasian–S.-W. Asian
	Malus orientalis Uglitzk. [*M. sylvestris* subsp. *orientalis* (Uglitzk.) Browicz]	Caucasian–S.-W. Asian
	Mespilus germanica L.	Euxino–Hyrcanian

Table 3. continued.

	Prunus avium (L.) L. [*Cerasus avium* (L.) Moench; *C. silvestris* Garsault]	European–Med.
	Prunus divaricata Ledeb.	Med.–S.-W. Asian (E. Med.–S.-W. Asian)
	Prunus georgica (Desf.) Eisenman (*Amygdalus georgica* Desf.)	Caucasian (endemic)
	Prunus incana (Pall.) Batsch [*Cerasus incana* (Pall.) Spach]	Caucasian–S.-W. Asian
	Prunus laurocerasus L. (*Laurocerasus officinalis* M. Roem**.**)	Euxino–Hyrcanian
	Prunus mahaleb L. [*Cerasus mahaleb* (L.) Mill.; *Padellus mahaleb* (L.) Vassilcz.]	European–Med.–S.-W. Asian
	Prunus spinosa L.	European–Med.
	Pyracantha coccinea M. Roem.	Euxino–Hyrcanian
	Pyrus caucasica Fed. [*Pyrus communis* subsp. *caucasica* (Fed.) Browicz]	Caucasian
	Pyrus demetrii Kuth.	Caucasian (endemic)
	Pyrus fedorovii Kuth.	Caucasian (endemic)
	Pyrus georgica Kuth.	Caucasian (endemic)
	Pyrus ketzkhovelii Kuth.	Caucasian (endemic)
	Pyrus sachokiana Kuth.	Caucasian (endemic)
	Pyrus salicifolia Pall.	Caucasian–S.-W. Asian
	Rosa canina L.	European–Med.–S.-W. Asian
	Rosa corymbifera Borkh.	European–Med.–S.-W. Asian
	Rosa marschalliana Sosn.	Caucasian (endemic)
	Rosa micrantha Borrer ex Sm.	European–Med.
	Rosa mollis Sm.	European
	Rosa prilipkoana Sosn.	Caucasian (endemic)
	Rosa spinosissima L.	Palearctic (W. Palearctic)
	Rosa transcaucasica Manden.	Caucasian (endemic)
	Rosa tomentosa Sm.	European
	Rubus anatolicus Focke	Med.–S.-W. Asian (E. Med.–S.-W. Asian)
	Rubus caesius L.	Palearctic (W. Palearctic)
	Rubus caucasicus Focke	Caucasian (endemic)
	Rubus dolichocarpus Juz.	Caucasian (endemic)
	Rubus hirtus Waldst. & Kit.	European–Caucasian
	Rubus ibericus Juz.	Caucasian (endemic)
	Rubus idaeus L.	Euro–Siberian (Euro–W. Siberian)
	Sorbus caucasigena Gatsch.	Caucasian (endemic)
	Sorbus graeca (Spach) S. Schauer	European–Med. (C. European–Med.)
	Sorbus torminalis (L.) Crantz	European–Med.
	Sorbus turcica Zinserl.	Med. (E. Med.) (conditionally)
	Spiraea hypericifolia L.	Eurasian steppe–Caucasian
Salicaceae	*Populus canescens* (Aiton) Sm.	European (with irradiation)
	Populus nigra L.	Palearctic (W. Palearctic)
	Populus tremula L.	Euro–Siberian
	Salix alba L.	Palearctic (W. Palearctic)

Table 3. continued.

	Salix caprea L	Euro–Siberian
	Salix elbursensis Boiss.	Caucasian–S.-W. Asian
	Salix excelsa S.G.Gmel.	S.-W. Asian–Turanian
	Salix kuznetzowii Goerz	Caucasian (endemic)
	Salix micans Andersson	Caucasian–Anatolian
	Salix pseudomedemii E. L. Wolf	Caucasian–Anatolian
	Salix triandra L.	Euro–Siberian
	Salix wilhelmsiana M. Bieb.	Irano–Turanian–C. Asian (Irano–Turanian–Jungaro–Kashgarian)
Sapindaceae *(Aceraceae)*	*Acer campestre* L.	European–Caucasian
	Acer cappadocicum Gled. (*A. laetum* C. A. Mey.)	Euxino–Hyrcanian
	Acer hyrcanum Fisch. & C. A. Mey.	Euxino–Hyrcanian
	Acer ibericum M. Bieb. [*A. monspessulanum* subsp. *ibericum* (M. Bieb. ex Willd.) Yalt.]	Caucasian (endemic)
	Acer platanoides L.	European–Caucasian
	Acer pseudoplatanus L.	European (C. European)
	Acer trautvetteri Medv. [*A. heldreichii* subsp. *trautvetteri* (Medw.) A. E. Murray]	Caucasian–Euxinian
Staphyleaceae	*Staphylea pinnata* L.	Submed.
Tamaricaceae	*Myricaria germanica* (L.) Desv.	Palearctic
	Tamarix ramosissima Ledeb.	S.-W. Asian–Turanian–C. Asian (Irano–Turanian–C. Asian)
	Tamarix smyrnensis Bunge (*T. hohenackeri* Bunge)	Med.–S.-W. Asian–Turranian (E. Med.–S.-W. Asian–Turanian)
Thymelaeaceae	*Daphne axilliflora* (Keissl.) Pobed. [*D. caucasica* subsp. *axilliflora* (Keissl.) Halda]	Caucasian (endemic)
	Daphne pontica L.	Euxinian (with irradiations)
	Daphne oleoides subsp. *transcaucasica* (Pobed.) Halda (*D. transcaucasica* Pobed.)	Caucasian (endemic)
Ulmaceae	*Celtis australis* subsp. *caucasica* (Willd.) C.C. Towns. (*C. caucasica* Willd.)	Caucasian–S.-W. Asian–M. Asian (S. Caucasian–S.-W. Asian–M. Asian)
	Celtis planchoniana K. I. Chr. (*C. glabrata* Steven ex Planch., nom. illeg.)	Submed. (E. Submed.)
	Ulmus elliptica K. Koch	European–Caucasian
	Ulmus glabra Huds.	European
	Ulmus minor Mill.	European–Med.
	Zelkova carpinifolia (Pall.) K. Koch	Euxino–Hyrcanian
Viburnaceae	*Sambucus nigra* L.	European–Med.
	Viburnum lantana L.	European–Med. (C. European–Med.)
	Viburnum opulus L.	Euro–Siberian (Euro–W. Siberian)
	Viburnum orientale Pall.	Euxinian (with irradiation)
Vitaceae	*Vitis sylvestris* C. C. Gmel. [*V. vinifera* subsp. *sylvestris* (C. C. Gmel.) Hegi]	Med.–S.-W. Asian
MONOCOTYLEDONEAE		
Asparagaceae *(Ruscaceae)*	*Ruscus aculeatus* L. [*R. ponticus* Woronow; *R. aculeatus* subsp. *ponticus* (Woronow) Gagnidze]	European–Med.
Smilacacea	*Smilax excelsa* L.	Euxino–Hyrcanian

Abreviations: C. – Central, Cauc. – Caucasus, E. – East, M. – Middle, N. – North, S. – South, W. – West.; Med. – Mediterranean, Submed. – Submediterranean.

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References

Browicz, K. 1989: Chorology of the Euxinian and Hyrcanian element in the woody flora of Asia. – Pp. 305- 314 in: Ehrendofer, F. (ed.), Woody Plants - Evolution and distribution since the Tertiary. – Wien.

Chasapis, M., Samaras, D. A., Theodoropoulos, K. & Eleftheriadou, E. 2020: The vascular flora of Mt Tzena (northern Greece). – Fl. Medit. **30:** 55-63. https://doi.org/10.7320/FlMedit30.055

Davlianidze, M., Gviniashvili, Ts., Mukbaniani, M., Jinjolia-Imnadze, L. & Jugheli, T. 2018: Nomenclatural checklist of flora of Georgia. – Tbilisi.

Euro+Med 2006+ [continuously updated]: Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. – http://www.europlusmed.org [Last accessed 10/04/2201].

Gagnidze, R. 2004: Up to date problems and tasks of botanical geography of the Caucasus. – Not. Syst. Geogr. Inst. Bot. Thbilissiensis **44-45:** 8-52 [in Russian].

— 2005: Vascular plants of Georgia. A nomenclatural checklist. – Tbilisi.

— & Davitadze, M. 2000: Adgilobrivi flora. – Batumi [in Georgian].

GBIF.org 2021: GBIF Home Page. – https://www.gbif.org [Last accessed 10/04/2021].

Gviniashvili Ts., 1984: *Cornaceae* Link. – Pp. 326-333 in: Ketskhoveli, N. (Ed.-in-Chief), Sakartvelos flora, **9.** –Tbilisi [in Georgian].

Imkhanitskaya, N. N. 2003: *Cupressaceae* S.F. Gray – Pp. 179-185 in: Takhtajan, A. L. (Ed.-in-Chief), Caucasian flora conspectus, **1.** – Saint-Petersburg [in Russian].

IPNI 2021: International Plant Names Index. – http://www.ipni.org [Last accessed 10/4/2021].

Ivanishvili, M. A. 1973: Flora formatsii kolucheastragalovykh tragakantnikov severnogo sklona Bol'shogo Kavkaza. – Tbilisi [in Russian].

Kavrishvili, K. V. 1964: Fiziko-geograficheskaya kharkteristika okrestnostei Tbilisi. – Tbilisi [in Russian].

Lachashvili J., Lachashvili N., Khachidze M. 2007: Conspectus of flora of Kiziki (East Georgia). – Tbilisi.

Lachashvili, N. J., Eradze, N. V. & Khetsuriani L. D. 2017: Conspectus of trees and shrubs of Tbilisi environs (East Georgia, South Caucasus). – J. Ann. Agrar. Sci. **15(1):** 118-129. https://doi.org/10.1016/j.aasci.2016.08.008

—, — & — 2020: Floristic composition of pistachio-woodland (*Pistacieta atlantici*) of Georgia (South Caucasus). – Fl. Medit. **30:** 39-53. https://doi.org/10.7320/FlMedit30.039

—, Khachidze M. N., Khetsuriani, L. D. & Eradze, N. V. 2013: Typology and distribution regularities of the vegetation of Tbilisi environs (East Georgia, South Caucasus). – J. Ann. Agrar. Sci. **13(3):** 55-62.

Makashvili, A. 1952: Tbilisis midamoebis flora, **1.** – Tbilisi [in Georgian].

— 1953: Flora of Tbilisi Environs, **2.** – Tbilisi [in Georgian].

Maruashvili, M. 1964: Sakartvelos fizikuri geografia. – Tbilisi [in Georgian].

Meusel, H. & Jäger, E. J. 1989: Ecogeographical differentiation of the Submediterranean deciduous forest flora. – Pp. 315-329 in: F. Ehrendofer (ed.), Woody Plants - Evolution and distribution since the Tertiary. – Wien.

Portenier, N. N. 2000a: Methodical aspects of the elaboration of geographical elements in Caucasian flora. – Bot. J. **85(6):** 76-84 [in Russian].

— 2000b: A system of geographical elements of the Caucasian flora. – Bot. J. **85(9):** 26-33 [in Russian].

Sakhokia, M. F. 1961: Botanical description of the environs of Tbilisi and of the route from Tbilisi to the Shiraki plateau. – Pp. 7-25 in: Sakhokia, M. F. (ed.), Botanical Excursions over Georgia. – Tbilisi.

Shetekauri, Sh. & Gagnidze, R. 2000: Diversity of high-mountain endemic flora of the Greater Caucasus. – Pp. 151-158 in: Beruchashvili, N., Kushlin, A. & Zazanashvili, N. (eds), Biological and landscape diversity of Georgia. – Tbilisi.

— & Chelidze, D. 2016: High mountain flora of Meskheti and Javakheti (Lesser Caucasus). –Tbilisi [in Georgian].

Solomon, J., Shulkina, T. & Schatz, G. E. (eds) 2013: Red list of the endemic plants of the Caucasus: Armenia, Azerbaijan, Georgia, Iran, Russia and Turkey. Monographs in systematic botany from the Missouri Botanical Garden (MSB) 125. – Saint Louis.

Takhtajan A. L. 1978: The Floristic regions of the World. – Leningrad [in Russian].

Tatashidze, Z. 2000: Tbilisi. – Pp. 200-207 in: Tatashidze, Z. (ed.), Sakartvelos Geografia, **1.** – Tbilisi [in Georgian].

The Plant List 2021: Version 1.1. – http://www.theplantlist.org/ [Last accessed 10/04/2021].

Tolmachev, A. I. 1986: Metody sravnitelnoi floristiki i problemy florogeneza. – Novosibirsk [in Russian].

Tropicos.org. Missouri Botanical Garden. – http://www.tropicos.org [Last accessed 10/04/2021].

Turrill, W. B. 1929: The plant life of the Balkan Peninsula. – Oxford.

Ukleba, D. 1968: Aghmosavlet Sakartvelos fizikur-geografiuli daraioneba. – Tbilisi [in Georgian].

— 1974: Aghmosavlet Sakartvelos mtiani mkhareebis landshaftebi da fizikur-geografiuli raionebi. – Tbilisi [in Georgian].

Urushadze, T. (ed.) 1999: Soil Map of Georgia. – Tbilisi.

— 2016: Soils of Georgia. – Tbilisi.

Vladimirov V., Bancheva S., Delcheva M., Vassilev K. & Pedashenko H. 2020: Contribution to the knowledge of habitat and vascular plant diversity of Alibotush Reserve, Slavyanka Mountain (Bulgaria). – Fl. Medit. **30:** 19-32. https://doi.org/10.7320/FlMedit30.019

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Short note

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Nora Sakhraoui

Bidens aurea (*Asteraceae*), un nouvel ajout à la flore exotique d'Algérie

Abstract

Sakhraoui, N.: *Bidens aurea* (*Asteraceae*), un nouvel ajout à la flore exotique d'Algérie. — Fl. Medit. 31: 153-157. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Bedens aurea (*Asteraceae*) a new addition to the alien flora of Algeria. — Algerian alien flora is enriched by a new *Asteraceae*, following the discovery of *Bidens aurea* since 2017 in several sites within the region of Skikda (NE-Algeria). A description of its distinctive macromorphological characters as well as its different habitats are presented. An analytical key to the different species of the genus *Bidens* in Algeria is also provided.

Key words: *Coreopsis aurea*, alien species, new record, *Compositae*, North Africa.

Introduction

Le genre *Bidens* L. (*Asteraceae*, *Asteroideae*, *Coreopsideae*) est représenté en Algérie par seulement deux espèces, *Bidens tripartita* L., dotée en Algérie d'un statut de protection (D.E. 2012) et *B. pilosa* L., une adventice cosmopolite (Quézel & Santa 1963). Des prospections botaniques entretenues dans différentes localités de la wilaya de Skikda (au nord-est Algérien) entre les années 2014 et 2021 (see e.g. Sakhraoui & al. 2019a, 2019b, 2020), nous ont permis de découvrir une troisième espèce de ce genre, *Bidens aurea* (Aiton) Sherff. Il s'agit d'une ornementale cultivée qui semble échapper des jardins et pépinières de la région d'étude et qui tente à coloniser des superficies bien élargies notamment sur sols sablonneux. Connue pour son caractère envahissant (Sanz Elorza & al. 2004), la plante est bien installée dans le secteur où elle a été observée pendant quatre années consécutives avec des populations étendues, reconnue ici comme plante nouvelle pour la flore non-native Algérienne.

Matériel et méthodes

L'étude est basée pour l'essentiel sur des prospections botaniques entretenues depuis 2014 dans de nombreuses zones de la région de Skikda riches en jardins publics et pépinières, cultivés par beaucoup d'espèces végétales exotiques introduites, accompagnée d'une analyse pertinente de la littérature.

L'identification, la description et la caractérisation morphologique des spécimens collectés, ont été effectuées selon Cullen & al. (2011).

Résultats

Description et répartition géographique

Bidens aurea (Aiton) Sherff
≡ *Coreopsis aurea* Aiton

Morphologie: Herbe annuelle à vivace à tige dressée de 50 à 180 cm (Fig. 1A). Feuilles opposées, linéaires lancéolées, entières ou profondément divisées en 3 lobes irrégulièrement dentées, vert sombre. Fleurs regroupées en corymbe lâche, ligules jaunes parfois très pâles (Fig. 1B), généralement à 5 ou 6 pétales (Hibon 1935; Cullen & al. 2011). Une thérophyte à hémicryptophyte, originaire d'Amérique centrale (Sherff 1937). Introduite en Algérie en tant qu'ornementale dans les différents espaces verts et les jardins de l'Université de Skikda où elle est cultivée depuis plus qu'une quinzaine d'années.

Fig. 1. *Bidens aurea* en Algérie: A) Biotope de l'une des populations (commune de Hamadi Krouma, Skikda, NE Algérie); B) Détail des fleurs avec ligules jaunes très pâles (voire blanchâtres). Photos par N. Sakhraoui (10.04.2019).

L'espèce a été introduite comme plante d'ornement dans différentes parties du monde où elle s'est naturalisée notamment dans les pays méditerranéens tels que la France (Rodier 1954; Tison & al. 2014), la Grèce (Arianoutsou & al. 2010) et l'Italie (Celesti-Grapow & al. 2009; Galasso & al. 2018; Domina & al. 2018). En Espagne, par contre, elle est considérée comme envahissante avérée (Capdevilla Argüelles & al. 2006). En Afrique du Nord, son introduction remonte à 1952 où elle a été citée naturalisée par Le Floc'h & al. (1990) sans indication précise de pays. Par la suite, elle a été rapportée naturalisée uniquement au Maroc (Valdés & al. 2002; Greuter 2006+; Dobignard & Chatelain 2011; APD 2021; GBIF 2021) alors qu'en Algérie, elle n'a jamais été officiellement signalée.

Zones d'observation, habitats et modalités de reproduction

L'espèce a été repérée pour la première fois, en 2017, au bord de la route reliant la cité Larbi Ben M'Hidi à la ville de Skikda, échappée de la lisière de la pépinière privée nommée Vergers d'Algérie pour l'aménagement des espaces verts où elle se maintient et gagne du terrain chaque année puis en janvier 2021, elle a été retrouvée en fleurs dans un autre point à la même cité, plus exactement au poste 2, où elle se cantonne au bord de la route menant à la ville de Filfilla à quelques mètres seulement du maquis littoral. En janvier 2019, mars 2020 et janvier 2021, deux autres populations bien plus importantes ont été enregistrées dans deux stations non éloignées, rattachées à la commune de Hamadi Krouma. Les populations retrouvées aux endroits dits el guelta et trente-trois sont cantonnées au bord de la route menant à la commune de Filfilla où elles se mêlent aux espèces herbacées indigènes. De nouveaux points de prolifération ont été détectés le 20 novembre 2020 au bord de la route menant à l'Université de Skikda en passant par le cimetière de Zefzef et le 07 février 2021 au bord de la route menant à Chaaibat Ziane, commune de Salah Bouchaour.

Dans certaines stations d'observation, la plante occupe des terrains où des fuites d'eau potable ou usée ont été enregistrées, ce qui lui permet vraisemblablement de subsister pendant l'été. Dans toutes les stations, les ligules des fleurs des individus répertoriés pendant différentes périodes de l'année : de novembre à décembre 2018, de décembre à janvier 2020 ou de mars à juin 2019 et 2021 sont toujours d'un jaune très pâle (Fig. 1B), des individus produisant des fleurs à ligules purement jaunes n'ont jamais été observés dans les zones prospectées.

Il parait que l'expansion rapide de l'aire de répartition de cette plante en Algérie (au moins pour le secteur de Skikda) a été facilitée par le fait que la plante montre au moins deux modalités de reproduction; i) une végétative via ses tiges qui se marcottent naturellement au contact du sol en émettant des rejets responsables de la formation de nouvelles touffes denses et ii) une sexuée via ses cypsèles où des plantules issues de la germination ont été recensées dans différentes stations.

Bien que l'espèce se maintient dans les points d'observation, se mêle à la flore indigène et son aire de répartition s'élargit progressivement, le statut de plante naturalisée ne peut lui être attribué car son apparition dans la région demeure récente d'où elle est ici considérée en voie de naturalisation. Une clé des espèces du genre *Bidens* en Algérie suivra.

Clé des espèces du genre **Bidens** *en Algérie*

Feuilles caulinaires médianes indivises ou à segments primaires indivises .... ***B. aurea***
– Feuilles caulinaires médianes entières, pennatipartites ou pennatiséquées, à segments latéraux, si présents, sessiles ou portés par un court pétiolule ailé ……………....…..…. **2**
2. Cypsèles généralement à 3 arêtes hérissées, arête médiane généralement plus courte que les arêtes externes, cypsèles centrales plates …...……….…….............… *B. tripartita*
– Cypsèles tétragonales, linéaires, avec 3-4 arêtes hérissées inégales, toutes fusiformes… ………………………………………………………....................……........ *B. pilosa*

Références

APD (African Plant Database) 2021: *Bidens aurea* (Aiton) Sherff – Genève: Conservatoire et Jardin botaniques; Pretoria: South African National Biodiversity Institute. – http://www.ville-ge.ch/musinfo/bd/cjb/africa/details.php?langue=an&id=136172 [Last accessed 18/07/2021].

Arianoutsou, M., Bazos, I., Delipetrou, P. & Kokkoris, Y. 2010: The alien flora of Greece: Taxonomy, life traits and habitat preferences. – Biol. Invas. **12:** 3525-3549. https://doi.org/10.1007/s10530-010-9749-0

Capdevilla Argüelles, L., Iglesias Garcia, A., Orueta, J. F. & Zilleti, B. 2006: Especies exoticas invasoras : Dignostico y bases para la prevencion y el manejo. Série Técnica. – Madrid

Celesti-Grapow, I., Alessandrini, A., Arrigoni, P. V., Banfi, E., Bernardo, I., Bovio, M., Brundu, G., Cagiotti, M. R., Camarda, I., Carli, E., Conti, F., Fascetti, S., Galasso, G., Gubellini, I., La Valva, V., Lucchese, F., Marchiori, S., Mazzola, P., Peccenini, S., Poldini, I., Pretto, F., Prosser, F., Siniscalco, C., Villani, M. C., Viegi, I., Wilhalm, I. & Blasi, C. 2009: Inventory of the non-native flora of Italy. – Pl. Biosyst. **143:** 386-430. https://doi.org/10.1080/11263500902722824

Cullen, J., Knees, S. G. & Cubey, H. S. 2011: The European garden flora flowering plants, Boraginaceae to Compositae, 2nd ed., **5.** – New York.

D.E. 2012: Décret exécutif du 18 janvier 2012, portant la liste des espèces végétales non cultivées et protégées. – J. Off. Rép. Algérienne **3-12:** 12-38.

Dobignard, A. & Chatelain, C. 2011: Index synonymique de la flore de l'Afrique du Nord. Dicotyledoneae, *Acanthaceae-Asteraceae*, **2.** – Genève.

Domina, G., Galasso, G., Bartolucci, F. & Guarino, R. 2018: Ellenberg Indicator Values for the vascular flora alien to Italy. – Fl. Medit **28:** 53-61. https://10.7320/FlMedit28.053

Galasso, G., Conti, F., Peruzzi, L., Ardenghi, N. M. G., Banfi, E., Celesti-Grapow, L., Albano, A., Alessandrini, A., Bacchetta, G., Ballelli, S., Bandini Mazzanti, M., Barberis, G., Bernardo, L., Blasi, C., Bouvet, D., Bovio, M., Cecchi, L., Del Guacchio, E., Domina, G., Fascetti, S., Gallo, L., Gubellini, L., Guiggi, A., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E., Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Podda, L., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R. P., Wilhalm, T. & Bartolucci, F. 2018: An updated checklist of the vascular flora alien to Italy. – Pl. Biosyst. **152 (3):** 556 -592. https://doi:10.1080/11263504.2018.1441197

GBIF (Global Biodiversity Information Facility) 2021: *Bidens aurea* (Aiton) Sherff – http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:32316-2 [Last accessed 19/07/2021]

Greuter, W. 2006+: *Bidens aurea* (Aiton) Sherff – in: Greuter, W. & Raab-Straube, E. von (eds): *Compositae*. Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. – http://www.europlusmed.org/cdm_dataportal/taxon/edd35e64-e660-48d1-9c35-0743d59117da [Last accessed 18/07/2021].

Le Floc'h, E., Le Houerou, H.N. & Mathez, J. 1990: History and patterns of plant invasion in Northen Africa. – Pp. 105-133 in: Di Castri, F., Hansen, A. J. & Debussche, M. (eds), Biological invasions in Europe and the Mediterranean Basin. – Dordrecht.

Quézel, P. & Santa, S. 1963: Nouvelle flore d'Algérie et des régions désertiques méridionales, **2.** – Paris.

Rodier, J. 1954: contribution à la flore de France.– Bull. Soc. Bot. Fr. **101(7-9):** 369-372. https://doi.org/10.1080/00378941.1954.10837731

Sakhraoui, N., Metallaoui, S. & Chefrour, A. 2019a: Naturalisation d'*Anredera cordifolia* (*Basellaceae*) en Algérie. – Fl. Medit. **29:** 159-162. https://doi.org/10.7320/FlMedit29.159

—, —, — & Hadef, A. 2019b: La flore exotique potentiellement envahissante d'Algérie : première description des espèces cultivées en pépinières et dans les jardins. – Biotechnol. Agron. Soc. Environ. **23(2):** 63-73. https://doi.org/10.25518/1780-4507.17902

—, Boussouak, R., Metallaoui, S., Chefrour, A. & Hadef, A. 2020: La flore endémique du Nord Est Algérien face à la menace des espèces envahissantes. – Acta Bot. Malacitana **45:** 67-79. https://doi.org/10.24310/abm.v45i0.6138

Sanz Elorza, M., Dama, E. D. & Sobrino, E. 2004: Atlas de las Plantas Alóctonas Invasoras en España. – Madrid.

Sherff, E. E. 1937: The genus *Bidens*, Publ. Field Museum Nat. History. – Bot. Ser. **16:** 16 -74.

Tison, J.-M., Jauzein, P. & Michaud, H. 2014: Flore de la France méditerranéenne continentale. – Turriers.

Valdés, B., Rejdali, M., Achhal El Kadmiri, A., Jury, J. L. & Montserrat, J. M. 2002: Catalogue des plantes vasculaires du Nord du Maroc, incluant des clés d'identification, **2.** – Madrid.

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Article

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A. Benaradj, H. Boucherit, O. Hasnaoui & B. Babali

Phytoécologie de la formation steppique à Drinn (*Stipagrostis pungens*) dans la région de Naâma (ouest Algérien)

Abstract

Benaradj, A., Boucherit, H., Hasnaoui, O. & Babali, B.: Phytoécologie de la formation steppique à Drinn (*Stipagrostis pungens*) dans la région de Naâma (ouest Algérien). — Fl. Medit. 31: 159-171. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Phytoecology of the steppic formation at Drinn (Stipagrostis pungens) in the Naâma region (western Algeria). — The steppic plateaus of N-Africa are remarkably affected by silting up and desertification. Sanding favors the installation of psammophytic formations dominated by *Stipagrostis pungens*, *Thymelaea microphylla* and *Retama raetam* on sandy accumulations and wind deposits.
The study focuses on the eco-floristic aspects of the psammophytic grassland steppe of *Stipagrostis pengens* in the Naâma region (W-Algeria). Its objective is to illustrate the current state and to describe the floristic settlement characteristic of a type of steppe grouping very widespread in the summit Oran plateaus.
The Drinn-dominated grasslands (*Stipagrostis pungens*) can form a homogeneous steppe very adapted to drought, by physiological reactions, as well as by ecological strategies, facilitating their spreading. The Drinn is loosely distributed in large, dense, branched tufts, more than one meter high on sandy accumulations in an arid climate.
Several parameters are studied to approach the quantitative and qualitative aspects of the floristic settlement. This is followed by a statistical approach, to better interpret the different results obtained. 51 plant species belonging to 14 botanical families and 37 genera of vascular plants have been identified. The results obtained show that the phytoecological inventories are an useful tool to assess and develop natural resources.

Key words: steppe, psammophyte, *Stipagrostis*, ecology, Naâma, Oran.

Introduction

En Algérie, les écosystèmes steppiques arides sont marqués par une grande diversité paysagère en relation avec une variabilité des facteurs écologiques (Nedjraoui & Bedrani 2008).

La végétation steppique est caractérisée par un ensemble de communautés qui doivent leurs physionomies, à caractère herbacé et/ou plus ou moins arbustif, à l'abondance soit de graminées cespiteuses à base d'alfa (*Stipa tenacissima*) ou sparte (*Lygeum spartum*) ou des chamaephytes tel que l'armoise et le Remth (*Hammada scoparia*). Ces communautés se développent en touffes espacées dans lesquels la fréquence et le mode de distribution restent le plus souvent irréguliers. La végétation steppique joue un rôle fondamental dans la structure et le fonctionnement de l'écosystème dont elle constitue une expression du potentiel biologique. Cependant, le couvert végétal naturel est soumis à un double stress édapho-climatique d'une part et au stress anthropozoogène d'autre part (Djebaili 1978; Kaabeche 1990; Moulay & al. 2011).

La typologie des parcours steppiques peut, valablement, être calquée sur les types physionomiques définis par des végétaux pérennes spontanés dominants à base des graminées (Poacées) qui demeurent des indicateurs écologiques et d'usages (Le Houérou 1995). Les steppes graminéennes à alfa, à sparte et à Drinn jouent à la fois un rôle socio-économique important par la pratique de l'élevage ovin. Ces steppes sont dominées par des graminées pérennes cespiteuses telles que l'alfa (*Stipa tenacissima* L.), le sparte (*Lygeum spartum* L.) et certaines autres moins sociables comme le Drinn (*Stipagrostis pungens* subsp. *pungens* (Desf.) De Winter.), le zouaï (*Stipa lagascae* Roem & Schult., *S. barbata* subsp. *brevipila* (Coss. & Durieu) ou *S. parviflora* Desf.) et le Chiendent, n'djem (*Cynodon dactylon* L.) (Le Houérou 1995; Aidoud & Touffet 1996; Marcenò & al. 2019). Le Drinn (three-awn grass), *Stipagrostis pungens* est une Poacee vivace, rhizomenteuse, originaire de l'Afrique du Nord (Quézel & Santa 1962-1963; Chehma 2006; Dobignard 2008). Les steppes à Drinn constituent des meilleurs pâturages des ovins et des camelins en période disette (Chehma & al. 2004). La multiplicité des fonctions sociales et le rôle écologique de ces steppes en font un type de paysage important et particulier à comprendre et à gérer (Ghennou 2014).

Le présent travail consiste en une étude phyto-écologique (quantitative et qualitative) du groupement psammophyte à base de *Stipagrostis pungens* sur les hautes plaines steppiques dans la région sud-oranaise de Naama et cela dans le but de mieux appréhender la dynamique de la végétation et mieux comprendre les facteurs écologiques qui régissent ces formations végétales.

Matériel et méthodes

Notre choix a porté sur une zone située au sud de la ville de Naâma « appelé communément Souiga ». C'est une zone représentative de la formation steppique à *Stipagrostis pungens* d'où l'intérêt de ce choix. Elle est située à 17 Km au Sud de la ville de Naâma. Sur le plan géomorphologique la zone présente une pente moyenne de 3%. Elle est localisée entre 33°10' Nord en latitude et 22°et 90' Ouest en longitude et une altitude de 1191 m. Elle constitue un ensemble topographique homogène sans accident topographique majeur. Elle est dominée par la formation psammophytique à base de Drinn (*Stipagrostis pungens*).

La région d'étude constitue une transition entre le milieu aride des hautes plaines et le domaine aride de l'atlas saharien. Du point de vue climatique, elle appartient à l'étage bioclimatique méditerranéen aride à hiver doux (Q_2 = 13.38 et m = 6.7°C) (Benaradj, 2017). Sur le plan géologique, la région d'étude se localise sur du Pliocène continental, est caractérisée hydrologiquement de faible réseau hydrographique. Sur le plan pédologique, les sols sont de type Sols minéraux brut d'apport. Ce sont des sols squelettiques développés sur les formations superficielles minces. Ils sont représentés par plusieurs types de régosols et lithosols. Les accumulations sableuses sous forme de micro-dunes et de placage sableux,

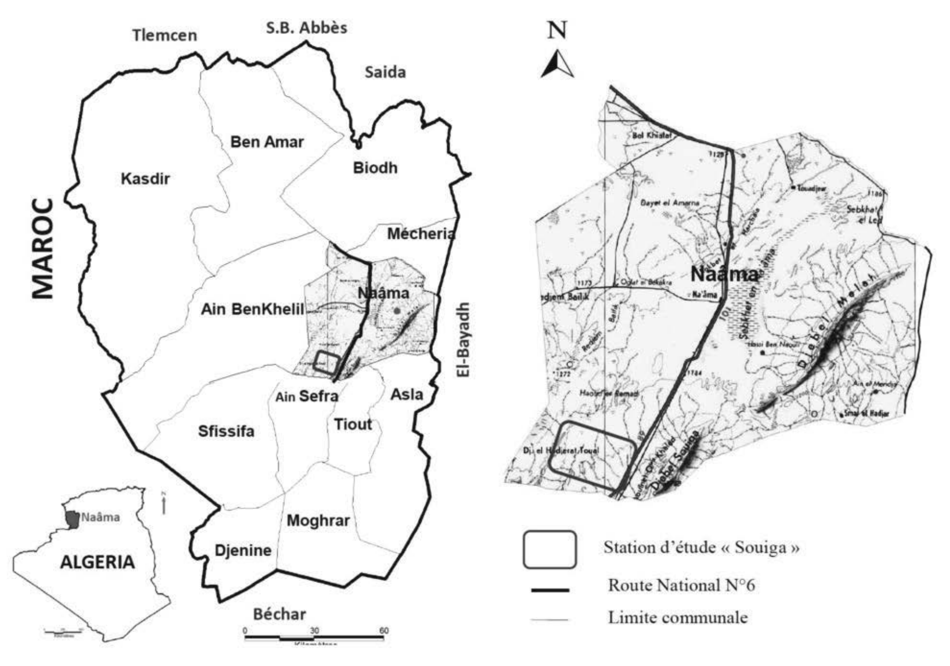

Fig.1. Situation de la zone d'étude (Souiga/Naâma).

correspondent à des sols minéraux bruts, d'apport éolien. Sur le plan phytogéographique, la zone d'étude appartient à la région méditerranéenne qui s'inscrit dans l'empire floral holarctique et au domaine maghrébin-steppique et secteur Hautes Plaines steppiques.

Réalisation des relevées phytoécologique

Selon Djebaili (1978), l'aire minimale joue un rôle de premier ordre dans la comparaison floristique des relevés. Il est connu que cette aire minimale varie en fonction de chaque groupement végétale. Selon Lemée (1967), l'aire minimale est la plus petite surface nécessaire pour que la plupart des espèces y soient représentaient. C'est un recensement de toutes les espèces rencontrées dans une aire représentative dans le but d'établir une liste floristique des communautés homogènes (Gounot 1969).

Dans cette approche nous nous sommes basés sur les techniques élaborées par Blanquet (1964). Quarante relevés phytoécologiques ont été effectués lors des prospections menées au cours de mois avril et Mai durant le printemps de l'année 2018; saison considérée comme optimale pour les observations du tapis végétal (Electronic Supplementary File 1). L'emplacement de nos relevés floristiques a été choisi d'une façon systématique (au sens de Gounot 1969). Chaque relevé phytoécologique (de $100m^2$) consiste à faire un inventaire exhaustif de toutes les espèces végétales rencontrées avec leur abondance –dominance et le taux recouvrement estimé (Djebaili 1984; Benaradj 2017).

Fig. 2. Payasage steppique à *Stipagrostis pungens* dans la zone d'étude.

Analyse quantitative de la composition floristique

Le recouvrement d'une espèce est défini théoriquement comme le pourcentage de la surface du sol qui serait recouverte, si on projetait verticalement sur le sol les organes aériens des individus de l'espèce (Gounot 1969).

La richesse floristique d'un territoire est le nombre total d'espèces qu'il renferme, cette richesse floristique est en générale d'autant plus élevée que la surface du territoire est plus grande, mais croit naturellement moins vite que la superficie considérée. Dans notre cas nous avons utilisé l'échelle de Daget et Poissonet (1991) et qui comme suit:

Raréfiée:	< de 5 espèces
Très pauvre:	de 6 à 10 espèces
Pauvre	de 11 à 20 espèces
Moyenne:	de 21 à 30 espèces
Assez riche	de 31 à 40 espèces
Riche:	de 41 à 60 espèces
Très riche:	de 61 à 75 espèces

Analyse qualitative (recouvrement et richesse floristique)

Plusieurs paramètres ont été pris en considération pour cerner l'aspect quantitatif de la végétation. Ces paramètres nous ont permis de recenser les espèces végétales et de dégager la structure de la végétation sur plusieurs plans:

- Plan biologique selon Raunkiaer (Raunkiaer 1934) et Daget (1980),
- Plan systématique selon les travaux de Quézel & Santa (1962-1963); Ozenda (1977), Fennane & Ibn Tattou (1999); Fennane & al. (2007) et l'APG III (Angiosperm Phylogeny Group 2009).
- Plan biogéographique selon Quéze l& Santa et Le Houérou (1995).

Traitement des données floristiques

Les explications sont étayées par une Analyse Factorielle des Correspondances (A.F.C) combiné à la Classification Hiérarchique Ascendante (C.A.H) afin de mieux cerner les facteurs écologiques prépondérants. Cette analyse statistique fine, nous a permis de connaitre les divers facteurs qui interviennent dans la distribution et la répartition de la formation steppique psmmophytique à Drinn (*Stipagrostis pungens*) dans la région d'étude.

Résultats et discussion

Aspect qualitatif

Le recouvrement moyen de la végétation dans la station d'étude est très ouvert. Il comprise entre 5 à 25%, cela peut être expliqué par le type de formation steppique se développent sur un milieu dunaire (sableux). Le milieu dunaire de cette formation à *Stipagrostis pungens* se caractérise par un faible recouvrement. D'après Daget & Godron (1995), le taux de recouvrement en tant qu'indicateur de dégradation est indiscutable du moins sur le plan environnemental dans des régions similaires menacées par la désertification.

De point de vue richesse floristique, on a enregistré plus de 51 espèces dans les dans la station de Souiga. D'après Daget & Poissonet (1991), la station est riche en espèces, parce que le nombre d'espèces inventorié durant notre investigation est supérieur à 40 espèces. D'après Aidoud (1989), la richesse floristique en zone aride dépend essentiellement des espèces annuelles, des conditions du milieu et de la corrélation de l'ensemble des caractères (climat, édaphisme et exploitation). Lemée (1953), lie la richesse floristique des biotopes aux déterminismes édaphiques (texture et nature chimique du sol) et anthropozoïque qui provoque l'enrichissement des sols en matières azotées à travers le surpâturage.

Selon Kerroum (2014), la variation de la composition floristique est sous l'effet de l'action synergique de l'aridité et de l'anthropique. En effet, l'aridité du climat, la sécheresse, l'ensablement et la désertification de la zone d'étude ont un impact négatif sur la richesse floristique (Boucherit 2018).

Aspect qualitatif de la composition floristique

L'inventaire floristique permet de recenser 51 taxons, répartis en 15 familles et 44 genres. Donc, le cortège floristique cache une phytodiversité hétérogène sur plan quantitatif et qualitatif; celle-ci est liée à la position géographique, nature édaphique, climatique et l'action anthropique.

Sur le plan systématique, les espèces représentées sont variables, la répartition des familles est hétérogène. D'après la figure 2.b, on note une nette dominance de la famille des *Poaceae* (avec 8 genres et 10 espèces), suivis par les *Astéraceae* (6 genres et 7 espèces), des *Fabaceae* (avec 5 genres et 6 espèces), des *Lamiaceae* (3 genres et 3 espèces) puis respectivement suivis par les familles bigénériques (*Amaranthaceae*, *Brassicaceae* et *Borraginaceae*, *Caryophyllaceae* (2 genres et 2 espèces). Les familles restantes sont monospécifiques: *Cleomaceae*, *Geraniaceae*, *Plantaginaceae*, *Ranunculaceae*, *Tamaricaceae*, *Thymeliaceae*.

Sur le plan biologique la liste floristique établie, montre la prédominance des thérophytes sur les autres formes avec 19 espèces soit 45%. Cette prédominance est caractéristique de la végétation des régions arides qui s'adaptent qu'offre les milieux steppiques et sahariens.

Sur le plan biogéographique**,** il ressort la prédominance de l'élément méditerranéen (25%); ce qui confirme l'affinité méditerranéenne de la flore de la région qui s'agence entre les deux ensembles les hautes plaines steppique et l'atlas saharien au Sud. Pour les

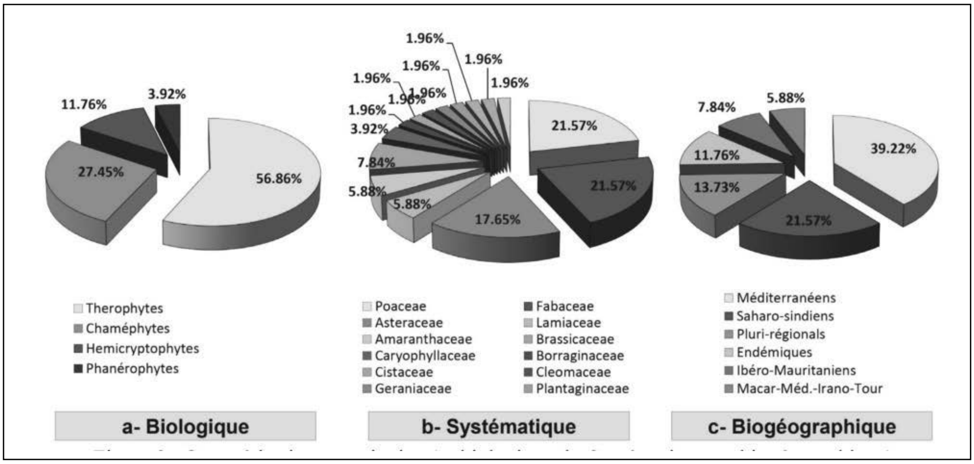

Fig.3. Caractérisation quantitative (a- biologique, b- systématique, c- biogéographique).

autres éléments biogéographique on note la forte présence de l'élément Saharo-sindien (15%), suivi par l'endémique (12.5%), le Saharien (10%), Pluri régionale avec (12.5 %). Les autres éléments ont une présence réduite c'est le cas de: Ibéro Mauritanien (5%), Macar-Méd.-Irano-Tour (7.5%).

Le groupement graminéen à *Stipagrostis pungens* présente une importante diversité floristique sur le plan biologique, systématique et biogéographique. Les types biologiques et phytogéographiques permettent d'apprécier les différentes stratégies d'adaptation de vie et une large répartition géographique.

L'inventaire floristique permet de recenser 51 taxons, répartis en 15 familles et 44 genres. Donc, le cortège floristique cache une phytodiversité hétérogène sur plan quantitatif et qualitatif; celle-ci est liée à la position géographique, nature édaphique, climatique et l'action anthropique.

Sur le plan systématique, la forte proportion des Poaceae dans la zone d'étude peut s'expliquer par le fait que ces taxons possèdent une très grande possibilité de tallage et une plus grande vitesse de repousse après le passage des troupeaux. Les Poaceae et les Fabaceae offrent un potentiel fourrager très important; ce qui favoriserait l'exploitation des parcours à des fins pastorales (Yoka & al. 2013). Les familles des Asteraceae, Poaceae présentent un plus grand pouvoir d'adaptation aux changements des conditions écologiques et aux pressions anthropiques (surpâturage) dans ces milieux.

Sur le plan biologique, la prédominance des thérophytes est caractéristique de la végétation des régions arides qui s'adaptent qu'offre les milieux steppiques et sahariens. Plusieurs auteurs soulignent que les thérophytes dépendent directement des précipitations (Quézel 1965; Barkoudah & Van Der Sar 1982; Carriere 1989; Grouzis 1992; Monod 1992). D'autres lient leur présence à l'état de la surface du sol (Negre 1966; Kadi-Hanifi 2003). Daget (1980) et Barbero & al. (1990) soulignent que la thérophytie est une stratégie d'adaptation à la sécheresse. Grime (1977), lie la présence des thérophytes aux perturbations des milieux. Guinochet & Quézel (1954) indiquent que la présence de sable même en couche réduite dans les habitats entraine le développement des psammophytes, surtout annuelles. D'un autre coté la chamephytisation semble très lie à la dégradation d'origine anthropique du milieu avec la prolifération des espèces non palatables (*Thymelaea microphylla* Coss., *Atractylis serratuloides* Sieber ex Cass., *Echinops spinosus* L., etc.). Sur le plan biogéographique, d'après ces différents éléments, il ressort que le milieu d'étude est diversifié sur le plan phytogéographique. Cette diversité est liée d'après Quézel (1995) à deux séries majeures de causes: les changements climatiques qui provoquent la migration des flores et le transport à longues distances par les vents et les oiseaux.

Traitement des données

L'A.F.C. réalisée sur une matrice de 40 relevés floristiques et 51 espèces, nous a permis de dégager les divers facteurs qui influent sur le développement des espèces accompagnatrices de la steppe à *Stipagrostis pungens*.

Tableau 1. Valeur propre et taux d'inertie (%) de l'A.F.C.

Plan factoriel	**Axe 1**	**Axe 2**	**Axe 3**	**Total**
Valeurs propres	0,526	0,094	0,087	0,708
Taux d'inertie (%)	14,728	2,645	2,446	19,820
Cumul (%)	14,728	17,373	19,819	

Dans cette analyse, seul le plan factoriel (1/2) semble être le plus intéressant, puisqu'il absorbe le maximum d'informations et explique 17.373% de la variation totale (Tab. 1). Les valeurs propres de deux axes (1 et 2) sont respectivement de 0,526 et 0,094. Elles témoignent d'une structuration hétérogène du nuage. Les espèces sont distribuées selon un nuage centré sur l'origine des axes dans le plan 1/2, qui se traduit par une assez nette séparation spatiale des relevés, ceci a permis d'individualiser 3 groupes de relevés (Fig.4 et Fig.5).

Le CAH des relevés floristiques a permis de distinguer les différents groupes d'espèces les plus caractéristiques du groupement à *Stipagrostis pungens*. Les résultats sont présentés sous forme de dendrogramme regroupant les relevés selon le degré de similitude. Celle –ci est estimée par un critère de proximité ou de distance choisi à priori (Kaabèche 1990).

Dans notre cas (Fig.4), les 29 espèces les plus représentatives ont été prises en considération, car elles sont largement répandues et donc les plus dominantes et les plus abondantes dans les relevés floristique réalisés au niveau du groupement à *Stipagrostis pungens*. Pour les autres espèces qui ne figurent pas dans la dendrogramme (Fig.4), ces espèces ont une fréquence très réduite (à faible similarité et/ou faible présence). Elles sont non représentatives numériquement et écologiquement. Elles peuvent être considérées soit comme des espèces accidentelles ou rares, soit sont des espèces notées hors relevés effectués.

L'information donnée par les deux axes de l'analyse factorielle des correspondances (AFC) (plan F1/F2= 18%), suivie de l'analyse hiérarchique des correspondances (C.A.H., Fig. 4), nous a permis d'identifier la présence de trois groupements de végétaux à savoir:

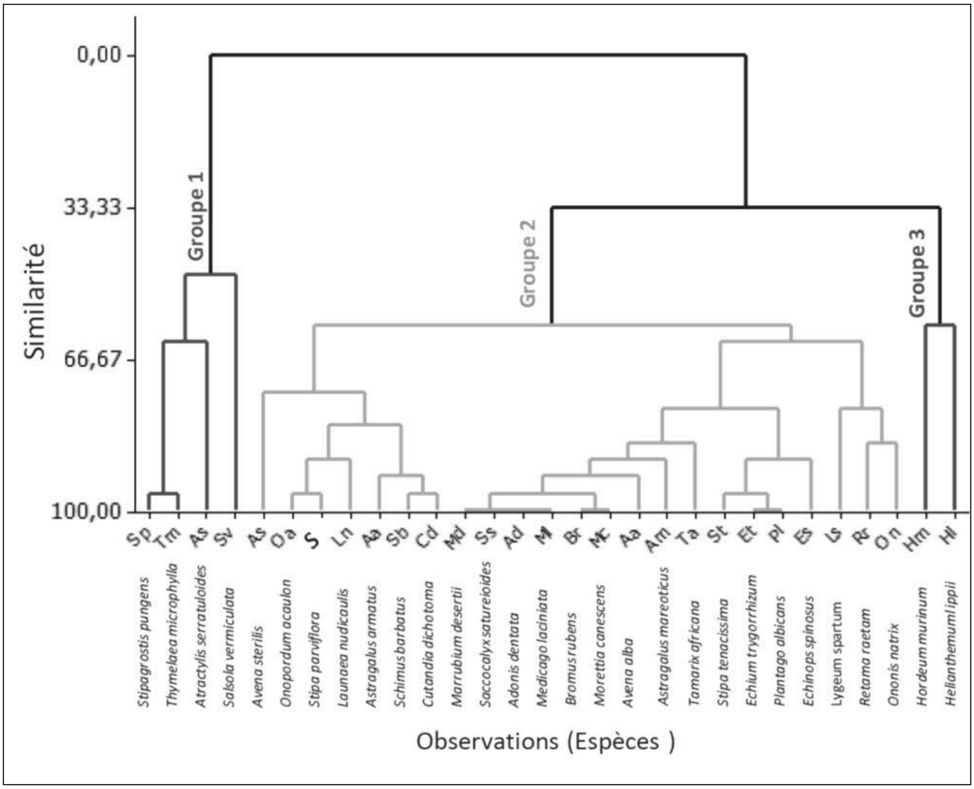

Fig. 4. Dendrogramme de la C.A.H de la matrice totale des espèces.

-Groupe 1: à base de steppe graminéennes à *Stipagrostis pungens*en association avec les espèces de *Thymelaea microphylla* Coss*., Atractylis serratuloides* Sieber ex Cass*., Salsola vermiculata* L., où s'individualise nettement et regroupe plus 90% des relevés floristique.

- ***Groupe 2***: ce groupe est constitué par le cortège floristique suivant: *Retama raetam* (Forssk.) Webb, *Atractylis serratuloides* Cass., *Lygeum spartum* L., *Stipa tenacissima* L., *Echium trygorrhizum* Pomel, *Plantago albicans* L., *Avena alba* Vahl, *Stipa parviflora* Desf., *Schimus barbatus* L., *Cutandia dichotoma* (Forssk.) Trab., *Bromus rubens* L., *Morettia canescens* Boiss., *Ononis natrix* L., *Astragalus mareoticus* Delile., *Launaea nudicaulis* Hook.f., *Astragalus armatus* subsp. numidicus (Murb.) Emb. & Maire, *Onopordum acaulon* L., *Saccocalyx satureioides* Coss. & Durieu., *Marrubium desertii* Noé ex Coss., *Echinops spinosus* L., *Adonis dentata* Delile., *Medicago laciniata* L., etc.

- ***Groupe 3*** « Hm et Hl»: est dominé de l'espèce *Hordeum murinum* L*.,* leur présence presque dans tous les relevés floristiques, ainsi la présence de l'espèce ligneuse *Helianthemum lippii* L.

L'information donnée par les deux axes de l'analyse factorielle des correspondances (AFC) (plan F1/F2= 18%), suivie de l'analyse hiérarchique des correspondances (C.A.H., Fig. 4), nous a permis d'identifier la présence de trois groupements de végétaux à savoir:

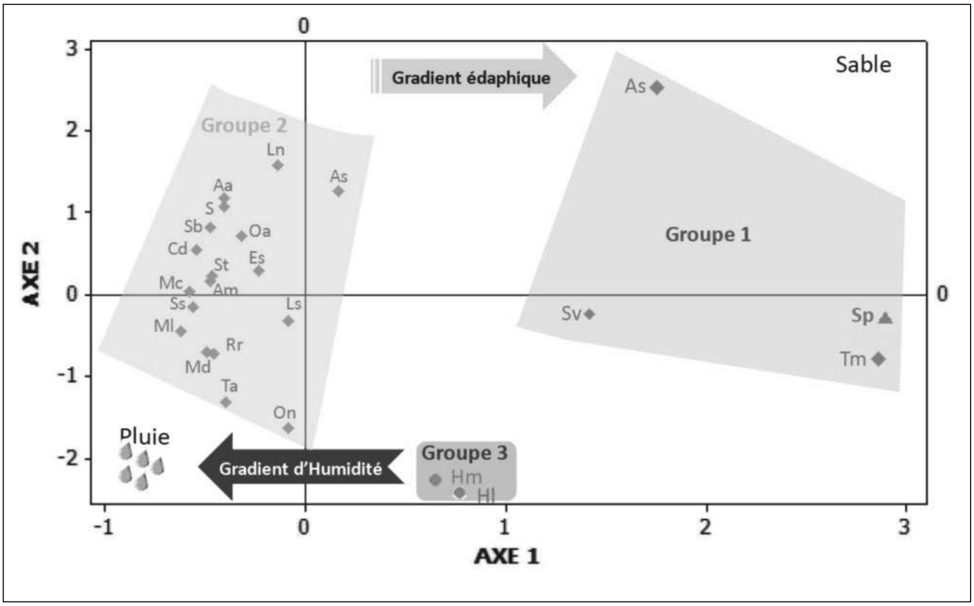

Fig 5. Plan Factoriel du premier/deuxième axe des espèces accompagnatrices de la steppe à *Stipagrostis pungens*.

-Groupe 1: Cet ordre à *Stipagrostis pungens* se rattache à l'ordre des *Aristidetalia pungentis* (Guinochet, 1952) et de l'alliance *Aristidion pungentis* au sens de Géhu, Kaabèche & Gharzouli (1993). En effet, Gauthier Pilters (1972); Chehma & longo (2004); rapportent que les peuplements de Drinn (*Stipagrostis pungens*) constituent d'immenses peuplements homogènes dans les massifs dunaires. Dajoz (1970) et Djebaili (1978) rapportent que les sols sableux sont essentiellement caractérisés par la dominance de *Stipagrostis pungens*. Cette steppe graminéenne s'installe également sur les glacis dès que l'accumulation sableuse devient supérieure à 50 cm mais n'atteint cependant pas une forme aussi sociale que le sparte ou l'alfa. L'installation du Drinn a été observée suite à la destruction de l'alfa et à de fortes accumulations de sable dans la station d'étude.

- ***Groupe 2***: Ces espèces sont généralement liées à l'humidité des formations pré-steppiques. Ces dernières sont toutes représentatives de groupements à caractère psammophile liés aux dunes vives relevant des *Aristidetalia* (Guinochet 1952). Elles sont concentrées au centre des axes. Cette concentration est expliquée par le fait que l'ensemble des espèces citées, trouvent l'humidité optimale pour leurs développements.

- ***Groupe 3:*** il est dominé par les 2 espèces, espèce ligneuse (*Helianthemum lippii* L.) et l'espèce herbacée (*Hordeum murinum* L.) est très fréquente partout dans les zones arides méditerranéennes. Cela indique que l'*Hordeum murinum* à stratégie « r », caractéristique d'espèces qui ont une grande vitesse de multiplication, ce qui leur permet, sous certaines conditions favorables, d'occuper l'espace.

Cet axe du pôle négatif au pôle positif oppose les espèces xérophytes à celles qui poussent sur des biotopes humides. La matrice de corrélation montre que l'axe 1 est très corrélé au sable du côté négatif (*Thymelaea microphylla* Coss.*, Atractylis serratuloides* Coss. & Durieu.*, Schismus barbatus* L.*, Salsola vermiculata* L., *Malcolmia aegyptiaca* Spreng.*, Astragalus armatus* Willd.*, Euphorbia guyoniana* Boiss. & Reut.), alors que l'axe 2 est fortement corrélé du côté positif à l'humidité.

Ozenda (1954) indique que le Faciès à Drinn (*Stipagrostis pungens*) est physionomiquement dominant où pousse au niveau des grandes accumulations sableuses dont le sable est faiblement fixé, cette espèce est caractéristique des milieux à accumulations sableuses.

Selon Kaabèche (1990), le Faciès à Drinn présente un déterminisme édaphique lié à un gradient d'ordre textural. Il est plus fréquent en zones arides steppiques et présahariennes sur les accumulations sableuses. Il est dominé par les espèces psmmophytes telles que *Thymelaea microphylla* Coss., *Salsola vermiculata* L. et *Avena sterilis* L.. Ces espèces sont distribuées largement dans les dunes et s'adaptent à leur environnement par des réactions physiologiques, ainsi que par des stratégies écologiques, permettant de faire face aux pénuries d'eau en évitant ou en tolérant le stress (Djebaili 1984; Gamoun & al. 2018). Cela s'explique par le caractère psammophile de ces espèces qui se développent aisément sur substrat sableux et s'adaptent bien à la sécheresse et résistent à la rigueur des conditions climatiques (Le Houérou 1995; Hellal & al. 2004). De même Le Houérou (1995) et Ozenda (2004) rapportent que les sols sableux dans les steppes nord africaines sont généralement dominés par les *Poaceae*. Cette famille assure un grand rôle dans la fixation des dunes.

Les résultats font ressortir une dynamique régressive de la végétation qui se traduit par un changement de composition floristique et édaphique (accumulations sableuses), accompagné par le remplacement de l'alfa et de sparte par le *Stipagrostis pungens, Thymelaea microphylla* Coss. et *Retama raetam* (Forssk.) Webb, toutes ces espèces étant favorisées par l'ensablement de surface.

Conclusion

La région de Nâama est dominée par une steppe graminéenne à base de *Stipagrostis pungens.* C'est une formation basse, très ouverte, xérophyte, physionomiquement sous forme des touffes dominantes sur des accumulations sableuses d'origine éolienne. Elle apparaît après une dégradation des formations à base d'alfa (*Stipa tenacissima*) et/ou de sparte (*Lygeum spartum*). Le faciès à *Stipagrostis pungens* est très adapté aux conditions arides et possède une puissance de prolifération importante puisqu'il peut former à lui seul des vastes steppes homogènes.

Devant les conditions actuelles des changements globaux (synergie climato-anthropique) ces formations jouent un rôle non négligeable dans la limitation de l'avancé du désert, chose qui préoccupe les gestionnaires et les scientifiques. Ces formations végétales sont aussi des sources d'alimentation pour le cheptel camelin (Chehma & al. 2004).

A travers ses différentes caractéristiques éco-physiologiques, *Stipagrostis pungens* offre de multiples possibilités de valorisation sur le plan écologique, agropastoral, artisanal, ethnobotanique, alimentaire et technologique (Ferhi & al. 2014).

Références

Aïdoud, A. 1989: Contribution à l'étude des écosystèmes steppiques pâturés des hautes plaines Algéro-oranaises (Algérie). – Thèse Doct. U.ST.H.B. Alger.

— & Touffet, J. 1996: La régression d'alfa (*Stipa tenacissima* L.), graminées pérennes, un indicateur de désertification des steppes algériennes. – Cahier «Sécheresse» **7(3):** 187-193.

APG III., 2009. An update of the Angiosperm Phylogeny Group Classification for the orders and families flowering plants: APG III. – Bot. J. Linn. Soc. **161:** 105-121. https://doi.org/10.1111/j.1095-8339.2009.00996.x

Barkoudah, Y. & Van Der Sar, D. 1982: L'*Acacia raddiana* dans la région de Béni-Abbés (Algérie). – Bull. Soc. Hist. Nat. Afr. Nord **70(1-4):** 79-121.

Barbero, M., Bonin, G., Loisel, R. & Quézel, P.1990: Changes and disturbances of forest ecosystems caused by human activities in the Western part of Mediterranean Basin. – Vegetatio **87:** 151-173.

Benaradj, A. 2017: Étude phyto-écologique des groupements à *Pistacia atlantica* Desf. dans le sud Oranais (Sud-Ouest algérien). – Thèse Doctorat en Foresterie. Département des Ressources Forestières. Faculté des Sciences de la nature de la vie et sciences de la terre et de l'univers. Université Abou Bakr Belkaid Tlemcen.

Braun-Blanquet, J. 1964: Pflanzensoziologie, Grundzüge der Vegetationskunde, 3rd Ed. – Berlin. http://dx.doi.org/10.1007/978-3-7091-8110-2

Boucherit, H. 2018: Etude ethnobotanique et floristique de la steppe à *Hammada scoparia* (Pomel) dans la région de Naâma (Algérie). – Thèse Doctorat en Agronomie. Département des Sciences agronomiques. Faculté des Sciences de la nature de la vie et sciences de la terre et de l'univers. Université Abou Bakr Belkaid Tlemcen.

Carriere, M. 1989: Les communautés végétales sahéliennes en Mauritanie (région de Kaédi); analyse de la reconstitution annuelle du couvert herbacé. – Thèse Doct. Sc., Univ. Paris Sud (Orsay).

Chehma, A. 2006: Catalogue des plantes spontanées du Sahara septentrional algérien. – Montpellier.

— & Longo, H. F. 2004: Nitrogenous record and weight gains in dromedary and sheep fed with date palm, barley straw, and drinn "*Aristida pungens*" by-products. – Cah. Agric. **13(2):** 221-226.

—, Gaouar, A., Semadi, A. & Faye, B. 2004: Productivité fourragère des parcours camelins en Algérie: cas des pâturages a base de «Drinn» *Stipagrostis pungens* (Desf.). – Sci. Technol. **21:** 45-52. http://revue.umc.edu.dz/index.php/c/article/view/1328

Djebaili, S. 1984: Steppe algérienne, phytosociologie et écologie. – Alger.

Daget, P. 1980: Sur les types biologiques en tant que stratégie adaptative. (Cas des thérophytes). – Pp. 89-114 in: Recherches d'écologie théorique, les stratégies adaptatives. – Paris.

— & Poissonet, J. 1991: Prairies permanentes et pâturages. Méthodes d'étude. Montpellier.

— and Godron, M. 1995: Pastoralisme: Troupeaux, espaces et sociétés. – Hatier, Aupelf, Uref.

Dajoz, R. 1970: Précis d'écologie. – Paris.

Djebaili, S. 1978: Recherches phytosociologiques et phytoécologiques sur la végétation des Hautes plaines steppiques et de l'Atlas saharien ». – Thèse Doct. Univ. Montpellier.

Dobignard, A. 2008: Index synonymique et bibliographique de la flore d'Afrique du Nord. Base de données des plantes à fleurs d'Afrique. – Genève.

Fennane, M. & Ibn Tattou, M. 1999: Observations sur la flore vasculaire endémique, rare ou menacée du Maroc. – Fl. Medit. **9:** 13-124.

Ferhi, F., Das, S., Moussaoui, Y., Elaloui, E. & Garrido Yanez, J. 2014: Paper from *Stipagrostis pungens*. – Industr. Crops Prod. **59:** 109-114. https://doi.org/10.1016/j.indcrop.2014.05.015

—, Ibn Tattou, M., Ouyahya, A. & El Oualidi, J. 2007: Flore pratique du Maroc, **2.** – Rabat.

Gauthier-Pilters, H. 1972: Observation sur la consommation d'eau du dromadaire en été dans la région de Beni Abbés (Sahara Nord Occidental). – Bull. I. F. A. N. T., sér. A, **34(1):** 219-259.

Gehu, J-M., Kaabeche, M. & Gharzouli, R. 1993: Une remarquable toposéquence phytocoenotique en bordure du Chott El Hodna (Algérie). – Fragm. Flor. Geobot. Suppl. **2(2):** 513-520.

Ghennou, S. 2014: Contribution à une étude dynamique de *Stipa tenacissima* L dans le Sud-ouest de la région de Tlemcen. – Mémoire Magister en Ecologie, Département d'Ecologie et Environnement. Faculté des Sciences de la nature de la vie et sciences de la terre et de l'univers. Université Abou Bakr Belkaid Tlemcen.

Gamoun, M., Ouled Belgacem, A. & Louhaichi, M. 2018. Diversity of desert rangelands of Tunisia. – Pl. Diversity **40(1):** 1-9. https://doi.org/10.1016/j.pld.2018.06.004

Gounot, M. 1969: Méthodes d'étude quantitatives de la végétation. – Paris.

Guinochet, M. 1952: Contribution à l'étude phytosociologique du sud tunisien. – Bull. Soc. Hist. Nat. Afr. Nord. **42:** 131-153.

— & Quézel, P. 1954: Reconnaissance phytosociologique autour du Grand Erg occidental. – Trav. Inst. Rech. Saharienne **12:** 11-27.

Grime, J. P. 1977: Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. – Amer. Naturalist **111:** 1169-1194.

Grouzis, M. 1992: Germination et établissement des plantes annuelles sahéliennes. – Pp. 245-263 in Le Floch, E., Grouzis, M., Cornet, A., Bille, J.-C. (eds), L'Aridité une Contrainte au Développement. – Montpellier.

Hellal, B., Benseddik, B., Ayad, N. & Benhassaini, H. 2004: La régénération dans la steppe du sud oranais en Algérie occidentale. – Sécheresse **15(1):** 1-7.

Nedjraoui, D. & Bedrani, S. 2008: La désertification dans les steppes algériennes: causes, impacts et actions de lutte. Revue électronique en sciences de l'environnement. – VertigO **8:** 7-15.

Kaabeche, M. 1990: Les Groupements Végétaux de la Région de Bou-Saada. Contribution à la Synsystématique des Groupements steppiques du Maghreb. – *Thèse de Doctorat d'Université*. 2 Vol., Université de Paris-Sud, Centre d'Orsay, France.

Kadi-Hanifi, H. 2003: Diversité biologique et phytogéographique des formations à *Stipa tenacissima* L. de l'Algérie. – Sécheresse **14(3):** 169-179.

Kerroum, Z. 2014: Contribution à l'Etude phytoécologique des groupements à matorrals de Bouriche (Daïra de Youb Wilaya de Saida). – Mémoire de Master en Master en Ecologie et Environnement. Département de Biologie. Faculté des Sciences. Université Dr. Tahar Moulay, Saïda.

Le Houérou, H. N. (1995). Considérations biogéographiques sur les steppes arides du Nord de l'Afrique (A). – Sécheresse **6(2):** 167-82.

Lemée G., 1953: Sur la végétation postglaciaire du Lévezou d'après l'analyse pollinique. – Bull. Soc. Bot. Fr. **100:** 26-29.

— 1967: Précis de biogéographie. – Paris.

Marcenò, C., Guarino, R., Mucina, L., Biurrun, I., Deil, U., Shaltout, K., Finckh, M., Font, X. & Loidi, J. 2019: A formal classification of the *Lygeum spartum* vegetation of the Mediterranean Region. – Appl. Veg. Sci. **22:** 593-608. https://doi.org/10.1111/avsc.12456

Monod, T. 1992. Du désert. – Sécheresse **3(1):** 7-24.

Moulay, A., Benabdeli, K. & Morsli, A. 2011: Contribution à l'identification des principaux facteurs de dégradation des steppes a *Stipa tenacissima* du sud-ouest Algérien. – Mediterranea, Ser. Estud. Biol., **22:** 149-188. http://dx.doi.org/10.14198/MDTRRA2011.22.06

Negre, R. 1966: Les thérophytes. – Mém. Soc. Bot. Fr. **113:** 92-108.

Ozenda, P. 1954: Observation sur la végétation d'une région semi- aride: les hauts plateaux du sud Algérien. – Bull. Soc. Hist. Nat. D'Afr. du Nord, Alger, **45(3-4):** 189-223.

— 1977: Flore du Sahara, 2ème Ed. – Paris.

— 2004: Flore et végétation du Sahara. – Ecol. Medit. **30(2):** 1-247.

Quézel, P. 1965: La végétation du Sahara, du Tchad à la Mauritanie. – Paris.

— 1995: La flore du bassin méditerranéen: origine, mise en piace, endémisme. – Ecol. Medit. **20(1/2):** 19-39.
— & Santa, S. 1962-1963: Nouvelle flore de l'Algérie et des régions désertiques méridionales, **1-2.** – Paris.
Raunkiaer, C. 1934: The Life Forms of Plants and Statistical Plant Geography. – London.
Yoka, J., Loumeto, J. L, Djego, J., Vouidibio, J. & Epron, D. 2013: Évaluation de la diversité floristique en herbacées des savanes de la cuvette congolaise (République du Congo). – Afrique Sci. **9(2):** 110-123.

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Acclimatization, distribution and potential economic use of *Argania spinosa* (*Sapotaceae*) in southern Italy

Abstract

Gargano, M. L., De Mastro, G., D'Amico, F. S., Di Gristina, E. & Barone, G.: Acclimatization, distribution and potential economic use of *Argania spinosa* (*Sapotaceae*) in southern Italy. — Fl. Medit. 31: 173-181. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The authors report updated notes on the acclimatization, distribution, areas suitable for cultivation and, potential use of *Argania spinosa* (*Sapotaceae*) in southern Italy. Based on observations carried out on the plants cultivated in Bari and the Botanical Garden of Palermo, and on ecological requirements of the species it is possible to consider *A. spinosa* as a woody species easily adaptable to the coastal climate of southern Italy.

Key words: *Argania*, medicinal plant, zoning model.

Introduction

Argania spinosa Skeels (syn. *Argania syderoxylon* L., *Sideroxylon spinosum* L.), the argan tree, belongs to the *Sapotaceae* family and it is the only species of its genus (Khallouki & al. 2005; Zunzunegui & al. 2010; Ait Aabd & al. 2019).

As a plant of particular botanical interest, ecological services, and socioeconomic value, it has been investigated at different levels. The structural organization and phylogenetic relationships in *Sapotaceae* was clarified by Khayi & al. (2020). Chakhchar & al. (2020) highlighted morphological aspects and physiological and biochemical mechanisms related to the roots to justify the tolerance of *A. spinosa* to abiotic stresses.

The adaptation to aridity of *A. spinosa* has been pointed out by Tahrouch & al. (2011) analyzing the leaves, stems and thorns which show a high concentration of myricetin. An ethobotanical investigation was carried out by Moukal (2004) in the rural areas of South-West Morocco on the several uses of the argan tree as therapeutic and cosmetic. Guillaume & al. (2019) highlighted the antioxidant and pharmacological properties of argan oil and the value of by-products derived from it.

Description

A. spinosa is a slow growing spiny tree with a maximum height of ca. 10 m (Charrouf & Guillaume 1999), able to live up to an age of about 200 years. (Khallouki & al. 2005). The leaves are small (20 mm), with entire margin and spatulate shape. Although the plant is evergreen, the leaves may fall off, totally or partially, especially in response to summer stress. So it is preferable to consider this species as a facultative summer semi-deciduous (M'Hirit & al. 1998).

Flowering occurs mainly in spring, with great variation among individuals, and with a secondary peak in autumn. Fruits are olive-like, stalkless drupes with a hard endocarp protecting an oil rich kernel (Zunzunegui & al. 2010). Therefore, fruit production extends over a long period and fruits can be found in different ripening phases from April to September (M'Hirit & al. 1998).

Ecology and distribution

A. spinosa is endemic to the arid and semiarid areas of South-western Morocco, mostly in the Souss Valley, between Safi and Goulimime (Msanda & al. 2021), where it occupies more than 8.000 km^2 on a wide range of altitude, from sea level to 1.500 m (Justamante & al. 2017). Other populations are found in Algeria in the Tindouf region (Khallouki & al. 2017; Kechairi & Benmahioul 2019). The range is in the transitional area between the Mediterranean iso-climatic zone in the north and the Saharan region in the south and has a wide opening to the Atlantic Ocean (Msanda & al. 2021). This species is cultivated and subspontaneous in the Canary Islands (WCSP 2021), continental Spain (Castroviejo 1997), and Libya (APD 2021).

A. spinosa is the second most common tree in Morocco, preceded only by *Quercus ilex* L. (Khallouki & al. 2005). The argan tree is adapted to grow in a harsh environment, surviving extreme drought and poor soil. The optimal rainfall pattern for the species is 500 mm per year; nevertheless, 120 mm of rain make up the minimum necessary for its development (Raimondo & al. 2005). It can resist to temperatures below 0 °C only a short time (Alouani & Bani-Aameur 2017).

A. spinosa is the only species of the tropical *Sapotaceae* family, whose range extends to the subtropical zone (Charrouf & Guillaume 2002). It could be a relict of the Tertiary flora and in that period its range could have been wider, also including the northern part of Africa and Southern Europe; after, the Quaternary glaciations contracted its range. This hypothesis would justify the current existence of the small relict populations distributed in the area of Rabat and even further north, near the Mediterranean coast of north-east Morocco (Raimondo & al. 2005; Ait Aabd & al. 2019).

In Morocco, *A. spinosa* has an indispensable ecological function. Its roots grow deep in search of water and thus help retain the soil, preventing erosion and limiting the advance of the desert (Khallouki & al. 2005). In addition to these important ecological aspects, argan trees also economically support indigenous populations (Morton & Voss 1987; Mechqoq & al. 2021). Their large canopy maintains soil fertility by shading domestic cultures that guarantee most of the dietary needs of small scale farmers (Charrouf &

Guillaume 2002). Furthermore, the argan leaves constitute a real pasture suspended for dromedaries and goats. Indeed, these last they climb up to the highest branches to graze the leaves that have considerable forage value (Nouaim & al. 1991).

However, nowadays, the argan woodlands is steadily decreasing in terms of density and surface covered. This is mainly a consequence of the overuse of argan trees, for wood or forage production, by the native dwellers but has also recently been deeply accentuated by several consecutive unprecedented arid years (Charrouf & Guillaume 1999). Therefore, sustainable management strategies are needed for the conservation of the species and its genetic diversity (Msanda & al. 2021).

Economic use

The argan tree also supports more directly the economy of the region (M'Hirit & al. 1998) since its fruits provide an edible and marketable oil for cooking, cosmetic and, medicinal purposes (Khallouki & al. 2005).

The oil provides up to 25% of the dweller daily lipid diet (Collier & Lemaire 1974) and possesses a lot of dietary interesting properties. Its quality makes it a great product sought after, much more expensive than olive oil in reason also of its limited availability (Yaghmur & al. 2001).

In the traditional pharmacopoeia the argan oil is used to fight physiological aging and drying of skin, in the treatment of children's pimples, and more particularly in juvenile acne. By its pharmacological properties, argan oil is also included in the composition of creams used in cosmetics (Khallouki & al. 2005).

Recognizing its ecological value and local economic importance, the argan forest region was declared a UNESCO Biosphere Reserve in 1998 (Msanda & al. 2021).

Distribution in Italy and acclimatization

Acclimatization tests for *A. spinosa* date back to the 17th century in Holland, the 18th century in Germany, the 19th century in France and, the early 20th century in America (Southern California and Illinois). Recently they have also been carried out in Tunisia, Libya, and Israel, Kuwait, and Mexico (Peltier & al. 1990; Raimondo & al. 2005; Falasca & al. 2018).

In Italy, a plant of *A. spinosa* is cultivated in the Botanical Garden of Cagliari (Sardinia), where the plant is cultivated in open field and vegetatively multiplied by layering. The oldest argan tree, at the side of the central tank of the Botanical Garden and producing fruits, died about 15 years ago (G. Bacchetta, *in verbis*). Since 1998 two plants have also been cultivated in the Botanical Garden of Palermo (Sicily) where they bloom and bear fruit regularly (Raimondo & al. 2005).

Two plants were introduced and cultivated outdoors, initially in pots. The plants showed a regular and vigorous growth, keeping their leaves all year round, contrary to what happens in nature. Flowering, occurred for the first time in 2003, was followed by fructification 6 years after planting. As part of a census of the trees and shrubs of the city of Bari

(Apulia, southern Italy) (Gargano & al. 2021), a vigorous tree of *A. spinosa* was observed inside the University Campus near the Department of Agricultural and Environmental Science (DiSaat) while the other plant is located in the Botanical Garden of Bari (Fig. 1).

This is one of the plants previously pointed out by Campese & al. (2011) who reported five argan trees in the University Campus, including two of about 3 m in height in the ground and three others in pots, in the greenhouses of the former Department of Biology and Plant Pathology of the University of Bari. Campese & al. (2011) also reported other two specimens cultivated in the province of Bari. Argan plants were introduced from Morocco by Prof. Daniele Sisto, plant pathologist at the University of Bari. A plant was given to Prof. Francesco Macchia, at the time director of the Botanical Garden of Bari for acclimatization. Another was planted in the University Campus, near the former Faculty of Agriculture. In about 20 years, the plant has reached the typical size of the species, bears fruit regularly and abundantly and does not present particular pathologies.

Suitable areas for cultivation in Italy

A preliminary bibliographic search was undertaken to highlight the sites of the wild plant populations of *Argania spinosa*. The Moroccan populations have been chosen as a reference because the range in Algeria has been enlarged by man and many populations have been artificially reinforced (Kechairi & Benmahioul 2019). For trees favoured or cultivated by man, sometimes for millennia, it is necessary to develop approaches combining phylogeography and paleoecology at the scale of the distribution area (Médail & al. 2019). The selected Moroccan populations were mapped on a GIS system. The climatic requirements and tolerances of *A. spinosa* have been outlined in relation to the environmental conditions of its natural distribution range. Similarly to Falasca & al. (2012; 2018) an agro-climatic zoning model was developed on the basis of the WorldClim data from the period 1950-2000 (https://www.worldclim.org/). The WorldClim data consist of climate grids with a resolution of 1 km^2 with an interval of 30”. Basic data in determining this similarity were: Annual Mean Temperature, Minimum Temperature of Coldest Month, Temperature Annual Range, Mean Temperature of Coldest Quarter, Annual Precipitation, Precipitation of Coldest Quarter. We present four suitability classes based on the percentages of surface occupied in the native range of the species: Optimal, Very suitable, Suitable and, Unsuitable and we have projected with the GIS system the areas that represent these classes on the Italian territory.

Results

According to our elaborations, in its native range the Argan tree is found in coastal and intra montane areas. Most localities have an annual mean temperature from 13.5 to 20.2 °C and average rainfall from 127 to 413 mm. The minimum temperatures of the coldest month fluctuate from -2.0 to 9.8 °C. The average temperature of Coldest Quarter ranges from 6.0 to 15.4°C. The ranges of the 4 classes that have been defined on the basis of the percentiles are shown in Table 1. These data, obtained directly on the basis of the climatic

Fig. 1. *Argania spinosa:* a) in the University Campus of Bari; b) in the Botanical Garden of Bari; c) detail of flowers and fruits.

Table 1. Climatic parameters of the suitability classes realized.

Suitability	**Annual Temp. (°C)**	**Min. Temp. Coldest Month (°C)**	**Mean Temp. Coldest Quarter (°C)**	**Max Temp. Warmest Month (°C)**	**Annual Rainfall (mm)**	**Precipitation Coldest Quarter (mm)**
Optimal	16.4–18.3	2.8–6.8	10.2–13.2	27.5–31.2	221–307	104–135
Very suitable	15.1–16.3, 18.4–19.5	-0.1–2.7, 6.9–8.2	8.3–10.1, 13.3–14.5	24.0–27.4, 31.3–33.4	163–220, 308–352	79–103, 136–144
Suitable	9.6–15.0, 19.6–23.4	-4.3–0.2, 8.3–10.9	2.9–8.2, 14.6–15.8	22.9–23.9, 33.5–45.1	28–162, 353–579	10–78, 145–210
Non suitable	<9.6, >23.4	<-4.3, >10.9	<2.9, >15.8	<22.9, >45.1	<28, >579	<10, >210

Fig. 2. Areas where the cultivation of *Argania spinosa* is possible in Italy divided into suitability classes Suitability classes: Very suitable in light blue; Suitable in green.

indices of the cells in which the plant is present in Morocco, are more accurate than those presented by Falasca & al. (2018) on the basis of available literature.

It should however be considered that the Argan takes advantage of the occult precipitations derived from oceanic influence which is difficult to quantify.

The successful introduction of this species outside the natural range depends essentially on the degree of similarity of climate in the natural area to that of the new areas with agro-climatic suitability.

Of the four defined suitability classes identified there are no optimal zones for the Argan tree in Italy, and few areas are very suitable for its cultivation in the southeast coast of Sardinia and on the island of Pantelleria. Anyhow, large areas in Sicily, Sardinia and, Apulia are suitable for its use (Fig. 2). The plants grown in Palermo and Bari, which fall into areas classified as suitable, demonstrate the good adaptability of the argan tree in this areas.

Conclusion

Based on observations carried out on the plants cultivated in Bari and the Botanical Gardens of Cagliari and Palermo, it is possible to consider *A. spinosa* as a woody species easily adaptable to the coastal climate of southern Italy and other areas in Mediterranean Europe. The presence of leaves on trees throughout the years shows that the character of deciduous plant, in *A. spinosa*, depends on climatic conditions and that the plant, in a cooler and rainy climate, recovers, recovers its possible nature of evergreen species typical of tropical climates.

An experimentation on the territory, based on these forecasting model, can provide further data on the use of this species for urban green, agriculture in marginal areas and reclamation of deteriorated land in south Italy.

The seeds of the argan plant can be find through commercial channels from the Canary Islands however the acclimatization of the *A. spinosa* plants in southern Italy would provide seeds and material for vegetative reproduction of plants that have already proved to be adapted to the territory for a future use for cultivation and to improve the economy of marginal agricultural areas.

References

Ait Aabd, N., Bouharroud, R., Tahiri, A., Wifaya, A., Mimouni, A. & El Mousadik, A. 2019: Genetic Diversity and Breeding of Argan Tree (*Argania spinosa* L. Skeels). – Pp. 31-56 in: Al-Khayri, J. M., Jain, S. M., Johnson, D. V. (eds) Advances in plant breeding strategies: Nut and beverage crops. – Cham.

Alouani, M. & Bani-Aameur, F. 2017: Effect of Cold Stress on Nursery Argan (*Argania spinosa* (L.) Skeels) Seedlings Production. – J. Environ. Sci. Toxicol. Food. Technol. **11(4):** 61-66. https://doi.org/10.9790/2402-1104016166

APD 2021: African Plant Database (version 3.4.0). Conservatoire et Jardin botaniques. – Genève. https://www.ville-ge.ch/musinfo/bd/cjb/africa/recherche.php. [Last accessed 10/07/2021].

Campese, E., Tommasi F, Sisto D. & Mastropasqua L. 2011: Presenza di *Argania spinosa* (L.) Skeels in Puglia. – Inform. Bot. Ital. **43 (1):** 36-37.

Castroviejo, S. 1997: *Argania* – Pp. 6-8 in: Castroviejo, S., Aedo, C., Laínz, M., Morales, R., Muñoz Garmendia, F., Nieto Feliner, G. & Paiva J. (eds), Flora Iberica, **5.** – Madrid.

Chakhchar, A., Lamaoui, M., El Kharrassi, Y., Bourhim, T., Filali-Maltouf, A. & El Modafar, C. 2020: A Review on the Root System of *Argania spinosa*. – Curr. Agric. Res. J. **8(1):** 7-17. https://doi:10.12944/CARJ.8.1.03

Charrouf, Z. & Guillaume, D. 1999: Ethnoeconomical, ethnomedical, and phytochemical study of *Argania spinosa* (L.) Skeels. – J. Ethnopharmacol. **67:** 7-14. https://doi.org/10.1016/s0378-8741(98)00228-1

— & — 2002: Secondary metabolites from *Argania spinosa* (L.) Skeels. –Phytochem. Rev. **1:** 345-354. https://doi.org/10.1023/a:1026030100167

Collier, A. & Lemaire, B. 1974: Etude des caroténoïdes de l'huile d'argan. – Cah. Nutr. Diet. **9:** 300-301.

Falasca, S. L., Ulberich, C. A. & Ulberich, E. 2012: Developing an agro-climatic zoning model to determine potential production areas for castor bean (*Ricinus communis* L.). – Industrial Crops Prod. **40:** 185-191. https://doi.org/10.1016/j.indcrop.2012.02.044

Falasca, S. L., Pitta-Alvarez, S. & Ulberich, A. 2018: The Potential Growing Areas for *Argania spinosa* (L.) Skeels (*Sapotaceae*) in Argentinean Drylands. – Int. J. Agron. **2018:** 9262659. https://doi.org/10.1155/2018/9262659

Gargano, M. L., Di Gristina, E., Domina, G. & Venturella, G. 2021: Trees and shrubs in the city of Bari (Italy). – Fl. Medit. **31:** 23-30. https://doi.org/10.7320/FlMedit31.023

Guillaume, D., Pioch, D. & Charrouf, Z. 2019: Argan [*Argania spinosa* (L.) Skeels] Oil. – Pp- 317-352, in: Ramadan M. (ed.) Fruit Oils: Chemistry and Functionality. – Cham. https://doi.org/10.1007/978-3-030-12473-1_16

Justamante, M. S., Ibáñez, S., Villanova, J. & Pérez-Pérez, J. M. 2017: Vegetative propagation of argan tree (*Argania spinosa* (L.) Skeels) using in vitro germinated seeds and stem cuttings. – Sci. Hortic. **225:** 81-87. https://doi.org/10.1016/j.scienta.2017.06.066

Kechairi, R. & Benmahioul, B. 2019: Comportement des plants d'Arganier (*Argania spinosa* L. Skeels, *Sapotaceae*) au sud-ouest Algérien (Tindouf, Bechar et Adrar). – Int. J. Environm. Stud. **76(5):** 800-814. https://doi.org/10.1080/00207233.2019.1602378

Khallouki, F., Spiegelhalder, B., Bartsch, H. & Owen, R.W. 2005: Secondary metabolites of the argan tree (Morocco) may have disease prevention properties. – Afr. J. Biotechnol. **4(5):** 381-388.

—, Eddouks, M., Mourad, A., Breuer, A. & Wyn Owen, R. 2017: Ethnobotanic, Ethnopharmacologic Aspects and New Phytochemical Insights into Moroccan Argan Fruits. – Int. J. Mol. Sci. **18:** 2277. https://doi.org/10.3390/ijms18112277

Khayi, S., Gaboun, F., Pirro, S., Tatusova, T., El Mousadik, A., Ghazal, H. & Mentag, R. 2020: Structural organization and phylogenetic relationships in *Sapotaceae*. – Plants **9(10):** 1354. https://doi.org/10.3390/plants9101354

M'Hirit, O., Benzyane, M., Benchekroun, F., El Yousfi, S. M. & Bendaanoun, M. 1998: L'arganier: une espèce fruitière-forestière àusages multiples. – Sprimont.

Mechqoq, H., El Yaagoubi, M., El Hamdaoui, A., Momchilova, S., Guedes da Silva Almeida, J. R., Msanda F. & El Aouad, N. 2021: Ethnobotany, phytochemistry and biological properties of Argan tree (*Argania spinosa* (L.) Skeels) (*Sapotaceae*) - A review. – J. Ethnopharmacol. **281:** 114528. https://doi.org/10.1016/j.jep.2021.114528.

Médail, F., Monnet, A. C., Pavon, D., Nikolic, T., Dimopoulos, P., Bacchetta, G., Arroyo, J., Barina, Z., Albassatneh, M. C., Domina, G., Fady, B., Matevski, V., Mifsud, S. & Leriche, A., 2019: What is a tree in the Mediterranean Basin hotspot? A critical analysis. – For. Ecosyst. **6:** 17. https://doi.org/10.1186/s40663-019-0170-6

Morton, J. F. & Voss, G. L. 1987: The argan tree (*Argania sideroxylon*, Sapotaceae), a desert source of edible oil. – Econ. Bot. **41:** 221-233. https://doi.org/10.1007/bf02858970

Moukal, A. 2004: L'arganier, *Argania spinosa* L. (skeels), usage thérapeutique, cosmétique et alimentaire. – Phytotherapie **2:** 135-141. https://doi.org/10.1007/s10298-004-0041-2

Msanda, F., El Mayad, H. & Furze. J. M. 2021: Floristic biodiversity, biogeographical significance, and importanceof Morocco’s Arganeraie Biosphere Reserve. – Environ Sci. Pollut. Res. https://doi.org/10.1007/s11356-020-11936-0

Nouaim, R., Chaussod, R., El Aboudi, A., Schabel, C. & Peltier, J. P. 1991: L’arganier: essay synthése des connaissances sur cet arbre. In: Physiologie des Arbres et Arbustes en Zones Arides et Semi-arides. – Paris.

Peltier, J. P., Carlier, G. & El Aboudi, A. 1990: Evolution journaliere de l’etat hydrique des feuilles d’arganier (Argania spinosa L. Skeels.) sous bioclimat aride a forte infuence oceanique (plaine du Souss, Maroc). – Acta Oecol. **11(5):** 643-668.

Raimondo, F. M., Spadaro, V. & Speciale, M. 2005: Acclimatazione di *Argania spinosa* (*Sapotaceae*) nell’Orto botanico di Palermo. – Quad. Bot. Amb. Appl. **16:** 83-86.

Tahrouch, S., Hatimi, A., Rapior, S., Mondolot, L., Gargadennec, A. & Andary, C. 2011: Phenolic compounds of Argan Tree, *Argania spinosa* (Endemic species of South Western Morocco). – Online J. Sci. Technol. **1(4):** 17-23.

WCSP 2021: World Checklist of Selected Plant Families. Facilitated by the Royal Botanic Gardens, Kew. – http://wcsp.science.kew.org/ [Last Accessed 15/7/2021]

Yaghmur, A., Aserin, A., Mizrahi, Y., Nerd, A. & Garti, N. 2001: Evaluation of Argan Oil far Deep-Fat Frying.– Lebensm. Wiss. Technol. **34:** 124-130. https://doi.org/10.1006/fstl.2000.0697

Zunzunegui, M., Ain-Lhout, F., Jáuregui, J., Díaz Barradas, M. C., Boutaleb, S., Álvarez-Cansino, L. & Esquivias, M. P. 2010: Fruit production under different environmental and management conditions of argan, *Argania spinosa* (L.). – J. Arid Environ. **74(10):** 1138-1145.

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Article

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The Libyan Collections of vascular plants by Fridiano Cavara: museological importance and holdings of nomenclatural types

Abstract

Cuccuini, P., Stinca, A., Vallariello, R. & Santangelo, A.: The Libyan Collections of vascular plants by Fridiano Cavara: museological importance and holdings of nomenclatural types. — Fl. Medit. 31: 183-197. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The first description of Cavara Libyan collection in NAP is given, highlighting its relevance among the Libyan collection present in Italian Herbaria in terms of specimen number and diversity of genera represented.
The names of 19 taxa belonging to 9 families and described by Cavara, sometimes jointly with Trotter, or Grande, and by other botanists (Pampanini and Hackel) on material collected by Cavara, are here typified. Types previously designated by others are also listed and referenced. A new combination and status novus *Limonium hirtiflorum* (Cavara) Cuccuini is proposed

Key words: historical collections, nomenclature, taxonomy, Flora of Libya.

Introduction

Fridiano Cavara [*Mongardino (Bologna), 1857 – †Naples, 1929] started his research activities with cryptogams, especially fungi, at the University of Pavia (Rodio 1930). When, in 1906, he became Professor at Naples University and Director of the local Botanical Garden, he worked hard to make it a modern research institute fit to lend support to the colonial policy of the Italian Government (Catalano 1958). In 1918 the *Stazione sperimentale per le piante officinali* was founded within the Botanical Garden, dedicated exclusively to the cultivation of and research on medicinal plants. In this context, Cavara was appointed member of the Commission of Study for Tripolitania and Cyrenaica (Libya). In this position he undertook several expeditions to North Africa, alone or together with other colleagues from the University of Naples, such as Alessandro Trotter (1874-1967), Professor of Plant Pathology at the Agronomy Faculty of Portici (Naples), and Loreto Grande (1878-1965), curator of the Herbarium of the Botanical Institute of Naples. They were among the contributors to the project to investigate the flora and vegetation of the two regions of Libya occupied by Italy, Tripolitania and Cyrenaica (Cuccuini & al. 2015). In 1913 Cavara and Trotter investigated Tripolitania (Cavara & Trotter 1914). In

1922 and 1925 Cavara alone and in 1924 together with Grande investigated Cyrenaica (Cavara 1923; Cavara & Grande 1925; Cavara 1928).

In addition to his floristic contributions Cavara published an interesting paper on the Libyan vegetation (Cavara 1926). The herbarium materials of vascular plants from Libyan expeditions by Cavara were stored in *Herbarium Neapolitanum* (NAP) (Santangelo & al. 1995). Several specimens were also sent to Renato Pampanini for study purpose and are now stored in Natural History Museum of Florence University (FI) in Libyan Herbarium, currently included in *Herbarium Centrale Italicum* (Cuccuini & al. 2015). Materials collected with Trotter are stored also in *Herbarium Porticense* (PORUN), in the Trotter collection (De Natale 2007). Of course, there are also numerous collections distributed in several Herbaria related to Libyan cryptogams (Zanfrognini 1914; Zodda 1914, 1926).

The aim of this work is to study the Libyan collections of vascular plants by Cavara to highlight their interest within the scope of the typification of taxa described for Libya, to give a first description of the materials stored, and to evaluate the contribution of Cavara's research to the knowledge of Libyan flora.

Materials and methods

The study of the collections focuses on the original materials related to taxa described by Cavara as result of the Libyan expeditions. Due to lack of knowledge about the Cavara Libyan collection preserved in NAP, a survey of all the bundles was carried out to allow the search of original material. Indeed, there is no original index of this collection and specimens still have not been catalogued (Santangelo & al. 1995). The collection consists of 114 bundles that are not originally ordered and numbered (Fig. 1a). A provisional numeration was provided in 2016 to allow a temporary translocation of the collection during the restructuring of the Herbarium room. One hundred and ten bundles are marked with the name "Cirenaica" and 4 with "Tripolitania". Specimens are not mounted and are kept in folders, individually or in more than one (from 1 to 4-5). In this case specimens are frequently separated by newspaper sheets. In other cases, the same method is used to separate more individuals of the same specimen bearing a single original label.

Finding the herbarium specimens is possible thanks to protruding labels, on which the name of the genera preserved in the folders are reported. All genera reported on the protruding labels was recorded to obtain data on represented families (according to Euro+Med 2006-) and genera. Information, for every bundle, about the estimated number of folders, the preservation status, the title of labels (if present), the name of collectors, the date of gathering and presence/absence of specimen arrangement were also recorded. Random sampling on number of specimens per folders was made to give quantitative data about material stored in the collection.

Moreover, the material collected in Tripolitania expedition of 1913 with Trotter stored in PORUN and the material sent to Renato Pampanini in FI were investigated. Therefore about 11,000 specimens were handled in NAP, 26 in PORUN and about 1000 in FI. Materials by Cavara were required to Herbaria K, MI, MSNM, PAD, PAL, PI, RO, TO and Virtual Herbaria were consulted too, in particular BM, F, FH, G, MPU, NY, P, PRC, S, W, WU (abbreviations according to Thiers 2020). To obtain the list of the new taxa described by Cavara, all the names used by Cavara in the publications regarding Libyan vascular flora (Cavara & Trotter 1914; Cavara 1923; Cavara & Grande1925; Cavara 1926, 1928) were checked.

Taxonomical and nomenclatural check and update of the obtained list was carried out through main Floras and floristic accounts of North Africa (Täckholm & Täckholm 1941; Maire & Weiller 1939; Maire 1942; Maire & al. 1952-1987; Täckholm & Drar 1950, 1954; Täckholm 1956; Quézel & Santa 1962, 1963; Boulos 1999, 2000, 2002, 2005; Le Floc'h & al. 2010; Dobignard & Chatelain 2010, 2011a, 2011b, 2012, 2013; Domina & El Mokni 2019) as well as through the Flora of Libya (Ali 1977; El Gadi 1977; Alavi 1983; Qaiser & Siddiqi 1984; Erteeb & Sherif 1985; Siddiqi 1985; Siddiqi & Sherif 1988) or taxonomic revisions of some taxa or general inventory (Bor 1948; De Wilde-Duyfjes 1976; Brullo 1978; Brullo & Furnari 1979; Greuter & al. 1984, 1986, 1989; Guittonneau 1990; Wiklund 1992; Greuter 2003; Greuter & Raab-Straube 2008)

The typification was carried out according to the International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) (Turland & al. 2018, hereafter ICN).

Organization of the herbarium collections

The Cavara Libyan collection in *Herbarium Neapolitanum* (NAP) includes more than 6,850 folders, for a total estimated number of about 10,700 specimens.

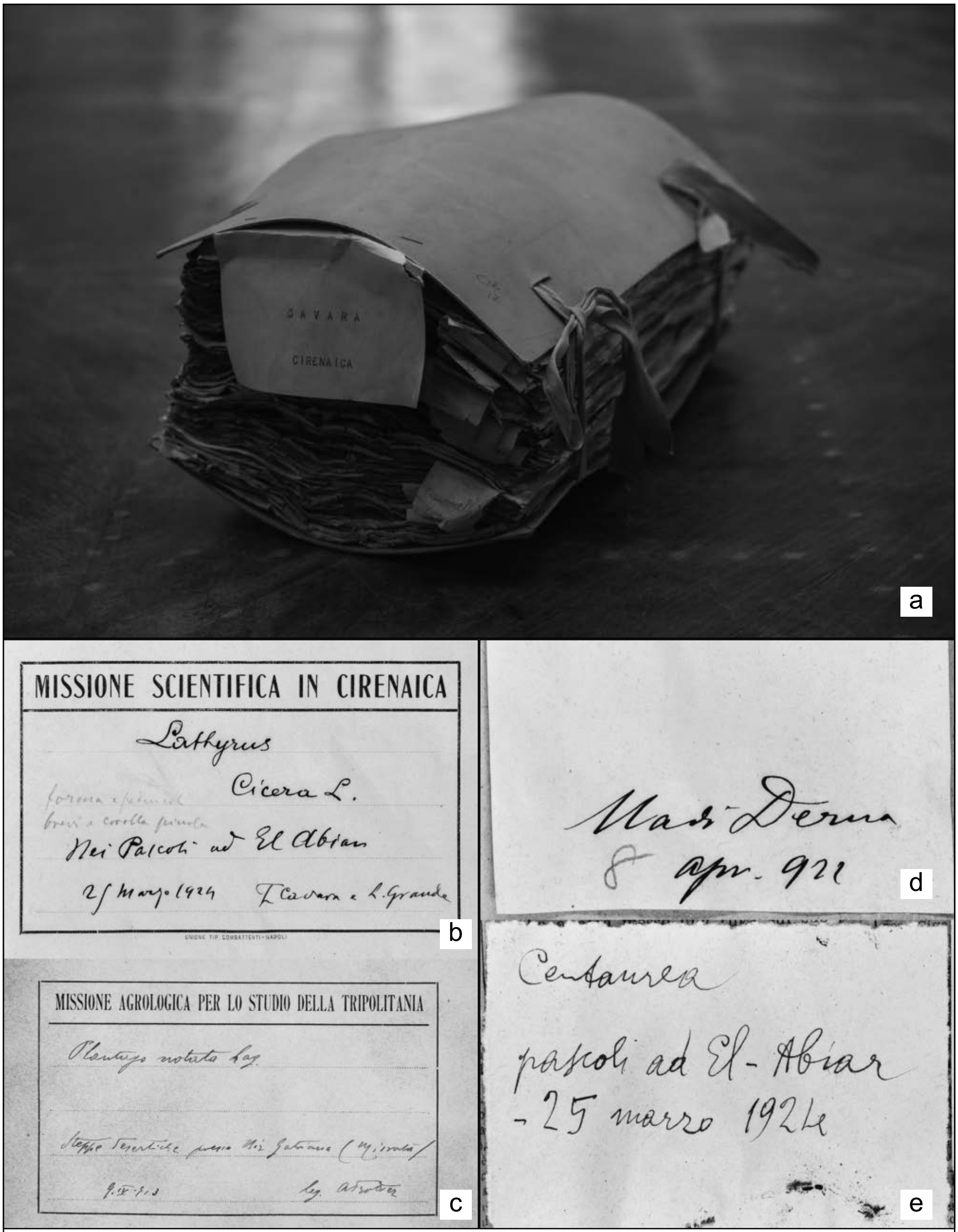
The overall collection's conservation status is mediocre but, apart from few exceptions, it is enough to allow the analysis of morphological characters of the specimens.

The carried-out survey of the collection showed that the collection never had a definitive arrangement. There are no differences among bundles named in different ways. All the bundles store specimens gathered in the different expeditions *(Missione agrologica per lo studio della Tripolitania*; *Missione scientifica in Cirenaica*), in addition to specimens received from other Institutions (*Flora Libyca exsiccata - Beguinot & Vaccari*). Together with specimens labelled with official label of the expedition or holding organization (Figs. 1b, 1c), several specimens with field labels are present (Figs. 1d, 1e).

Specimens were collected by Cavara, but also by Grande, Trotter, and by other contributors (e.g., Peglion, A. Maugini, H. Scaetta), mainly in the years corresponding to Cavara's expeditions (1913, 1922, 1924, 1925). Only few specimens were revised by other botanists, and among those Pampanini was the most represented.

The species names are not always reported on labels, but specimens are grouped based on genera and family. Frequently genera and families are arranged in taxonomic order in the bundles, but specimens of the same family and genera are also present in different bundles, clearly collected in different periods and localities. During the investigation a list, albeit provisional, of the genera preserved in Cavara Libyan collection was made (Electronic Supplementary File 1). Vascular plants are well represented, with a clear dominance of angiosperms families (88) compared to ferns (3) and gymnosperms (3). Two folders of Algae are also present, related to *Codium* and *Chara*, the latter at the time included in vascular cryptogams (Cuccuini 1997; Khan & Sarma 1984). Most represented families are *Asteraceae* (65 genera), *Poaceae* (52), *Fabaceae* (31), *Brassicaceae* (29) and *Apiaceae* (28).

A small part of specimens collected by Cavara is stored in the *Herbarium Porticense* (PORUN) which is part of the Botanical Museum "Orazio Comes" (De Natale 2007) at the Museum Center "Museums of Agricultural Sciences" of the University of Naples Federico



MISSIONE SCIENTIFICA IN CIRENAICA
Lathyrus
Cicera L.
forma a peduncoli
brevi e corolla piccola
Nei Pascoli ad El Abiar
25 Marzo 1924 F. Cavara e L. Grande
UNIONE TIP. COMBATTENTI - NAPOLI

MISSIONE AGROLOGICA PER LO STUDIO DELLA TRIPOLITANIA
Plantago notata Lag.
Steppe desertiche presso Bir Gatrana (Misrata)
9.IX.913 leg. A. Trotter

Uadi Derna
8 apr. 924

Centaurea
pascoli ad El-Abiar
- 25 marzo 1924

Fig. 1. a) Bundle of "Cavara Cirenaica" collection in NAP. The protruding labels with names of the genera are visible on the front; b) Institutional label in Cavara Libyan Collection in NAP, *Missione Scientifica in Cirenaica* (expedition in 1924, together with Loreto Grande) Cavara's handwriting; c) Cavara Libyan Collection in NAP, *Missione Agrologica per lo studio della Tripolitania* (expedition in 1913, together with Alessandro Trotter), Trotter's handwriting; d) Field label in Cavara Libyan Collection in NAP, Cavara's handwriting; e) Cavara Libyan Collection in NAP, Grande's handwriting.

II. The *exsiccata* are included in the Tripolitania Phanerogamic collection by Trotter, which is currently organized in 33 bundles with over 2300 sheets of mounted and accessioned plants arranged alphabetically by family (De Natale 2007; De Natale & Pollio 2012). Genera and infrageneric taxa are alphabetically ordered within families. However, there is no detailed and computerized catalogue for this collection. On each sheet there are one or more specimens of the same species collected in different locations. Each specimen has the original label handwritten by Trotter. In addition, almost all labels show the following printed words "*Missione agrologica per lo studio della Tripolitania*".

As far as we know, only one official accession of Libyan materials from Neapolitan botanists is present in FI. It regards 40 specimens by Trotter, collected during the expedition in Tripolitania in 1914 (Trotter 1915). No records exist regarding materials sent directly by Cavara or Grande, despite the well documented working relationship with Pampanini (Cuccuini & al. 2015). A search for original material by Cavara, Cavara and Trotter or Cavara and Grande has been done in FI-HCI in 'Africa' and 'Africa-Libya' folders, if present, or generic 'Foreign' folders.

Catalogue

Hereafter all the taxa described by Cavara and other authors on material collected by him are reported. They are grouped per family and arranged alphabetically. The names of species and infraspecific taxa inside the families are arranged in alphabetical order too. Moreover, even some specimens related to 3 invalidly published names and 2 unpublished names are presented. The original material and nomenclatural types of the taxa are selected. If they have already been typified, bibliographical reference is given.

Legend of format. -

Geographical data: Cyrenaica, Tripolitania are shown in full only once for each taxon "Type" and in "Other original material", and subsequently, at times, abbreviated as follows: Tripolitania = T.; Cyrenaica = C.

Herbarium: according to Thiers (2020) at the end of the entry, which may or may not include a bar code.

The format of each record is arranged under 5 fields (if all present):

New taxon: only the name of the new taxon is reported, without the name of the field. For the infraspecific taxa only the name of the Author of last epithet is given.

Accepted name (=/): taxonomical and/or nomenclatural updating.

Type: selected type or Author of previous typification and related bibliographic reference.

Other original materials: other specimens (syntypes) gathered in localities corresponding with those reported in the protologues, kept in all consulted Herbaria.

Note: any nomenclatural, taxonomic or museological notes.

Alliaceae

Allium ampeloprasum var. *gracile ('gracilis')* Cavara (1928: 44) = ***Allium ampeloprasum*** L. (1773: 294) subsp ***ampeloprasum***. **Type**: Cirenaica: nei seminati a Guarscia, 4/04/1922, Cavara NAP (lectotype designated here). **Note**: De Wilde-Duyfies (1976:

65) designated a different Type: “Libya, Cyrenaica, Uadi Derna, Bu Msafer, Cavara, s.n. (not seen)”; but this is not a specimen but refers to a locality based on Cavara’s field notes, and has no standing.

Asteraceae

Carduncellus eriocephalus var. *glaucescens* Cavara, Cavara, (1928: 52) = ***Carthamus eriocephalus*** (Boiss.) Greuter, (2003: 53). **Type:** Cirenaica: Dune marine a nord della ridotta Tilgher (Agedabia), 28/04/1925, Cavara NAP (lectotype designated here); FI (FI003404 isolectotype).

Carduncellus eriocephalus var. *leucanthus* Cavara & Trotter, (1914: 153) = ***Carthamus eriocephalus*** (Boiss.) Greuter, (2003: 53). **Type:** Tripolitania: colline di Azizia (M. Bathus), F. Cavara NAP (lectotype designated here). **Other original material:** Tripolitania: pianura sotto M. Bathus, F. Cavara, NAP, PI.

Carlina sicula var. *libyca* f. *longebracteata* Cavara (1928: 51) = ***Carlina sicula*** subsp ***mareotica*** (Asch. & Schweinf.) Greuter, (2003: 52**). Type:** Cirenaica: Bir Sebil, nel greto dell’Uadi, 21/04/1922, Cavara, NAP, lectotype designated by Meusel & Kästner (1994: 264). **Other original material:** C.: Uadi Bent (Derna), aprile 1922, Cavara, NAP.

Centaurea alexandrina f. *basiantha* Cavara (1928: 52) = ***Centaurea alexandrina*** Delile (1813: 280, t. 49, f. 3). **Type:** Cirenaica: Piana di Casr Gebeila sulla carovaniera Merg-Gerdes, 14/04/1925, Cavara, NAP (lectotype designated here); FI (FI003389 isolectotype). **Other original material:** pascoli di El Abiar, 25/03/1924, Cavara & Grande, NAP (2 specimens). **Note:** the lectotype comprises one folder, in which are present 2 individuals with only one institutional label.

Centaurea alexandrina f. *magnispina* Cavara (1928: 52) = ***Centaurea alexandrina*** Delile. (1813: 280, t. 49, f. 3.). **Type:** Cirenaica: Uadi Derna, aprile 1922, Cavara, NAP (lectotype designated here). **Other original material:** Costoni dell’Uadi Derna, aprile 1922, Cavara, NAP. **Note**: the lectotype consists of two individuals separated by newspaper sheet with only one institutional label by Cavara.

Centaurea bimorpha f. *integrifolia* Cavara, (sub *C. dimorpha*) (1928: 52.) = ***Centaurea bimorpha*** Viv. (1824: 58. t. 24) **Type:** Cirenaica: Bengasi alla Berca, marzo 1922, Cavara, NAP (lectotype designated here). **Other original material:** Bengasi, al cimitero arabo, marzo 1922, Cavara, NAP; Bengasi, alla Giuliana, 27/3/1922, Cavara, NAP.

Centaurea cyrenaica var. *cavarae* Grande (1928: 52) = ***Centaurea cyrenaica*** Bég. & Vaccari (1912: 3) **Type:** Cirenaica: lungo la camionabile Merg-Sidi Cheila nei pratelli, 16/03/1922, Cavara NAP (lectotype designated here). **Other original material:** Uadi Derna, 8/4/1922, Cavara, NAP; rupi sull’Uadi Derna, 8/04/1922, Cavara, FI. **Note:** Grande recognized the new taxon after its gathering. He added the name of the new varietas on the original labels by Cavara and put in the sheet the labels with the new name and its description. That information (in *schedulae herbarii libyci* by Grande) is published in Cavara (1928). The lectotype consists of 3 individuals put together in one folder.

Cynara cardunculus var. *elata* Cavara (1923:12-13) = ***Cynara cyrenaica*** Maire & Weiller (1939: 286). **Type:** Cirenaica**:** sulle rupi dell’Uadi Sambar (Cirene), aprile 1922, Cavara, NAP, sh. 1, (lectotype designated here); isolectotype, sh. 2, NAP**. Note:** recent floras include it in *Cynara cardunculus* subsp. *cardunculus* (Dobignard & Chatelain 2011, 2: 254). Wiklund (1992) in her revision of genus *Cynara* assumed that Cavara’s taxa could be referred to the endemic *Cynara cyrenaica* based on the description and provenance of specimens reported in Cavara (1923), even without seeing the type. The lectotype is in a poor state of preservation, but the diagnostic characters in the protologue are recognizable. In fact, both the basal leaves and the bracts of the flower heads are present (the upper ones assembled in a small envelope conserved on the sheet). Besides the adiaxally green leaves and small capitula, the involucral bracts allow to refer the specimen to *C. cyrenaica*. The specimen "Uadi Derna, 1922, Cavara ", cited in the protologue, *non vidi*.

Caprifoliaceae

Lonicera persica var. *occidentalis* Pamp. (1928: 581-582) ≡ ***Lonicera nummulariifolia*** subsp. ***occidentalis*** (Pamp.) Brullo & Furnari (1979: 171). **Type:** Cirenaica, Cirene: Mattan Borgu, nei boschetti presso la Ridotta, 04/1922, Cavara (sub *L. biflora* Desf.), (lectotype, FI, by Cuccuini & al. 2015: 62). Isolectotype NAP. **Other original material:** C.: Derna, Uadi Chersa, nei boschetti della macchia, 04/1922, Cavara, NAP, FI; C.: Uadi El Kuf, sulla via nuova tra Merg e Messa, 24/04/1922, Cavara, NAP; C: Nei pressi dell'Uadi Surrak, 06/1919, Maugini, FI; Cirene: Uadi El Kuf, 24/04/1922, Maugini, FI; C.: Cirene: Ghegab, 03/1923, Casilli, FI.

Cyperaceae

Carex divisa f. *pumila* Cavara (1928: 43) = ***Carex divisa*** Huds., (1762: 348) **Type:** Cirenaica: Cirene ne' prati umidi, 7/4/22, Cavara, NAP (lectotype designated here). **Other original material:** siti erbosi secchi a Gubba, 13/3/1924, Cavara & L. Grande, NAP; in herbidis siccis! presso la macchia di Gubba, 15/3/1924, Cavara & L. Grande, NAP.

Fabaceae

Argyrolobium uniflorum f. *compacta* Cavara **(**1928: 45**)** = ***Argyrolobium uniflorum*** (Decne.) Jaub. & Spach, (1843: 45)**. Type:** Cirenaica: dune a Nord-ovest di Agedabia, aprile 1925, Cavara, NAP (lectotype designated here). **Note**: specimen: sebka di Zuetina, 1925, Cavara, *non vidi*.

Dorycnium rectum var. *glaber* Cavara & Trotter (1914: 147) = ***Dorycnium rectum*** (L.) Ser. De Candolle (1825: 208). **Type:** Tripolitania: lungo il vallone di Ain Mimuna presso Casr Garian, 17/5/1913, Trotter, PORUN (lectotype designated here). **Note:** the lectotype consists of several stems, severely damaged on the upper parts. Diagnostic characters are however clearly visible.

Lathyrus cicera f. *contracta* Cavara **(**1928: 47) **=** ***Lathyrus cicera*** L., (1753: 730). **Type:** Cirenaica: nei pascoli di el Abiar, 25/3/1924, Cavara & Grande, (sub. *L. cicera*), NAP (lectotype designated here). **Other original material:** scarso ad El-Abiar, 25 /3/1924, Cavara & Grande, NAP. **Note:** In the protologue the date of gathering is 1922, but no specimens collected in El-Abiar during the expedition of 1922 are present. Instead, all the specimens are collected in the expedition of 1924 with Grande, as documented both by institutional label (Cavara's handwriting) and the field's ones (Grande's handwriting). Moreover, the diagnostic characters, that perfectly agree with the protologue, are written in pencil on the institutional label by Cavara. Therefore, we suppose that the published date is reported for mistake, and we select the specimen with institutional label as lectotype.

Lupinus hirsutus var. *micranthus* f. *leucotrichus* Cavara (1928: 45) = ***Lupinus micranthus*** Guss. (1828: 400). **Type:** Cirenaica: Bassa macchia. Merg sulla strada per Tolmetta, 11/04/1925, F. Cavara, NAP (lectotype designated here).

Geraniaceae

Erodium hirtum var. *cyrenaicum* Pamp. (1931: 295) = ***Erodium cyrenaicum*** (Pamp.) Guitt. (1990: 76). **Type:** [Libia], Cirenaica, Derna: primo gradino dell'altipiano e al sommo, gennaio-febbraio 1912, leg. Longa (FI, lectotype FI003779, by Cuccuini & Nepi in Bocconea 27(2): 88. 2015). Isolectotype FI, (FI003778) (the 2nd specimen kept on the top of sheet with lectotype). **Other original materials**: Cirenaica: Derna al faro, 18/3/1924, F. Cavara & L. Grande, NAP; Uadi Bent, 1922, Cavara. *non vidi.*

Lamiaceae

Thymus capitatus f. *albiflorus* Cavara & Trotter (1914: 151) = ***Coridothymus capitatus*** (L.) Reichenb. f. (1857: 161). **Type:** Tripolitania: rupestri presso Fonduc Ngasa lungo l'Uadi, 8/05/1913, "*flore albo*", Trotter, PORUN (lectotype designated here). Isolectotype PORUN.

Plumbaginaceae

Statice pruinosa var. *hirtiflora* Cavara (1928: 49) ≡ ***Limonium hirtiflorum*** (Cavara) Cuccuini comb. et stat. nov. **Type:** Cirenaica: Costoni aridi di Porto Bardia, 21/02/1924, F. Cavara, FI (lectotype designated by G. Domina in Cuccuini & al. (2016) as *S. pruinosa* var. *hirtiflora* Cavara & Grande), NAP, Isolectotypes (4 specimens). **Note**: the taxonomic position of this taxon is critical (see Brullo 1978; Qaiser & Siddiqi, 1984; Dobignard & Chatelain 2013). Nevertheless, the characters considered by Qaiser & Siddiqi (1984), the only ones among those indicated by the various authors that are constantly present (short hairiness of the bracts and of the calyx), together with the distribution and ecology of the taxon are different from those of the typical specie. Therefore the new name and combination are here proposed.

Poaceae

Avena barbata f. *glabra* Cavara (1928: 43) = ***Avena barbata*** Pott ex Link, (1799: 315) [in Ref. see Link]. **Type:** Cirenaica: Sidi Resig, 25/02/1924, (Marmarica), Cavara e Grande, NAP (lectotype designated here, Fig. 2).

Catapodium tuberculosum f. *simplex* Cavara & Trotter (1914: 142) = ***Castellia tuberculosa*** (Moris) Bor (1948: 90). **Type:** Tripolitania: presso Uadi Ngasa (Homs), 3/04/1913, Trotter, PORUN, (lectotype designated here, the plant on the top left of the sheet). **Note:** The lectotype is mounted on the same sheet with two samples of the typical form.

Cutandia divaricata var. *laxiflora* Hackel *in litt.*, Cavara & Trotter (1914: 142) = ***Cutandia divaricata*** (Desf.) Benth. (1881: 118). **Type:** Tripolitania: steppa presso l'Uadi el Madernel Tarhouna, 13/05/1913, Trotter, PORUN (lectotype designated here, plant on the left of the sheet).

Phalaris minor var. *integra* f. *phaeosperma* Cavara (1928: 42) = ***Phalaris minor*** Retz., (1783: iii. 8). **Type:** Cirenaica: nei coltivati alla fattoria Zorda (Merg), 11/04/1925,

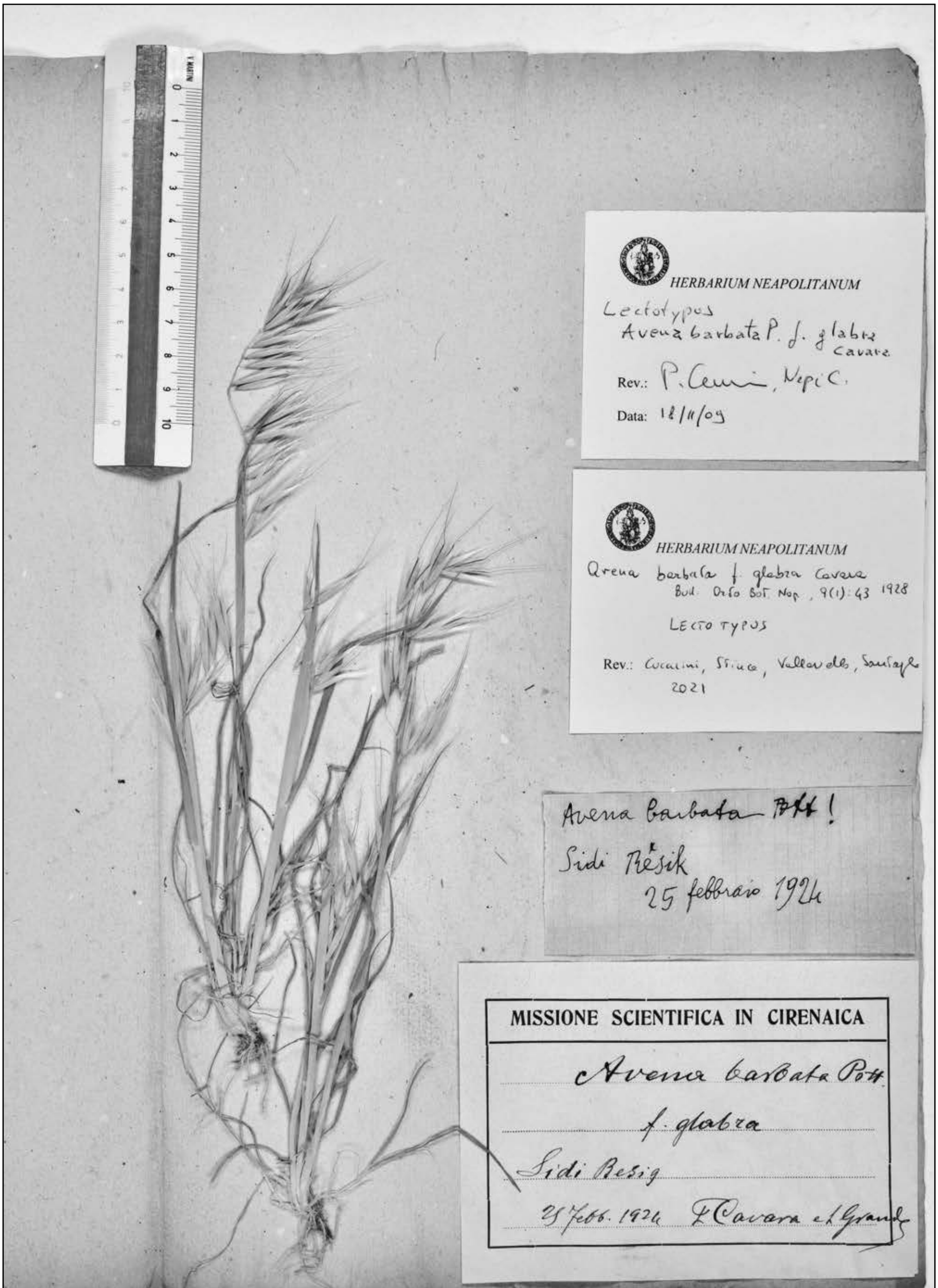


Fig. 2. Lectotype of *Avena barbata* f. *glabra* Cavara here designated.

Cavara, NAP (lectotype designated here). **Other original material:** Cirenaica: Piana di Casr Gebeila presso Got es Sas, 13/04/1925, leg. Cavara, NAP; sulla strada di Got es Sas, 13/04/1925, leg. Cavara, NAP.

Trisetum macrochaetum var. *pilosum* Cavara (1928: 43) = ***Trisetaria macrochaeta*** (Boiss) Maire, (1942: 92). **Type:** Cirenaica: Piana di Feteja (Derna), 19/03/ 1924, Cavara e Grande, "*differt a Tris. macrochaetum, cui affinis, glumellis pilosis, ac setulis crebris farcto*", NAP (lectotype designated here).

Invalidly published names

Atractylis prolifera var. *albiflora* Cavara, Bull. Orto Bot. Regia Univ. Napoli, (1928: 51). *Nomen nudum.*

Cirsium syriacum var. *albiflorum* Cavara, Bull. Orto Bot. Regia Univ. Napoli, (1928: 51). *Nomen nudum.*

Note: these names invalidly published by Cavara were used by Pampanini (1931), who correctly indicated that these taxa were merely a *nomen nudum* without adding any description. Also today these names, are wrongly listed as validly published taxa in several floras (Dobignard & Chatelain 2011a; Alavi 1983).

Hedypnois polymorpha var. *tubaeformis* f. *intermedia* Cavara, Bocconea 27(2): 51. 2015. *Nomen inval.*

Unpublished material

"*Hedypnois polymorpha* var. *tubaeformis* f. nana Cavara" (in herb. NAP, Sched.)
"*Hedypnois polymorpha* var. *tubaeformis* f. acaulis Cavara" (in herb. NAP., Sched.)

Conclusions

This research has highlighted the structure of the Libyan collection by Fridiano Cavara kept in the *Herbarium Neapolitanum* (NAP). It is probably the second Libyan collection for historic importance, after FI, among the Italian Herbaria.

The survey conducted in the main Italian and foreign Herbaria clearly show the lack of distribution of Libyan phanerogamic collections in the face of a large presence of other collections by Cavara related to Fungi or other Italian collections. This is probably because Cavara studied the Libyan collection at the end of his career. He died in 1929, one year after the last contribution related to his research on Libyan Flora (Cavara 1928).

Nevertheless, these collections were very fruitful from the scientific point of view as attested by both bibliographical research and this study. The materials from Cyrenaica collected by Cavara resulted in the publication of several interesting records for the Libyan flora: 126 taxa (Fungi, Bryophyte, Lichen, Phanerogams) new for Cyrenaica and Libya and 26 new described taxa (7 Fungi, 1 Lichen, 18 Phanerogams), as reported by Pampanini (1931). The expedition to Tripolitania led to publication of a list of 161 taxa (Cavara & Trotter 1914), among which 72 new for Libyan flora and 4 for Africa. Five new taxa were described thanks to this expedition.

Considering only the new phanerogamic taxa in Cavara's and Cavara and Trotter's collections, we listed them alphabetically in a catalogue that includes all the specimens stored in the Herbaria NAP, PORUN, FI, PI.

The catalogue includes 51 specimens of original collections used by Cavara and other authors to study 23 new taxa. In the present work nineteen names have been typified, while the reference of the typification for the others is reported. In more detail, the original collection encompasses 22 lectotypes, 9 isolectotypes, 20 other materials of original collection. The herbaria in which they are stored are reported in Table 1. Moreover, 3 invalidly published names and 2 unpublished (*herbarium sched.*) names are listed, the latter to make them available for citations in further research.

Among the authors of the taxa we find Cavara, in some cases together with Trotter, Grande, and also the scientists who received the Libyan material by Cavara for study purpose, like Pampanini or Hackel. Regarding the collaboration with Trotter, it is interesting to note that the two botanists, while participating in the same expedition and publishing together the result of their research, kept their collections separate, as clearly reported in the published floristic list (Cavara & Trotter 1914). Only 7-8% of the specimens were collected by both botanists. Very different was the collaboration with Grande in the expedition of 1924, during which 75% of the specimens were collected by the two botanists (Cavara & Grande 1925).

From the results of this study, we can argue that Cavara was certainly a passionate researcher of the Libyan flora but, although he was a pioneer among the Italian scholars, he could not devote as much time as he would have liked to this topic. It is a fact, however, that both at the time and today the main Italian researchers of North African flora such as Pampanini and Béguinot (Pampanini 1914, 1931; Béguinot & Vaccari 1912a, 1912b, 1913a, 1913b, 1914) considered almost all taxa named by him, recognizing their validity, sometimes recombining them in various ways. Among the foreign scholars, it was certainly Maire with his collaborators (Maire & al. 1952-1987) to mention the taxa he described - more than the half - often recognizing their validity. This is the case of *Lupinus hirsutus* var. *micranthus* f. *leucotrichus* Cavara, recognised as valid in another form (*status novus*) by Quézel (Maire & Quézel 1987), or *Statice pruinosa* var. *hirtiflora* Cavara, moved to

Table 1. Different type material of new taxa in Libyan collections by Cavara kept in the consulted Herbaria.

Herbaria	**Lectotypes no.**	**Isolectoytpes no.**	**Other original exsiccata no.**
NAP	16	6	17
PORUN	4	1	-
FI	2	2	2
PI	-	-	1

genus *Limonium*, reported in one of the last Egyptian Flora (Täckholm 1956) and in the only Flora of Lybia (Qaiser & Siddichi 1984) and as *Limonium hirtiflorum* (Cavara) Cuccuini *comb.* et *stat. nov.* in the present study. Moreover, the taxonomic revision of *Cynara cardunculus* var. *elata* in this work allowed the correct placement of the taxon, confirming the proposal by Wiklund (1992). Finally, it is useful to remember the positive opinion on Cavara's work by Arabian scholars (Saaed & al. 2019) who recently have attempted a scientific assessment of the contribution of various botanists to the study of Libyan flora and vegetation. They cite "The Flora of Libya" (Cavara 1926) as the first attempt of approaching the definition of the Libyan vegetation and underline the importance of the collections by Cavara. The present research highlights the relevance of the Libyan collection of Cavara in NAP, but it represents only a first contribution to its knowledge. Only a complete and accurate study of the collection will allow its definitive reorganization and revaluation.

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References

Alavi, S. A.1983: *Asteraceae*. – Pp. 1-455 in: Jafri, S. M. H. & El Gadi, A. (eds), Flora of Libya, **107.** – Tripoli.

Ali, S. I. 1977: *Caprifoliaceae*. – Pp. 1-7 in: Ali, S. I. & Jafri, S. M. H. (eds), Flora of Libya, **24.** – Tripoli.

Béguinot, A. & Vaccari, A. 1912: Specie nuove o rare per la Flora della Libia, **3.** – Padova

Bentham, G. 1881: Notes on *Gramineae.* – J. Linn. Soc. Bot. **19:** 14-134.

Bor, N. L. 1948: *Castellia tuberculosa* (Miris) Bor in India. – Indian Forester **74(3):** 90-92.

Boulos, L. 1999, 2000, 2002, 2005: Flora of Egypt, **1-4.** – Cairo.

Brullo, S. 1978: Il genere "*Limonium*" Miller in Cirenaica. – Webbia **33(1):** 137-158. https://doi.org/10.1080/00837792.1978.10670114

— & Furnari, F. 1979: Taxonomic and nomenclatural notes on the Flora of Cyrenaica (Libya). – Webbia **34(1):** 155-174. https://doi.org/10.1080/00837792.1979.10670168

Catalano, G. 1958: Storia dell'Orto Botanico di Napoli. – Delpinoa **11:** 1-170.

Cavara, F. 1923: Di alcune piante nuove o rare della Cirenaica. – Bull. Soc. Bot. Ital. **1-2:** 8-13.

— 1926: La Flora della Libia. – Atti Soc. Ital. Progr. Sci. **1926:** 319-340.

— 1928: Piante nuove o rare della Libia (IV contributo). – Bull. Orto Bot. Regia Univ. Napoli **9(1):** 41-54.

— & Grande, L. 1925: Altre piante rare o nuove della Cirenaica. – Bull. Soc. Bot. Ital. **1925:** 100-105.

— & Trotter, A. 1914: Novità floristiche della Tripolitania. – Bull. Orto Bot. Regia Univ. Napoli **4:** 139-153.

Cuccuini, P. 1997: L'Erbario Crittogamico Italiano – Storia e struttura di una collezione. – Firenze.

—, Nepi, C., Abuhadra, M. N., Cecchi, L., Freitag, H., Luccioli, E., Maier Stolte, M., Marcucci, R., Peruzzi, L., Pignotti, L., Stinca, A., Wallnöfer, B. & Wood, J. 2015: The Libyan Collections in FI (Herbarium Centrale Italicum and Webb Herbarium) and Studies on the Libyan Flora by R. Pampanini – Part 1. – Bocconea **27(2):** 3-132. https://doi.org/10.7320/Bocc27.1.001

—, —, —, Banfi, E., Domina, G., Luccioli, E. Miranda, S., Pagitz, K., Thiv, M. & Vela, E. 2016: The Libyan Collections in FI (Herbarium Centrale Italicum and Webb Herbarium) and Studies on the Libyan Flora by R. Pampanini – Part 2. – Fl. Medit. **26:** 81-143. https://doi.org/FlMedit26.081

De Candolle, A. P. 1825: Prodromus Systematis Naturalis Regni Vegetabilis, **2.** – Paris.

De Natale, A. 2007: *Herbarium Porticense*. – Pp. 52-74 in: Mazzoleni, S. & Pignatelli, S. (eds), I Musei delle Scienze Agrarie. L'evoluzione delle Wunderkammern. – Napoli.

— & Pollio, A. 2012: A forgotten collection: the Libyan ethnobotanical exhibits (1912-14) by A. Trotter at the Museum O. Comes at the University Federico II in Naples, Italy. – J. Ethnobiol. Ethnomed. **8(1):** 1-19.

De Wilde-Duyfjes, B.E.E. 1976: A revision of the genus *Allium* (*Liliaceae*) in Africa. – Wageningen.

Dobignard, A. & Chatelain, C. 2010, 2011a, 2011b, 2012, 2013: Index synonimique de la flora d'Afrique du nord, **1-5.** – Genève.

Delile, A. 1813: Description de l' Égypte. Histoire Naturelle, **2.** Paris.

Domina, G. & El Mokni, R. 2019: An inventory of names of vascular plants endemic to C. Mediterranean and described from Tunisia. – Phytotaxa **409 (3):** 105-128 https://doi.org/10.11646/phytotaxa.409.3.1

El Gadi, A. 1977a: *Alliaceae*. – Pp. 1-24 in: Jafri, S. M. H. & El Gadi, A. (eds.), Flora of Libya, **33.** – Tripoli.

Erteeb, F. B. & Sherif, A. S. 1985: *Cyperaceae*. – Pp. 1-8146 in: Jafri, S.M.H. & El Gadi, A. (eds), Flora of Libya, **120.** – Tripoli.

Euro+Med (2006-) Euro+Med Plantbase – the information resource for Euro-Mediterranean plant diversity. Available from: http://ww2.bgbm.org/EuroPlusMed/ [Last accessed 15 October 2021].

Greuter, W. 2003: The Euro + Med Treatment of *Cadueae* (*Compositae*) – generic concepts and required new names. – Willdenowia **33(1):** 49-61.

— & Raab-Straube, E. von (eds) 2008: Med-Cheklist, **2.** – Palermo & Berlin.

—, Burdet, H.M. & Long, G. (eds) 1984, 1986, 1989: Med-Cheklist **1, 3, 4.** – Genève & Berlin.

Guittonneau, G. G. 1990: Taxonomy, ecology and phylogeny of genus *Erodium* L'Her. in the Mediterranean region. – Pp. 71-91 in: Vorster, P., (ed.), Proceedings of the International *Geraniaceae* Symposium. – Stellenbosch.

Gussone, G. 1828: Florae Siculae Prodromus, p. 586. – Neapoli

Hudson, W. 1762: Flora Anglica exibens per Regnum Angliae sponte crescente. i-vii, 506. – Londini

Jafri, S. M. H. 1980: *Fabaceae*. – Pp. 1-304 in: Jafri, S. M. H. & El Gadi, A. (eds), Flora of Libya, **86.** – Tripoli.

Jaubert, H. F. & Spach E. 1843: *Argyrolobia hemisphaere septentrionalis*, – Ann. Sci. Nat., Bot. Sér. 2**, 19:** 42-52.

Khan, M. & Sarma, Y.S.R.K. 1984: Cytogeography and cytosystematics of *Charophyta*. – Pp. 303-330 in: Irvine, D.E.G. & John, D.M. (eds), Systematics of the Green Algae. – London, Orlando.

Le Floc'h, E., Boulos, L. & Vela, E. (eds.) 2010: Catalogue synonymique commente de la Flore de Tunisie. – Tunis.

Link, J. H. F. 1799: Nachricht von einer reise nach Portugal nebst botanischen in einem Schreiben an den Herausgeber von dem Hrn. Prof. Link – J. Bot. **2(5):** 297-326.

Linneo, C. 1753: *Species Plantarum*, **1-2.** – Holmiae

Maire, R. 1942: Contribution á l'étude de la Flore de l'Afrique du Nord. – Bull. Soc. Hist. Nat. Afrique N: **33(1-4)**: 88-102.

— & Weiller, M. 1939: Contribution á l'étude de la Flore de la Libye. – Bull. Soc. Hist. Nat. Afrique N. **30(4-5):** 255-314.

—, Weiller, M., Guinochet, M., Faurel, L. & Quezel, P. 1952-1987: Flore de l'Afrique du Nord, **1-16.** – Paris.

Meusel, H. & Kastner, A. 1994: Lebensgeschichte der Gold- und Silberdisteln. Monographie der mediterran-mitteleuropäischen Compositen-Gattung Carlinain. – Denkschr. Österr. Akad. Wiss., Mat.-Naturwiss. **128:** 1-656.

Pampanini, R. 1914: Plantae Tripolitanae ab auctore anno 1931 lectae et repertorium Florae Vascularis Tripolitanae. – Firenze.

— 1928: Le due Lonicere della Cirenaica, in Adunanza del giorno 13 dicembre 1928. – Bull. Soc. Bot. Ital. **35:** 580-584.

— 1931: Prodromo della Flora Cirenaica. – Forlì.

Qaiser, M & Siddiqi, M. A. 1984: *Plumbaginaceae*. – Pp. 1-30 in: Jafri, S. M. H. & El Gadi, A. (eds), Flora of Libya, **109.** – Tripoli.

Quézel, P. & Santa, S. 1962: Nouvelle Flore de l'Algérie et des régions désertiques méridionales. Ptéridophytes - Gymnospermes - Monocotylédones – Dicotylédones. (p.p.): (Salicacées-Leguminoses), **1.** – Paris.

— & —1963: Nouvelle Flore de l'Algérie et des régions désertiques méridionales. Dicotyledones (fin): Geraniacées – Synanthéracées, **2.** – Paris.

Reichenbach, H. G. f. 1857: Uber drei nauaufgestellte Labiaten- Gattung. – Oersterr. Bot. Wochenbl. **7:** 159-161.

Retzius, A. J. 1783: Observationum Botanicarum. **3.** – Lipsia.

Rodio, G. 1931: Fridiano Cavara. – Boll. Soc. Naturalisti in Napoli **42:** 229-251.

Santangelo, A., Caputo, G., La Valva, V., 1995: L'*Herbarium Neapolitanum*. – Allionia **33:** 103-120.

Siddiqi, M. A. 1985: *Lamiaceae*. – Pp. 1-116 in: Jafri, S. M. H. & El Gadi, A. (eds), Flora of Libya, **118.** – Tripoli.

— & Sherif, A. S. 1988: *Poaceae*. – Pp. 1-336 in: El Gadi, A. A. (ed.), Flora of Libya, **145.** – Tripoli.

Täckholm, V. 1956: Students' Flora of Egypt. – Cairo.

— & Drar, M. 1950: *Angiospermae*, part 2, *Monocotyledonae*: *Cyperaceae* - *Juncaceae* – Flora of Egypt, **2.** – Cairo.

— & — 1954: *Angiospermae*, part 3 *Monocotyledonae*: *Liliaceae* – Flora of Egypt, **3.** – Cairo.

— & Täckholm, G. 1941: *Pteridophyta*, *Gymnospermae*, *Angiospermae*, part 1, *Monocotyledonae*, *Typhaceae-Graminae*. – Flora of Egypt, **1.** – Cairo.

Thiers, B. 2020: *Index Herbariorum*: A global directory of public herbaria and associated staff. – New York Botanical Garden's Virtual Herbarium. –http://sweetgum.nybg.org/ih/ [Last accessed 10 October 2021].

Trotter, A. 1914: A proposito di alcune piante del Gébel Tripolino. – Bull. Orto Bot. R. Univ. Napoli **4:** 235-238.

Trotter, A. 1915: Nuovi materiali per la Flora della Tripolitania. – Nuovo Giorn. Bot. Ital. **22(3):** 319-362.

Turland, N. J., Wiersema, J. H., Barrie, F. R., Greuter, W., Hawksworth, D. L., Herendeen, P. S., Knapp, S., Kusber, W.-H., Li, D.-Z., Marhold, K., May, T. W., McNeill, J., Monro, A. M., Prado, J., Price, M. J. & Smith, G. F. (eds) 2018: International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) adopted by the Nineteenth International Botanical

Congress Shenzhen, China, July 2017. – Regnum Vegetabile **159.** Glashütten. https://doi.org/10.12705/Code.2018.
Viviani, D. 1824: Florae libycae specimen. – Genuae.
Wiklund, A. 1992: The genus *Cynara*. (*Asteraceae – Cardueae*) – Bot. J. Linn. Soc. **109(1):** 75-123.
Zanfrognini, C. 1914: Licheni libici. – Bull. Orto Bot. R. Univ. Napoli **4:** 193-204.
Zodda, G. 1914: Manipoli di Briofite della Tripolitania. – Bull. Orto Bot. R. Univ. Napoli **4:** 205-209.
— 1926: Di alcune briofite della Cirenaica raccolte dal Prof. Cavara. – Bull. Orto Bot. R. Univ. Napoli **4:** 235-238.

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Article

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Euphorbia hirta (*Euphorbiaceae*): a new naturalized xenophyte in the vascular flora of Morocco

Abstract

Khamar, H., Benkhnigue, O. & Zidane, L.: *Euphorbia hirta* (*Euphorbiaceae*): a new naturalized xenophyte in the vascular flora of Morocco. — Fl. Medit. 31: 199-206. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The occurrence of *Euphorbia hirta* (*Euphorbiaceae*) is reported here for the first time in Morocco. It is a neophyte native to tropical and sub-tropical regions. Discriminating morphological characters, taxonomic note, photographic illustrations, as well as data on habitats and geographic distribution of the taxon in Morocco and worldwide are provided for easy identification.

Key words: Alien flora, new record, N Africa.

Introduction

In the course of our steady efforts to further study the vascular flora of Morocco, interesting specimens of a plant belonging to the genus *Euphorbia* L. caught our attention during an excursion trip in the vicinity of Rabat (the administrative capital of the Kingdom). Due to its morphological characters, this plant could not be identified using the current floristic references for Morocco (Valdés & al. 2002; Fennane & al. 2007), the monography devoted to this genus in Morocco (Vindt 1953, 1960) of the current floristic references for surrounding countries (Quézel & Santa 1963; Pottier-Alapetite 1981; Jafri & El-gadi 1982; Castroviejo & al. 1997). Nevertheless, the Flora of Egypt (Boulos 2000) and the Flora of Mauritania (Barry & Celles 1991) led us to *Euphorbia hirta* L.

The present work takes stock on the discovery of this new species, its morphology, and its geographic distribution and current ecology in Morocco.

Materials and Methods

Fresh samples of *Euphorbia hirta* were collected on the side of the N1 highway nearby the Prince Moulay Abdellah sports complex in Rabat, in September and

December 2020. Appropriate data about the plant and its natural habitat were collected, and digital photographs were taken. The plant was identified using the Flora of West Tropical Africa (Hutchinson & al. 2014) in addition to the floras of Egypt (Boulos 2000) and Mauritania (Barry & Celles 1991). The protologue of the type species (Linnaeus 1753) was checked, and then identification was confirmed by viewing digital images of type specimens kept in the Linnean Collections (LINN) (http://www.linnean-online.org/), as well as true specimens examined based on the Jstor (https://plants.jstor.org) and Global Biodiversity Information Facility (GBIF) (http://www.gbif.org/occurence) databases, whose images of herbarium specimens are available online and on their websites. Voucher herbarium specimens were prepared and deposited in the National Herbarium (RAB) of the Scientific Institute-Rabat. Herbarium acronym is according to Thiers (2021+).

Results and Discussion

Taxonomy

Euphorbia hirta L., Sp. PI. 454. 1753.

Lectotype (designated by Wheeler 1939:72): Habitat in India, LINN (Herb. Linn. No. 630.7, image available at http://linnean-online.org/4601/).

Among all *Euphorbia* species found in Morocco, *E. hirta* is easily recognizable thanks to the following combination of characters: a stalk that grows dichotomous very near its base (the short main stalk rapidly branches off into secondary stalks); the tomentose and villose pubescence of its stalks, composed of long multicellular spread out yellowish simple tector hairs and of dense ± curved short whitish hairs; its inflorescences formed of axillary cyathia grouped in thyrsi made of dense small globular cymes 15-18 mm in diameter, borne by a peduncle 10-20 mm long, covered with a pubescence made of short simple appressed whitish tector hairs similar to that of the petiole; thyrsi laid out at the leaf base in an alternate pattern between nodes; old thyrsi dichotomically divided into two or three globulose glomerules (Fig. 1).

The Flora of Morocco (Fennane & al. 2007) considers the genus *Chamaesyce* S. F. Gray distinct from the genus *Euphorbia* L. when classifying the species characterized by opposite stipulate leaves, a ± dissymetric limb base, cyathium-type inflorescences and caruncle-less seeds (i.e., *C. canescens* (L.) Prokh., *C. granulata* Forsskål, *C. inaequilatera* Sonder, *C. peplis* L. *C. scordifolia* Jacq.).Yet, the classification of the genus *Euphorbia* L. drastically changed during the last decade following a series of molecular phylogenetic studies that considerably improved our understanding of the relationships among its members (Steinmann & Porter 2002; Bruyns & al. 2006; Zimmermann & al. 2010; Horn & al. 2012; Yang & al. 2012; Dorsey & al. 2013; Peirson & al. 2013; Riina & al. 2013). Consequently, some previously distinct genera are now included in *Euphorbia* L. Thus, a new infrageneric classification was proposed that considers the main four clades of the

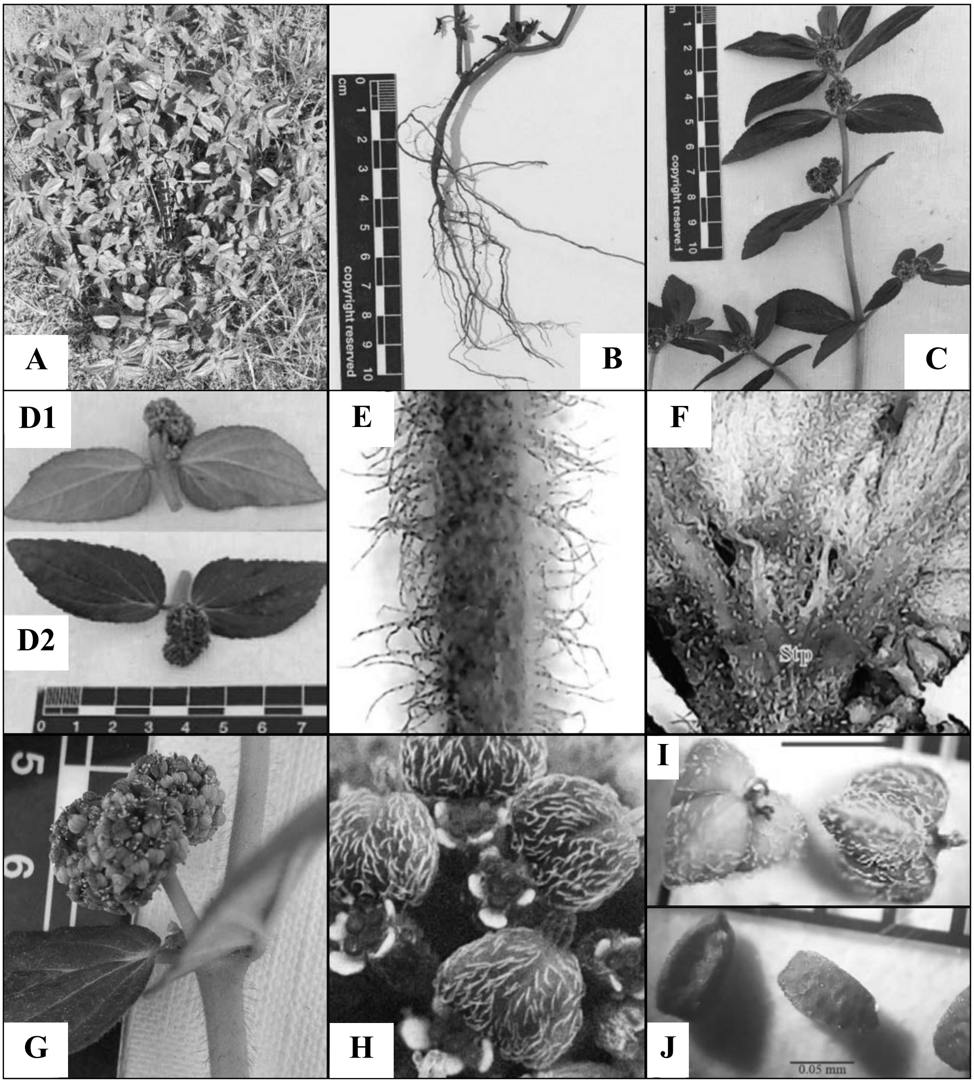

Fig. 1. *Euphorbia hirta*: **A)** Habit; **B)** Root; **C)** Flowering stalk; **D)** Leaves (***D1.*** abaxial surface, ***D2.*** adxaial surface); **E)** tector hair on the stem; **F)** Stipules (Stp); **G)** Inflorescence showing old cymes dichotomically divided into three globulose glomerules of Cyathia; **H)** Cyathia with whitish petaloid deltoid glands; **I)** Capsule, top view (left) and lateral view (right); **J)** Seeds.

genus as monophyletic subgenera (subg. *Athymalus* Necker (Peirson & al. 2013), subg. *Chamaesyce* Raf. (Yang & al. 2012), subg. *Esula* Persoon (Riina & al. 2013), and subg. *Euphorbia* (Dorsey & al. 2013). These subgenera are divided into sections (Horn & al. 2012; Peirson & al. 2013).

Thus, by adding 5 species belonging to the subgenus *Chamaesyce sensu* Yang & al. (2012) in addition to the new species described in the present article, the number of taxa in the genus *Euphorbia* in Morocco increases from 51 (41 species and 10 subspecies) (Fennane & Ibn Tattou 2005; Fennane & al. 2007; Dobignard & Chatelain 2011) up to 57 taxa (47 species and 10 subspecies), including 9 endemic ones.

Examined specimens (new record)

MOROCCO**:** Rabat nearby the Prince Moulay Abdellah sports complex, on side of the N1 highway (33°57'55.1"N 6°53'37.1"W), in Sept. 2020. *H. Khamar* 375 *& L. Zidane.* (RAB111693, RAB111694, RAB111695, RAB111696).

Discovery site and ecology in Morocco

In the present state of our knowledge, the distribution area of *Euphorbia hirta* in Morocco is limited to the Morocco-north Atlantic phytogeographic region (Man-3 in the present study). We only observed it in the region of Rabat on the side of highway N1. It grows about 100 m of altitude, on clayey-sandy, more or less humid soil.

About thirty mature *E. hirta* plants or so were observed on the discovery site, along with *Mercurialis annua* L. *Euphria peplus* L., *E. lathyris* L., *E. paniculata* Desf., *E. terracina* L., *Verbascum sinuatum* L., *Lupinus atlanticus* Dladst., *Lotus arenarius* Brot*., Ononis laxiflora* Desf., *Erigeron canadensis* L., *Plantago major* L., *Emex spinosa* L., *Parietaria mauritanica* Durieu, and *Urtica urens* L.

According to Waterhouse (1994), one *E. hirta* plant can produce up to 3,000 seeds. Seeds are dispersed thanks to an explosive mechanism of the capsule, as described by Bolaji *&* al. (2020). However, this dispersal mechanism only sends seeds a few meters away around the mother plant (Hufhuis & Hay 2017). The seeds do not display any morphological feature (hooks, gluey substances, wings, etc.) that would allow them to get hooked to animals (exozoochory) or be wind-borne. Studies on the potential of animals (e.g., migratory birds) to disperse this species by endozoochory (they would transport the seeds in their intestinal tract) (Bolaji & al. 2020) are lacking. The proximity of a main highway and of the highly frequented sports complex would be at the origin of the incidental introduction of this species in Morocco. This mode of dispersal has been greatly implied in the intentional introduction and the naturalization of species belonging to the same genus in certain European countries (i.e., *E. davidii* Subils in Switzerland (Hoffer-Massard 2011) and Bulgaria (Vladimirov & Petrova 2009); *E. serpens* Kunth in Bulgaria (Petrova, 2018), *E. glyptosperma* Engelm and *E. serpens* Kunthen in Romania (Sîrbu and Sușnia (TONE) 2018), *E. prostrata* Aiton in Hungary (Bátori & al. 2012) and *E. hypericifolia* L in Malta (Mifsud 2018)).

Geographic distribution around the world and habitat

Euphorbia hirta is a ruderal, messicolous plant; it is found from the seaside level up to more than 1500 m of altitude (Steinmann & Felger 1997; Santana *&* al. 2015, 2016; Levin & Gillespie 2016). It is fond of humid places bared by erosion, but it can adapt to clayey or more or less rich soils (CABI 2021). It is found in highly diverse environments like the rims of conurbations, roadsides and trail sides, uncultivated lands, or wastelands (Li & al. 2008; Halford & Harris 2012; Silva & al. 2014). It is tolerant to high temperatures and drought within its distribution area (Santana & al. 2015; CABI 2021). According to the literature, *E. hirta* is native to central tropical America (Li & al. 2008; Huang & al. 2012; Levin & Gillespie 2016; CABI 2021). It is currently among the common *Euphorbia* species of tropical and sub-tropical regions around the world (Klopper & al. 2006; Li & al. 2008; Yang & Berry 2011; Hutchinson & al. 2014; Govaerts 2019; POWO 2019; CABI 2021; etc.).

Conclusion

Euphrobia hirta was collected in the vicinity of Rabat (Morocco). Its presence in Morocco is reported for the first time in the present study. This discovery further enriches the vascular flora of Morocco and brings the number of taxa of the genus *Euphorbia* up to 57 (47 species and 10 subspecies).

With this study, our record of *E. hirta* as naturalized alien highlights how important field investigations are; it also shows that many phytogeographic sectors of Morocco still remain under-prospected.

On the other hand, as long as *E. hirta* is widely used as a medicinal plant in several regions of its range (e.g. Agra & al. 2008; Huang & al. 2012; Santana & al. 2015) and for the richness in secondary metabolites (e.g. Hore & al. 2006; Ogunlesi & al. 2009, Al-Snafi 2017; etc.), it will constitute an important addition for the country's medicinal flora and also has opened the path for further investigations in pharmacology and phytochemical screening in order to discover newer and potential bioactive compounds.

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References

Al-Snafi, A. E. 2017: Pharmacology and therapeutic potential of *Euphorbia hirta* (Syn: *Euphorbia pilulifera*)- A review. – IOSR J. Pharm. **7**(**3**)**:** 7-20.

Agra, M. F., Silva, K. N., Basílio, I. J., Freitas, P. F. & Barbosa-Filho, J. M. 2008: Survey of medicinal plants used in the region Northeast of Brazil. – Rev. Bras. Farmacogn. **18**(**3**)**:** 472-508.

APD 2021: African Plant Database (version 3.4.0). Conservatoire et Jardin botaniques de la Ville de Genève and South African National Biodiversity Institute, Pretoria. – http://africanplantdatabase.ch [Last Accessed 03 May 2021].

Barry, J. P. & Celles, J. C. 1991: Flore de Mauritanie, **1.** – Sophia-Antipolis.

Bátori, Z., Erdős, I. & Somlyay, I. 2012: *Euphorbia prostrata* (*Euphorbiaceae*), A new alien in the Carpathian Basin. – Acta Bot. Hung. **54**(**3-4**)**:** 235-243. https://doi.org/10.1556/abot.54.2012.3-4.2

Bolaji, A. O., Idowu-Aiye, M. & Moronfade, H. O. 2020: Reproductive biology of four weedy euphorbia species from ile-ife, Nigeria. – Ife J. Sci. **22**(**1**)**:** 1-8. https://doi.org/10.4314/ijs.v22i1.1

Boulos, L. 2000: *Euphorbiaceae*. – Pp. 36-67 in: Flora of Egypt, **2.** – Cairo.

Bruyns, P. V., Mapaya, R. J. & Hedderson, T. 2006: A new subgeneric classification for *Euphorbia* (*Euphorbiaceae*) in Southern Africa based on ITS and psbA-trnH sequence data. – Taxon **55:** 397-420. http://dx.doi.org/10.2307/25065587

CABI. 2021: *Euphorbia hirta* (garden spurge). In: Invasive Species Compendium. Wallingford. – http://www.cabi.org/isc [Last Accessed 05 April 2021]

Castroviejo, S., Aedo, C., Benedi, C., Lainz, M., Munoz Garmendia, F., Nieto Feliner, G. & Paiva, J. (eds) 1997: Flora iberica, **3.** –Madrid.

Dobignard, A. & Chatelain, C. 2011: Index synonymique de la flore d'Afrique du Nord, **3.** – Genève.

Dorsey, B. L., T. Haevermans, X. Aubriot, J. J. Morawetz, R. Riina, V.W. Steinmann, P. E. Berry 2013: Phylogenetics, morphological evolution, and classification of *Euphorbia* subgenus *Euphorbia*. – Taxon **62:** 291-315. http://dx.doi.org/10.12705/622.1

Fennane, M. & Ibn Tattou, M. 2005: Flore vasculaire du Maroc, **1.** – Rabat

—, —, M., Mathez, J., Ouyahya, A. & El Oualidi, J. 2007: Flore Pratique du Maroc, **2.** – Rabat.

GBIF 2020: GBIF Home Page. – http://www.gbif.org/occurence [Last Accessed 15 January 2021].

Govaerts, R. 2019: WCSP: World Checklist of Selected Plant Families (version Aug 2017). In: Roskov, Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P. M., Bourgoin, T., DeWalt, R. E., Decock, W., Nieukerken, E. Van, Zarucchi, J. & Penev, L. (eds), Species 2000 & ITIS Catalogue of Life, 2019 Annual Checklist Digital resource – www.catalogueoflife.org/annual-checklist/2019. Species 2000. – Leiden. [Last Accessed 04 June 2021].

Halford, D. A. & Harris, W. K. 2012: A taxonomic revision of *Euphorbia* section *Anisophyllum* Roeper (*Euphorbiaceae*) in Australia. – Austrobaileya **8**(**4**)**:** 441-600.

Hoffer-Massard, F. 2011: *Euphorbia davidii* Subils, une nouvelle espèce pour la Suisse? – Bull. Cercle Vaudois Bot. **40:** 93-94.

Horn, J. W., B. W. Van, J. J. Morawetz, R. Riina, V. W. Steinmann, P. E. Berry & K. J. Wurdack 2012: Phylogenetics and the evolution of major structural characters in the giant genus *Euphorbia* L. (*Euphorbiaceae*). – Molec. Phylogenet. Evol. **63:** 305-326.

Huang, L., Chen, S. & Yang, M. 2012: *Euphorbia hirta* (Feiyangcao): A review on its ethnopharmacology, phytochemistry and pharmacology. – J. Med. Pl. Res. **6**(**39**)**:** 5176-5185. https://doi.org/10.5897/JMPR12.206.

Hufhui, H. & Hay, A. 2017: Explosive seed dispersal. – New Phytol. **216:** 339-342.

Hutchinson, J., Dalziel, J. M., Keay, R. W. J. & Nigel Hepper, F. 2014: Flora of West Tropical Africa: All territories in West Africa South of latitude 18°N, and to the West of Lake Chad, and Fernando Po. – Kew. https://archive.org/details/FloraOfWestTropi00hutc

Jafri, S. M. & EL-Gadi, A. A. 1982: Flora of Libya, **89.** – Tripoli.

Klopper, R. R., Chatelain, C., Banninger, V., Habashi, C., Steyn, H. M., De wet, B.C., Arnold, T. H., Gautier, L. Smith, G. F. & Spichiger, R. 2006. Checklist of the flowering plants of Sub-Saharan Africa: An index of accepted names and synonyms. – South African Bot. Diversity Network Rep. **42:** 282.

Levin G. A. & Gillespie, L. J. 2016: *Euphorbiaceae* Jussieu. – In Flora of North America Editorial Committee (ed.), Flora of North America North of Mexico, **12.** – New York and Oxford. http://www.efloras.org/florataxon.aspx?flora_id=1&taxon_id=10327

Li, B., Qiu, H., Ma, J., Zhu, H., Gilbert, M. G., Esser, H. J., Dressler, S., Hoffmann, P., Lynn, J., Gillespie, M., Vorontsova, M. & McPherson, G. D. 2008: *Euphorbiaceae*. – in Wu, Z. Y., Raven, P. H., Hong, D. Y. (eds), Flora of China, **11.** – Beijing, St. Louis. http://www.efloras.org

Linnaeus, C. 1753: Species Plantarum: exhibentes plantas rite cognitas ad genera Relatas. – Stockholm. https://doi.org/10.5962/bhl.title.669

Mifsud, S. 2018: Contribution to the flora of the Maltese Islands: *Euphorbia* subg. *Chamaesyce* and *Euphorbia exigua* s. l. (*Euphorbiaceae*). – Phytotaxa **372**(**2**)**:** 153-166. https://doi.org/10.11646/phytotaxa.372.2.2

Peirson, J. A., Bruyns, P. V., Riina, R., Morawetz, J. J. & Berry, P. E. 2013: A molecular phylogeny and classification of the largely succulent and mainly African *Euphorbia* subg. *Athymalus* (*Euphorbiaceae*). – Taxon **62:** 1178-1199. http://dx.doi.org/10.12705/626.12

Petrova, A. S. 2018: *Amaranttus viridis* and *Euphorbia serpens*, new alien species records for the flora of Bulgaria. – Compt. Rend. Acad. Bulg. Sci. **71**(**1**)**:** 46-52.

Pottier-Alapetite, G. 1981: Flora of Tunisia, **2.** – Tunis.

POWO. 2019: Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. – http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:101651-2 [Last Accessed 28 January 2021].

Quézel, P. & Santa, S. 1963: Nouvelle Flore de l'Algérie et des Régions désertiques méridionales, **2.** – Paris.

Riina, R., Peirson, J. A, Geltman, D. V., Molero, J., Frajman, B., Pahlevani, A., Barres, L., Morawetz, J. J., Salmaki, Y., Zarre, S., Kryukov, A., Bruyns, P. V., Berry, P. E. 2013: A worldwide molecular phylogeny and classification of the leafy spurges, *Euphorbia* subgenus *Esula* (*Euphorbiaceae*). – Taxon **62:** 316-342.

Santana, K. C. B., Pinangé, D. S. B., Randau, K. P., Alves, M. V. S., & Benko-Iseppon, A. M. 2015: The medicinal species *Euphorbia hirta* and *E. hyssopif*olia (*Euphorbiaceae*): uses, phytochemical data and genetic diversity. – Pp. 154-173 in: Duarte, M. C. T. & Rai, M. (eds) Therapeutic medicinal plants: from lab to the market. – Boca Raton. https://doi.org/10.1201/b19773-9

—, —, Vasconcelos, S., Oliveira, A. R., Brasileiro-Vidal, A. C., Alves, M. V., & Benko-Iseppon, A. M. 2016. Unraveling the karyotype structure of the spurges *Euphorbia hirta* Linnaeus, 1753 and *E. hyssopifolia* Linnaeus, 1753 (*Euphorbiaceae*) using genome size estimation and heterochromatin differentiation. – Comp. Cytogenet. **10**(**4**)**:** 657-669. https://doi.org/10.3897/CompCytogen.v10i4.8193

Silva, O. L. M., Cordeiro, I. & Caruzo, M. B. R. 2014. Synopsis of *Euphorbia* (*Euphorbiaceae*) In the state of São Paulo, Brazil. – Phytotaxa **181**(**4**)**:** 193-215. https://doi.org/10.11646/phytotaxa.181.4.1

Sîrbu, C. & Sușnia (Tone), I. 2018: New records in the alien flora of Romania: *Euphorbia serpens* and *E. glyptosperma*. – J. Pl. Develop. **25:** 135-144. https://doi.org/10.33628/jpd.2018.25.1.135

Steinmann, V. W. & Felger, R. S. 1997: The *Euphorbiaceae* of Sonora, Mexico. – Aliso **16:** 1-71.

— & Porter, J. M. 2002: Phylogenetic relationships in *Euphorbieae* (*Euphorbiaceae*) based on ITS and ndhF sequence data. – Ann. Missouri Bot. Gard. **89:** 453-490. https://doi.org/10.2307/3298591

Thiers, B. 2021+ [continuously updated]: Index herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's virtual herbarium. – http://sweetgum.nybg.org /science/ih/ [Last Accessed 15 October 2020].

Valdés, B., Rejdali, M., Achhal, A., Jury, S. L. & Montserrat, J. M. 2002. Catalogue des plantes vasculaires du Nord du Maroc, incluant clés d'identification, **1-2.** – Madrid.

Vindt, J. 1953. Monographie des Euphorbiacées du Maroc. Première partie : Révision et systématique. – Rabat.

— 1960. Monographie des Euphorbiacées du Maroc. Deuxième partie: Anatomie. – Rabat.

Vladimirov, V. & Petrova, A. S. 2009: A new *Euphorbia* species for Bulgaria. – Phytol. Balcan. **15(3):** 343-345.

Waterhouse, D. F. 1993: The major arthropod pests and weeds of agriculture in Southeast Asia. – Canberra.

Wheeler, L. C. 1939: A miscellany of the new world *Euphorbiaceae*. – Contr. Gray Herb. **124:** 48-78.

Yang, Y. & Berry, P. E. 2011: Phylogenetics of the *Chamaesyce* clade (*Euphorbia*, *Euphorbiaceae*): reticulate evolution and long-distance dispersal in a prominent C4 lineage. – Amer. J. Bot. **98(9):** 1486-1503 https://doi. org/10.3732/ajb.1000496

—, Riina, R., Morawetz, J. J., Haevermans, T., Aubriot, X. & Berry, P. F. 2012: Molecular phylogenetics and classification of *Euphorbia* subgenus *Chamaesyce* (*Euphorbiaceae*). – Taxon **61:** 764-789. http://dx.doi.org/10.1002/tax.614005

Zimmermann, N. F. A., Ritz, C. M. & Hellwig, F. H. 2010: Further support for the phylogenetic relationships within *Euphorbia* L. (*Euphorbiaceae*) from nrITS and trnL–trnF IGS sequence data. – Pl. Syst. Evol. **286:** 39-58. http://dx.doi.org/10.1007/s00606-010-0272-7

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Article

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Phenotypic and cytogenetic diversity of local beet hybrids from *Beta macrocarpa* and *B. vulgaris* subsp. *vulgaris* crosses in Morocco

Abstract

Oumouss, S., Tobi, G., Rahmouni, I., Tahiri, H. & El Bahloul, Y.: Phenotypic and cytogenetic diversity of local beet hybrids from *Beta macrocarpa* and *B. vulgaris* subsp. *vulgaris* crosses in Morocco. — Fl. Medit. 31: 207-222. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

Several barriers and challenges meet interspecific hybridization between taxa belonging to the genus *Beta* under Moroccan environmental conditions. Sugar beet (*Beta vulgaris* s. l.), is a socioeconomically important recent crop, developed mainly for the sugar production in Morocco. *B. macrocarpa*, a beet wild relative, is characterized by a wide genetic richness and high adaptative capacity. Obtaining viable hybrids from crosses between these two taxa is challenging. Hence, we studied 75 beet hybrids harvested on two cultivated (CH) and two wild (WH) parents separately. Twentyone effective agro-morphological traits were used as well as flux cytometry analysis to confirm the success of interspecific crosses. High phenotypic diversity was estimated both within and between hybrid groups. Plants of all WH hybrids and 50% of CH hybrids were rather similar to respective parents from the behavior and morphological points of views. The remaining CH hybrids were closer to their cultivated parent for phenotypical characteristics, vernalization requirement, and biannual vegetative cycle. Heritability rate in progeny generation was variable for cultivated and wild types, H2WP = 3-95% / H2CP = 3-91% and of H2WP = 4-89% / H2CP = 3-89%. Diploid and tetraploid cytotypes were observed in hybrids and their parents. Tetraploid plants of Beta macrocarpa detected for the first time in Morocco provide novel insights on the cytogenetic diversity of Beta genus. The results obtained in this study show that Moroccan beet germplasm might provide a valuable reservoir of gene to improve genetic and cytogenetic diversity, adaptation and resistance to biotic and abiotic.

Key words: sugar beet, interspecific hybridization, phenotypical characterization, ploidy level.

Introduction

Beta L. (*Betoideae* Ulbr., *Chenopodiaceae* Vent.) compreises 9 species, whereas the number of infraspecific taxa (subspecies and varieties) is undefined at present including both wild and cultivated morphotypes which are mainly included in the high variable *Beta vulgaris* L. (see e.g., Kadereit & al. 2006; Uotila 2011; Iamonico 2019).

The classification of the genus (and the whole subfamily *Betoideae*) was recently revised by Iamonico (2019) who recognized two tribes, i.e. *Beteae* (Moq.) G. Kadereit & al. and *Halbitziae* Ulbr.; for the tribe *Betae* three sections and four subsections were accepted.

The Flora of Morocco includes native *Beta* species, i.e. *Beta macrocarpa* Guss. and (sugar beet) (see El Bahloul 2007; Uotila 2011; Hellier & al. 2013). Sugar beet (*Beta vulgaris* s. l.) is a relatively young crop in Morocco, which supposedly has a narrow genetic base. Natural genetic diversity in wild *Beta* species, including *B. macrocarpa*, is used for genetic improvement of cultivated beet.

Beta macrocarpa [*Beta* sect. *Macrocarpae* Iamonico (Iamonico 2019: 154)] is a widespread species in the central-west Mediterranean basin (Pottier-Alapetite 1979; Uotila 2011). In Morocco, it is widely found on the inland 30 km away from the sea and up to 1000 m above sea level, on balanced and non-saline soils (El Bahloul & al. 2006; El Bahloul 2007). While this herbaceous annual plant has also been considered as a halophytic or semi-halophytic species, mostly grown in coastal lands (within 1 km of the sea). It is mainly found in disturbed habitats (Flowers & al. 1977; Hessini & al. 2005; Slama & al. 2016). Many authors reported that this species contains diploid, tetraploid and hexaploid cytotypes (Letschert 1993; Castro & al. 2013; Leys & al. 2014). Tetraploid and hexaploid cytotypes were first reported in the Canary Islands and in Portuguese territory. This variability of polyploidization level is probably resulting from allopolyploidy hybridizations between *B. macrocarpa* and *B. vulgaris* subsp. *maritima* (L.) Arcang. (Villain 2007). From the genetical point of view, high genetic diversity is attributed to *B. macrocarpa* with occurrence of some unique isozyme alleles (Nagamine & al. 1989; Abe & Shimamoto 1989).

For these reasons, *B. macrocarpa* wild germplasms might provide a valuable reservoir of resistant genes to biotic and abiotic stress (Peltier & al. 2012; Fan & al. 2015; Slama & al. 2016). That could potentially be used for sugar beet breeding and improvement. The introduction of important agronomic characteristics of wild *B. macrocarpa* into cultivated beets is generally operated through interspecific crosses. Hybridization using a genetic locally material will generate new combinations of traits and will increase the adaptability to local environments (Abbott & al. 2013; Soltis & al. 2015).

The present work aims: 1) to succeed in obtaining viable interspecific hybrids resulting from crosses between annual wild *B. macrocarpa* (plant) and biannual cultivated sugar beet (*B. vulgaris* subsp. *vulgaris*) grown locally under the Moroccan environmental conditions; 2) to evaluate agro-morphological diversity within hybrids and between hybrids and their parents; 3) investigate the behavior of both hybrid plants collected on cultivated and wild parents separately; 4) evaluate heritability of studied traits; 5) characterize the ploidy levels of the beet hybrids and their parents. This study represents the first evaluation of Moroccan *B. macrocarpa* and its prospective implication in breeding program at national scale.

Material and methods

Plant material – Interspecific hybridizations have been carried out between wild (*B. macrocarpa*) and cultivated beet (*B. vulgaris* subsp. *vulgaris*).

Parental plant material involved in interspecific hybridizations, consisted of two populations of *B. macrocarpa* collected two different sites in Morocco (Fès, center of north of Morocco at 820 m, and Ouajda in the extreme north-east at 463 m) during the reproductive period in 2010. 15 individuals were collected from each wild population and grown in the greenhouse under controlled conditions and spatial isolation.

Two different half-sib families of sugar beet originating from the national breeding program were used as cultivated parents. 25 seeds from each family were planted at Merchouch, experimental station of the National Institute of Agronomic Research-Morocco (33°36’48.8”N; 6°43’03.3”W; 340 m a.s.l.). Plants required a period of vernalization.

Experimental field was characterized by an annual cumulative rainfall ranging from 246.4 to 542.8 mm and a mean temperature reaching 4 °C in January and 45 °C in August during 2017 and 2018.

Hybrids evaluation trial was conducted in the greenhouse under semi-controlled conditions at 25 ± 2 °C, a 16/8 h light/dark regimen and relative humidity rate above 60%. A month after seeds sowing, seedlings of uniform size were transplanted in black hard plastic pots (one plant per pot), under spatial isolation. A total of 75 viable hybrids, 35 collected from wild parent and 40 from cultivated parent, were evaluated.

Hybridization technique – Two genotypes were randomly selected from wild populations and cultivated plants of sugar beet for the interspecific crosses, that have flourished in very close periods.

In October 2017, the samples of cultivated beet *B. vulgaris* subsp. *vulgaris* were transplanted to the field one month after sowing. To synchronize flowering season between parental forms, annual genotypes of *Beta macrocarpa* were sown in an average period of 70 days after sowing date of biannual cultivated genotypes.

Before flowering time, wild plants were transported to the field. Two branches, one from each plant, were bagged with white parchment bags (12 × 18 cm) to control interspecific hybridization until the end of the reproductive phase and seed formation. The maternity of each seed is known. At maturity, seed-balls were harvested from both wild (WH-01 and WH-02) and cultivated (CH-01 and CH-02) branches separately. Parent genotypes were sown and characterized based on agro-morphological characteristics in 2016-2017, one year before the evaluation of interspecific crosses.

Agro-morphological approach - A total of 21 morphological traits (Table 1), including 16 quantitative and 5 qualitative were analyzed following the *Beta* descriptors published by Bioversity International (formerly IPGRI, 1991) for characters related to vegetative and reproductive, developmental stages and yield. Concerning leaf characters, 10 leaves were randomly measured from each studied genotype. The measurements were carried out on the plants before bolting at a consistent stage to standardize the morphological evaluation.

Cytogenetic approach – Ploidy level was evaluated using flow cytometry procedure for nuclear isolation (Galbraith & al. 1983). Analyses were performed on young leaves obtained from 4 different hybrid groups (WH-01, WH-02, CH–01 and CH-02), 2 wild and 2 cultivated parent genotypes.

Analysis were performed by Partec CyFlow Space flow cytometer (Partec GmbH., Görlitz, Germany) Nuclei isolated from 5 mm2 discs of leaf tissue of fresh tissue were finely chopped with a sharp razor blade in a Petri dish (diameter, 5 cm) placed in the presence of 400 µl of extraction buffer (0.2 M Tris–HCl, 4 mM MgCl2·6H2O, 1% Triton X-100, 2 mM Disodium Ethylene Dinitrilo Tetraacetic acid EDTA Na2.2H2O, 86 mM NaCl, 10 mM metabisulfite, 1% PVP-10, pH adjusted to 7.5) at room temperature. Nuclear suspension was then filtered using a 50 µm nylon filter and 1.6 ml of CyStain® solutions from Sysmex Partec (containing 4’, 6-diamidino-2-phenylindole: DAPI) was added to the sam-

Table 1. Agro-morphological descriptors used to characterize interspecific hybrids and their parents.*0*

	Descriptor	**Measurement and rating scales**
Qualitative traits	Leaf color	1 = Yellow ; 2 = Light green , 3 = Green
	Petiole color	1 = White ; 2 = Yellow , 3 = Green ; 4 = Pink ; 5 = Red
	Stem color	1 = Green ; 2 = Green and red ; 3 = Red
	Leaf pigmentation	0 = Absent ; 1 = Spotted ; 2 = Red vein ; 3 = Entire red
	Growth habit	1 = Erect; 2 = Erect and procumbent; 3 = Procumbent; 4 = Erect and prostrate; 5 = Prostrate
Quantitative traits	Leaf blade width	Centimeter (cm)
	Petiole length	Centimeter (cm)
	Petiole width	Centimeter (cm)
	Plant height	Centimeter (cm)
	Rosette diameter	Centimeter (cm)
	Number of stem	Main stem + side stems
	Number of days to germination (days)	From sowing to seedling emergence
	Germination rate	Percentage (%)
	Number of days at bolting (days)	From sowing to main stem elongation
	Number of days to flowering (days)	From sowing to the start of flowering
	Flowering time (days)	From the beginning to the ending of flowering
	Number of days at seed formation (days)	From sowing to seeds formation
	Life span (days)	From sowing to last harvest
	Number of seeds plant^{-1}	At the end of the vegetative cycle
	Weight of seeds plant^{-1}	Gramme (g)
	Weight of 1000 seeds	Gramme (g)

ple tubes to stain the DNA. To calibrate the output, the first sample introduced in the flow cytometer was the external standard, in this study, it was a diploid *Beta vulgaris* subsp. *maritima* plant (reference standards with $2n = 2x = 18$). The voltage of the photomultiplier was adjusted in order to fix the signal of the diploid standard at channel position 200. During the course of the flow cytometric measurements of samples of unknown ploidy, diploid and tetraploid signals, respectively, were fixed at positions 200 and 400.

Data analysis – Morphological data were statistically analyzed using SPSS software (version 23). Variations among the hybrid plants for each morphological trait were computed using the analysis of variance (ANOVA). Coefficients of variation (CV%) were calculated for each quantitative parameter. Principal component analysis (PCA) was carried out on hybrids using the 14 quantitative characters we considered (see e.g., Kiers 1989; Agudelo-Jaramillo & al. 2016). Similarly, the linear regression coefficient was computed to obtain an estimate of broad sense heritability in quantitative traits (Hansche & al. 1972). Heritability analysis concerned wild parent (H^2_{WP}) and cultivated parent (H^2_{CP}). Two traits related to the number and weight of seeds per plant were excluded from PCA and linear regression analyses, due to the clear difference between grain yield of cultivated and wild plants. For the morphological qualitative characteristics, the frequency distribution of each morphotype was evaluated.

Results

Phenotypical characterization

Characterization data of four parent populations and progeny groups, harvested both on wild (WH-01 and WH-02) and cultivated genotypes (CH-01 and CH-02) were analyzed as follow.

Qualitative agro-morphological traits

The high variation was found in the hybrid groups, WH and CH for qualitative morphological descriptors (Fig. 1). The most differentiating traits are colour of petiole and stem, pigmentation of leaves, and habit. On the contrary, homogeneous character is green colour of the blades which was observed in both parental (WP and CP) and progeny groups (WH and CH). Hybrid beet plants showed petioles with three different colour characteristics (green, red, and red-streaked) and two morphotypes related to stem colour (green and green/red in variable proportions; Fig. 1, A and B). These hybrids were generally characterized by green leaves without any pigmentation. However, the accumulation of red pigments in leaf veins was recorded at a percentage of 22.2% and 10% in WH and CH hybrids, respectively (Fig. 1, C). Regarding phenotypic profiles related to habit (Fig. 1, D), erect plants are predominant and commonly observed in the hybrids. Another morphotype (erect and procumbent) was identified at a frequency of 33.33% and 10% noticed in WP and HC genotypes, respectively.

For parent generation's qualitative phenotypic traits, wild and cultivated genotypes showed a lack of red pigmentation on leaf blade, petiole, and stem, except for the stems in wild parents (WH). The studied wild genotypes display erect habit, as well. Erect habit was observed in CP cultivated parents with erect and procumbent habit, at an equal frequency of 50%.

Red pigmentation was not overly present in all wild and cultivated beet genotypes. Therefore, it is probably an inherited trait from wild parent and transmitted to WH hybrids in particular, with a relatively higher percentage for red petioles (44.44%), red /green petioles (22.22%) and red veins (23%), compared to 10% recorded for this three morphotypes in CH hybrids. This could be explained by the expression of hidden or recessive alleles in WP parent, and expressed through the progeny. The results revealed that CH hybrids are more similar to cultivated parents 'CP'. Green stems observed in a much higher percentage in WH hybrids (89%) from wild parents, compared to CH hybrids (80%), suggests the predominant heritability of this morphotype by cultivated maternal parent. The red/green stems were observed at low frequency [but higher in CH (20%) if compared to WH (11.11%)] and was probably an intermediate phenotype inherited by both parents. Basically, CH hybrids tend to be similar to cultivated parents for the green coloured stems (78.6%), in comparison with wild parents. Wild parent "*Beta macrocarpa*" was involved in the transmission of erect habit to progeny, at a frequency of 90% and 67% in CH and WH hybrids, respectively. While the erect/procumbent habit observed in WH hybrids (22.22%) with a higher percentage than CH (10%) could be an inherited morphotype from their cultivated parents.

All things considered, both WH and CH hybrid plants show an intermediate level of petiole and stem colour, growth habit, and leaves pigmentation between their parents (Fig. 1).

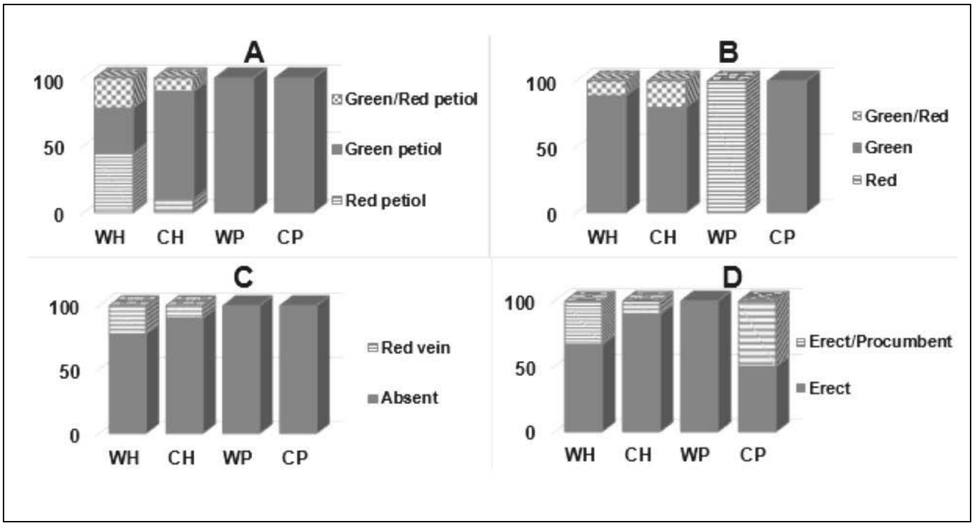

Fig. 1. Qualitative traits related to petiole color (A), stem color (B), leaf pigmentation (C) and growth habit (D), used for the phenotypic characterization of "WH/CH" hybrids obtained from crosses between *Beta vulgaris* subsp. *vulgaris* × *B. macrocara,* as well as their wild parents "WP" and cultivated parents "CP".

2. *Quantitative agro-morphological traits*

2.1. Characterization and variation study

ANOVA analysis of all quantitative phenotypic data showed statistically significant difference among the two hybrid groups WH and CH, excepting for the width of petiole (Table 2). A genetic variation among the evaluated beet hybrid genotypes is generated by the crosses.

According to seed maternity, highly significant differences were recorded for descriptors related to the size (length and width) of leaf blade and plant height, as well as to number of days to germination, bolting, flowering, seed formation, number and weight of seeds per plant, and 1000-seeds weight, observed in WH hybrids from wild maternal branch, compared to their cultivated parent CP. Analysis of variance also showed a significant difference between CH hybrids and their cultivated parents for width of leaf blade, plant height, rosette diameter, flowering, reproduction, number and weight of seeds per plants and 1000-seeds weight. A moderate difference was observed between CH hybrids and their wild relatives for the germination trait (Table 2).

Coefficient of variation (CV) was calculated for each agro-morphological trait (Table 2). CV% values were generally variable in beet hybrid groups. They ranged from 6.68% to 70.47% in WH and from 6.95% to 76.17% in CH. In the parental forms, CV% values were variable, ranging from 0% to 111.06% for wild parents and of 5.28% to 91.04% for cultivated parents.

Mean values of quantitative traits comparative study, provided a clear phenotypic characterization between the two types of hybrids (Table 2). Hybrids harvested from cultivated maternal parent (CH) were characterized by developed plant biomass and extensive

Table 2. Means of quantitative traits used for morphological classification of local hybrids, wild and cultivated parents of *Beta vulgaris* subsp. *vulgaris*.

Variables	**WP**	**WH**	**CH**	**CP**
Leaf blade length (cm)	10.42	8.03^{***CP}	10.45^{***}	16
Leaf blade width (cm)	6.22	6.48^{***CP}	8.23^{***CP}	14
Petiole length (cm)	12.71	13.13^{***}	11.27^{***}	14
Petiole width (cm)	0.35	0.33	0.5	1
Number of stem (cm)	4.5	4.67^{***}	5^{***}	10
Plant height (cm)	53	48.89^{***CP}	63.6^{***CP}	119
Rosette diameter (cm)	46.25	48.69^{***}	37.7^{**CP}	60
Number of days to germination (days)	22	14^{***CP}	15.6^{**WP}	7
Number of days at bolting (days)	83	80.67^{***CP}	78.33^{***CP}	237
Number of days to flowering (days)	88.5	111.7^{***CP}	123.3^{***CP}	240
Flowering time (days)	15.5	12.11^{***}	11.75^{***}	48
Number of days at seed formation (days)	181.5	143.7^{***CP}	151^{***CP}	261
Life span (days)	257.5	170.2^{**}	194.3^{**}	309
Number of seeds/plants	57.5	144.4^{***CP}	175^{***CP}	2598
Weight of seeds/plant (g)	0.65	3.67^{***CP}	2^{***CP}	133
Weight of 1000 seeds (g)	11.33	22.85^{***}	14.8^{***}	22
CV (%) interval	0-111.06	6.68-70.47	6.95-76.17	5.28-91.04

*(*) significant difference (*P<0.05, **P<0.01, ***P<0.001). CV: coefficient of variation. WP: Wild Parent "Beta macrocarpa"; CP: Cultivated Parent "Beta vulgaris* subsp. *vulgaris"; WH: hybrids from wild maternal branch; CH: hybrids from cultivated maternal branch.*

branching, late vegetative and reproductive stages, and higher number of seeds per plant. On the other hand, hybrids from wild maternal parents (WH) had relatively low above-ground biomass and a higher grain yield. These hybrids were characterized by early stages of plant development, a relatively late bolting stage with an average of 2 days compared to CH hybrids.

2.2. Heritability and phenotypic similarity

Phenotypic relatedness between progeny and their parents was estimated by parent-offspring regression (H^2) from quantitative morphological data (Fig. 2).

High heritability (more than 50% in percentage) was obtained according to wild parental genotypes for width of leaf blade (H^2_{WP} = 54-78%) and number of stems (H^2_{WP} = 63-69%) in WH hybrids. High heritability was also estimated in the progeny of WH-01 for petiole width (H^2_{WP} = 54%), leaf diameter (50%), bolting (H^2_{WP} = 51%) and cycle length (H^2_{WP} = 67%), compared to their wild relative. However, a dominant phenotypic inheritance from cultivated parents was potentially noted in WH-01 hybrids for germination performance (H^2_{WP} = 95%).

In CH hybrids, traits related to leaf blade width (H^2_{CP} = 64-82%) and plant height (H^2_{CP} = 68-88%) showed a high level of heritability from cultivated parent. Cultivated parent was also involved in the transmission of phenotypic traits at relatively high percentages (50%) for germination, 61% for span life and 53% for 1000-seed weight, to CH-01 hybrids. While a high heritability was estimated between CH-01 hybrids and their wild relatives for quantitative traits related to petiole length (H^2_{WP} = 89%), leaf diameter (H^2_{WP} = 76%), and branching (H^2_{WP} = 71%).

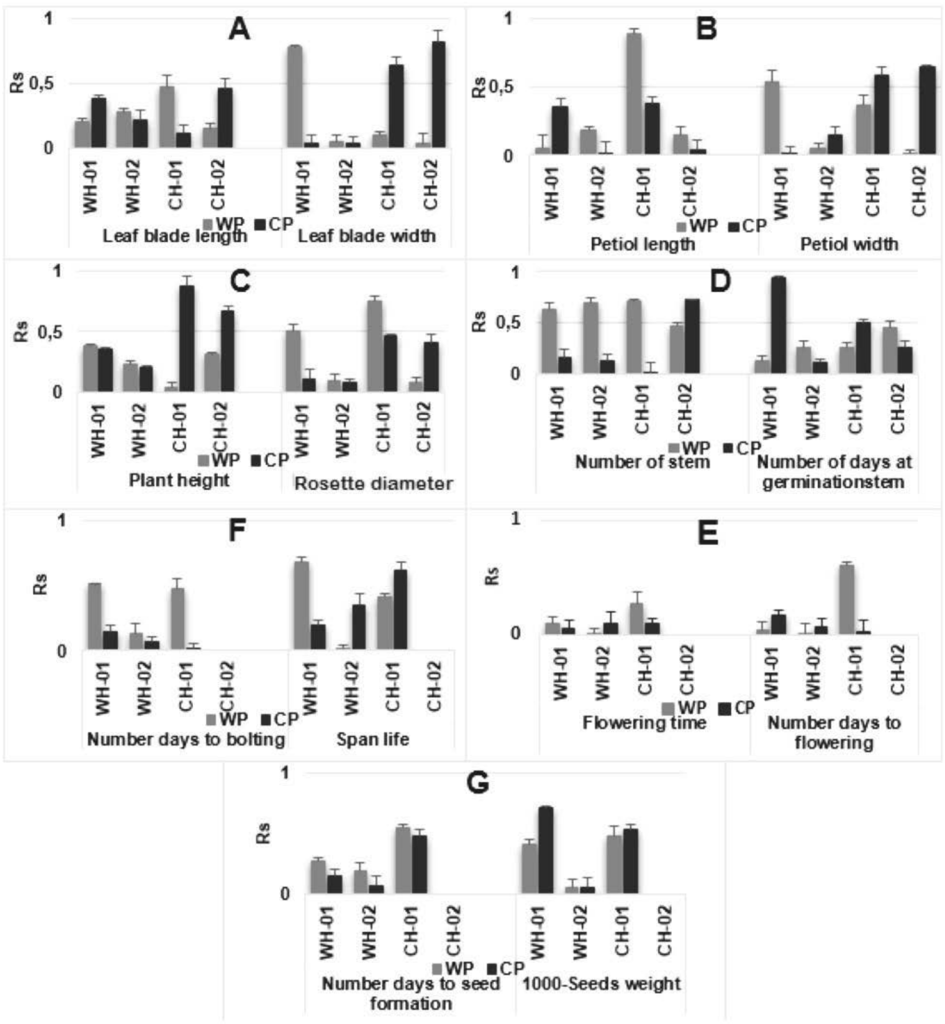

Fig. 2. Histograms of H^2 based on R-square values of parent-offspring regression for fourteen quantitative traits of beet interspecific hybrids: (A) Leaf blade length, (B) Leaf blade width, (C) Petiole length, (D) Petiole width, (E) Number of stems, (F) Plant height, (G) Rosette diameter, (H) Number of days to germination, (I) Number of days at bolting, (J) Number of days to flowering, (K) Flowering time, (L) Number of days at seed formation, (M) Life span and (N) 1000-seeds weight. WP = wild maternal parent and CP = cultivated maternal parent.

Eigenvalues obtained by the PCA for the 14 quantitative morphological traits indicated that two first components explained 78.30% of the total variability (Table 3). Eight variables showed high correlation with the first eigenvectors (component 1), namely blade length, blade width, petiole width, number of stems, plant height, number of days at bolt-

Table 3. Eigenvalues of the Principal Component as well as the percentage of the total variance accounted for each component.

Variable	Composant	
	1	**2**
Leaf blade length (cm)	**0.78**	0.50
Leaf blade width (cm)	**0.73**	0.48
Petiole length (cm)	0.04	-0.29
Petiole width (cm)	**0.83**	0.49
Number of stem (cm)	**0.88**	0.46
Plant height (cm)	**0.87**	0.26
Rosette diameter (cm)	0.30	0.34
Number of days to germination (days)	-0.35	**-0.91**
Flowering time (days)	0.29	**0.90**
Number of days at bolting (days)	**0.81**	0.53
Number of days to flowering (days)	0.62	**0.77**
Number of days at seed formation (days)	**0.90**	0.34
Life span (days)	**0.95**	0.17
Weight of 1000 seeds (g)	0.54	**0.83**
% of variance	**73.33**	**13.97**

ing, number of days to formation and life span. Number of days to germination, flowering time, number of days to flowering, and 1000-seed weight traits showed high correlation with the second eigenvectors (component 2).

Three distinct groups occur in PCA analysis (Fig. 3):

1) group 1: it comprises all WH interspecific hybrids (WH-01 and WH-02) as well as CH-01 hybrid, which represent 69% of total studied genotypes. This group was characterized by short, broad leaf blades, reduced height and low branching. The hybrid plants of this group are characterized by early bolting (73.03 days), productivity (138.06 days) and maturity (169.89 days) than the two parents (WP and CP). The wild parent has an annual cycle of 257.50 days and small vegetative size, against the well-developed vegetative mass of the cultivated parent with biennial cycle of 311.40 days;

2) group 2: hybrid plants of CH-02 and their cultivated parent (CP) were grouped together. This group was distinguished by a much more developed plant biomass and significant branching. Hybrid plants remained in the vegetative state without being able to flower the first year under the homogeneous conditions of the greenhouse. A high phenotypic similarity was revealed between all plants of this hybrid with their cultivated parent;

3) group 3: it includes WP parental genotypes, showed low aboveground biomass and grain yield. Plants of this group were characterized by early development stages with an annual cycle.

Cytogenetical characterization

Both diploid and tetraploid cytotypes were found in tested interspecific hybrids as well as their wild and cultivated parents. Diploid and tetraploid hybrids were obtained from interspecific hybridizations of diploid *B. macrocarpa* × diploid *B. vulgaris* s. s. and

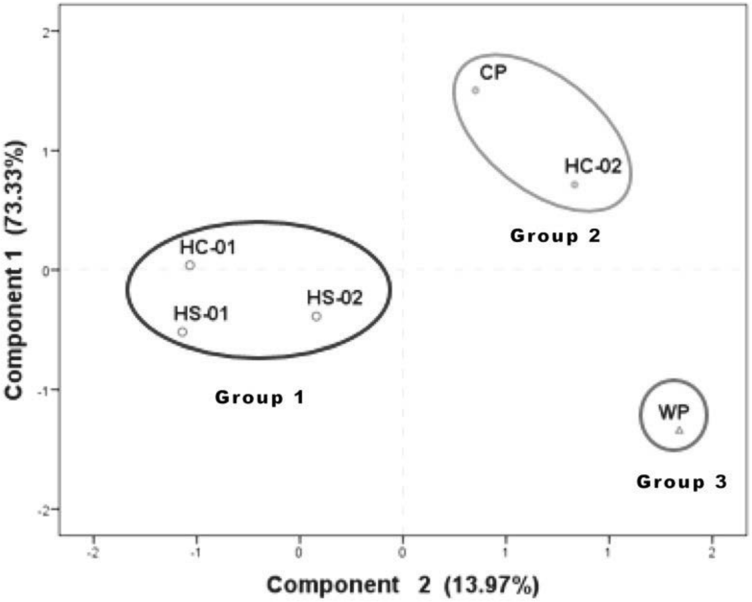

Fig. 3. PCA of interspecific hybrid and parent groups based on fourteen phenotypic traits upon the first two axes, explaining 87.30% of the total variation. WP = wild parent of *Beta macrocarpa,* CP = cultivated parent of *Beta vulgaris* subsp. *vulgaris*, WH = hybrid from wild maternal branch, CH = hybrid from cultivated branch.

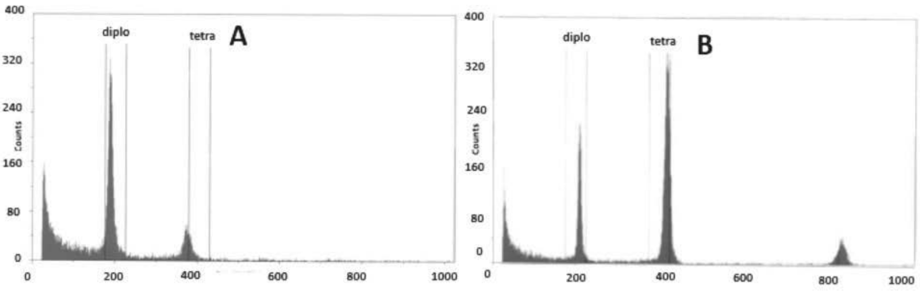

Fig. 4. Relative fluorescence histograms of DAPI (4’, 6-diamidino-2-phenylindole) stained nuclei isolated from fresh leaf tissues of diploid (A) and tetraploid (B) interspecific hybrids of beet. Simultaneous analysis of nuclei isolated from *Beta vulgaris* subsp. *maritima* ($2n = 2x = 18$) used in this study as a reference standard.

tetraploid *B. macrocarpa* × tetraploid *B. vulgaris* s. s., respectively. Presence of tetraploid *B. macrocarpa* genotypes (2*n* = 36) is very rare in nature (see Letscher 1993; Iamonico, 2019) and was detected for the first time in Moroccan germplasm in this study.

Discussion

Natural hybridization between *B. vulgaris* subsp. *vulgaris* and *B. macrocarpa* is apparently absent in Morocco. Sugar beet production areas are not vernalizing zones and no seed production is operated in the country. Bolting-resistant sugar beets grown in the Moroccan cultivated field, are mainly intended for sugar production and not for seed production. General climate prevailing in Morocco is not favorable for the induction of flowering in sugar beet, except for some very limited vernalizing areas, as “Merchouch”. Only few specific zones are used for experiments and trials.

Obtaining a viable and fertile hybrid between *B. macrocarpa* × *B. vulgaris* subsp. *vulgaris*, for the first time under Morocco climatic conditions, is a great success giving originality to our work. All obstacles of interspecific hybridizations of *B. vulgaris* s. s. were overcome by establishing favorable conditions for crosses between wild annual species and biennial sugar beet, in terms of synchronization of the flowering period as well as by choice of experimental site favorable to flowering induction seed production in cultivated beet.

Under the vernalizing climatic conditions during the study, cultivated sugar beet genotypes required a cold period of 4 to 7 °C to induce bolting and flowering, 65 to 77 days after sowing. In most commercial cultivars of sugar beet, requires a cold period from 10 to 16 weeks of exposure to optimal temperatures between 4°C and 6°C (McGrath 2018). Cold period was reported to influence the probability of flowering in beet (Van Dijk & Desplanque 1999; Boudry & al. 2002; Reeves 2007).

The high variability observed among the hybrid plants, indicates that genetic segregating process between parents was established. Several qualitative morphotypes have been observed in the progeny, showing a high phenotypic diversity. New morphotypes reveled in the hybrids, and not presented in parental genotypes, could be explained by the expression of hidden or recessive alleles in parents, which were expressed through the progeny. An example is the red pigmentation by WP wild parents or the erect and procumbent habit by CP cultivated parents. In general, studied hybrids presented an intermediate behavior between the two parents regarding the studied descriptive parameters, in particular WH-01, WH-02 and CH-01, with a spontaneous flowering and annual vegetative cycle. CH-02 hybrid from the cultivated maternal branch is more similar to their cultivated parent for vernalization requirement, indicating probably the recessive inheritance B-gene by cultivated parent. However, it has been shown that beet genotypes carrying the dominant B allele flower under long days without vernalization requirement (Van Dijk & al. 1997; Boudry & al. 1994; Hôft & al. 2018). Vernalization requirement appears to be strongly related to temperature, photoperiod, geographical latitudinal gradients cold treatment (Boudry & al. 2002; Limin & Fowler 2006; Rhoné & al. 2008; Michael & al. 2020).

Phenotypic variation detected, between and within hybrids, would be explained by the allogamy and cross-fertilization of *Beta* species and infraspecific taxa, and to genetic richness of *B. macrocarpa* probably associated with its wide adaptative capacity. Studied wild genotypes were originated from arid and semiarid inland regions, where climate is generally characterized by extreme seasonal variations in temperatures in addition to low rainfall. The studied genotypes could serve as a source of genes for genetic improvement to biotic and abiotic resistance stress, through the accumulation of genetic variation (Cholastova & Knotova 2012; Böhm & al. 2017; Biancardi & al. 2012; 2020).

For the first time in 1975, McFarlane reported natural hybrids, with the characteristics of segregates between *B. vulgaris* subsp. *vulgaris* and *B. macrocarpa* in the Imperial Valley, California. He speculated that the presence of male sterility in the identified hybrid plants (7% of the total studied plants) arose from crosses between a male-sterile mother and *B. macrocarpa*. McFarlane (1975) also theorized that seeds of *B. macrocarpa* species are thought to have been introduced from the Mediterranean area prior to 1928.

We detected for the first time of tetraploid cytotypes in *Beta macrocarpa* and in beet hybrids. Tetraploid *Beta macrocarpa* genotypes are rarely found in nature, they were exclusively sampled in Canary Island and in Portugal mainland (see e.g., Bartsch & al. 2003; Villain 2007; Castro 2013). Authors of earlier studies, were of the opinion that all plants of *B. macrocarpa*, growing on the Canary Islands are tetraploid (Buttler 1977; Lange & al. 1989). It has been suggested that the origin of tetraploid cytotype discovered in *Beta macrocarpa* populations of Canary Islands result probably from at allopolyploidy hybridization events between diploid *B. macrocarpa* and *B. vulgaris* subsp. *maritima* (Buttler 1977; Villain 2007).

Tetraploid *B. macrocarpa* genotypes found in the Moroccan collection, supports the hypothesis of existing of seed and pollen flow contributing to the transfer of genes, species colonization into new environment and dissemination in time and space of tetraploid *B. macrocarpa* populations from the Portugal or Canary Islands, as land areas are geographically close to Morocco.

Infrequency of tetraploid cytotype could be explained by the competitive ability of pollen released by diploid beet is much higher compared to pollen produced by tetraploid plants, as suggested by Scott & Longden (1970). Indeed, only few triploids (3n) see beet individuals were detected during collections in 17 Danish seas, showing that the levels of gene flow from tetraploid pollinators are very low (Andersen & al. 2005). In a first study on natural polyploidy in wild populations of annual beet, Buttler (1977) reported that plant morphology and pollen diameter were useless for distinguishing diploid and tetraploid types of *B. macrocarpa*. This was in consistent with our results which show that diploid and tetraploid hybrid plants did not show a difference in their morphology. Kishima & al. (1987) reported a difference in restriction fragment pattern of chloroplast DNA of diploid and tetraploid *B. macrocarpa.*

Studied hybrids represent a percentage of 83% of viable plants with normal growth. However, the remaining 17% on-germinating seeds could be non-viable seed triploid plants. In this context Trueblood and his team (2010) showed that seedlings produced by the triploid clone in *Hypericum androsaemum* L. died shortly after germination. According to Nghiem & al. (2018), less than 25% of germinated progeny from triploid clone of *Acacia* Mill. (between tetraploid *A. mangium* and diploid *A. auriculiformis*). survived at 3 months after sowing with sever stunting and arrested growth. Our results could prove the success of the hybridization seed method with a complete control to avoid external pollen crosses (controlled pollination) and that hybridization was carried out under full isolated conditions.

Conclusion

In order to use Moroccan *B. macrocarpa* genotypes as a natural reservoir of gene and genetic diversity for adaptation to abiotic and biotic constraints and for broadening the genetic base of sugar beet, interspecific hybridizations were carried out. Efforts were focused on developing the appropriate environment for developing hybrids adapted to Moroccan climatic conditions.

Obtaining a viable and fertile beet hybrid resulting from *B. macrocarpa* (rare in nature) is an important and encouraging step towards the genetic improvement of sugar beet.

Hybrid showed a wide variability of morphological and developmental characteristics. The majority of the hybrids (WH hybrids harvested in wild maternal plants and 50% of CH hybrids cultivated maternal plants) are annual plants. They showed normal seed set within the first year without any vernalization requirements, probably explaining the considerable impact of the wild parent performance for the transmission of phenotypic traits to the progeny. Remaining CH hybrids were closer to their cultivated parent for biomass, branching, and vernalization requirement.

Tetraploid cytotypes in *Beta macrocarpa* were here first detected in Morocco with natural polyploidy in sect. *Beta*. Results provide novel insights on the genetic and cytogenetic diversity of *Beta* genus for breeding programs and biodiversity for climate change adaptation.

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References

Abbott, R. J., Albach, D., Ansell, S., Arntzen, J. W., Baird, S. J. E., Bierne, N., Boughman, J., Brelsford, A., Buerkle, C. A., Buggs, R. & Butlin, R. K. 2013: Hybridization and speciation. – J. Evol. Biol. **26(2):** 229-246. https://doi. org/10.1111/j.1420-9101.2012.02599.x

Abe, J. & Shimamoto, Y. 1989: Evolutionary aspects and species relationships. International Crop Network Series (IBPGR). Workshop, held at Wageningen, the Netherlands, 7–10 February 1989.

Agudelo-Jaramillo, S., Ochoa-Mu˜noz, M. & Zuluaga-Díaz, F. I. 2016: Principal Component Analysis for MixedQuantitative and Qualitative Data. – Medellin.

Andersen, N. S., Siegismund, H. R., Meyer, V. & Jørgensen, R. B. 2005: Low level of gene flow from cultivated beets (*Beta vulgaris* L. ssp. *vulgaris*) into Danish populations of sea beet (*Beta vulgaris* L. ssp. *maritima* (L.) Arcangeli). – Molec. Ecol. **14(5):** 1391-1405. https://doi.org/10.1111/j.1365-294X.2005.02490.x

Bartsch, D., Cuguen, J., Biancardi, E. & Sweet, J. 2003: Environmental implications of gene flow from sugar beet to wild beet-current status and future research needs. – Environ. Biosafety Res. **2(2):** 105-115. https://doi.org/10.1051/ebr:2003006

Biancardi, E., Panella, L. W. & McGrath, J. M. 2020: *Beta maritima* – The Origin of Beets, 2°ed. – Cham.

Böhm, J., Schipprack, W., Utz, H. F. & Melchinger, A. E. 2017: Tapping the genetic diversity of landraces in allogamous crops with doubled haploid lines: a case study from European flint maize. – Theor. Appl. Genet. **130(5):** 861-873. https://doi.org/10.1007/s00122-017-2856-x.

Boudry, P., Wieber, R., Saumitou-Laprade, P., Pillen, K., Van Dijk, H. & Jung, C. 1994: Identification of RFLP markers closely linked to the bolting gene B and their significance for the study of the annual habit in beets (*Beta vulgaris* L.). – Theor. Appl. Genet. **88(6-7):** 852-858. https://doi.org/10.1007/BF01253996

—, —, McCombie, H. & Van Dijk, H. 2002: Vernalization requirement of wild beet *Beta vulgaris* ssp. *maritima*: among population variation and its adaptive significance. – J. Ecol. **90(4):** 693-703. https://www.jstor.org/stable/3072271

Buttler, K. P. 1977: Variation in wild populations of annual beet (*Beta*, *Chenopodiaceae*). – Pl. Syst. Evol. **128(1-2):** 123-136. https://doi.org/10.1007/BF00985176

Castro, S., Romeiras, M. M., Castro, M., Duarte, M. C. & Loureiro, J. 2013: Hidden diversity in wild *Beta t*axa from Portugal: insights from genome size and ploidy level estimations using flow cytometry. – Pl. Sci. **207:** 72-78. https://doi.org/10.1016/j.plantsci.2013.02.012

Cholastova, T. & Knotova, D. 2012: Using morphological and microsatellite (SSR) markers to assess the genetic diversity in Alfalfa (*Medicago sativa* L.). – World Acad. Sci. Engin. Technol. **69:** 856-862.

El Bahloul, Y. 2007: Détermination de la distribution des principales espèces sauvages du genre *Beta* au Maroc, Caractérisation morphologique et analyse moléculaire de leur diversité génétique. – Doctoral dissertation. Faculté de sciences, Département de Biologie. Faculté Universitaire Notre-Dame de la Paix, Belgique.

Fan, H., Zhang, Y., Sun, H., Liu, J., Wang, Y., Wang, X., Li, D., Yu, J. & Han, C. 2015: Transcriptome analysis of *Beta macrocarpa* and identification of differentially expressed transcripts in response to Beet necrotic yellow vein virus infection. – PLoS One **10(7):** p.e0132277. https://doi.org/10.1371/journal.pone.0132277

Flowers, T. J., Troke, P. F. & Yeo, A. R. 1977: The mechanism of salt tolerance in halophytes. – Ann. Rev. Pl. Physiol. **28(1):** 89-121. https://doi.org/10.1146/annurev.pp.28.060177.000513

Galbraith, D. W., Harkins, K. R., Maddox, J. M., Ayres, N. M., Sharma, D. P. & Firoozabady, E. 1983: Rapid flow cytometric analysis of the cell cycle in intact plant tissues. – Science **220(4601):** 1049-1051. 10.1126/science.220.4601.1049

Hansche, P. E., Hesse, C. O. & Beres, V. 1972: Estimates of genetic and environmental effects on several traits in peach. – J. Amer. Soc. Hortic. Sci. **97:** 76-79.

Hellier, B. C., Richardson, K., El Bahloul Y. & Qariouh, N. 2013: Status Report on the *Beta* Collection at the Western Regional Plant Introduction Station (WRPIS) to the Sugar beet Crop Germplasm Committee. – Barbara Hellier (Curator), Sugar Beet CGC Meeting February 27.

Hessini, K., Lachaâl, M. & Soltani, A. 2005: Physiological response to sodium chloride of wild Swiss chard. – J. Pl. Nutr. **28(5):** 877-888. https://doi.org/10.1081/PLN-200055567

Hôft, N., Dally, N., Hasler, M. & Jung, C. 2018: Haplotype variation of flowering time genes of sugar beet and its wild relatives and the impact on life cycle regimes – Frontiers Pl Sci. **8:** 2211. https://doi.org/10.3389/fpls.2017.02211

Iamonico, D. 2019: Remarks on the nomenclature of *Betoideae* (*Chenopodiaceae*/*Amaranthaceae* sensu APGIV). – Phytotaxa **400(3):** 145-164. https://doi.org/10.11646/phytotaxa.400.3

IPGRI, 1991: Descriptors for *Beta* (*Beta* ssp). International Plant Genetic Resources Institute. – Rome.

Kadereit, G., Hohmann, S. & Kadereit, J. W. 2006: A synopsis of *Chenopodiaceae* subfam. *Betoideae* and notes on the taxonomy of *Beta*. – Willdenowia **36(Special Issue):** 9-12**.** https://doi.org/10.3372/wi.36.36101

Kiers, H.A.L. 1989: Three-way methods for the analysis of qualitative and quantitative two-way data. – Leiden.

Kishima, Y., Mikami, T., Hirai, A., Sugiura, M. & Kinoshita, T. 1987: *Beta* chloroplast genomes: analysis of fraction I protein and chloroplast DNA variation. – Theor. Appl. Genet. **73(3):** 330-336. https://doi.org/10.1007/BF00262497

Lange, W. & De Bock, T. S. 1989: The diploidised meiosis of tetraploid *Beta macrocarpa* and its possible application in breeding sugar beet. – Pl. Breeding. **103(3):** 196-206. https://doi.org/10.1111/j.1439-0523.1989.tb00371.x

Letschert, J. P. W. 1993: *Beta* Section *Bet*a: Biogeographical Patterns of Variation and Taxonomy. PhD dissertation, – Wageningen Agric. Univ. Pap. **93:** 1-137.

Leys, M., Petit, E. J., El-Bahloul, Y., Liso, C., Fournet, S. & Arnaud, J. F. 2014: Spatial genetic structure in *Beta vulgaris* subsp. *maritima* and *Beta macrocarpa* reveals the effect of contrasting mating system, influence of marine currents, and footprints of postglacial recolonization routes. – Ecol. Evol. **4(10):** 1828-1852. https://doi.org/10.1002/ece3.1061

Limin, A. E. & Fowler, D. B. 2006: Low-temperature tolerance and genetic potential in wheat (*Triticum aestivum* L.): response to photoperiod, vernalization, and plant development. – Planta **224(2):** 360-366. https://doi.org/10.1007/s00425-006-0219-y

McFarlane, J. S. 1975: Naturally occurring hybrids between sugar beet and *Beta macrocarpa* in the Imperial Valley of California. – J. Amer. Soc. Sugar Beet Technol. **18:** 245-251.

McGrath, J. M. & Panella, L. 2018: Sugar beet breeding. – Pl. Breeding Rev. **42:** 167-218. https://doi.org/10.1002/9781119521358.ch5

Michael, T. E. B., Faigenboim, A., Shemesh-Mayer, E., Forer, I., Gershberg, C., Shafran, H., Rabinowitch, H. D. & Kamenetsky-Goldstein, R. 2020: Crosstalk in the darkness: bulb vernalization activates meristem transition via circadian rhythm and photoperiodic pathway. – BMC Pl. Biol. **20(1):** 1-16. https://doi.org/10.1186/s12870-020-2269-x

Nagamine, T., Catty, J. P. & Ford-Lloyd, B. V. 1989: Phenotypic polymorphism and allele differentiation of isozymes in fodder beet, multigerm sugar beet and monogerm sugar beet. – Theor. Appl. Genet. **77(5):** 711-720. https://doi.org/10.1007/BF00261249

Nghiem, C. Q., Griffin, R. A., Harbard, J. L., Harwood, C. E., Le, S., Nguyen, K. D. & Van Pham, B. 2018: Reduced fertility in triploids of *Acacia auriculiformis* and its hybrid with *A. mangium*. – Euphytica **214(4):** 284-287. https://doi.org/10.1007/s10681-018-2157-8

Peltier, C., Klein, E., Hleibieh, K., D'Alonzo, M., Hammann, P., Bouzoubaa, S., Ratti, C. & Gilmer, D. 2012: Beet necrotic yellow vein virus subgenomic RNA3 is a cleavage product leading to stable non-coding RNA required for long-distance movement. – J. General Virol. **93(5):** 1093-1102. https://doi.org/10.1099/vir.0.039685-0

Pottier-Alapetite, G. 1979: *Daucus* – Pp. 615-621 in : Flore de la Tunisie, **1.** – Tunis.

Reeves, P. A., He, Y., Schmitz, R. J., Amasino, R. M., Panella, L. W. & Richards, C. M. 2007: Evolutionary conservation of the FLOWERING LOCUS C-mediated vernalization response: evidence from the sugar beet (*Beta vulgaris*). – Genetics **176(1):** 295-307. https://doi.org/10.1534/genetics.106.069336

Rhoné, B., Remoué, C., Galic, N., Goldringer, I. & Bonnin, I. 2008: Insight into the genetic basis of climatic adaptation in experimentally evolving wheat populations. – Molec. Ecol. **17(3):** 930-943. https://doi.org/10.1111/j.1365-294X.2007.03619.x

Scott, R. K. & Longden, P. C. 1970: Pollen release by diploid and tetraploid sugar-beet plants. – Ann. Appl. Biol. **66(1):** 129-135. https://doi.org/10.1111/j.1744-7348.1970.tb04610.x

Slama, I., Jdey, A., Rouached, A., Talbi, O., Debez, A., Ghnaya, T., Limami, M. A. & Abdelly, C. 2016: Comparative responses to water deficit stress and subsequent recovery in the cultivated beet *Beta vulgaris* and its wild relative *B. macrocarpa*. – Crop Pasture Sci. **67(5):** 553-562. https://doi.org/10.1071/CP15145

Soltis, P. S., Marchant, D. B., Van de Peer, Y. & Soltis, D. E. 2015: Polyploidy and genome evolution in plants. – Curr. Opin. Genet. Developm. **35:** 119-125. https://doi.org/10.1016/j.gde.2015.11.003

Trueblood, C. E., Ranney, T. G., Lynch, N. P., Neal, J. C. &, Olsen, R. T. 2010: Evaluating fertility of triploid clones of *Hypericum androsaemum* L. for use as non–invasive landscape plants. – HortScience **45(7):** 1026-1028. https://doi.org/10.21273/HORTSCI.45.7.1026

Uotila, P. 2011: *Chenopodiaceae* (pro parte majore), *Juglandaceae*, *Loranthaceae*, *Molluginaceae*, *Moraceae*, *Nyctaginaceae*, *Phytolaccaceae*, *Santalaceae*, *Typhaceae*. In Euro+ Med Plantbase-the information resource for Euro-Mediterranean plant diversity. Euro+ med plantbase. – http://ww2.bgbm.org/EuroPlusMed/PTaxonDetail.asp?NameId=7721045&PTRefFk=7300000 [Last accessed 8/11/2021]

Van Dijk, H. & Desplanque B. 1999: European *Beta*: crops and their wild and weedy relatives. – Pp. 257-270 in: Van Raamsdonk, L. W. D. & Den Nijs, J. C. M. (eds), Plant Evolution in Man–Made Habitats. – Amsterdam. https://doi.org/10.1016/S1146-609X(97)80080-X

—, Boudry, P., McCombre, H. & Vernet, P. 1997: Flowering time in wild beet (*Beta vulgaris* ssp. *maritima*) along a latitudinal cline. – Acta Oecol. **18(1):** 47-60.

Villain, S. 2007: Histoire évolutive de la section *Beta*, : mise en évidence des phénomènes d’hybridation et de spéciation au sein de la section dans le bassin méditerranéen. – PhD. Université des Sciences et Technologies de Lille.

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Article

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Belkacem Gordo & Nashwa A. M. Mostafa

Onopordum* (*Asteraceae*) in Algeria with special focus on *O. ambiguum

Abstract

Gordo, B. & Mostafa, N. A. M.: *Onopordum* (*Asteraceae*) in Algeria with special focus on *O. ambiguum*. — Fl. Medit. 31: 223-232. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The flora of Algeria includes six species of *Onopordum* (*Asteraceae*). Twenty-one morphological characters were recorded from herbarium specimens and identification keys were built using the program suite DELTA. Information on the distribution of these species in Algeria is provided. After studying aspects related to populations size and ecology, provisional regional conservation status for *O. ambiguum* is given: Endangered (EN).

Key words: Taxonomy, Key, DELTA, Ecology, Distribution, Ksour Mountains, Aïn Sefra.

Introduction

Asteraceae is the largest family of angiosperms in Algeria. It includes 557 taxa in 136 genera (Dobignard & Chatelain 2011). Members of this family are often herbaceous plants and shrubs, rarely bushes. *Onopordum* L. (*Asteraceae*, *Carduoideae-Cardueae*), with about 60 accepted species, is mainly distributed in central and western Asia, Europe, North Africa and the Canary Islands (Susanna & Garcia-Jacas 2007; POWO 2021). In Algeria, only five species of this genus are reported in the main floras, of which *Onopordum algeriense* (Munby) Pomel is endemic to the country (Quézel & Santa 1963; African Plant Database 2021). It is customary to point out that only Bouraada & al. (2014) reported this taxon in the High Plains of eastern Morocco at Tendrara and Bouârfa. However, according to Fennane (2017), this notice is still doubtful as no specimens have been deposited in a known herbarium of Morocco or appear in any online databases such as Euro+MedPlant Base and Plants of the World Online (POWA).

In the course of numerous surveys carried out in the Ksour Mountains, especially in the region of Aïn Sefra (Nâama Province), a number of observations were directed to populations growing in the famous dune north of Mekter Mountain and the adjacent gardens of the Ksar (Gordo 2021). Close examination of these populations led to the recognition of two different *Onopordum* species occurring in the same station. The first corresponds to *Onopordum arenarium* (Desf.) Pomel, while the second remained unidentifiable by the keys available in the Flora of Algeria by Quézel & Santa (1963), or in other floras of neighboring countries such as that of Morocco by Fennane & al. (2014) or Tunisia by Pottier-Alapetite (1981). It should be noted that this genus is not described in either the flora of the Sahara (Ozenda 1991) or that of Mauritania (Barry & Celles 1991). The specimens were identified provisionally as *O. ambiguum* Fresen. (Fig. 1). This species was recorded in the Algerian flora on the basis of a single specimen collected from Biskra by B. Balansa as early as 26 April 1853. This record was later seconded by another collection by Battandier & Trabut (1888) from the Aïn Sefra region in Nâama Province. Subsequently, the species has not been seen for more than a century since it does not appear in the floristic lists established later by other botanists who explored the Ksour Mountains, such as Bonnet & Maury (1888), Hochreutiner (1904) and Maire (1916), as well as the more recent accounts of the Algerian flora (e.g. Quézel & Santa 1963; Ozenda 1991).

The range of *O. ambiguum* extends from the eastern Mediterranean to Iraq and the Arabian Peninsula. It is present in the following countries: Egypt, Iraq, Palestine, Saudi

Fig. 1. Habit of *Onopordum ambiguum* (April 2021, Photo by B. Gordo).

Arabia, Sinai (Egypt) and Yemen (POWO 2021). It is worth noting that *O. ambiguum* has a markedly discontinuous distribution in N. Africa as it has so far been repeatedly recorded from the Sinai Peninsula in the extreme east and in Algeria in the west, with no records as yet from Libya, Tunisia and Morocco.

A computer-generated key for the identification of the six *Onopordum* species, together with detailed description of every species in terms of 21 characters recorded comparatively for each of them are provided using computer program package DELTA. A further objective of this contribution is to analyze ecology and regional conservation status of *O. ambiguum* confirmed for the country after more than one century of its last record.

Materials and Methods

Various botanical explorations were carried out from 2012 to 2021 throughout the city of Aïn Sefra which is administratively attached to the province of Nâama, a part of the biogeographic sector called the Western Saharan Atlas or Ksour Mountains (Fig. 2). Throughout these explorations, the majority of the Algerian *Onopordum* were collected

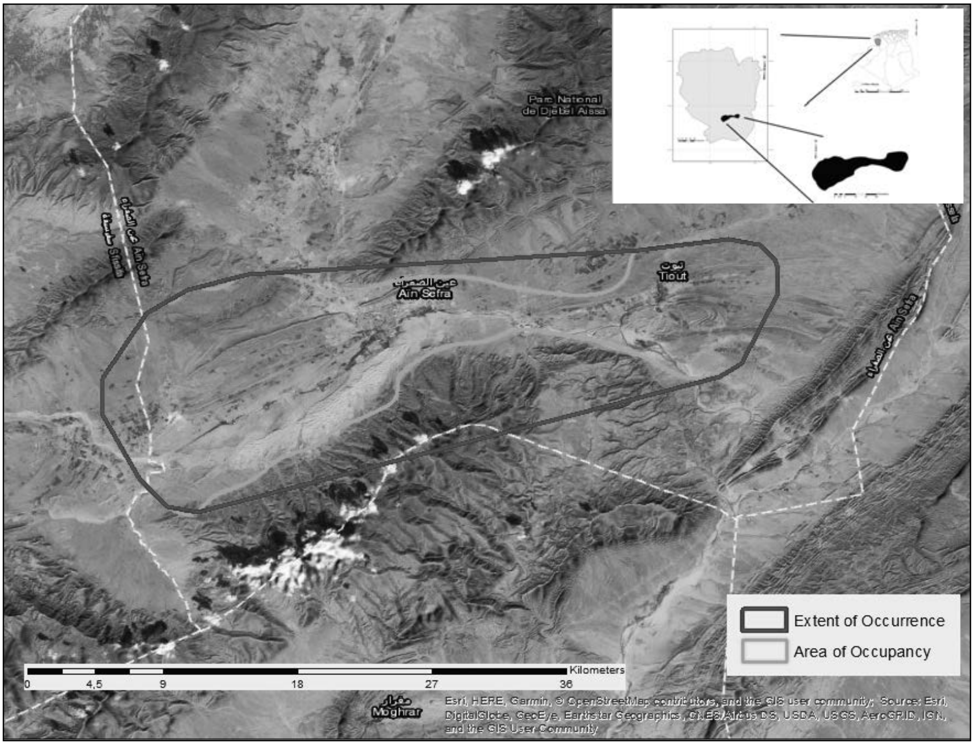


Fig. 2. Distribution of *Onopordum ambiguum* in Algeria. Range determined from GeoCat tool (http://geocat.kew.org/editor).

(Gordo 2021). In addition, we have surveyed *O. acaulon* and *O. macracanthum* in other more rocky habitats. These specimens are conserved in the personal herbarium of the first author (B. G.) which is deposited in the Herbarium of the University of Oran 1. Concerning *O. algeriense* and *O. acanthium*, we have referred to the digital version of the Herbarium specimens (P and MPU) and even digital photographs available online. We also took into account references from the literature: Marcel & Petit (1996) and Fennane & al. (2014). To determine the distribution of taxa in Algeria, we used the work of Pomel (1874), Battandier (1914), Quézel & Santa (1963) and Djelid & al. (2020). As for the specimens of *O. ambiguum* to which we paid special attention, they were collected from two sites around the famous dune and at altitude 1100-1300 m a.s.l. in the region of Aïn Sefra. Provisional identification of the specimens was carried out. Samples were re-affirmed using: (i) the computer-generated key to the spiny *Asteraceae* of Egypt (El-Gazzar & al. 2019), (ii) the keys in the local floras of Egypt (Boulos 2002) and Palestine (Feinbrun-Dothan 1977; 1978) (iii) the referral specimens collected from Egypt, Saudi Arabia and Yemen and kept in the Cairo University Herbarium (CAI) and (iv) matching with images of the same species in several virtual herbaria. The specimens are deposited in the Herbarium of Nâama University Centre, under the reference GB1-2021.

The regional assessment of *O. ambiguum* is based on the criteria determined by UICN (2018). We also used the GeoCat online platform (http://geocat. kew. org) to calculate AOO (Area of Occupancy) and EOO (Extent of Occurance). These weres used as bases for assigning a provisional status to the taxon.

For easy distinction between the six *Onopordum* species in Algeria, a data matrix was compiled to accommodate the variation in 21 morphological characters, which was subjected to analysis using the DELTA key-generating package of computer-programs (Dallwitz & al. 2000; 2005; Dallwitz 2010).

The following list of 21 characters includes are used in the generation of a conventional key to the six *Onoportdum* species in Algeria.

#1. Plant/ 1. erect/ 2. dwarf/
#2. Plant/ 1. green/ 2. greyish/
#3. Stem/ 1. grooved/ 2. not-grooved/
#4. Wings with spiny margin on stem/ 1. broad/ 2. inconspicuous/
#5. Leaves/ 1. basal only/ 2. basal and cauline/
#6. Leaf blad/ 1. narrowly linear/ 2. lanceolate-elliptic/
#7. Leaf blade/ 1. dissected to the mid-rib/ 2. with flat intercostal areas/
#8. Leaf blade upper surface/ 1. rugose/ 2. smooth/
#9. Spines on tips of leaf lobes/ 1. simple and bifurcate / 2. simple/
#10. Leaf veins/ 1. prominent/ 2. not prominent/
#11. Leaf veins/ 1. only midrib is white/ 2. all veins white/
#12. Capitula/ 1. in a basal aggregate/ 2. in two or more terminal aggregate/
#13. Capitula/ 1. peduncled/ 2. sessile/
#14. Outer phyllaries/ 1. linear-lanceolate/ 2. ovate/
#15. Outer phyllaries/ 1. longer than inner/ 2. shorter than inner/
#16. Outer phyllaries/ 1. convex outwards/ 2. flat/
#17. Outer phyllaries apical spine/ 1. pinkish/ 2. yellow/

#18. Outer phyllaries margin/ 1. pinkish/ 2. green/
#19. Inner phyllaries/ 1. linear-lanceolate / 2. ovate/
#20. Pappus/ 1. creamy-golden yellow/ 2. pinkish-white/
#21. Achenes/ 1. uniform/ 2. polymorphic/

Results and discussion

The Account of **Onopordum** *in Algeria*

Onopordum acanthium **L.**

Plant erect. Plant greyish. Stem grooved. Wings with spiny margin on stem broad. Leaves basal and cauline. Leaf blad lanceolate-elliptic. Leaf blade with flat intercostal areas. Leaf blade upper surface rugose. Spines on tips of leaf lobes simple. Leaf veins not prominent. Leaf veins only midrib is white. Capitula in two or more terminal aggregate. Capitula peduncled. Outer phyllaries linear-lanceolate. Outer phyllaries shorter than inner. Outer phyllaries flat. Outer phyllaries apical spine yellow. Outer phyllaries margin pinkish. Inner phyllaries linear-lanceolate. Pappus pinkish-white. Achenes uniform.

Uncultivated land, road and path margins in the Western High Plains, Hodna region; sub-Mediterranean Eurasian species (Quézel & Santa 1963; Tutin & al. 1976; Hanf 1983).

Onopordum acaulon **L.**

Plant dwarf. Plant greyish. Stem not-grooved. Wings with spiny margin on stem inconspicuous. Leaves basal only. Leaf blad lanceolate-elliptic. Leaf blade with flat intercostal areas. Leaf blade upper surface rugose. Spines on tips of leaf lobes simple and bifurcate. Leaf veins not prominent. Leaf veins only midrib is white. Capitula in a basal aggregate. Capitula sessile. Outer phyllaries ovate. Outer phyllaries longer than inner. Outer phyllaries convex outwards. Outer phyllaries apical spine pinkish. Outer phyllaries margin pinkish. Inner phyllaries linear-lanceolate. Pappus creamy-golden yellow. Achenes uniform.

Stony and clay mountain pastures, lowfertility soils in semi-arid areas of the Saharan Atlas region; western Mediterranean: Algeria, Andorra, Corse, France, Morocco, Spain, Tunisia (Quézel & Santa 1963; Euro+Med 2006-; USDA 2019).

Onopordum algeriense **(Munby) Pomel**

Plant erect. Plant green. Stem grooved. Wings with spiny margin on stem broad. Leaves basal and cauline. Leaf blad lanceolate-elliptic. Leaf blade dissected to the mid-rib. Leaf blade upper surface smooth. Spines on tips of leaf lobes simple and bifurcate. Leaf veins prominent. Leaf veins all are white. Capitula in two or more terminal aggregate. Capitula peduncled. Outer phyllaries linear-lanceolate. Outer phyllaries shorter than inner. Outer phyllaries convex outwards. Outer phyllaries apical spine pinkish. Outer phyllaries margin pinkish. Inner phyllaries linear-lanceolate. Pappus creamy-golden yellow. Achenes uniform.

The Baïnem Forest, in the Algiers region, whose altitude varies between 30 and 320 m, is characterised by a rugged terrain, a geological substrate composed of schist, gneiss and mica schist; endemic to Algeria (Djelid & al. 2020).

Onopordum ambiguum **Fresen.**

Plant erect. Plant greyish. Stem grooved. Wings with spiny margin on stem broad. Leaves basal and cauline. Leaf blad lanceolate-elliptic. Leaf blade with flat intercostal areas. Leaf blade upper surface rugose. Spines on tips of leaf lobes simple. Leaf veins prominent. Leaf veins all veins white. Capitula in two or more terminal aggregate. Capitula peduncled. Outer phyllaries linear-lanceolate. Outer phyllaries shorter than inner. Outer phyllaries convex outwards. Outer phyllaries apical spine yellow. Outer phyllaries margin pinkish. Inner phyllaries linear-lanceolate. Pappus creamy-golden yellow. Achenes uniform.

Granite and sandstone hillsides; Algeria, Egypt, Iraq, Palestine, Saudi Arabia, Sinai and Yemen (Boulos 2002).

After more than 130 years, the recording of *Onopordum ambiguum* in the flora of Algeria by B. Balansa in 1853 and later by Battandier & Trabut (1888) is confirmed. The two possible reasons why this species may have gone unnoticed for a long time are: (i) its very restricted range, (ii) and its close resemblance to *O. arenarium*.

O. ambiguum has been observed in two types of biotopes. The first corresponds to the edge of the dune of Aïn Sefra where it behaves as a psammophyte. The second is the gardens of the Ksar, especially the abandoned ones, where it changes its behaviour by sneaking through the weeds. Flowering and fructification occur during the months of May and June.

Field observations show that 105 individuals are distributed around the dune of Aïn Sefra as well as in the gardens located to the north (Fig.2). The estimated extent of occurrence (EOO) is 438 km^2 and the area of occupancy (AOO) is 200 km^2. Having no data on the numerical variations of the population, we used criteria B (geographical range). This taxon can be listed as regionally endangered (EN). Notably, goat grazing is a real threat to *O. ambiguum.*

Onopordum arenarium **(Desf.) Pomel**

Plant erect. Plant green. Stem grooved. Wings with spiny margin on stem inconspicuous. Leaves basal and cauline. Leaf blad narrowly linear. Leaf blade dissected to the midrib. Leaf blade upper surface smooth. Spines on tips of leaf lobes simple. Leaf veins prominent. Leaf veins all veins white. Capitula in two or more terminal aggregate. Capitula peduncled. Outer phyllaries ovate. Outer phyllaries longer than inner. Outer phyllaries convex outwards. Outer phyllaries apical spine pinkish. Outer phyllaries margin green. Inner phyllaries ovate. Pappus creamy-golden yellow. Achenes polymorphic.

Sandy deposits in Hodna, Western Sahara Atlas, and Northern Sahara regions; endemic to the Maghreb (Northwest Africa).

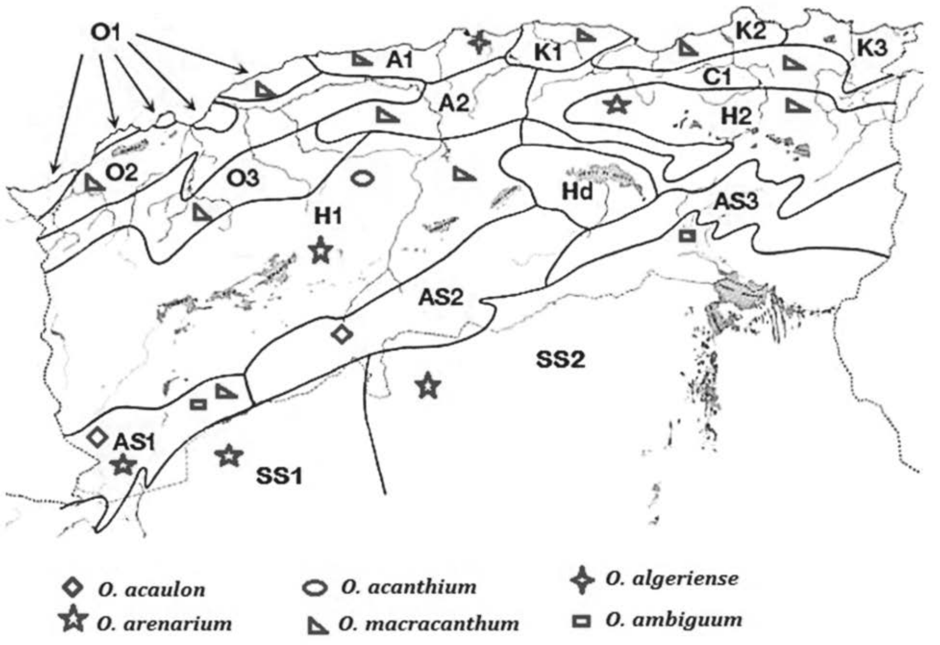
Onopordum macracanthum **Schousb.**

Plant erect. Plant greyish. Stem grooved. Wings with spiny margin on stem broad. Leaves basal and cauline. Leaf blad narrowly linear. Leaf blade with flat intercostal areas. Leaf blade upper surface smooth. Spines on tips of leaf lobes simple. Leaf veins prominent. Leaf veins all veins white. Capitula in two or more terminal aggregate. Capitula peduncled. Outer phyllaries linear-lanceolate. Outer phyllaries longer than inner. Outer phyllaries convex outwards. Outer phyllaries apical spine yellow. Outer phyllaries margin green. Inner phyllaries linear-lanceolate. Pappus pinkish-white. Achenes uniform.

Uncultivated land, pasture lands and forest in Algiers, Constantine, Kabylia and Numidia, Oran, High Plains, and Western Saharan Atlas regions,; western Mediterranean: Algeria, Baleares, Morocco, Portugal, Sardegna, Spain (Quézel & Santa 1963; POWA 2021).

Distributions

In order to better illustrate the distribution of *Onopordum* in Algeria, we have taken into account the biogeographical dimension. This led us to refer to the phytogeographical map of Algeria (Fig. 3). *O. arenarium* and *O. macracanthum* are two more widely distributed therophytes. Indeed, while the former is present in the Northern Sahara (SS), the High Plains (H) and the Western Saharan Atlas (AS1); the latter is known in the Tell, but its range extends beyond the Ksour Mountains which constitute its southern limit. Both species have remarkable ecological plasticity. Indeed, *O. arenarium* is found in the Saharan and arid bioclimate, whereas *O. macracanthum* is found in semi-arid, sub-humid and humid bioclimate. *O. acaulon* is a species of the Western and Central Saharan Atlas (AS1 and AS2). This hemicryptophyte occurs only in semi-arid bioclimate. On the other



Biogeographical sectors and subsectors from Quézel and Santa (1962): A1, A2: Algiers; AS1, AS2, AS3: Saharan Atlas; C1: Constantine; H1, H2, Hd (Hodna): High Plains; K1, K2, K3: Kabylia and Numidia; O1, O2, O3: Oran; SS1, SS2: Northern Sahara.

Fig. 3. Phytogeographic range of *Onopordum* taxa in Algeria.

hand, *O. ambiguum* occurs in an arid and Saharan bioclimatic. It shows a disjunct area divided into two subsets, one eastern (SS1: Eastern Northern Sahara) and one western (AS1: Ksour Mountains). Two species appear to be exceptions: *O. acanthium* and *O. algeriense*, which have a very restricted range. The first occurs in semi-arid bioclimate. It was indicated to the south of Tiaret (Cheddad), i. e. at the level of the Western High Plains (H1); the second is located in the Baïnem forest (A1: Algiers Coast). This therophyte can be observed in sub-humid bioclimate (Pomel 1874; Battandier 1914; Quézel & Santa 1963; Djelid & al. 2020).

Dichotomous key

1. Leaf blade upper surface rugose **2**
1. Leaf blade upper surface smooth **4**
2. Plant erect; stem grooved; wings with spiny margin on stem broad; leaves basal and cauline **3**
2. Plant dwarf; stem not-grooved; wings with spiny margin on stem inconspicuous; leaves basal only .... ***O. acaulon***
3. Leaf veins prominent; leaf veins all are white; outer phyllaries convex outwards; pappus creamy-golden yellow .... ***O. ambiguum***
3. Leaf veins not prominent; leaf veins only midrib is white; outer phyllaries flat; pappus pinkish-white .... ***O. acanthium***
4. Plant green; Leaf blade dissected to the mid-rib; outer phyllaries apical spine pinkish; pappus creamy-golden yellow **5**
4. Plant greyish; Leaf blade with flat intercostal areas; outer phyllaries apical spine yellow; pappus pinkish-white .... ***O. macracanthum***
5. Wings with spiny margin on stem broad; leaf blad lanceolate-elliptic; spines on tips of leaf lobes simple and bifurcate; outer phyllaries linear-lanceolate ....***O. algeriense***
5. Wings with spiny margin on stem inconspicuous; leaf blad narrowly linear; spines on tips of leaf lobes simple; outer phyllaris ovate .... ***O. arenarium***

Conclusion

Six species of *Onopordum* occurs in Algeria. The presence of *Onopordum ambiguum* in Aïn Sefra (Algeria) is confirmed after more than a century of its first recording from Biskra and its total absence in all subsequent floristic investigations of various localities. Indeed, this discovery is in line with the work previously undertaken since 2012 in this region (Gordo & Hadjadj-Aoul 2019, 2021; Gordo 2021). The study of aspects related to its ecology and the size of its populations allowed *O. ambiguum* to be given a regional conservation status: Endangered species (EN). The protection of its main habitat (dune) is becoming a priority as the gardens of the Ksar are facing strong anthropic pressure. We propose to include *O. ambiguum* in the next official lists dedicated to the preservation of threatened plants of Algeria. Accordingly, it seems plausible to suggest that a comprehensive effort to explore the different regions of the country to update the current floristic knowledge is worthwhile.

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References

African Plant Database 2021: Conservatoire et Jardin botaniques de la Ville de Genève and South African National Biodiversity Institute, Pretoria (Version 3.4.0). – http://www.ville-ge.ch/musinfo/bd/cjb/africa/ [Last accessed 20/04/ 2021].

Barry, J. P. & Celles, J. C. 1991: Flore de Mauritanie, **1, 2.** – Nice, Nouakchott.

Battandier, J. A. 1914 : Note sur quelques plantes d'Algérie nouvelles, rares ou critiques. – Bull. Soc. Bot. France. **61:** 51-54. http://dx.doi.org/10.1080/00378941.1914.10832527

— & Trabut, L. 1888: Excursion botanique dans le sud de la province d'Oran. – Bull. Soc. Bot. France **35:** 333-348.

Bonnet, E. & Maury, P. 1888: D'Aïn Sefra à Djenien Bou Resq. Voyage botanique dans le Sud-Oranais. – J. Bot. **2:** 277-301, 312-322.

Boulos, L. 2002: *Compositae*. – Pp. 134 - 317 in: Boulos, L. & Hind, D. J. N. (eds), Flora of Egypt, **3.** – Cairo.

Bouraada, K., Chavanon, G. & Chergui, H. 2014: Structure écologique des peuplements végétaux des dunes fixées par des graminées vivaces dans le Maroc oriental. – Rev. Mar. Sci. Agron. Vét., IAVHII, Rabat **2(1):** 72-91.

Dallwitz, M. J. 2010: Overview of the DELTA system. – http://delta- intkey.com/standard.htm [Last accessed 1/6/2021]

— & Paine, T. A. 2005: Definition of the DELTA format. – http://delta-intkey.com/standard.htm [Last accessed 1/6/2021]

—, — & Zurcher, E. J. 2000: User's guide to the DELTA system: genera system for processing taxonomic descriptions, 4.12 edition. CSIRO. Division of Entomology, Canberra, A.C.T, Australia. – http://delta-intkey.com [Last accessed 1/6/2021]

Djelid, S. A., Calvão, T. & Bensaid, S. 2020: Redécouverte et Écologie d´*Onopordum algeriense* (Munby) Pomel = *Carduus algeriensis* Munby, endémique stricte en voie d'extinction du secteur algérois. –Acta Bot. Malacitana **45:** 117-125. https://doi.org/10.24310/abm.v45i.5805.

Dobignard, A. & Chatelain, C. 2011: Index synonymique de la flore de l'Afrique du Nord, **2.** – Genève.

El-Gazzar, A., El Husseini, N., Khafagi, A. & Mostafa, N. A. 2019: Computer-generated Keys to the Flora of Egypt. 9. The Spiny Taxa of *Asteraceae*. – Egypt. J. Bot. **59(1):** 107-138.

Euro+Med (2006-): Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. – http://ww2. bgbm.org/Euro PlusMed/ [Last accessed 10/11/2021].

Fennane, M., 2014. *Onopordum* L. – Pp. 121-124 in: Fennane, M., Ibn Tattou, M. & El Oualidi, J. (eds), Flore Pratique du Maroc, **3.** – Rabat.

— 2017: Eléments pour un Livre rouge de la flore vasculaire du Maroc. Fasc. 3. *Asteraceae* (version 1, avril 2017). Edit. Tela-Botanica. Licence CC-BY NC ND. – http://www.tela-botanica.org/actu/article8066.html

Feinbrun-Dothan, N. 1977-1978: Flora Palaestina, **3 plates, 3 text.** – Jerusalem.

Gordo, B. 2021: Analyse de la flore et de la végétation des Monts des Ksour. Thèse Doctorat, Université Oran 1.

—, Hadjadj-Aoul, S. 2019: L'endémisme floristique algéro-marocain dans les Monts des Ksour. – Fl. Medit. **29:** 129-142. https://doi.org/10.7320/FlMedit29.129

— & — 2021: Confirmation de la présence de *Stipa apertifolia* subsp. *longiglumis* (H. Scholz) Vásquez & Devesa dans les Monts des Ksour. – Acta Bot. Malacitana **46.** https://doi.org/10.24310/abm.v46i.12422

Hanf, M. 1983: The arable weeds of Europe, with their seedlings and seeds. – Ludwigshofen.

Hochreutiner, B. P. G. 1904: Le sud oranais, étude floristique et phytogéographique. – Ann. Cons. Jard. Bot. Genève **7-8:** 22-278.

Maire, R.1916: La végétation des montagnes du sud Oranais. – Bull. Soc. Hist. Natur. Afr. Nord. **7:** 210-290.

Marcel, S. & Petit, D. 1996 : Le genre *Onopordum* (*Compositae*, *Cardueae*) au Maroc et l'utilisation de Winmaroc. – Fl. Medit. **6:** 11-22.

Mostafa, N.A. 2019: Generation of identification keys to the *Asteraceae* and *Liliaceae* in the flora of Egypt using the program suite DELTA. Ph.D. thesis, Al-Azhar University, Egypt.

Ozenda, P. 1991: Flore et végétation du Sahara. – Paris.

Pomel, A. N. 1874: Nouveaux matériaux pour la flore atlantique. – Bull. Soc. Clim. Alger. **1:** 1-260.

Pottier-Alapetite, G., 1981: Flore de la Tunisie, **2.** – Tunisie.

POWO, 2021: Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. – http://www.plantsoftheworldonline.org/ [Last accessed 20/04/2021]

Quézel, P. & Santa, S. 1962-1963: Nouvelle flore d'Algérie et des régions désertiques méridionales, **1-2.** – Paris.

Susanna, A. & Garcia-Jacas, N. 2007: Tribe *Cardueae*. – Pp. 123-146 in: Kadereit, J. W. & Jeffrey, C. (eds), The families and genera of vascular plants, **8.** – Berlin, Heidelberg & New York.

Tutin, T. G., Heywood, V. H., Burges, N. A., Moore, D. M.,Valentine, D. H., Walters, S. M. & Webb, D. A. 1976: Flora Europaea, **4.** – Cambridge.

UICN, 2018: Guide pratique pour la réalisation de listes rouges régionales des espèces menacées– Méthodologie de l'UICN & démarche d'élaboration. Seconde édition. – Paris.

USDA 2019: United States Department of Agriculture, Weed Risk Assessment for *Onopordum acaulon* L. (*Asteraceae*) – Raleigh.

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Article

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Phytodiversity of Limnos (North Aegean, Greece)—an update and evaluation

Abstract

Bergmeier, E., Ristow, M., Krause, J., Meyer, S. & Panitsa, M.: Phytodiversity of Limnos (North Aegean, Greece)—an update and evaluation. — Fl. Medit. 31: 233-246. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

The present update to the flora of the island of Limnos in the North Aegean, based on our field studies in 2016 and 2018–2021, raises the currently known number of vascular plant species to 960 native taxa, 63 established neophytes and 27 species of as yet casual status, a total of 1,050 taxa. To substantiate these figures, we provide a catalogue of about 740 annotated records of 264 plant taxa, of which 231 taxa were not previously known to occur in the island. Sixty-eight taxa were found as new to the flora of the North Aegean biogeographic region. Among the biogeographically most significant of the newly recorded native species are *Campanula lavrensis*, *Lactuca aculeata*, *Leontodon longirostris*, *Secale strictum* subsp. *anatolicum* and *Trifolium pachycalyx*. The new finds strengthen the biogeographic affinities of Limnos with the Aegean islands further south. Most of the records were from agricultural landscapes and small-scale habitats. Several richness focus areas of newly recorded plants were identified. As a conclusion, the alleged species poverty of Limnos cannot be confirmed.

Key words: Floristic status, island flora, Mediterranean flora, neophytes, plant geography, plant records, species richness.

Introduction

With its landscapes of flats and gentle slopes the island of Limnos (Lemnos, Λήμνος) in the centre of the North Aegean is unusual among the Aegean islands in terms of topography and geology as well as economically in its primacy of the agricultural sector. Favoured by the island's geomorphological and geological conditions, livestock and arable farming have a millennia-old tradition (Rauh 1949; Philippson 1959). With a population of about 16,000 inhabitants and a total area of 476 km^2 it is the ninth largest island of Greece and the seventh largest Aegean island (but with about 257 km coastline length it ranks as number four in the Aegean) (ELSTAT 2011). The nearest mainlands are the Athos peninsula (Chalkidiki) to the west-northwest 59 km away and the Dardanelles region in northwestern Turkey 61 km to the east. Its distances from the neighbouring islands are 75 km northwest to Thasos, 43 km north to

Samothraki, 22 km northeast to the Turkish island of Gökçeada (Imbros), 71 km southeast to Lesvos and 30 km south to Agios Evstratios. Limnos is amongst the earliest inhabited Aegean islands and already in the Early Bronze Age, around 3,000 BC, became an important place in the trade network (Kouka 2002).

The topography of Limnos is mostly gentle with extensive flatlands and low hills. The highest elevation, Vigla, is only 430 m above sea level and about two thirds of the island is lower than 100 m. A considerable part of the flatlands is covered by alluvial deposits, generating mostly sandy, loamy or gravelly soils. Arable fields prevail, grown chiefly with barley, wheat and triticale, less common are oats, legumes such as cowpea, maize, sorghum and sesame. Coastal dunes and temporary coastal lakes (Chortarolimni, Aliki) form unique landscapes which are of eminent importance in the East Mediterranean for wildlife, especially migratory birds. Much of the eastern lowlands are wetlands, saltmarshes, brackish marshes or wet-dry grasslands used as cattle or sheep pastures; they are ground-water influenced or temporarily flooded. Most of the hilly terrain is covered by silty or sandy soils derived from sedimentary rock (mostly Eocene to Oligocene molasse of sandstone, conglomerates and marl) and to about one third from Early Miocene volcanic rocks (mostly andesites) and tuffs (IGME 1993; Higgins & Higgins 1996). Most of the hillsides are, or have been, used mainly as sheep pasture. They carry phrygana (Aegean dwarf-shrub vegetation) and short grasslands. As a result of frequent irregular disturbance by tilling and fire the phrygana is dominated mostly by *Sarcopoterium spinosum*. Viticulture and cereal fields are locally common. Tall woody vegetation is fairly scarce on Limnos. Most remarkable are scattered trees and open woodlands of valonia oak (*Quercus ithaburensis* subsp. *macrolepis*), dense maquis of kermes oak (*Quercus coccifera*), riparian forests of *Ulmus minor* and *Salix alba*, brackish ground-water dependent open woods of *Elaeagnus angustifolia* and, in sites seasonally flooded by saline waters, *Tamarix* stands.

With the inventory by Panitsa & al. (2003) the flora of Limnos was considered well-studied. They surveyed in 1989 and 1996–97 a total of 79 sites all over the island and off-shore islets, focusing on semi-natural habitats. Moreover, the authors compiled many 20th century records scattered in literature from the times of Rechinger (1929, 1943) and Rauh (1949) through to Economidou (1981), Browicz (1991a), Yannitsaros & al. (2000), Biel (2000, 2002) and Tan & al. (2002). However, a number of notable floristic additions published subsequently showed that the flora was by no means exhaustively explored (e.g., Tan & al. 2008a, 2008b; Biel & Tan 2011, 2014a, 2015; Baliousis 2014). All these floristic works were considered by Strid (2016) in his Atlas of the Aegean Flora. He critically evaluated the data assembled in the Hellenic floristic database (FHD) which, since the first collections by Butcher cited by Turrill (1922), cover a century of botanical research on the island.

The present study is the result of botanical field studies carried out independently by two teams—J. Krause and M. Ristow in 2016 and 2018–2019, and E. Bergmeier, S. Meyer and M. Panitsa in 2016 and 2018–2021. The fieldwork by the latter team was focused initially on the species composition of selected fields and farmsteads (*mandras*) in the frame of the Terra Lemnia project (https://terra-lemnia.net/en/) to promote sustainable traditional agropastoral practices of Limnos. Despite the local scope, it soon turned out that a considerable number of species found was not known to occur in the island, including floristic additions of importance from biogeographic, cultural and ecological perspectives. It further turned out that many species were observed by both teams, while others were found by one team only, thus complementing individual expertise, seasonal and geographical coverage. Realizing the teams' respective attempts and progress we decided to join forces, aiming at updating the previous floristic milestones by Panitsa & al. (2003) and Strid (2016). The re-inventorying of the island flora is intended to not only update the plant richness numbers but also to improve the knowledge of the local flora in quantitative (plant population size, rarity) and qualitative terms (habitat affinities). We further ask whether there are focus areas of the new plant records and reconfirmations and where these floristic clusters are, to which habitats and landscapes the new findings belong, and which biogeographical conclusions can be drawn.

Matherials and methods

The present study is based on fieldwork carried out by the authors in 2016 and 2018–2021 covering spring (April, May) and autumn (end of September and October) seasons (Table 1). Our investigations were carried out in a total of 124 units of the arcminute grid (each unit has an area of about 263.5 ha), representing more than 70 % of the total number of units (arcminute units counted if terrestrial to more than 50 %). We did not attempt to perform a spatially comprehensive floristic mapping. In the present paper, we provide new floristic records for the island (or a wider area) and reconfirmations of species reported by Rechinger (1943) and Rauh (1949) after more than 70 years. We also highlight corrections of former erroneous reports and specify omissions. Specifically, the criteria of taxa found by us and treated in this paper are:

- Taxa previously not known to occur in Limnos (or the North Aegean or wider geographical area);
- Mapped in Limnos by Strid (2016) based on unpublished data;
- Reported in literature but apparently incorrect taxonomic identity;
- Reported in literature but omitted by Strid (2016);
- Reported in literature only at higher taxonomic level (species or species group);
- Apparently not found in Limnos since more than 70 years.

We also provide a list of taxa reported in previous works but not found by us. Such a list appears useful as it includes species that are extinct, rare, or possibly erroneous, hence should be regarded with particular attention in future studies.

The taxa in the catalogue of new records and confirmations are listed in alphabetical order of families, and therein genera and species again in alphabetical order. The family assignation and taxonomy follows Euro+Med (2006+), the taxonomy of species and subspecies mainly Dimopoulos & al. (2013) and Euro+Med (2006+). The annotations include taxon name, locality, elevation above sea level, coordinates (GPS data of WGS 84), habitat, date, observers or collectors with collection number. Voucher specimens are currently deposited in the cited authors' private herbaria.

Table 1. Fieldwork: seasons, duration and numbers of new vascular plant records and confirmations for the present update. Researchers: B, Bergmeier; K, Krause; M, Meyer; P, Panitsa; R, Ristow.

Year	Month	Number of days	Number of records	Researchers
2016	Apr	4	6	M
	Oct	13	85	K, R
2018	Apr	8	125	B, M, P
	May	12	112	K, R, M
2019	Apr	9	37	B, M, P
	May	15	105	K, R, M
	Oct	3	44	B, M
2020	Sep	4	34	B, M
	Oct	2	29	B, M
2021	May	13	169	B, M

Results and Discussion

The present update of the flora of Limnos lists about 740 records of 264 vascular plant taxa noteworthy for floristic, taxonomic or biogeographic reasons. A total of 231 taxa were not previously known to occur in the island, and 68 were found new to the North Aegean biogeographic region (which consists mainly of the islands of Limnos, Thasos, Samothraki and Aj. Evstratios). Several taxa were not currently known elsewhere in the Aegean (*Bromus arvensis* subsp. *parviflorus, Leontodon longirostris*, *Secale strictum* subsp. *anatolicum* and the established neophyte *Opuntia microdasys*), in Greece as a whole (*Trifolium pachycalyx* and the neophytes *Chenopodium suecicum, Datura wrightii*, *Lathyrus* cf. *undulatus* and *Styphnolobium japonicum*) or in Europe (*Lactuca aculeata*). Aegean endemics found as new in Limnos are *Limonium sieberi* and *Saponaria jagelii*, together with others confirmed by us, e.g. *Anthemis werneri*, *Consolida arenaria*, *Polygonum icaricum* and *Silene grisebachii*. In addition to the previously known local island endemic *Erysimum rechingeri*, we found a further three range-restricted species: *Campanula lavrensis*, an endemic of the Northwest Aegean, *Lathyrus* cf. *undulatus*, a showy endemic of Northwest Turkey which appears to be an established garden escape in Limnos, and *Trifolium pachycalyx*, described from Northwest Turkey but not reconfirmed there or anywhere else in the world since more than 80 years.

The complete floristic list is given in the Electronic Supplementary File 1 (ESF1).

Confirmations and non-confirmations

Our update includes confirmations of 16 species reported more than 70 years ago by botanists such as Rechinger (1929, 1943) and Rauh (1949). According to the compilation of published or otherwise communicated data in the FHD, these species have not been recorded since. Habitat continuity provided, there is remarkable perseverance in populations even of short-lived species. After almost a century, *Galium verticillatum* was found in the same site (the single known in the island) as Rechinger in 1927 (Rechinger 1929: 315). A population of wild pea, identified as *Pisum elatius*, was found in what appears to be the very same site (again the single one currently known in Limnos) as 50 years ago by the collector Jeavons whose specimen was documented under the name *P. sativum*.

The following taxa which were listed in the Limnos vascular plant inventory by Panitsa & al. (2003) but for various reasons not mapped for the island by Strid (2016) could also be confirmed by us: *Allium scorodoprasum* subsp. *rotundum* (L.) Stearn, *Allium flavum* L., *Allium commutatum* Guss., *Hainardia cylindrica* (Willd.) Greuter, *Nigella arvensis* subsp. *glauca* (Boiss.) A. Terracc., *Phalaris paradoxa* L., *Prasium majus* L. and *Rhagadiolus edulis* Gaertn.

We could not confirm the occurrence of 86 taxa reported in previous works and, except those marked with *, mapped for Limnos by Strid (2016). These taxa appear to be a heterogeneous group of (a) rare species overlooked by us, (b) species verifiable only in months that we did not cover such as between November and March, and (c) erroneous records, yet not clarified by obvious taxonomic, ecological or biogeographical reasons: *Agrimonia eupatoria* L., *Allium rhodopeum* Velen. (*A. paniculatum* subsp. *villosulum* (Halácsy) Stearn)*, *A. sphaerocephalon* var. *aegaeum* (Heldr. & Halácsy) Hayek*, *Anchusa azurea* Mill. (*A. italica* Retz.), *Arisarum vulgare* O. Targ.Tozz., *Armeria undulata* Boiss., *Arthrocaulon macrostachyum* (Moric.) Piirainen & G. Kadereit (*Arthrocnemum macrostachyum* (Moric.) K. Koch), *Asclepias fruticosa* L.*, *Berteroa obliqua* (Sm.) DC., *Brachypodium pinnatum* (L.) P. Beauv., *B. retusum* (Pers.) P. Beauv., *Brassica napus* L., *Callitriche stagnalis* Scop., *Capparis orientalis* Veill. (*C. spinosa* subsp. *rupestris* (Sm.) Nyman), *Cerastium brachypetalum* aggr.*, *Cercis siliquastrum* L., *Consolida phrygia* Soó, *Crocus cartwrightianus* Herb.*, *C. olivieri* J. Gay*, *Crucianella latifolia* L., *Dactylis glomerata* subsp. *hackelii* (Asch. & Graebn.) Cif. & Giacom., *Dianthus pinifolius* Tausch, *Erodium botrys* (Cav.) Bertol., *E. laciniatum* (Cav.) Willd., *Eruca vesicaria* (L.) Cav., *Euphorbia apios* L., *E. pubescens* Vahl, *Filago cretensis* Gand. subsp. *cretensis*, *Goniolimon sartorii* Boiss., *Hedera helix* L., *Herniaria hirsuta* subsp. *cinerea* (DC.) Cout., *Hornungia petraea* (L.) Rchb., *Juncus subulatus* Forssk., *Lathyrus articulatus* L., *L. sphaericus* Retz., *Lemna minor* L., *Limonium ocymifolium* (Poir.) Kuntze, *Lomelosia divaricata* (Jacq.) Greuter & Burdet, *Lupinus gussoneanus* J. Agardh (*L. micranthus* Guss.), *Luzula forsteri* (Sm.) DC., *Lythrum borysthenicum* (Schrank) Litv., *Malcolmia macrocalyx* K. Rechinger, *Malva nicaeensis* All., *M. pusilla* Sm., *Matthiola incana* (L.) W.T. Aiton, *Melilotus italicus* (L.) Lam., *M. segetalis* (Brot.) Ser., *Moenchia mantica* (L.) Bartl., *Muscari commutatum* Guss., *M. weissii* Freyn., *Ononis diffusa* Ten., *Onopordum Illyricum* L., *O. myriacanthum* Boiss., *Ophrys apifera* Huds., *O. umbilicata* Desf., *Origanum onites* L., *Orobanche amethystea* Thuill., *Parapholis marginata* Runemark, *Parietaria lusitanica* L., *Potamogeton nodosus* Poir., *Prunella laciniata* (L.) L., *Pterocephalus plumosus* (L.) Coult., *Ranunculus neapolitanus* Ten., *R. peltatus* subsp. *baudotii* (Godr.) C.D.K. Cook, *Romulea ramiflora* Ten.*, *Rosmarinus officinalis* L., *Rumex scutatus* L.*, *Ruppia cirrhosa* (Petagna) Grande, *Sambucus nigra* L., *Scandix grandiflora* L. (*S. australis* subsp. *grandiflora* (L.) Thell.), *Sideritis lanata* L.*, *Solanum dulcamara* L., *Spergula pentandra* L., *Spergularia media* (L.) C. Presl (*S. maritime* (All.) Chiov.), *Stachys germanica* L., *Stuckenia pectinata* (L.) Börner (*Potamogeton pectinatus* L.), *Tagetes minuta*

L., *Tamarix hampeana* Boiss. & Heldr., *Teucrium brevifolium* Schreb., *Trifolium grandiflorum* Schreb., *T. leucanthum* M. Bieb., *Tripolium pannonicum* (Jacq.) Dobrocz. (*Aster tripolium* L.), *Ulmus minor* subsp. *canescens* Bartolucci & Galasso, *Urtica dioica* L., *Velezia rigida* L., *Vicia melanops* Sm.

Plant geographical conclusions

The new records reinforce the biogeographic affinity of Limnos mainly with the south, i.e. linking it with other Aegean islands. Several native species among the newly recorded ones have their northernmost known populations in Limnos: *Ambrosia maritima* L*.*, *Arum concinnatum* Schott*, Atriplex davisii* Aellen, *Capparis sicula* Veill*.*, *Convolvulus oleifolius* Desr., *Crataegus azarolus* subsp. *aronia* (L.) Rouy & E. G. Camus (Fig. 1), *Echium arenarium* Guss*.*, *Hordeum vulgare* subsp. *spontaneum* (K. Koch) Thell., *Limonium sieberi* (Boiss.) Kuntze, *Lolium subulatum* Vis., *Lotus subbiflorus* Lag., *Medicago bonarotiana* Arcang., *Medicago tuberculata* (Retz.) Willd., *Ononis serrata* Forssk., *Paronychia echinulata* Chater, *Phelipanche hedypnoidis* Rätzel, Ristow & Uhlich, *Phragmites frutescens* H. Scholz, *Potamogeton schweinfurthii* A. Benn., *Saponaria jagelii* Phitos & Greuter (Fig. 2), *Secale strictum* subsp. *anatolicum* (Boiss.) Hammer, *Senecio leucanthemifolius* Poir*.*, and *Vulpia ligustica* (All.) Link. In contrast, only rather few have their southern-, southeastern- or southwesternmost Aegean occurrences in Limnos (*Bromus arvensis* subsp. *parviflorus* (Desf.) H. Scholz*, Campanula lavrensis* (Tocl & Rohlena) Phitos, *Salicornia perennans* Willd., *Verbascum rupestre* (Davidov) I.K. Ferguson (Fig. 3). Very few species have their westernmost (*Heliotropium lasiocarpum* Fisch. & C.A. Mey., *Lactuca aculeata* Boiss. & Kotschy, *Ononis serrata* Forssk., *Trifolium pachycalyx* Zohary) and only one of the newly recorded taxa (*Aira caryophyllea* L.) its easternmost known populations in the island.

Floristic focus areas

In Limnos, the most important arcminute grid units—in terms of floristic novelties—are the following: 39°54'/25°08' (to the west of Aj. Dimitrios), 39°51'/25°07' (southwest of Kontias), 39°51'/25°10' (Diapori), 39°50'/25°10' (isthmus and northernmost Fakos peninsula) and 39°52'/25°03' (Myrina, town). Altogether, we identified the following as the richest floristic areas of the island (single or clustered grid units): (a) The topographically diverse volcanic rock area between Therma and Aj. Dimitrios; (b) the town of Myrina with coast and fortress hill; (c) the coastal flats southwest of Kontias; (d) the coastal flats and andesite domes just E of Kontias; (e) the coastline and coastal flats at both ends of the isthmus of Diapori with the northern part of the Fakos peninsula; (f) the seasonal lake of Chortarolimni with the sand flat called Agiogiannides and Keros beach in the far east of Limnos; (g) the area north and northeast of the lagoon of Aliki in the island's far east; (h) the area north of Plaka in the far northeast and (i) the coastal area of Aj. Sozon and the beach of Louri in the far southeast of Limnos.

Focus habitats

An evaluation of our plant records with sufficiently unambiguous habitat specification, a total of 721, revealed that more than one third of the records were made in arable landscapes (cultivated and fallow arable land, field margins and other dry ecotones) which indeed represent about one third of the island's area, and that coastal and other small-scale

Fig. 1. *Crataegus azarolus* subsp. *aronia*, SW Aj. Dimitrios, 21 September 2021, photo E. Bergmeier.

Fig. 2. *Saponaria jagelii*, Paralia Louri SW Aj. Sozon, 9 May 2018, photo J. Krause.

Fig. 3. Verbascum rupestre, northern edge of Kontias, 10 May 2018, photo J. Krause.

habitats (dunes, ruderal, semiwet grassland, saltmarsh, rocks and cliffs, aquatic and other wet habitats) are represented by almost 40 % of our records (Table 2). Although most previously published plant records lack habitat specifications, it may be assumed that (a) the focus was then on large-scale seminatural habitats (such as phrygana and dry grasslands), and that (b) the habitats listed above as being well-represented among our records had remained understudied but are of considerable importance for the flora of Limnos.

Table 2. Habitat types represented by documented plant records.

Habitats	**Number of records (%)**
Arable land	20.8
Dry linear habitats	14.3
Phrygana	14.0
Coastal sands	8.3
Ruderal habitats	7.8
Dry herbaceous grassland	6.5
Semiwet grassland	6.5
Saltmarsh	5.3
Scrub and woods	5.0
Wet or semiwet linear habitats	4.6
Rocks and cliffs	3.7
Aquatic habitats and wetland	3.2

Species richness

The new records raise the currently known species richness of Limnos to a total of 1,050 vascular plant taxa growing spontaneously in the wild. This number comprises 1,035 species plus 15 additional subspecies (i.e. fifteen species are represented by two subspecies). By comparison, the island inventory by Panitsa & al. (2003) listed 642 taxa growing in the wild, and Strid (2016) mapped 783 such taxa in Limnos. The difference between the two works is chiefly due to 21st century records published after Panitsa & al. (2003), namely by Tan & al. (2008a, 2008b), Biel & Tan (2011, 2014a, 2015) and Baliousis (2014), and to a minor extent due to differences of opinion in questions of naturalization and status assessment or for taxonomic reasons.

The figures given above for taxa "growing spontaneously in the wild" include native species (including those assumed archaeophytes), established neophytes and casual, i.e. non-established, neophytes. Species cultivated in gardens or fields for agricultural or ornamental purposes without significant spontaneous occurrences remained disregarded. They include a total of 43 species in literature (chiefly Thomas & al. 2012). The above-mentioned figures are based on our census and differ slightly from those in the original works of Panitsa & al. (2003) and Strid (2016) owing to differences in the assessment of the naturalization status of certain species. In our updated census we assess 960 taxa as native (including archaeophytes), 63 as established neophytes, and 27 as non-established casuals. Of course, doubts remain as to the correct status assessment of some species.

Panitsa & al. (2003) attributed Limnos a "low floristic diversity" and an "unusually low [number of taxa] compared to other Greek islands with a comparable or even smaller size". Factors responsible for this, they assumed, are both genuine (low elevations, absence of limestone cliffs) and human-made (grazing, fires, camping). Certain habitats, otherwise more or less widely distributed and common in the North Aegean, such as calcareous cliffs, sea cliffs, thick sclerophyllous, coniferous and deciduous forests, rivulets and temporary streams, are indeed rare or absent in Limnos. It can also be expected that millennia-old human interference has much influenced the local flora and landscape over time. However, three facts can be ascertained: (1) The recent species pool of the habitats determining the overall appearance of the landscape of Limnos, such as arable land, land-use borderlines, phrygana, low-growing pastures, ruderal sites, saltmarshes, dunes and reed-beds, is by no means poor or impoverished compared to other island floras. (2) The difference in overall species richness between Limnos, with the unexpectedly large number of new records now better known than at the time of the first inventory twenty years ago, and other Aegean islands similar in size such as Samos (Christodoulakis 1986, Snogerup & Snogerup 1993) and Chios (Snogerup & al. 2001) is not as wide as it seemed. The remaining difference is easily explained by the much less marked topographic variation of Limnos and by the proximity of the two East Aegean islands to the (Anatolian) mainland. The fact that Samothraki, the northern neighbouring island and less than half the area extent of Limnos, equals the latter in floristic diversity (Biel & Tan 2014b) is also explained by the much more pronounced vertical extension of Samothraki. (3) We did not find evidence of pronounced floristic turnover but of considerable resilience and permanence, especially in view of the reconfirmations of plant records after more than 70 years. Over 91 % of the island's flora consists of native species most of which are expected to be long-time residents in Limnos (although it cannot be ruled out that some of the plants considered native in the Aegean or Greece were introduced to the island at some time). Only 2.6 % appear to be recent casual introductions that may or may not become established in Limnos.

Threats and conservation

It is remarkable that the impression that Rauh (1949: 610) got of Limnos as a "*Getreide-Insel*" (cereals island), is now, about 80 years later, still fully understandable. However, the proportion of cultivated land must have been considerably higher than it is today, mainly as a result of the 1950s–1970s Greek emigration waves which concerned among others especially islands such as Limnos (Afentoulis 2014). The decades since then have seen both ongoing abandonment of arable and pasture lands in the hilly and remote parts of the island as well as an intensification of agricultural practices including the use of synthetic fertilizers and pesticides. Both must have affected the populations of a number of now uncommon or rare wild arable (segetal) plants. While many segetal plants are still perhaps nearly as common in Limnos as they were in the days of Rauh (1949) who listed about 45 weeds of cereal crops and field margins, some species encountered by him have become scarcer (e.g., *Agrostemma githago*, *Bifora testiculata*, *Leontice leontopetalum*, *Lolium temulentum*, *Medicago scutellata*, *Papaver hybridum*, *Ranunculus arvensis*), and others, now restricted in Limnos to just one or few fields (*Allium cyrilli*, *Bupleurum subovatum*, *Gladiolus italicus*, *Glaucium corniculatum*, *Medicago bonarotiana* and *Vaccaria pyramidata*), were probably more widespread once. As far as we can see there appears to be no native species of natural environments in Limnos currently declining or in risk of extinction owing to traditional land-use, but some rare species of arable fields such as those mentioned above are threatened by intensification or neglect of the principles of traditional forms of smallholder farming (Bergmeier & Meyer 2018).

While mass tourism is one of the major drivers of habitat and biodiversity loss in the Mediterranean it is only of minor and rather local importance in Limnos, at least in comparison to other Aegean islands. As many of the island's roughly 30 sandy beaches are extensive and some remote, sizable populations of typical dune plants are extant and in good condition such as those of the flagship species *Pancratium maritimum* as well as of other important coastal matrix plants such as *Centaurea spinosa*. Red-listed or threatened dune plants such as the rare Aegean endemics *Consolida arenaria* and *Saponaria jagelii* as well as *Malcolmia nana* are local in Limnos and potentially vulnerable due to inadvertent habitat destruction.

The construction of the island's airport north of the Moudros Gulf, arguably the most severe impact in the landscape of Limnos in the last century, brought about severe losses of semi-wet pastures, coastal grasslands and saltmarsh with their associated characteristic flora and wildlife. Fortunately, there are extensive semi-wet grasslands and saltmarshes extant locally in the south and especially in the east of the island where typical plants of such endangered habitats occur, including *Trachomitum sarmatiense* and *Trifolium pachycalyx* which have not been recorded anywhere else in Greece, and rarities of ecological significance found as new such as *Leontodon longirostris*, *Trifolium squamosum* and *Vulpia ligustica*. Large stretches of these sin-

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* including those reported in the ESF1.

gularly important habitats still occur in exceptional size and excellent quality in Limnos. The maintenance of large hydrologically intact areas unaffected by construction works is one of the most vital necessities in the field of nature and landscape conservation in the island. The designation of three Natura 2000 areas, as part of the European network of nature protection areas, is an important step. They cover at least some of the floristic focus areas worked out above such as the Fakos peninsula, Diapori, and the temporary lakes of Aliki and Chortarolimni. However, they are not strictly protected in terms of how they are used or not used by people, and management plans still await completion.

Conclusion

Even with the present update, the state of knowledge of the Limnian flora should not be understood as complete. We can, however, conclude that the previous perception of the island's low floristic diversity was premature, apparently as a result of recording deficit chiefly in the agricultural landscapes. The high number of new records corroborates that the species richness of Limnos does not lag behind from a biogeographic point of view. There are several eminent floristic locations in the island that rank among the first in the Aegean and which deserve every effort for their conservation. Outstanding focus areas with extraordinary habitat characteristics as discussed above, in particular saltmarsh, dune, diverse traditional arable land, semi-wet rangeland and some rock habitats require careful multidisciplinary monitoring to avoid administrative attention deficits and deterioration.

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References*

Afentoulis, M. 2014: North Aegean Greek islander migration to Australia—1950s to 1970s—'For a better life we came…'. Oral History Society Annual Conference (Community voices: Oral history on the ground). – Manchester.

Baliousis, E. 2014: Recent data from the flora of the island of Limnos (NE Aegean, Greece): New alien invasive species affecting the agricultural economy of the island. – Edinb. J. Bot. **71(2):** 275-285.

Bergmeier, E. 2021a: *Leontodon longirostris* (Finch & P. D. Sell) Talavera – Pp. 356-357 in: Raab-Straube E. von & Raus Th. (eds), Euro+Med-Checklist Notulae, 14. – Willdenowia **51:** 355-368. https://doi.org/10.3372/wi.51.51304

— 2021b: *Datura wrightii* Regel – Pp. 363 in: Raab-Straube E. von & Raus Th. (eds), Euro+Med-Checklist Notulae, 14. – Willdenowia **51:** 355-368. https://doi.org/10.3372/wi.51.51304

—, Krause, J. & Ristow, M. 2021: *Trifolium pachycalyx* Zohary – Pp. 361-363 in: Raab-Straube E. von & Raus Th. (eds), Euro+Med-Checklist Notulae, 14. – Willdenowia **51:** 355-368. https://doi.org/10.3372/wi.51.51304

— & Meyer, S. 2018: Segetal plants of winter-annual crop fields in the Aegean islands – viewed in the contexts of landscape and traditional agricultural practice. – Ber. Reinhold-Tüxen-Ges. **30:** 73-84.

— & — 2021: *Lactuca aculeata* (*Asteraceae*), a crop wild relative new to Europe. – Fl. Medit. **31:** 53-58. https://doi.org/10.7320/FlMedit31.053

—, Sakellarakis, F.-N., Strid, A. & Swinkels, C. 2020. New additions to the flora of Prespa, Greece. – Phytol. Balcan. **26(1):** 103-130.

Biel, B. 2000: Zur Orchideenflora der Insel Limnos. – Ber. Arbeitskreises Heimischer Orchid. **17(2):** 51-78.

— 2002: Contributions to the flora of the Aegean islands of Lesvos and Limnos, Greece. – Willdenowia **32:** 209-219.

— & Tan, K. 2011: Reports 1-19. – Pp. 248-250 in: Vladimirov, V. & Tan, K. (eds): New floristic records in the Balkans: 16. – Phytol. Balcan. **17(2):** 247-264.

— & — 2014a: Reports 13-61. – Pp. 269-273 in: Vladimirov, V., Dane, F., Matevski, V. & Tan, K. (eds): New floristic records in the Balkans: 25. – Phytol. Balcan. **20(2-3):** 267-310.

— & — 2014b: Flora of Samothraki. – Athens.

— & — 2015: Reports 70-187. Pp. 62-72 in: Vladimirov, V., Dane, F. & Tan, K. (eds): New floristic records in the Balkans: 26. – Phytol. Balcan. **21(1):** 53-91.

Böhling, N. & Scholz, H. 2003: The *Gramineae* (*Poaceae*) of the Southern Aegean islands (Greece): Checklist, new records, internal distribution. – Ber. Inst. Landschafts- Pflanzenökol. Univ. Hohenheim, Beih. **16.** – Stuttgart.

Bothmer, R. von, Strid, A., Biel, B. & Tan, K. 2014: Report 113. – Pp. 279-280 in: Vladimirov, V., Dane, F., Matevski, V. & Tan, K. (eds): New floristic records in the Balkans: 25. – Phytol. Balcan. **20(2-3):** 267-310.

Boyce, P. 1993: The genus *Arum*. – London.

Browicz, K. 1991a: Trees and shrubs of Lemnos Is. (Greece). – Arbor. Kórnickie **36:** 5-25.

— 1991b: *Crataegus ×ruscinonensis* var. *aronioides* (*Rosaceae*), a new nothospecies and nothovariety for the flora of Greece. – Willdenowia **21:** 113-117.

Christensen, K. I. 1992: Revision of *Crataegus* sect. *Crataegus* and nothosect. *Crataeguineae* (*Rosaceae-Maloideae*) in the Old World. – Syst. Bot. Monogr. **35:** 1-199.

Christodoulakis, D. 1986: Die Flora und Vegetation der Insel Samos (Griechenland). – Patras [in Greek with German summary].

Del Carratore, F., Garbari, F. & Jarvis, C. 1998: The application of the Linnaean names *Salvia pratensis*, *S. agrestis*, *S. haematodes*, *S. verbenaca* and *S. clandestina* (*Lamiaceae*). – Pl. Biosyst. **132:** 169-176.

Dimopoulos, P., Raus, T., Bergmeier, E., Constantinidis, T., Iatrou, G., Kokkini, S., Strid, A. & Tzanoudakis, D. 2013: Vascular plants of Greece: an annotated checklist. – Englera **31:** 1-372.

Economidou, E. 1981: Le milieu terrestre de l'île de Limnos et ses reliques de forêts. – Biol. Écol. Médit. **8(3-4):** 129-138.

ELSTAT (Ellinikí Statistikí Archí) 2011: Statistical Yearbook of Greece 2009 & 2010. – Pireas [in Greek].

Euro+Med 2006+: Euro+Med Plantbase — the information resource for Euro-Mediterranean plant diversity. – https://www.emplantbase.org/home.html [Last accessed 27/8/2021].

Evthimiadis, P., Zamanis, A. & Skorda, E. 1985: The two-rowed wild barley from four islands of Greece. – Sveriges Utsädesfören. Tidskr. **95:** 63-70.

Flora Ionica Working Group 2016+: Flora Ionica — An inventory of ferns and flowering plants of the Ionian Islands (Greece). – Published at https://floraionica.univie.ac.at [Last accessed 26 Jun 2021].

Garve, E. 2016: *Atriplex* Linnaeus 1753. – Pp. 361-363 in: Kleinsteuber, A., Ristow, M. & Hassler, M. (eds), Flora von Rhodos und Chalki, **1.** – Karlsruhe.

Greuter, W. 2003: The Euro+Med treatment of *Cichorieae* (*Compositae*) — generic concepts and required new names. – Willdenowia **33:** 229-238.

Güemes J. & Molero J. 2006: 5. *Fumana* (Dunal) Spach. – Pp. 422-436 in: Castroviejo, S., Aedo, C., Cirujano, S., Laínz, M., Montserrat, P., Morales, R., Muñoz Garmendia, F., Navarro, C., Paiva J. & Soriano C. (eds) Flora Iberica, **3** (2nd ed.). – Madrid.

Hanelt, P. 1963: Monographische Übersicht der Gattung *Carthamus* L. (*Compositae*). Feddes Repert. **67:** 41-180.

Hedge, I. C. 1970: *Onobrychis* Adans. – Pp. 560-589 in: Davis, P. H. (ed.), Flora of Turkey and the East Aegean Islands, **3.** – Edinburgh.

Hempel, W. 2012: Revision und Phylogenie der Arten der Gattung *Melica* L. (*Poaceae*) in Eurasien und Nordafrika. – Feddes Repert. **122:** 1-253.

Higgins, M. D. & Higgins, R. 1996: A geological companion to Greece and the Aegean. – London.

Hügin, G. 1998: Die Gattung *Chamaesyce* in Europa. Bestimmungsschlüssel mit taxonomisch-nomenklatorischen Anmerkungen. – Feddes Repert. **109:** 189-223.

IGME (Institute of Geology and Mineral Exploration) 1993: Geological Map of Greece 1:50,000. Limnos Island. – Athens.

Koopman, J. & Więcław, H. 2017: The section *Phaestoglochin* (*Carex*, *Cyperaceae*) in the Netherlands. – Gorteria **39:** 79-87.

Kouka, Ou. 2002: Siedlungsorganisation in der Nord- und Ostägäis während der Frühbronzezeit (3. Jt. v.Chr.). Teil I, Text. (Internationale Archäologie **58**) – Rahden/Westf.

Mosyakin, S. L. 2017: Taxonomic and nomenclatural notes on Pontic-Mediterranean coastal and some Australasian taxa of *Salsola* (*Chenopodiaceae*). – Ukr. Bot. J. **74:** 521-531.

Panitsa, M., Snogerup, B, Snogerup, S. & Tzanoudakis, D. 2003: Floristic investigation of Lemnos island (NE Aegean area, Greece). – Willdenowia **33:** 79-105.

Philippson, A. 1959: Das Aegaeische Meer und seine Inseln. In: E. Kirsten (ed.), Die griechischen Landschaften. Eine Landeskunde von Alfred Philippson, **4.** – Frankfurt, Main.

Rauh, W. 1949: Klimatologie und Vegetationsverhältnisse der Athos-Halbinsel und der ostägäischen Inseln Lemnos, Evstratios, Mytiline und Chios. – Sitzungsber. Heidelberger Akad. Wiss., Math.-Naturwiss. Kl. **[1949](12):** 511-615.

Raus, T. & Kleinsteuber, A. 2016: *Cistaceae*. – Pp. 373-379 in: Kleinsteuber, A., Ristow & Hassler, M. (eds): Flora von Rhodos und Chalki, **1.** – Karlsruhe.

Rechinger, K. H. 1929: Beitrag zur Kenntnis der Flora der ägäischen Inseln und Ost-Griechenlands. – Ann. Naturhist. Mus. Wien **43:** 269-340 (+ 2 plates).

— 1949: Flora Aegaea. Flora der Inseln und Halbinseln des ägäischen Meeres. – Akad. Wiss. Wien, Math.-Naturwiss. Kl., Denkschr. **105(1):** i-xx + 1-924 + 25 plates + 3 maps.

Richards A. J., Biel B., Štěpánek J. & Kirschner J. 2015: *Taraxacum limnoticum* (*Asteraceae*) from the Aegean, Greece. – Phytol. Balcan. **21:** 149-154.

Rilke, S. (1999): Revision der Sektion *Salsola* s.l. der Gattung *Salsola* (*Chenopodiaceae*). – Bibl. Bot. **149:** 1-189.

Ristow, M. 2016: *Chenopodium* Linnaeus 1753. – Pp. 366–369 in: Kleinsteuber A., Ristow M. & Hassler M. (eds), Flora von Rhodos und Chalki, **1.** – Karlsruhe.

—, Krause, J. & Bergmeier E. 2021: *Saccharum spontaneum* L. – Pp. 360-361 in: Raab-Straube E. von & Raus Th. (eds), Euro+Med-Checklist Notulae, 14. – Willdenowia **51:** 355-368. https://doi.org/10.3372/wi.51.51304

Salas Pascual, M. & Verloove, F. 2019: *Opuntia microdasys* (Lehm.) Pfeiff. – P. 424 in: Raab-Straube E. von & Raus T. (ed.), Euro+Med-Checklist Notulae, 11 [Notulae ad floram euro-mediterraneam pertinentes No. 40]. – Willdenowia **49:** 421-445.

Scoppola, A. 2019: An annotated key to the species of *Gastridium* (*Poaceae*) with distributional novelties to the Italian territory. – Atti Soc. It. Sci. Nat. Museo Civ. Stor. Nat. Milano **6(2):** 29-36.

Snogerup, S. & Snogerup, B. 1993: Additions to the flora of Samos, Greece. – Fl. Medit. **3:** 211-222.

—, —, Phitos, D. & Kamari, G. 2001: The flora of Chios island (Greece). – Bot. Chron. (Patras) **14:** 5-197.

Strid A. 2016: Atlas of the Aegean flora. Part 1: Text & Plates. Part 2: Maps – Englera **33(1):** 1-700, **33(2):** 1-878**.**

Tan, K., Sfikas, G. & Vold, G. 2002: *Consolida arenaria* Carlström. – P. 203 in: Greuter, W. & Raus, T. (eds): Med-Checklist Notulae, 21. – Willdenowia **32:** 195-208.

—, — & — 2008a: Reports 99-104. – Pp. 146-147 in: Vladimirov, V., Dane, F. & Tan, K. (eds): New floristic records in the Balkans: **7**. – Phytol. Balcan. **14(1):** 131-148.

—, — & — 2008b: Reports 76–82. – Pp. 445-446 in: Vladimirov, V., Dane, F. & Tan, K. (eds): New floristic records in the Balkans: 9. – Phytol. Balcan. **14(3):** 429-451.

Telesca, L., Belluscio A., Criscoli A., Ardizzone G., Apostolaki E. T., Simonetta Fraschetti, S., Gristina M., Knittweis L., Martin, C. S., Pergent, G., Alagna A., Fabio Badalamenti F., Garofalo G., Gerakaris V., Pace, M. L., Pergent-Martini C. & Salomidi, M. 2015: Seagrass meadows (*Posidonia oceanica*) distribution and trajectories of change. – Sci. Rep. **5:** 12505 https://doi.org/10.1038/srep12505.

Thomas, K., Thanopoulos, R., Knüpffer, H. & Bebeli, P. J. 2012: Plant genetic resources of Lemnos (Greece), an isolated island in the Northern Aegean Sea, with emphasis on landraces. – Genet. Resour. Crop Evol. **59:** 1417-1440.

Turrill, W. B. 1922: A contribution to the flora of the Nearer East. – Bull. Misc. Inform. [**1922**](**9**)**:** 291-298.

Yannitsaros, A., Economidou, E., Delipetrou, P., Bazos, I. & Georghiou, K. 2000: New data on the distribution of some plant taxa in the Aegean area. – Pp. 118-121 in: Proceedings of the 8th Scientific Congress of the Greek Botanical Society. – Patras.

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Micromorphological study of some *Trifolium* taxa (*Fabaceae*) seeds from Greece and its systematic significance

Abstract

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Greece is considered a diversity center for the genus *Trifolium* L. (*Fabaceae*), which is represented in the country by 95 taxa. However, the classification of the genus may vary according to different taxonomic approaches. The current study aims to contribute to the study of the genus by describing the seed coat surface of 23 *Trifolium* taxa that were collected in various localities of southern Greece. The seeds were obtained from herbarium specimens and observed with Scanning Electron Microscope.

Key words: SEM, taxonomy, *Faboideae*, biosystematics.

Introduction

The genus *Trifolium* L. (*Fabaceae*) consists of approximately 255 species (Smýkal & al. 2015; Scoppola & al. 2018), distributed throughout the temperate and subtropical regions of the world, even though representatives of the genus can also be found restricted to the montane and alpine zones in the tropics of West Africa and South America (Zohary & Heller 1984). Greece, along with Anatolia, constitute a diversity center for the genus *Trifolium* (Zohary & Heller 1984), which is represented in the country by 95 taxa (species and subspecies), including 8 endemic ones (Dimopoulos & al. 2013). The number of *Trifolium* taxa frequently varies among the authors depending on their taxonomical approach, the progress of botanical explorations and the increase of systematic and evolutionary studies (Samaropoulou & al. 2019).

Trifolium taxa in Greece occur in various types of natural, semi-natural and anthropogenic habitats, generally at places that are exposed to high solar radiation (Ellison & al. 2006; Samaropoulou & al. 2019).

A significant number of publications are dealing with the seed coat morphological and micromorphological characteristics of various families and their systematic implications. Among the first relative studies concerning genera of the *Fabaceae* include those of Lersten (1979, 1981), Lersten & Gunn (1982), Manning & van Staden (1987) and Small & al. (1990).

In the framework of the revision of the genus *Trifolium*, Zohary & Heller (1984) examined the seed coat surface of 24 species, providing relative SEM photographs for 8 of them and they described 5 different types of seed coat patterns. According to Pinar & al. (2001) diploid and tetraploid forms of *Trifolium pratense* L. can be distinguished by their seed coat ornamentation. Taia (2004) examined eight *Trifolium* species and recognised three seed coat patterns, while Salimpour & al. (2007) studied the seed morphology of seven *Trifolium* taxa from Iran. Zorić & al. (2010) studied 38 *Trifolium* species and separated them into eight groups based on seed coat morphological characters.

However, the study of seed characteristics of this taxonomically, ecologically and economically important genus remains incomplete especially concerning Greek taxa. The present study aims to contribute to the taxonomy of the genus *Trifolium* by describing the seed coat surface patterns of 23 taxa from Greek populations.

Materials and Methods

Material was obtained from herbarium specimens collected by the first author from various localities of southern Greece and deposited in ACA (Table 1). The seeds were put directly onto carbon adhesive discs on aluminum stubs and sputter coated with approximately 25 nm of gold. The observation was carried out with a FEI Quanta Inspect SEM and it took place in the Electron Microscopy and Nanomaterials Laboratory, Department of Materials Science, Demokritos Institute. At least 15 seeds of each taxon were analysed and seed length and width, aspect ratio (L/W), shape and coat surface are given.

The determination of the seed shape follows Zorić & al. (2010) and takes into consideration aspect ratio and the length of the radical lobe. Seeds are characterised as round (aspect ratio up to 1.19), ovoid (aspect ratio 1.20-1.39), elongated-ovoid (aspect ratio more than 1.40) and, in the case of the radicle lobe being very prominent, heart-shaped.

The terminology of the coat surface follows Lersten (1981), Lersten & Gunn (1982), Manning & van Staden (1987) and Small & al. (1990).

Results and Discussion

The present study examines the seed micromorphological features in 23 taxa of the genus *Trifolium* including representatives from the major sections with Mediterranean floristic elements. Seed morphometric characters, shape and coat pattern is reported for the first time for 10 species, among them, the Greek endemic *Trifolium aurantiacum*. At least x5000 magnification is required in order to obtain a precise idea of the seed surface micromorphology and avoid inconsistencies among various reports concerning the same species. As mentioned by Lersten (1979), seeds of most *Fabaceae* are smooth and featureless at low magnification. The seed coat surface micromorphology of the examined taxa is demonstrated in Figs 1-6.

The seeds of the studied taxa vary in size from 0.8803 mm to 2.3333 mm in length and from 0.6092 mm to 1.9245 mm in width. Although *Trifolium subterraneum* has the largest seed dimensions measured, its aspect ratio is one of the smallest ones (1.1458). However,

Table 1. List of examined taxa.

Taxon	**Locality**	**Voucher No**
Trifolium angustifolium L.	Attiki, Mt. Pendelikon, hills N of Dionisovouni summit, near the chapel of Agios Ioannis, road margins, 490 m, 4 Jun 2018	12929
Trifolium arvense L.	Attiki, municipality of Thrakomakedones, ca. 1 km ESE of the monastery of Kimiseos Theotokou, recently burnt *Pinus halepensis* Mill. forest, coarse-grained fluviolacustrine formations on Parnitha piedmont, 350 m, 4 May 2018	12908
Trifolium aurantiacum Boiss. & Spruner	Peloponnisos, Mt. Aphrodisio, ca. 0.5 km SE of Dechouni village, *Quercus coccifera* L. scrub, limestones, 850 m, 24 May 2013	8154
Trifolium boissieri Guss.	Kiklades, the island of Kea, path margins on the way to Karthaia archaeological site, 50 m, 27 May 2018	12680
Trifolium campestre Schreb.	Attiki, municipality of Thrakomakedones, ca. 1 km ESE of the monastery of Kimiseos Theotokou, recently burnt *Pinus halepensis* Mill. forest, coarse-grained fluviolacustrine formations on Parnitha piedmont, 350 m, 4 May 2018	12906
Trifolium cherleri L.	Peloponnisos, Mt. Aphrodisio, ca. 1 km S of Nasia village, forest roadsides, 700-800 m, 26 May 2013	8699
Trifolium fragiferum L.	Attiki, Stamata village, near the chapel of Agia Paraskevi, damp places by *Platanus orientalis* L. stream, 350 m. 12 Jul 2007	4000
Trifolium glomeratum L.	Peloponnisos, Mt. Aphrodisio, ca. 1 Km S of Nasia village, *Quercus frainetto* Ten. forest and roadsides, radiolarites, 700-800 m, 26 May 2013	8749
Trifolium grandiflorum Schreb.	Kiklades, the island of Kea, path margins on the way to Karthaia archaeological site, 20-100 m, 27 May 2018	12678
Trifolium hirtum All.	Attiki, Mt. Pendelikon, in the locality Chrisouli Rachi, schistose slopes with phrygana, 650 m, 19 May 2002	858
Trifolium lappaceum L.	Peloponnisos, Mt. Aphrodisio, between Kondovazena and the crossroad to Peleki village, damp places by the roadsides, 650 m, 25 May 2013	8567
Trifolium leucanthum M. Bieb.	Peloponnisos, Mt. Aphrodisio, ca. 1 km S of Nasia village, forest roadsides, 700-800 m, 26 May 2013	8698
Trifolium nigrescens Viv.	Kiklades, the island of Kea, path margins on the way to Karthaia archaeological site, 20-100 m, 27 May 2018	12682
Trifolium patens Schreb.	Peloponnisos, Mt. Aphrodisio, between Dafni and the crossroad to Nasia, roadsides, 550-600 m, 26 May 2013	8645
Trifolium physodes M. Bieb.	Attiki, Mt. Pendelikon, near the water tanks of Dionisos municipality, path margins in densely regenerated *Pinus halepensis* Mill. forest, 550 m, 3 Jun 2007	3773
Trifolium pignantii Fauché & Chaub.	Peloponnisos, Mt. Aphrodisio, between Pera Vachlia village and the dam of Ladona lake, *Quercus frainetto* Ten. forest, mainly radiolarites, 500 m, 25 May 2013	8633
Trifolium repens L.	Peloponnisos, Mt. Aphrodisio, Dechouneika village, 620 m, walnut orchard, 620 m, 24 May 2013	8066
Trifolium resupinatum L. **subsp. *resupinatum***	Peloponnisos, Mt. Aphrodisio, between Dafni and the crossroad to Nasia village, roadsides, 550-600 m, 26 May 2013	8673
Trifolium stellatum L.	Peloponnisos, Mt. Aphrodisio, ca. 0.5 km SE of Dechouni village, forest roadsides, 850 m, 24 May 2013	8164

Table 1. continued.

Trifolium striatum L.	Peloponnisos, Mt. Aphrodisio, between Dechouneika village and the sanctuary of Aphrodite, road cuttings, 800 m, 26 May 2013	8822
Trifolium subterraneum L.	Peloponnisos, Mt. Aphrodisio, ca. 1 Km S of Nasia village, forest roadsides, 700-800 m, 26 May 2013	8755
Trifolium suffocatum L.	Attiki, Mt. Pendelikon, northern slopes of Megali Mavrinora, sparse *Quercus coccifera* L. scrub, marbles, 550 m, 14 May 2008	4195
Trifolium tomentosum L.	Attiki, NW part of Mt. Pendelikon, path margins near the chapel of Profitis Ilias, 550 m, 10 May 2003	1378

the smallest value of aspect ratio (1.1206) are observed in *T. suffocatum*. The longest seeds are observed in *T. stellatum* (2.3333 mm) which has one of the biggest aspect ratio (1.5908), forming elongated-ovoid seeds, while the most elongated seeds belong to *T. cherleri* (aspect ratio 1.6243). Both *T. repens* and *T. subterraneum* are characterised by a small aspect ratio with a prominent radical lobe, which makes them heart shaped (Fig. 5A1 and Fig. 6A1 respectively).

The main types of seed surface patterns recognised are the following: foveolate, reticulate, papillose, rugulate (rugose). Patterns with mixed characters also exist (Table 2).

One of the most common patterns observed is the "foveolate". However, this pattern is very diversified and, in some cases, obscured, observed only at a higher magnification. Each of the species belonging to this group of "foveolate" has a distinctive micromorphology. *T. arvense* and *T. nigrescens* exhibit the highest similarity in their seed coat surface characteristics. Together with *T. grandiflorum* they constitute a quite homogeneous subgroup within this type of pattern. The similarities of the aforementioned taxa though, are not justified by their affinities, as proposed by various infrageneric classifications. They are distantly related, as they belong to different sections as defined by Zohary & Heller (1984).

T. hirtum, *T. pignantii* and *T. angustifolium* constitute another subgroup within this type of pattern. These species belong to the same section, but in different subsections (Zohary & Heller 1984). In addition, seed coat surface of *T. hirtum* and *T. pignantii* exhibits many similarities with the one presented in Zohary & Heller (1984) for *Trifolium microcephalum* Pursh, even though the latter species is native to western North America and belongs to section Involucrarium Hook., which includes only American species (Zohary & Heller 1984).

T. hirtum and *T. cherleri* are closely related taxa, but they have very distinct seed coat patterns and they are easily distinguished based on this criterion. The same also applies for *Trifolium repens* and *T. nigrescens*.

On the other hand, the similarities observed in the seed coat surface of *T. tomentosum* and *T. physodes* justify their affinities proposed by classical methods.

T. aurantiacum, which is considered a Greek endemic (Dimopoulos & al. 2013), has a peculiar pattern. The papillae of the seed surface are obscurely discerned owning to the overlying cuticular reticulum.

Some unusual micromorphological features that are observed in the examined species enhance the deviation from the patterns which have been described by now and increase considerably their diversity. These features are a criterion to distinct the investigated taxa

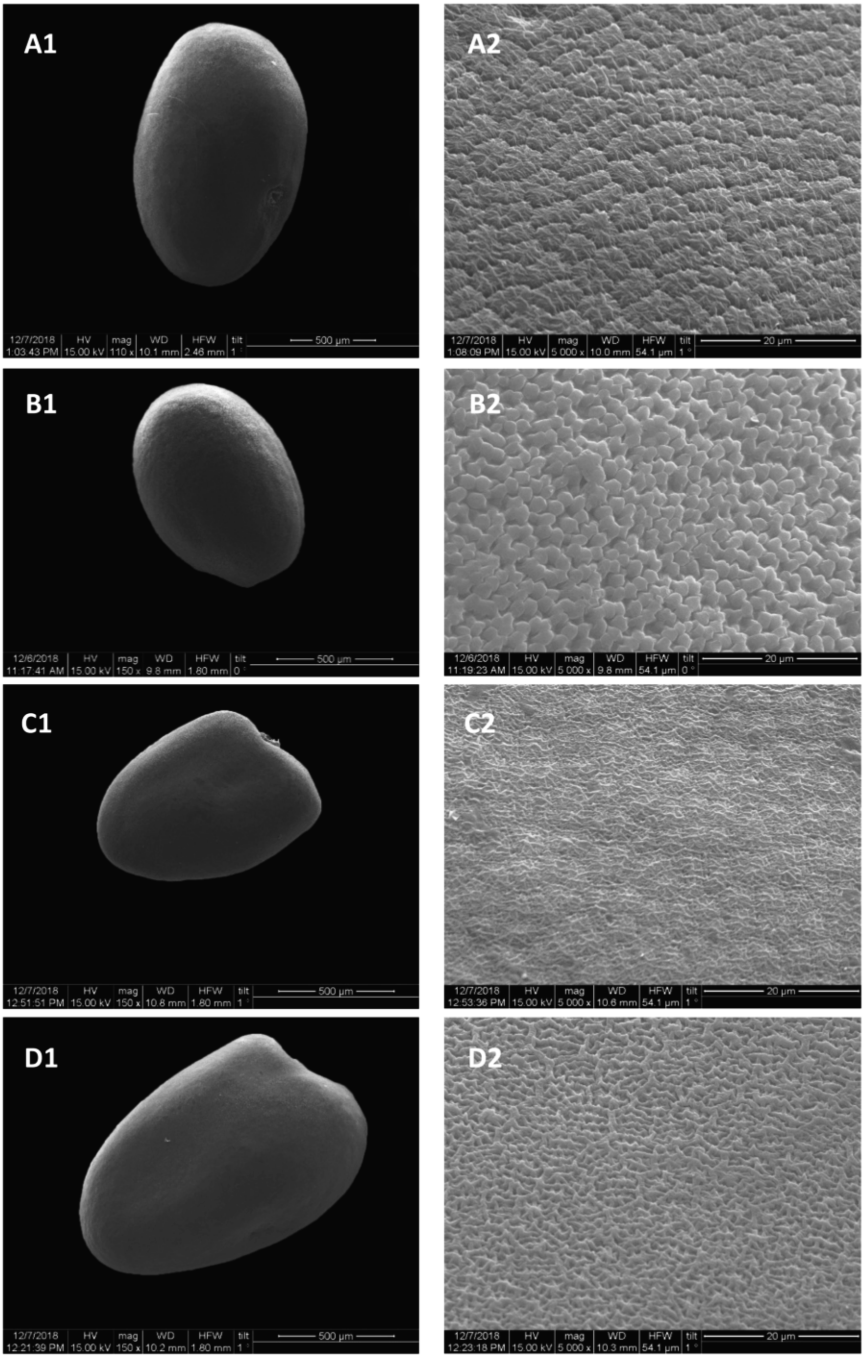

Fig. 1. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium angustifolium*; B) *T. arvense*; C) *T. aurantiacum*; D) *T. boissieri*.

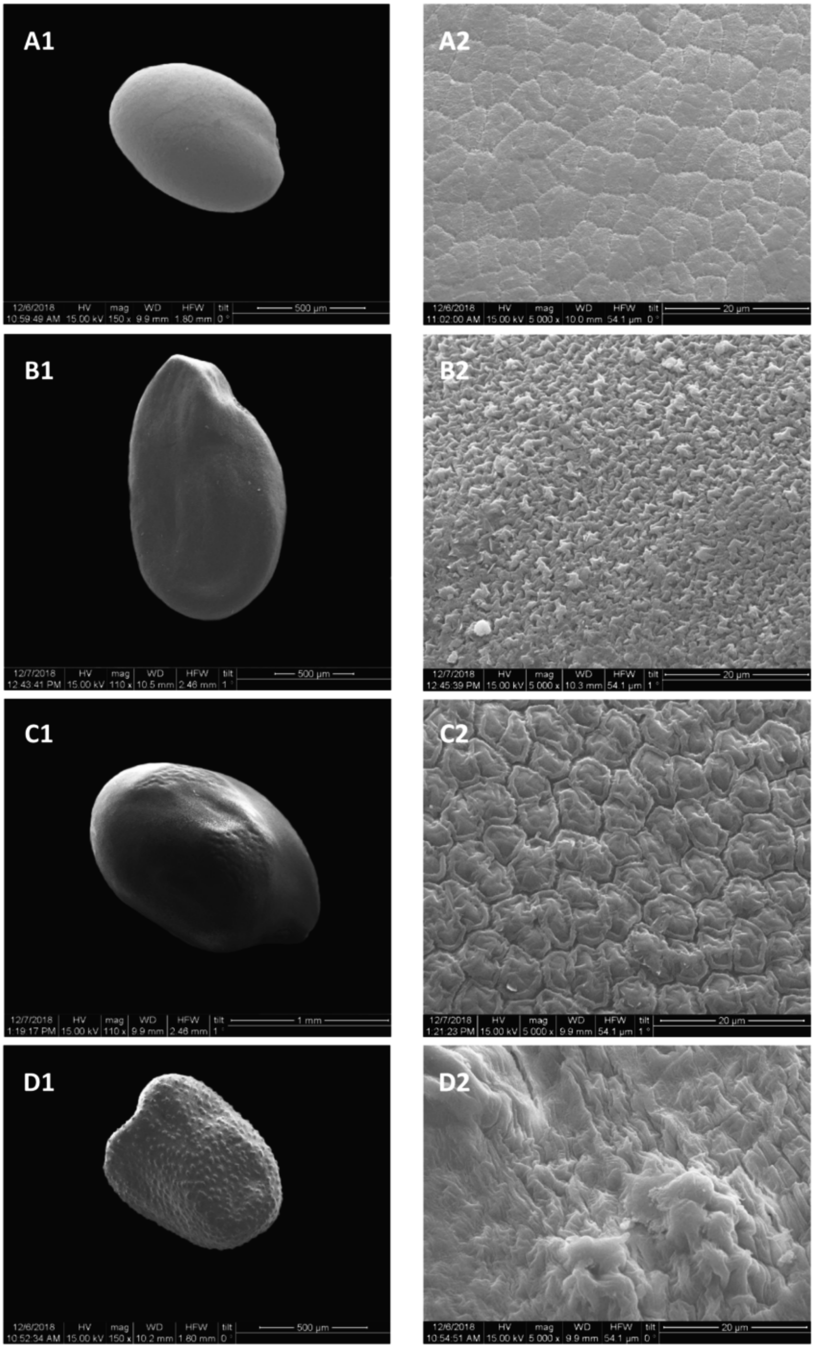

Fig. 2. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium campestre*; B) *T. cherleri*; C) *T. fragiferum*; D) *T. glomeratum*.

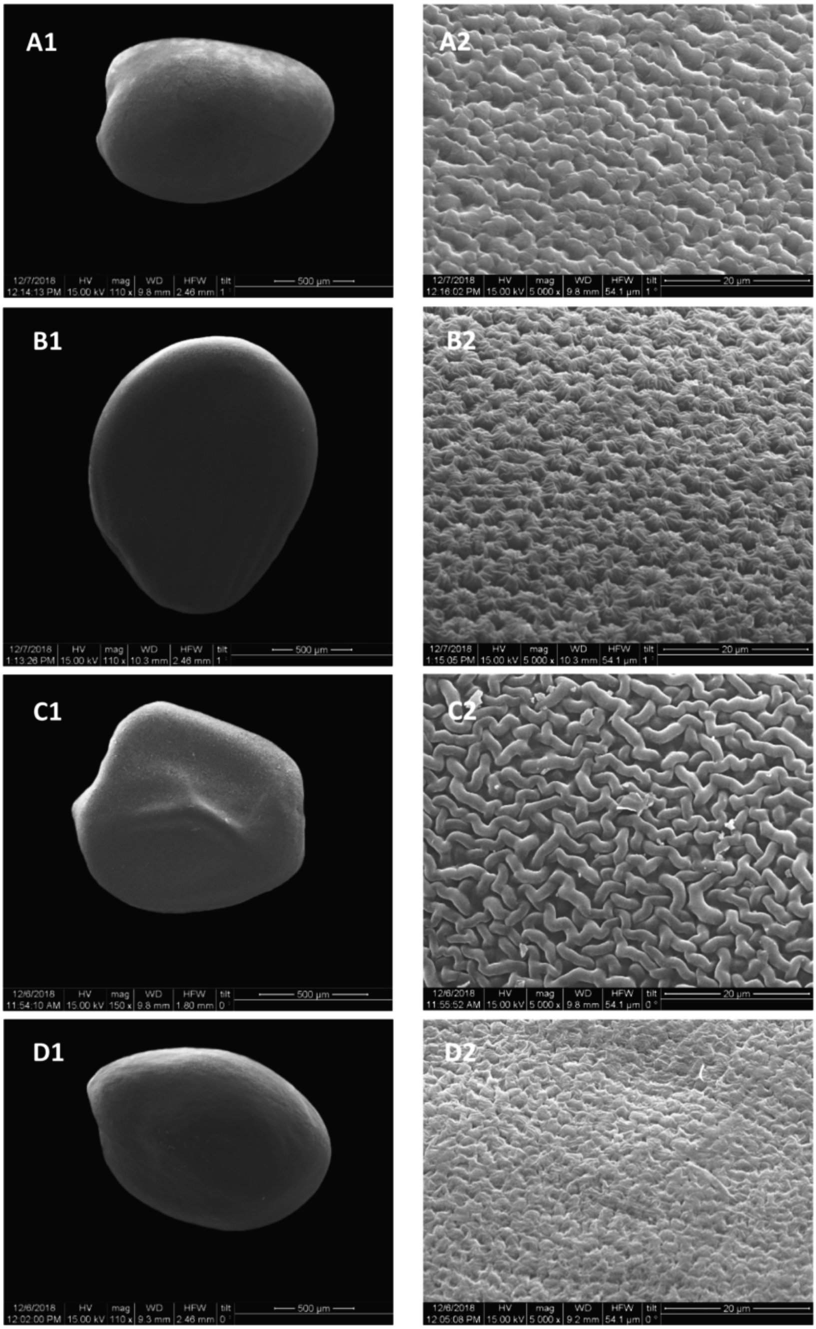

Fig. 3. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium grandiflorum*; B) *T. hirtum*; C) *T. lappaceum*; D) *T. leucanthum*.

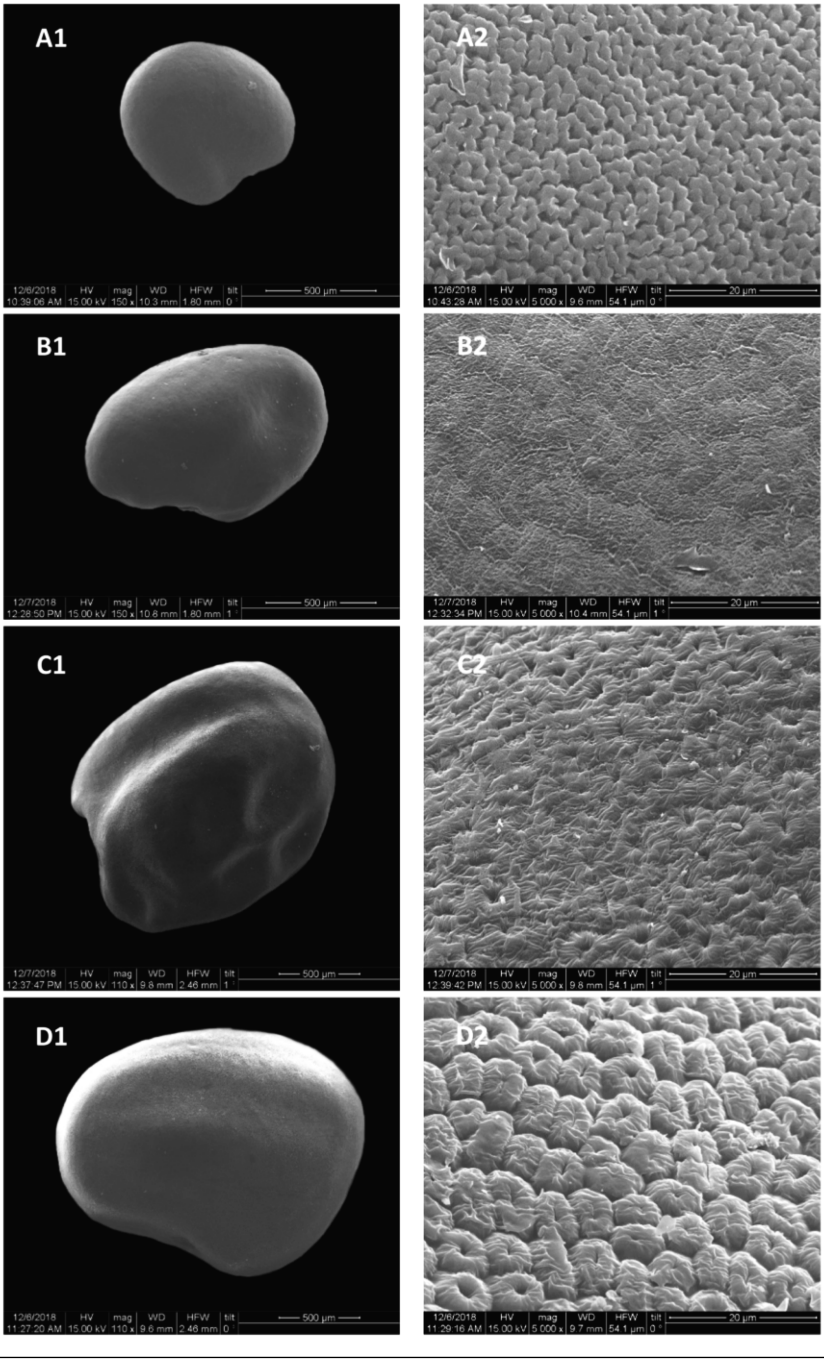

Fig. 4. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium nigrescens*; B) *T. patens*; C) *T. physodes*; D) *T. pignantii*.

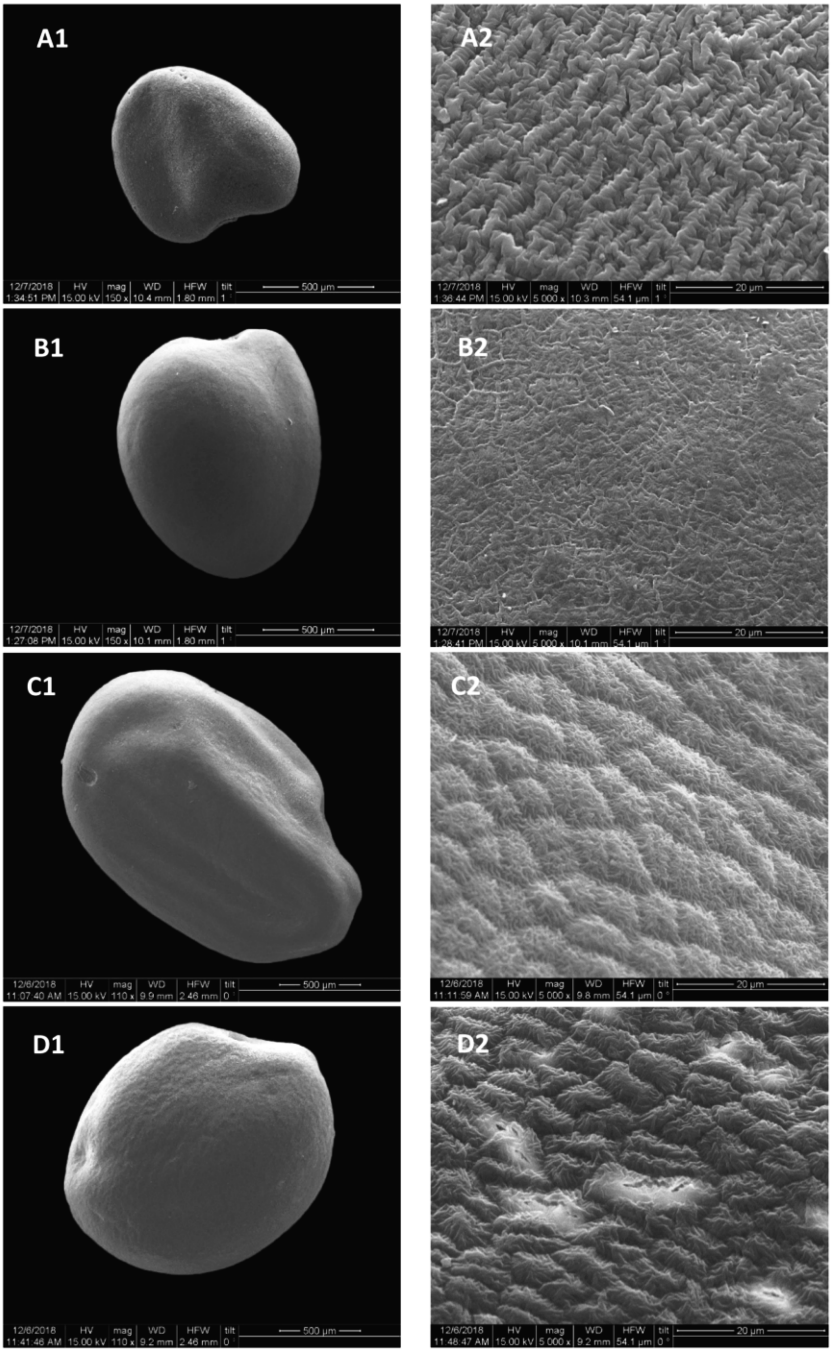

Fig. 5. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium repens*; B) *T. resupinatum* subsp. *resupinatum*; C) *T. stellatum*; D) *T. striatum*.

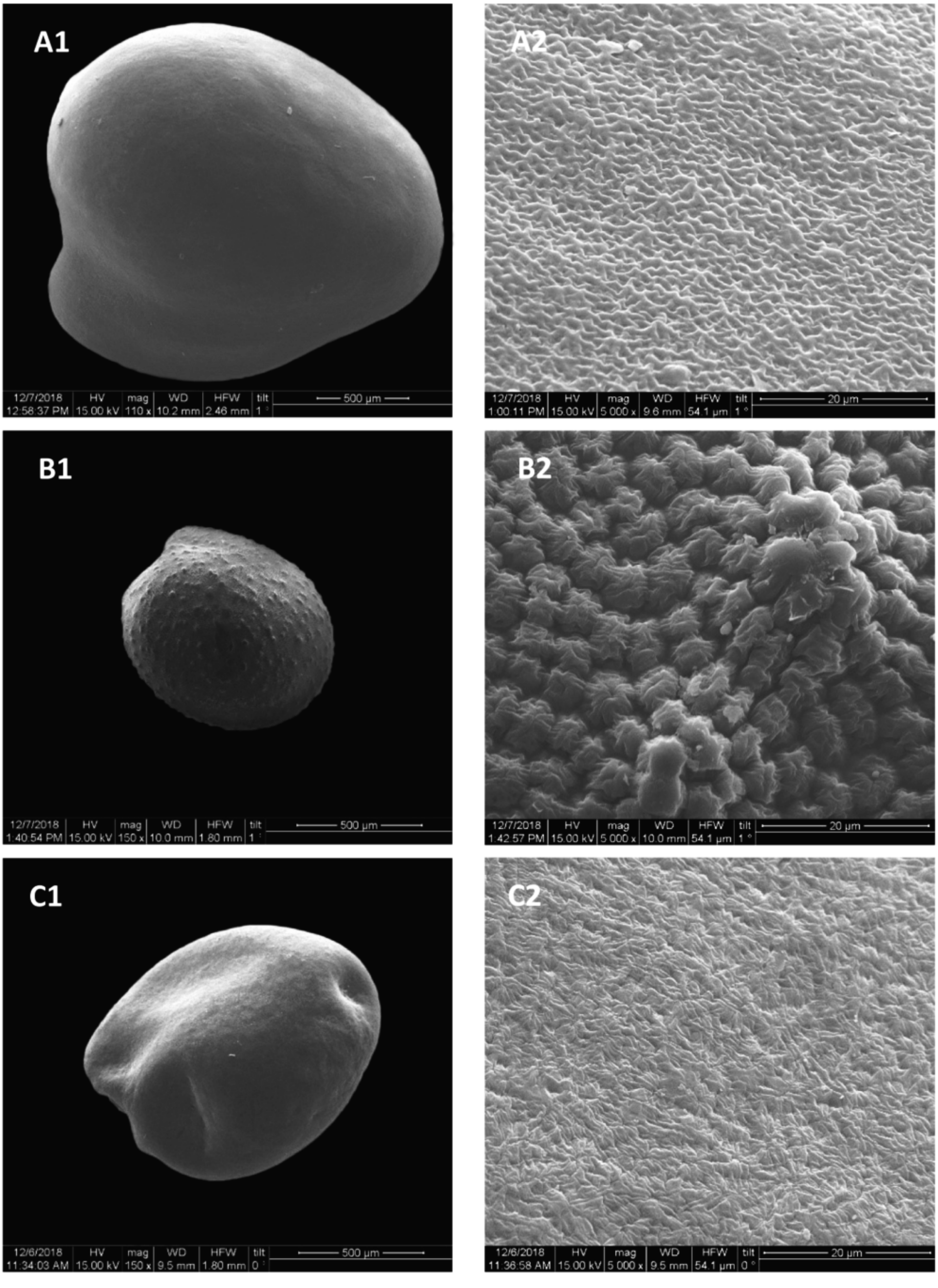

Fig. 6. 1. Seed overview; 2. seed coat surface micromorphology of: A) *Trifolium subterraneum*; B) *T. suffocatum*; C) *T. tomentosum.*

Table 2. Seed characters of *Trifolium* species. The mean value of length and width in mm is given along with standard deviation (SD). Taxa studied for the first time are indicated with an asterisk (*).

Taxon	**Length (SD)**	**Width (SD)**	**Aspect ratio (L/W)**	**Seed shape**	**Seed coat surface**
T. angustifolium	1.4881 (0.0894)	1.0127 (0.0304)	1.4695	Elongated-ovoid	Foveolate (obscurely)
T. arvense	0.9053 (0.0171)	0.6388 (0.0422)	1.4172	Elongated-ovoid	Foveolate
**T. aurantiacum*	0.9596 (0.0792)	0.6793 (0.0649)	1.4126	Elongated-ovoid	Low papillose with overlying cuticular reticulum
**T. boissieri*	0.9044 (0.1281)	0.7666 (0.1476)	1.1798	Round	Multi-reticulate
T. campestre	0.8904 (0.0263)	0.6092 (0.0085)	1.4616	Elongated-ovoid	Foveolate (obscurely)
**T. cherleri*	1.6133 (0.0812)	0.9932 (0.0154)	1.6243	Elongated-ovoid	Rugulate
T. fragiferum	1.6157 (0.0209)	1.2723 (0.0714)	1.2699	Ovoid	Papillose (irregular)
T. glomeratum	0.8803 (0.0238)	0.6580 (0.0662)	1.3379	Ovoid	Obscure papillose with mounds
**T. grandiflorum*	1.5655 (0.0547)	1.0788 (0.0366)	1.4512	Elongated-ovoid	Foveolate
**T. hirtum*	1.8361 (0.0654)	1.3965 (0.0860)	1.3148	Ovoid	Foveolate
**T. lappaceum*	1.1338 (0.0802)	0.9510 (0.0513)	1.1922	Round	Multi-reticulate
**T. leucanthum*	1.6018 (0.0669)	1.1429 (1.1022)	1.4015	Elongated-ovoid	Foveolate (obscurely)
T. nigrescens	1.3766 (0.1055)	0.8812 (0.0621)	1.5622	Elongated-ovoid	Foveolate
T. patens	1.0812 (0.0294)	0.7711 (0.0581)	1.4022	Elongated-ovoid	Rugulate - reticulate
**T. physodes*	1.7731 (1.1502)	1.5123 (0.0794)	1.1724	Round	Foveolate
**T. pignantii*	1.9324 (0.0439)	1.5643 (0.0931)	1.2353	Ovoid	Foveolate
T. repens	0.8828 (0.0002)	0.7559 (0.0012)	1.1679	Heart shaped	Rugulate
T. resupinatum subsp. *resupinatum*	1.1339 (0.0223)	0.9162 (0.0445)	1.2376	Ovoid	Reticulate - obscurely foveolate
T. stellatum	2.3333 (0.1227)	1.4667 (0.1084)	1.5908	Elongated-ovoid	Papillose - rugose
T. striatum	1.7557 (0.0451)	1.4042 (0.0553)	1.2503	Ovoid	Papillose-rugose
T. subterraneum	2.2052 (0.1991)	1.9245 (0.0752)	1.1458	Heart shaped	Multi-reticulate
**T. suffocatum*	0.8948 (0.0669)	0.7985 (0.0383)	1.1206	Round	Papillose with mounds
T. tomentosum	1.2204 (0.0455)	0.9417 (0.0629)	1.2960	Ovoid	Foveolate (obscurely)

and may be proved useful for delimiting taxa with dubious status at species rank that have not been examined yet. Examining more species will enable us to reassess these patterns and to describe new ones.

The general appearance of the seed surface at low magnification (43× and 150×) is tuberculate for *T. suffocatum* and *T. glomeratum* and smooth for the rest of the examined taxa. Thus, the examined species display two of the three relevant patterns found by Small & al. (1990) in the genus *Medicago* L.

There is a remarkable diversity in seed surface micromorphology of the examined species and each one has unique features making their classification a difficult task. As a result, seed surface characteristics are very suitable for the delimitation of taxa at species rank. According to the present study, seed micromorphological characters proved to be very useful for the delimitation and identification of the examined species, but generally the recognised patterns cannot support current taxonomic approaches at higher ranks. This is in agreement with the conclusions of other studies, such as Zohary & Heller (1984) and Zorić & al. (2010). However, there are some cases that infrageneric classification is supported by evidences derived from seed coat patterns. Thus, taxonomic implications of seed surface characters at ranks higher than species concern only some groups of species. Seed coat patterns cannot also support phylogenetic hypotheses nor do they reveal broader evolutionary trends as already stated by Lersten (1981).

The study will continue focusing mainly in pairs of taxa with dubious taxonomic status. Furthermore, the examination of more taxa will allow us to conduct the appropriate statistical analysis and draw broader conclusions. A more holistic approach of the study of the seed morphology and especially coat surface and its patterns will take into consideration not only its taxonomic and evolutionary significance, but its ecological-functional one too.

References

Dimopoulos, P., Raus, Th., Bergmeier, E., Constantinidis, Th., Iatrou, G., Kokkini, S., Strid, A. & Tzanoudakis, D. (eds) 2013: Vascular plants of Greece: An annotated checklist. – Berlin & Athens.

Ellison, N. W., Liston, A., Steiner, J. J., Williams, W. M. & Taylor, N. L. 2006: Molecular phylogenetics of the clover genus (*Trifolium-Leguminosae*). – Molec. Phylogen. Evol. **39:** 688-705. http://dx.doi.org/10.1016/j.ympev.2006.01.004

Lersten, N. R. 1979: A distinctive seed coat pattern in the *Vicieae* (*Papilionoideae*; *Leguminosae*). – Proc. Iowa Acad. Sci. **86(3):** 102-104.

— 1981: Testa topography in *Leguminosae*, subfamily *Papilionoideae*. – Proc. Iowa Acad. Sci. **88(4):** 180-191.

— & Gunn, C. R. 1982: Testa characters in tribe *Vicieae*, with notes about tribes *Abreae*, *Cicereae*, and *Trifolieae* (*Fabaceae*). – Agric. Res. Serv. U.S.D.A. Technical Bull. No. 1667.

Manning, J. C. & van Staden, J. 1987: The systematic significance of testa anatomy in the *Leguminosae* – an illustrated survey. – S. African J. Bot. **53(3):** 210-230.

Pinar, N. M., Büyükkartal, H. N. & Çölgeçen, H. 2001: Pollen and seed morphology of diploids and natural tetraploids of *Trifolium pratense* L. (*Leguminosae*). – Acta Biol. Cracov., Ser. Bot. **43:** 27-32.

Salimpour, F., Mostafavi, G. & Sharifnia, F. 2007: Micromorphologic study of the seed of the genus *Trifolium*, section *Lotoidea*, in Iran. – Pakistan J. Biol. Sci. **10(3):** 378-382. http://dx.doi.org/10.3923/pjbs.2007.378.382

Samaropoulou, S., Baliousis, E. & Bareka, P. 2019: Karyological study of eight *Trifolium* L. taxa from Greece. – Bot. Chron. **22:** 159-170.

Scoppola, A., López Tirado, J., Manzano Gutiérrez, F. & Magrini, S. 2018: The genus *Trifolium* (*Fabaceae*) in south Europe: a critical review on species richness and distribution. – Nord. J. Bot. **36**: http://dx.doi.org/10.1111/njb.01723

Small, E., Brookes, B. & Lassen, P. 1990: Circumscription of the genus *Medicago* (*Leguminosae*) by seed characters. – Canad. J. Bot. **68:** 613-629.

Smýkal, P., Coyne, C. J., Ambrose, M. J., Maxted, N., Schaefer, H., Blair, M. W., Berger, J., Greene, S. L., Nelson, M. N., Besharat, N., Vymyslický, T., Toker, C., Saxena, R. K., Roorkiwal, M., Pandey, M. K., Hu, J., Li, Y. H., Wang, L. X., Guo, Y., Qiu, L. J., Redden, R. J. & Varshney, R. K. 2015: Legume Crops Phylogeny and Genetic Diversity for Science and Breeding. – Crit. Rev. Pl. Sci. **34:** 43-104. https://doi.org/10.1080/07352689.2014.897904

Taia, W. K. 2004: Tribe *Trifolieae*: Evidence from seed characters. – Pakistan J. Biol. Sci. **7(7):** 1287-1302.

Zohary, M. & Heller, D. 1984: The Genus *Trifolium*. – Jerusalem.

Zorić, L., Merkulov, L., Luković, J. & Boža, P. 2010: Comparative seed morphology of *Trifolium* L. species (*Fabaceae*). – Period. Biol. **112(3):** 263-272.

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Mediterranean plant germination reports – 3

edited by Sara Magrini & Cristina Salmeri

Abstract

Magrini, S. & Salmeri, C. (eds): Mediterranean plant germination reports – 3. — Fl. Medit. 31: 261-333. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

This is the third issue of the series of germination reports from Mediterranean areas (sensu Med-Checklist). It comprises germination protocols for 40 taxa: *Teucrium* from Sardinia by M. Porceddu & al. (Nos. 46-47); *Campanula* from North Italy by S. Villa & al. (No. 48); *Anacamptis* from Greece by S. Oikonomidis & C. A. Thanos. (No. 49); *Astragalus*, *Iris*, *Jacobaea*, and *Klasea* from central Italy by V. Di Cecco & al. (No. 50-53); *Drimia*, *Periploca*, *Asparagus*, *Myrtus*, and *Pancratium* from Malta by J. Buhagiar & al. (Nos. 54-58); *Thymus* from Sicily by G. Gugliuzza & al. (No. 59); *Agrostemma*, *Bupleurum*, and *Xeranthemum* from North Italy by A. Cucchietti & al. (Nos. 60-62); *Salsola* from Sicily and Central Italy by S. Magrini & al. (Nos. 63-65); *Physoplexis*, *Primula*, and *Spiranthes* from North Italy by S. Pierce & al. (Nos. 66-69); *Euphorbia* from Sicily by F. Carruggio & al. (Nos. 70-74); *Helichrysum* from Sicily by C. Salmeri & C. Brullo (Nos. 75-85).

Editorial

This third issue of the series of germination reports from Mediterranean areas (sensu Med-Checklist) comprises eleven contributions reporting germination protocols for 40 taxa from Greece, Italy, Malta, Sardinia, and Sicily, among them twenty endemics.

In the first report, Porceddu & al. (2021, Nos. 46-47) reported germination data for two species of the genus *Teucrium* from Sardinia, *T. massiliense* L. and *T. flavum* subsp. *glaucum* (Jord. & Fourr.) Ronniger (*Lamiaceae*).

Two contributions are focused on eight species listed in Annexes II and IV of the EU Habitats Directive. In particular, Pierce & al. (2021, Nos. 66-69) reported germination protocols for four species from Lombardy, North Italy: *Physoplexis comosa* (L.) Schur (*Campanulaceae*), *Primula glaucescens* Moretti and *P. spectabilis* Tratt. (*Primulaceae*), and *Spiranthes aestivalis* (Poir.) Rich. (*Orchidaceae*). Di Cecco & al. (2021, Nos. 50-53) reported germination protocols of four policy species from Abruzzo, central Italy: *Jacobaea vulgaris* subsp. *gotlandica* (Neuman) B. Nord., *Klasea lycopifolia* (Vill.) Á.

Löve & D. Löve. (*Asteraceae*) , and two endemic species, *Astragalus aquilanus* Anzal. (*Fabaceae*) and *Iris marsica* I. Ricci & Colas. (*Iridaceae*).

Two other contributions are focused on plants from North Italy, reporting germination protocols for four taxa. Germination data for *Campanula raineri* Perp. (*Campanulaceae*), a stenoendemic chasmophyte of the Italian calcareous Prealps, are reported by Villa & al. (2021, No. 48). Cucchietti & al. (2021, Nos. 60-62) reported the germination requirements of seeds of three segetal plant species collected in the Italian Western Alps, Piedmont: *Agrostemma githago* L. (*Caryophyllaceae*), *Bupleurum rotundifolium* L. (*Apiaceae*), and *Xeranthemum inapertum* (L.) Mill. (*Asteraceae*).

Oikonomidis & Thanos (2021, No. 49) successfully tested several media to improve asymbiotic germination performance in seeds of *Anacamptis sancta* (L.) R.M. Bateman, Pridgeon & M.W. Chase (*Orchidaceae*) from Greece.

Buhagiar & al. (2021, Nos. 54-58) described germination protocols for five species of the Maltese Islands, predominantly occurring in coastal garrigue habitats: *Drimia maritima* (L.) Stearn (*Asparagaceae*), *Periploca angustifolia* Labill. (*Apocynaceae*), *Asparagus aphyllus* L. (*Asparagaceae*), *Myrtus communis* L. (*Myrtaceae*), and *Pancratium maritimum* L. (*Amaryllidaceae*).

Germination protocols for 18 other taxa from Sicily are reported in: Gugliuzza & al. (2021, No. 59) which provide the first germination reports for *Thymus richardii* subsp. *nitidus* (Guss.) Jalas (*Lamiaceae*), endemic to Marettimo; Carruggio & al. (2021, Nos. 70-74), where the germination behaviour of five *Euphorbia* species is described, i. e. *E. hirsuta* L., *E. platyphyllos* L., and the endemic *E. ceratocarpa* Ten., *E. gasparrinii* Boiss. subsp. *gasparrinii*, and *E. meuselii* Geltman (*Euphorbiaceae*); Salmeri & Brullo (2021, Nos. 75-85) reported germination data for 11 endemic *Helichrysum* (*Asteraceae*) from Sicily: *H. archimedeum* C. Brullo & Brullo ex Greuter, *H. errerae* Tineo, *H. hyblaeum* Brullo, *H. italicum* subsp. *siculum* (Jord. & Fourr.) Galbany, L. Sáez & Benedí, *H. litoreum* Guss., *H. nebrodense* Heldr., *H. panormitanum* Tineo ex Guss. subsp. *panormitanum*, *H. panormitanum* subsp. *messeriae* (Pignatti) C. Brullo & Brullo, *H. panormitanum* var. *stramineum* (Guss.) Raimondo, *H. preslianum* C. Brullo & Brullo subsp. *compactum* (Guss.) Guarino & Ilardi, *H. stoechas* (L.) Moench, while Magrini & al. (2021, Nos. 63-65) reported germination data for *Salsola soda* L. from Sicily, together with other two halophytes from Central Italy: *Salsola squarrosa* subsp. *controversa* (Tod. ex Lojac.) Mosyakin and *S. tragus* L. subsp. *tragus* (*Amaranthaceae*).

The “Mediterranean plant germination reports” column is becoming a useful tool for researchers, conservationists, botanists, and other specialists, providing species-specific information on the pre-treatments and key factors to enhance germination of native seeds. Moreover, these germination data will flow into an online, open-access database managed by the RIBES association to make them available to a wider audience.

For the preparation of the manuscript, please, follow the general instructions for the authors of *Flora Mediterranea* (http://www.herbmedit.org/guide.html) and the specific instructions for the *Mediterranean plant germination reports* (Magrini & Salmeri 2019; https://www.herbmedit.org/flora/FL29_269-271.pdf). Authors are invited to submit by e-mail their manuscripts in English to one of the editors.

References

Buhagiar, J. A., Lamoliere, A. & Iannaccone, M. 2021: Seed germination reports for coastal and inland garrigue species from the Maltese Islands. – Fl. Medit. **31:** 283-290. http://dx.doi.org/10.7320/FlMedit31.283

Carruggio, F., Impelluso, C., Castrogiovanni, M. & Cristaudo, A. 2021: Germination behavior in some Sicilian species of *Euphorbia*. – Fl. Medit. **31:** 315-321. http://dx.doi.org/10.7320/FlMedit31.315

Cucchietti, A., Lonati, M., Gallino, B., Carasso, V. & Mucciarelli, M. 2021: Germination requirements of three segetal species of the Italian flora. – Fl. Medit. **31:** 294-298. http://dx.doi.org/10.7320/FlMedit31.294

Di Cecco, V., Frattaroli, A. R., Di Musciano, M., Di Santo, M. & Di Martino, L. 2021: Seed germination reports for Policy species in central Apennines. – Fl. Medit. **31:** 277-282. http://dx.doi.org/10.7320/FlMedit31.277

Gugliuzza, G., Domina, G. & Giovino, A. 2021: Seed germination of *Thymus richardii* subsp. *nitidus* (*Lamiaceae*). – Fl. Medit. **31:** 291-293. http://dx.doi.org/10.7320/FlMedit31.291

Magrini, S. & Salmeri, C. (eds) 2019: Mediterranean plant germination reports – 1. – Fl. Medit. **29:** 269-306. http://dx.doi.org/10.7320/FlMedit29.269

—, Alonso Simón, A., Zucconi, L. & Cristaudo, A. 2021: Seed germination protocols for the genus *Salsola* (*Amaranthaceae*) in Italy. – Fl. Medit. **31:** 299-304. http://dx.doi.org/10.7320/FlMedit31.299

Oikonomidis, S. & Thanos, C. A. 2021: Germination of *Anacamptis sancta* (*Orchidaceae*) in nutrient media, water agar and various light regime. – Fl. Medit. **31:** 271-276. http://dx.doi.org/10.7320/FlMedit31.271

Pierce, S., Bellingardi, J., Villa, S., Ferrario, A., Armiraglio, S., Cerabolini, B. E. L. & Ceriani, R. M. 2021: Seed germination protocols for four species of the EU Habitats Directive from northern Italy. – Fl. Medit. **31:** 305-314. http://dx.doi.org/10.7320/FlMedit31.305

Porceddu, M., Barros Torres, S. & Bacchetta, G. 2021: Seed germination reports for *Teucrium massiliense* and *T. flavum* subsp. *glaucum* (*Lamiaceae*).– Fl. Medit. **31:** 264-266. http://dx.doi.org/10.7320/FlMedit31.264

Salmeri, C. & Brullo C. 2021: Seed germination reports for Sicilian endemic taxa of the genus *Helichrysum* (*Asteraceae).* – Fl. Medit. **31:** 322-333. http://dx.doi.org/10.7320/FlMedit31.322

Villa, S., Ceriani, R. M., Cerabolini B. E. L. & Pierce, S. 2021: Germination response across populations of the stenoendemic chasmophyte *Campanula raineri* (*Campanulaceae*). – Fl. Medit. **31:** 267-270. http://dx.doi.org/10.7320/FlMedit31.267

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Seed germination reports for *Teucrium massiliense* and *T. flavum* subsp. *glaucum* (*Lamiaceae*)

Abstract

Porceddu, M., Barros Torres, S. & Bacchetta, G.: Seed germination reports for *Teucrium massiliense* and *T. flavum* subsp. *glaucum* (*Lamiaceae*) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 264-266. 2021. http://dx.doi.org/10.7320/FlMedit31.264

The present work gathers new germination assays of two *Teucrium* species from Sardinia. The studied taxa are: *Teucrium massiliense* and *T. flavum* subsp. *glaucum*. Seeds were collected at the time of natural seed dispersal in two different localities of Sardinia (Italy). The germination tests were carried out at the Sardinian Germplasm Bank (BG-SAR). Our results showed a high germination capability and germination rate for the tested plant species.

Key words: *Lamiaceae*, Mediterranean species, Sardinia.

The genus *Teucrium* L. includes ca. 300 taxa belonging to the *Lamiaceae* family; their distribution is mainly concentrated in the Mediterranean region (Navarro & El Oualidi 2000). Many taxa of the genus *Teucrium* have been used in traditional medicine. Regarding the species studied for this report, *T. massiliense* L. has been used as antimalarial, febrifuge, and cicatrizing, while *T. flavum* subsp. *glaucum* (Jord. & Fourr.) Ronniger as cicatrizing, antiseptic, febrifuge, antirheumatic, and to treat sciatica and dislocation (Maccioni & al. 2021). Given the indisputable importance of these two species, understanding the reproductive mechanisms and indicating the best conditions for seed germination of these taxa are fundamental.

This work illustrated new germination data of these two *Teucrium* species collected in two different localities of Sardinia (Italy). The germination tests were carried out at the Sardinian Germplasm Bank (BG-SAR; Porceddu & al. 2017). Our results showed a high germination capability and germination rate for the tested plant species.

46. *Teucrium massiliense* L. (*Lamiaceae*)

Accession data

Sa: Gonnosfanadiga (Sud Sardegna), Foresta Demaniale Montimannu (WGS84: 39.443036°N, 8.648336°E), garrigue, 1022 m a.s.l., 03 Aug 2018, *M. Porceddu,* *G. Bacchetta, G. Calvia & S. Fantini* (BG-SAR-2018-24, Sardinian Germplasm Bank).

Germination data

Pre-treatments: no treatment.

Germination medium: 1% agar.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
84.0%	constant 10°C	12/12h	13.0	14.6	44.0	17.0
80.0%	constant 15°C	12/12h	9.0	9.3	36.0	11.7
80.0%	constant 20°C	12/12h	6.0	7.0	15.0	8.5
90.0%	constant 25°C	12/12h	6.0	8.8	36.0	12.5
87.0%	alternating 25/10°C	12/12h	10.0	11.3	28.0	13.2

Observations

Teucrium massiliense is an evergreen small shrub with grey-green leaves and rose-pink flowers that blooms from July to September. It grows wild in some areas of the Mediterranean basin, particularly in Sardinia and Corsica.

Seeds of *T. massiliense* germinated in a wide range of temperatures, from 10°C to 25°C; in addition, high germination percentage was also detected at alternating temperature 25/10°C. Low germination (ca. 30%) was detected at 5°C. Very few germination data are present in the literature for this species. The results obtained by BG-SAR for *T. massiliense* from Sardinia showed faster germination than rates reported in the RBG Kew's Seed Information Database (Royal Botanic Gardens Kew, 2021) for the same species.

47. ***Teucrium flavum*** subsp. ***glaucum*** (Jord. & Fourr.) Ronniger (*Lamiaceae*)

Accession data

Sa: San Vito (Sud Sardegna), loc. Bacu Is Angius (WGS84: 39.338719°N, 9.466844°E), garrigue and shrubs, 145 m a.s.l., 08 Aug 2018, *G. Bacchetta & G. Calvia* (BG-SAR-2018-37, Sardinian Germplasm Bank).

Germination data

Pre-treatments: no treatment.

Germination medium: 1% agar.

Sample size: 80 seeds (20 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
86.3%	constant 15°C	12/12h	7.0	9.5	16.0	11.3
81.3%	constant 20°C	12/12h	7.0	10.4	37.0	12.8

Observations

Teucrium flavum subsp. *glaucum* is an evergreen small shrub with green leaves and white flowers that blooms from May to July. It grows spontaneously in Sardinia, Calabria, Basilicata (Bartolucci & al. 2018), and in Corsica (Jeanmonod & Gamisans 2007). Seeds of *T. flavum* subsp. *glaucum* reached high germination percentages at 15 and 20°C. Germination of 49%, 45% and 71% were recorded at 10, 25 and 25/10°C, respectively, while no germination was observed at 5°C. Very few germination data are present in the literature for this species. The results obtained by BG-SAR for *T. flavum* subsp. *glaucum* from Sardinia are consistent with those reported by the RBG Kew's Seed Information Database (Royal Botanic Gardens Kew, 2021) for the same taxon, however, the seeds tested by BG-SAR showed faster germination, reaching the T_{50} values within 11 days both at 15 and 20°C.

References

Bartolucci, F., Peruzzi, L., Galasso, G., Albano, A., Alessandrini, A., Ardenghi, N. M. G., Astuti, G., Bacchetta, G., Ballelli, S., Banfi, E. & al. 2018: An updated checklist of the vascular flora native to Italy. – Pl. Biosyst. **152:** 179-303. https://doi.org/10.1080/11263504.2017.1419996

Jeanmonod, D. & Gamisans, J. 2007: Flora Corsica. – Aix-en-Provence.

Maccioni, A., Falconieri, D., Sanna, C., Porcedda, S., Piras, A. & Maxia, A. 2021: Characterization of Essential Oils from Different Taxa Belonging to the Genus *Teucrium* in Sardinia Island, Italy. – Plants **10:** 1359. https://doi.org/10.3390/plants10071359

Navarro, T., & El Oualidi, J. 2000: Synopsis of *Teucrium* L. (*Labiatae*) in the Mediterranean region and surrounding areas. – Fl. Medit. **10:** 349-363.

Porceddu, M., Santo, A., Orrù, M., Meloni, F., Ucchesu, M., Picciau, R., Sarigu, M., Cuena Lombraña, A., Podda, L., Sau, S., Fogu, M. C. & Bacchetta, G. 2017: Seed conservation actions for the preservation of plant diversity: the case of the Sardinian Germplasm Bank (BG-SAR). – Pl. Sociol. **54(2):** 111-117. https://doi.org/10.7338/pls2017542S1/11

Royal Botanic Gardens Kew 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/ [Last accessed 07/10/2021]

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S. Villa, R. M. Ceriani, B. E. L. Cerabolini & S. Pierce

Germination response across populations of the stenoendemic chasmophyte *Campanula raineri* (*Campanulaceae*)

Abstract

Villa, S., Ceriani, R. M., Cerabolini, B. E. L. & Pierce S.: Germination response across populations of the stenoendemic chasmophyte *Campanula raineri* (*Campanulaceae*) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 267-270. 2021. http://dx.doi.org/10.7320/FlMedit31.267

This study describes a successful germination protocol for *Campanula raineri* (*Campanulaceae*), a protected rock-face dwelling species, endemic to the Italian calcareous Prealps. Germination tests were performed on seed lots from nine different populations across the geographical range of the species. Mean germination rates higher than 80% were reached within 28 days for almost all of the populations under analysis. The populations from the highest elevations exhibited the highest mean germination rates.

Key words: alpine species, endemic, calcareous cliffs vegetation, protected flora.

Introduction

Campanula raineri Perp. is a stenoendemic chasmophyte of the Italian calcareous Prealps, typical of the *Physoplexido comosae - Potentillenion caulescentis* plant association (Aeschimann & al. 2004; Pignatti & al. 2018). It grows with scattered populations in a limited area among Lake Como, Lake Garda and the valley of Valtellina (Lombardy Region and Trentino Alto Adige/Südtirol, northern Italy), occupying crevices on cliffs and screes between 1000 and 2000 m a.s.l. (Pignatti & al. 2018; S.Villa personal observations). The species is legally protected by regional law (annex C of Deliberazione della Giunta Regionale. 27.01.2010 - n. 8/11102) by inclusion in the list of species in need of strict protection, along with 10 congeneric species. For the purposes of this study, a collection permit was granted by Regione Lombardia (Decreto n. 9336).

This perennial species reproduces both by rhizomes creeping between rock crevices and by seed. Between July and August, rosettes produce dense clusters of flowers that develop into trilocular, poricidal capsules (Pignatti & al. 2018; Fig. 1A). Between September and October, mature seeds are released.

Ex-situ cultivation of *C. raineri* has already been carried out by the University of Insubria (B.E.L. Cerabolini & R.M. Ceriani, unpublished data) with the aim of reintroducing the species to Monte Barro regional park (LC, Italy), where it seems to have become locally extinct (Brusa 2005). Reintroduction was successful, but more than 15 years later the re-established plants are no longer evident (S.Villa, personal observations).

This study investigated the germination response of seeds from nine different populations of *C. raineri* scattered across the geographical range of the species. Ripe capsules were collected during dry weather, transported in paper bags and stored in a drying room (relative humidity: 15-17%) at the Lombardy Seed Bank (LSB at the Centro Flora Autoctona, Galbiate -LC-, CFA) for 4 months before performing *in vitro* sowing. Dry seeds were cleaned by hand and with an Aspirator & Gravity Separator machine (PETKUS Selecta Zig-Zag aspirator, v ZIG7-EN-11).

48. ***Campanula raineri*** Perp. (*Campanulaceae*)

Accession data

It: Moggio (LC), Piani di Artavaggio (WGS84: 45.94221°N, 9.53642°E), calcareous screes, 1789 m a.s.l, 30 Sep 2020, *S. Villa*, (LC930, Lombardy Seed Bank)
It: Taleggio (BG), Monte Venturosa (WGS84: 45.92875°N, 9.61602°E), calcareous cliffs, 1885 m a.s.l, 15 Sep 2020, *S. Villa*, (BG970, Lombardy Seed Bank)
It: Canzo (CO), Sasso Malascarpa (WGS84: 45.85045°N, 9.31893°E), calcareous cliffs, 1159 m a.s.l, 9 Sep 2020, *S. Villa*, (CO745, Lombardy Seed Bank)
It: Lecco (LC), Resegone (WGS84: 45.86306°N, 9.46189°E), calcareous cliffs, 1645 m a.s.l, 14 Sep 2020, *S. Villa*, (LC931, Lombardy Seed Bank)
It: Mandello del Lario (LC), Grigna Meridionale (WGS84: 45.91710°N, 9.39356°E), calcareous cliffs, 1728 m a.s.l, 18 Sep 2020, *S. Villa*, (LC932, Lombardy Seed Bank)
It: Valleve (BG), Monte Cavallo (WGS84: 46.03302°N, 9.69508°E), calcareous cliffs, 2130 m a.s.l, 15 Sep 2020, *S. Villa*, (BG971, Lombardy Seed Bank)
It: Colere (BG), Pizzo della Presolana (WGS84: 45.95129°N, 10.06785°E), calcareous cliffs/screes, 1856 m a.s.l, 28 Sep 2020, *S. Villa*, (BG972, Lombardy Seed Bank)
It: Oltre il Colle (BG), Pizzo Arera (WGS84: 45.92852°N, 9.80295°E), calcareous cliffs/screes, 1934 m a.s.l, 28 Sep 2020, *S. Villa*, (BG973, Lombardy Seed Bank)
It: Canzo/Valbrona (CO), Corni di Canzo (WGS84: 45.86281°N, 9.32315°E), calcareous cliffs/screes, 1226 m a.s.l, 9 Sep 2020, *S. Villa*, (CO746, Lombardy Seed Bank)

Germination data

Pre-treatments: Seed sterilization in 10% sodium hypochlorite (NaOCl) solution containing a few drops of detergent acting as a surfactant for 5 minutes, followed by six rinses in sterilized distilled water.

Germination medium: sterile agar medium (6 g L^{-1}) enriched with sucrose (20 g L^{-1}) for carbohydrate supply, Murashige & Skoog (1962) mineral salts (2.2 g L^{-1}) for nutrient supply and activated charcoal powder (0.5 g L^{-1}) to prevent the accumulation of toxic secondary metabolites. The pH was adjusted to 5.7 and the medium was autoclaved at 121°C and 1 atm for 20 minutes. Filter-sterilised gibberellic acid (GA_3; 40 mg L^{-1}) was added to the substrate when a non-contact infra-red thermometer determined that the substrate had cooled to 60˚C (modified from Cerabolini & al. 2004).

Sample size: 250 seeds for each test (25 × 10 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]	Accession
90.4%	alternating 20/10°C	16/8 h	13.2	14.5	28.0	21.2	BG971
86.2%	alternating 20/10°C	16/8 h	14.8	16.0	28.0	21.8	CO746
86.1%	alternating 20/10°C	16/8 h	10.3	14.3	28.0	21.1	BG973
83.2%	alternating 20/10°C	16/8 h	14.0	15.1	28.0	21.5	LC932
82.7%	alternating 20/10°C	16/8 h	15.6	16.7	28.0	22.4	LC930
82.6%	alternating 20/10°C	16/8 h	13.5	15.2	28.0	21.6	LC931
82.3%	alternating 20/10°C	16/8 h	14.0	15.1	28.0	21.5	BG972
80.2%	alternating 20/10°C	16/8 h	15.0	16.2	28.0	22.0	BG970

Observations

The low concentration (0.6%) of agar in the germination medium was chosen because lower agar gel concentrations exhibit lower surface tensions (Ichinose & Ura 2020), and thus greater contact between substrate and seed, which should facilitate resource acquisition by the seed. Moreover, *in vitro* germination of other *Campanula* species has previously been achieved using either half-strength or full-strength Murashige & Skoog (1962) medium (MS) and relatively low concentrations (< 1%) of agar (Airò & al. 2009; Seglie & al. 2012; Stamenkovic & al. 2012; Frattaroli & al. 2013). Here, we supplied nutrients (rather than using water agar) because our aim was to encourage growth after germination, for the production of plants. We used half-strength MS medium because previous studies suggest that plants dwelling calcareous rock crevices prefer lower concentrations of mineral salts (Prevalek-Kozlina & al. 1997, 1999). Petri dishes containing sown seeds were incubated in a growth chamber for 28 days and positions randomized once a week. Germination was periodically monitored through weekly counting (Fig. 1B), and samples exhibiting mould development were progressively discarded. Only 17 out of 90 Petri dishes (< 20%) were discarded due to contamination, and at least 5 replicates per population were preserved. High germination responses (> 80%) were obtained for all populations under analysis, with the sole exception of Sasso Malascarpa, the population at the lowest altitude, which exhibited a significantly lower mean germination percentage (69.1 ± 7.3%) with respect to all other populations (ANOVA: F-ratio = 4.35, df = 8, $p = 0.0003$; data not shown). In contrast, the highest germination rates (> 90%) were evident for seeds from Monte

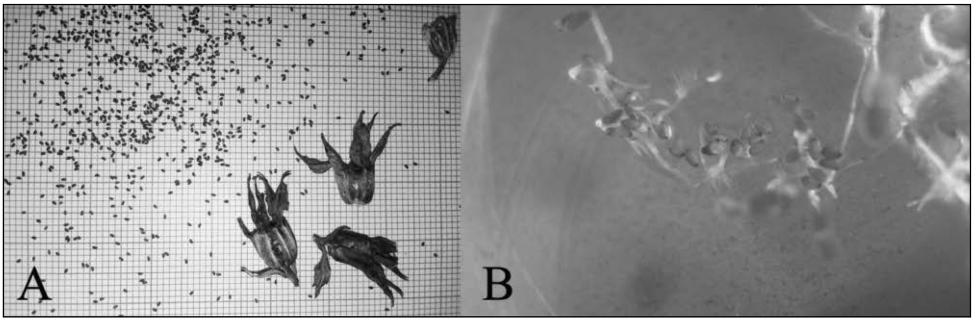

Fig. 1. Mature capsules and seeds (A) and several seedlings (B) of *Campanula raineri* observed two weeks after sowing on agar medium (photo by S. Villa).

Cavallo, the population at the highest elevation. A month after the end of the experiment, seedlings were transferred to soil and grown in a greenhouse, while the remaining seeds were deposited in a drying room at the Lombardy Seed Bank (LSB).

References

Aeschimann, D., Lauber, K., Moser, D. M. & Theurillat, J.-P. 2004: Flora alpina, **2.** – Bologna.

Airò, M., Savona, M., Mascarello, C., De Benedetti, L., Nicoletti, F., Casazza, G., Ruffoni, B. & Minuto, L. 2009: Analysis of *in vitro* performances and genetic variability of several *Campanula sabatia* populations in Italy. – Acta Hortic. **890:** 109-112 https://doi.org/10.17660/ActaHortic.2010.860.15

Brusa, G. 2005: Reintroduzione di *Campanula raineri* Perpenti sul Monte Barro (Lecco). Pp. 79-82 in: Rinaldi, G. & Rossi, G. (eds), Orti botanici, conservazione e reintroduzione della flora spontanea in Lombardia. Quaderni della Biodiversità, **2.** – Bergamo.

Cerabolini, B., De Andreis, R., Ceriani, R. M., Pierce, S. & Raimondi, B. 2004: Seed germination and conservation of endangered species from the Italian Alps: *Physoplexis comosa* and *Primula glaucescens*. – Biol. Conserv. **117:** 351-356. https://doi.org/10.1016/j.biocon.2003.12.011

Frattaroli, A. R., Di Martino, L., Di Cecco, V., Catoni, R., Varone, L., Di Santo, M. & Gratani, L. 2013: Seed germination capability of four endemic species in the Central Apennines (Italy): relationships with seed size. – Lazaroa **34:** 43-53.

Ichinose, N. & Ura, H. 2020: Concentration dependence of the sol-gel phase behavior of agarose-water system observed by the optical bubble pressure tensiometry. – Sci. Rep. **10:** 2620. https://doi.org/10.1038/s41598-020-58905-8

Murashige, T. & Skoog, F. 1962: A revised medium for rapid growth and bioassays with tobacco tissue cultures. – Physiol. Pl. **15:** 473-497. https://doi.org/10.1111/j.1399-3054.1962.tb08052.x

Pevalek-Kozlina, B., Pavlica, M. & Vujevic, M. 1999: Micropropagation of *Degenia velebitica* (Deg.) Hay., a Croatian endemic plant species. – Phyton **39:** 293-296.

Pignatti, S., Guarino, R. & La Rosa, M. (eds) 2018: Flora d’Italia 2° ed & Flora digitale, **3.** – Milano.

Prevalek-Kozlina, B., Kostovic-Vranjes, V. & Slade, D. 1997: In vitro propagation of *Fibigia triquetra* (DC.) Boiss., a rare stenoendemic species. – Pl. Cell Tissue Org. **51:** 141-143. https://doi.org/10.1023/A:1005965114749

Seglie, L., Scariot, V., Larcher, F., Devecchi, M. & Chiavazza, P. M. 2012: *In vitro* seed germination and seedling propagation in *Campanula* spp. – Pl. Biosyst. **146(1):** 15-23. http://dx.doi.org/10.1080/11263504.2011.578088

Stamenkovic, V., Jelencic, B. & Tkalec, M. 2012: Propagation and antioxidative enzymes of *Campanula velebitica* Borbás grown *in vitro*. – Period. Biol. **114(1):** 77-82.

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Spyridon Oikonomidis & Costas A. Thanos

Germination of *Anacamptis sancta* (*Orchidaceae*) in nutrient media, water agar and various light regimes

Abstract

Oikonomidis, S. & Thanos, C. A.: Germination of *Anacamptis sancta* (*Orchidaceae*) in nutrient media, water agar and various light regime. [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 271-276. 2021. http://dx.doi.org/10.7320/FlMedit31.271

The asymbiotic seed germination of orchids is a complex process with considerable technical difficulties, due to the natural requirement of a plant-fungus symbiotic relationship under field conditions. Only on rare occasions, orchid seeds are known to germinate readily in water. *Anacamptis sancta* is a relatively common orchid species with its main distribution around the East Mediterranean Sea (Greece, Cyprus, Turkey, Lebanon, Syria and Israel). Germination of *A. sancta* seeds was tested in different nutrient media, water agar and under various light regimes, in asymbiotic culture. In most experimental conditions tested, high germination percentages were observed with the highest germination (85.5%) obtained with a modified version of Malmgren medium without coconut water, under white light (12/12 h) at 20°C. In this study, results from all the experiments carried out are presented.

Key words: asymbiotic germination, Greece, holy orchid, phytochrome.

Introduction

Orchid seeds are among the smallest-sized ones. They consist of a spindle-shaped, thin seed coat that encloses the underdeveloped embryo. Due to the rudimentary structure of the orchid embryo, comprised of just a cluster of undifferentiated cells, there are no well-shaped embryonic organs, in most cases, and thus germination cannot be defined by the concept of radicle emergence from the seed coat. A system of developmental stage evaluation has been put forward for the assessment of orchid seed germination (Zettler & Hofer 1998) and it is commonly used in most relevant studies. Therefore, in this work, according to Zettler & Hofer (1998), germination is considered to take place as soon as the rhizoids have started to develop.

Anacamptis sancta (L.) R.M. Bateman, Pridgeon & M.W. Chase, commonly known as the holy orchid, is a relatively common species with its main distribution around the East Mediterranean Sea (Greece, Cyprus, Turkey, Lebanon, Syria and Israel). In Greece, it is found growing in numerous small populations, mostly in Mediterranean grasslands and phrygana, from sea level up to 500 m. It is a species that is commonly collected for salep production and in some cases, especially in Turkey, its populations are threatened due to overcollection (Bozdemir & al. 2018).

A. sancta is one of the eleven taxa of the genus *Anacamptis*, native in Greece. While the rest of the members of the genus are deceptive species regarding pollination, *A. sancta* and its closely related *A. coriophora* (L.) R.M. Bateman, Pridgeon & M.W. Chase are rewarding ones (Claessens & Kleynen 2011).

Regarding seed germination data, the *Anacamptis* genus is regarded as one of the easier to germinate Mediterranean orchid genera (Rasmussen 1995; Magrini & al. 2011; Dulic & al. 2020). Most of the *Anacamptis* taxa, occurring in Greece, tested so far exhibit final germination percentages over 60% and in most cases full germination is achieved (> 80-90%) with the only exception of *A. collina* (Banks & Sol. ex Russell) R.M. Bateman, Pridgeon & M.W. Chase the germination of which did not exceed 15% (unpublished data of our lab). *A. sancta* is a relatively easily germinating species, known from previous studies by Bozdemir & al. (2018) and Pritchard (1989) with germination levels of 74 and 84%, respectively; in these studies, germination was tested in continuous darkness while the media with the highest germination percentages were a modified version of Waes & Debergh with the addition of 40 g/L sucrose and Norstog medium, respectively.

In the present work, we investigated the asymbiotic germination of *A. sancta* seeds, collected from a population in Paros Island (Cyclades Islands, Aegean Sea), with various nutrient media and water agar, under various light regimes, at two different temperatures; it is noteworthy that the germinability both in water and under various light conditions are tested for the first time.

49. *Anacamptis sancta* (L.) R.M. Bateman, Pridgeon & M.W. Chase (*Orchidaceae*)

Accession data

Gr: Greece, loc. Paros Island (Cyclades Islands) (WGS84: 37.0820°N, 25.1634°E), 314 m a.s.l., 15 Jun 2019, *K. Zafiriou* (NKUA/GR-Acc. OR003, Seed Bank of National and Kapodistrian University of Athens).

Germination data

Pre-treatments: Disinfection with 5% $Ca(OCl)_2$ + 1% Tween 80 solution for 15 min followed by three rinses in sterilized distilled water.

Germination media: Mm) modified (type 1) Malmgren medium (Malmgren 1996, modified by Kitsaki & al. 2004): 75 mg/L $(Ca)_3PO_4$, 75 mg/L KH_2PO_4, 75 mg/L $MgSO_4(H_2O)_7$, 10 mg/L sucrose, 50 mL/L coconut water, 6 g/L agar and 0.5 g/L charcoal, at pH 5.8; M1) modified (type 2): Mm without coconut water.

Sample size: ca. 250 seeds for each test (50 × 5 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
85.5%[1]	constant 20°C	12/12h	7.0	4.2	20.0	8.0
83.1%[2]	constant 20°C	0/24h	-	-	-	-

[1] M1 medium and white light/darkness (L/D-2) with z = 1.44

[2] Mm medium and continuous darkness (CD)

Observations

Mature seed pods were collected in June 2019 from a wild population (56 mature individuals) of *A. sancta* in Paros Island. A total of 76 seed pods from 35 individuals (2-3 per plant) were collected and they were taken to the Seed Bank of the National and Kapodistrian University of Athens where seeds were extracted and placed in glass vials, at 4 ºC, until the end of the experiments (Fig. 1).

It should be noted that the seed lot viability, as assessed via a TTZ + Trypan blue test (Magrini & al. 2019), was found to be relatively low (60.9 ± 9.5%).

For the experiments, we tested another pre-treatment, cold stratification for 20 days at 5°C, and other four germination media: modified (type 3) Malmgren (M2): Mm with the addition of 0.2 g/L NH_4NO_3; modified (type 4) Malmgren (M3): Mm with the addition of 1 g/L casein tryptic peptone; modified (type 5) Malmgren (M4): Mm with the addition of 0.2 g/L NH_4NO_3 and 1 g/L casein tryptic peptone; (WA) 2% agar.

The dishes were incubated at 15 and 20°C under several light regimes: i) continuous darkness (CD), the seeds remained in the dark until the end of the experiment, germination was counted only once at the end; ii) 12/12 h white light/darkness (L/D-2) with z = 1.44. The z, the ratio of the wavelengths 660 nm and 730 nm, was calculated with a Skye red/far red sensor); iii) total darkness (TD), seed imbibitions took place under green safelight and thereafter as in CD; iv) 12/12 h white light/darkness (L/D-1) with z = 7.93; v) 12/12 h white light/darkness (L/D-2) with z = 1.44; vi) 5/55 min red light/darkness (R); vii) 5/55 min far-red light/darkness (FR); viii) continuous red light (CR); ix) continuous far-red light (CFR); x) continuous white light, z = 1.44 (CWL); xi) continuous blue light (CBL); xii) 5/5/50 min far-red light/red light/darkness (FR/R/D); xiii) 5/5/50 min red light/far-red light/darkness (R/FR/D); xiv) Darkness (D), the seeds remained in the dark with short exposures (~1-2

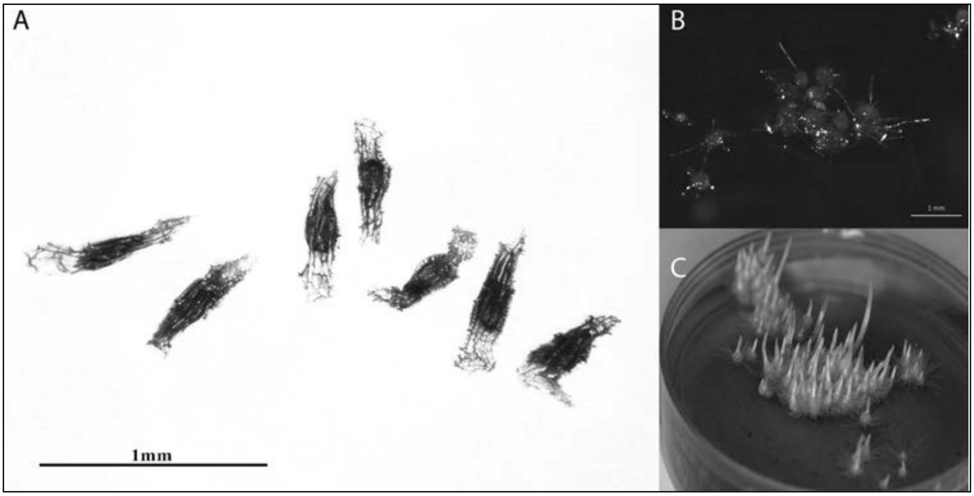

Fig. 1. *A. sancta*. A: dry seeds; B: germinated seeds in modified (type 2) Malmgren (Mm), at the developing rhizoids stage; C: germinated seed in modified (type 2) Malmgren (Mm) at the protocorm plus initial shoot stage (scale bar: 1 mm).

min) to stereomicroscope light during the germination counts. Except for TD, where the sowing took place in a dark chamber under a green safelight, for the rest of the experiments the seeds were sown under the light of the laminair (to avoid fungal or bacterial infections).

A. sancta is an apparently 'easy' species to germinate (Pritchard 1989; Bozdemir & al. 2018). In our study, optimal germination results were reached in most of the treatments used, and in some cases higher than previously reported (Pritchard 1989; Bozdemir & al. 2018; 74% and 84%, respectively), taking also into account the rather low viability of the seed lot. The highest final germination of seeds pretreated with 5% $Ca(OCl)_2$ + 1% Tween 80 for 15 min (85.5%) was achieved in M1 medium and under L/D (12/12, z = 7.93), while the lowest germination (53.7%) was observed in Mm medium after 20 days of chilling (5°C), in darkness. From the six media tested, M1 gave the highest results while M2 gave the lowest ones (64.9% at 20°C under L/D – 12/12, z = 1.44), while M3 and M4 media both yielded similar final germination (75-77%) both in darkness and in L/D (12/12).

In addition, it is the first time that the germination of *A. sancta* is observed in water agar. Almost optimal germination (72.9%) was achieved at 20°C when seeds were imbibed on 2% agar (no nutrients added). Regarding temperature, both 20 and 15°C resulted in high germination (> 70%) with only slight differences between them.

Despite the well-known fact that germination of small seeds is usually promoted by light, an increasing number of orchids have been reported to have seeds with photoinhibited germination (Rasmussen 1995; Carta & al. 2017). *A. sancta* is an exception to this group of orchids; seed germination of *A. sancta* is over 50% under every light regime used in this study. For Mm, which is the medium used in each different light regime test, the highest germination percentage was obtained in continuous darkness although the difference (~4%) with continuous white light (z = 1.44) is not significant. Regarding the light regime, the lowest final germination observed was under continuous blue light (58.2%) which may imply a negative effect of blue light in the germination of *A. sancta* seeds, while both R and FR light did not affect significantly the high germination levels. Therefore, under the conditions tested, we cannot detect any phytochrome control on seed germination of *A. sancta*. Most terrestrial orchid germination is tested in darkness (Rasmussen 1995) but further experimentation with light conditions might reveal a number of species whose seeds are indifferent to (or even promoted by) light.

Conclusion

Orchid minuscule seeds with their underdeveloped embryos lack sufficient nutrients to support germination and early seedling development. In most cases, in nature, a mycosymbiont provides nutrients (Bernard 1899, 1909) to the seedling in the first stages of its development, while in the laboratory, nutrients are provided by the culture media used (Knudson 1921, 1922). Relatively few species of the family *Orchidaceae* can readily germinate in water and the final germination level is usually low (Rasmussen 1995). In this study, we present a successful protocol for germination of *A. sancta* which yielded higher final germination than previously reported in nutrient media. We also demonstrate, for the first time, the ability of the species to readily germinate in water agar without any nutrients added, as recently reported also for *Neotinea maculata* (Desf.) Stearn (Oikonomidis & al. 2020). However, seeds sown in nutrient media reached a stage 4-5 in the Zettler & Hofer scale (Zettler & Hofer 1998), while seeds imbibed in water agar reached 3-4. Moreover, we additionally report the 'insensitive nature' of seed germination towards light or darkness.

The temperatures tested (15 and 20°C) did not show any significant difference in the final germination results during the initial experiments and henceforth we used 20°C, as this temperature is most common for orchids (Rasmussen 1995). The highest germination (85.5%) was observed in the M1 medium. *A. sancta* is one of the few orchid species known (Rasmussen 1995) to readily germinate in water with almost full germination, while it is one, if not the only, species reported to reach the protocorm stage in water agar.

Species that readily germinate in water like *A. sancta* can be utilized as means for further understanding the germination physiology of species that exhibit hindered germination either in common orchids (e.g. in the genus *Neotinea*, Oikonomidis & al. 2020) or in rare and endangered ones (e.g. in the genus *Dactylorhiza* where germination in water was also observed in several species, Rasmussen 1995).

The germination of *A. sancta* starts roughly at 24 h from the onset of imbibition while final germination is reached two weeks after, and protocorms are ready for the first nutrient medium transfer (repotting) one month after the seed sowing. This make *A. sancta* one of the fastest germinating terrestrial orchid species. Taking into additional consideration the high demand for orchid tubers, collected in the wild in the Eastern Mediterranean for salep powder, *A. sancta* may prove a good candidate for further studying germination and development of protocorms for field or greenhouse cultivation. This would provide leverage against overcollection from wild populations and enhance in situ conservation of the species.

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References

Bernard N. 1899: Sur la germination du *Neottia nidus-avis*. – C. R. Hebd. Sceances Acad. Sci. **128:** 1253-1255.

— 1909: L'evolution dans la symbiose, les orchidées et leurs champignons commensaux. – Ann. Sci. Nat. **9:** 1-196.

Bozdemir, H., Cig, A. & Turkoglu, N. 2018: Effects of different concentrations of carbohydrate forms on *Orchis sancta* L. propagation in vitro. – Appl. Ecol. Environm. Res. **16:** 4849-4864. https://doi.org/10.15666/aeer/1604_48494864

Carta, A., Skourti, E., Mattana, E., Vandelook, F. & Thanos, C. A. 2017: Photoinhibition of seed germination: Occurrence, ecology and phylogeny. – Seed Sci. Res. **27:** 131-153. https://doi.org/10.1017/S0960258517000137

Claessens, J. & Kleynen, J. 2011: The flower of the European orchid: Form and function. – Voerendaal, Stein.

Dulic, J., Ljubojevic, M., Savic, D., Ognjanov, V., Dulic, T., Barac, G. & Milovic, M. 2020: Implementation of SWOT analysis to evaluate conservation necessity and utilization of natural wealth: Terrestrial orchids as a case study. – J. Environ. Plan. Manag. **63(12):** 2265-2286. https://doi.org/10.1080/09640568.2020.1717935

Kitsaki, C. K., Zygouraki, S., Ziobora, M., Kintzios, S. 2004: In vitro germination, protocorm formation and plantlet development of mature versus immature seeds from several *Ophrys* species (*Orchidaceae*). – Pl. Cell. Rep. **23:** 284-290. https://doi.org/10.1007/s00299-004-0841-8

Knudson, L. 1921. La germinacion no simbiotica de las semillas de orquideas. – Bull. R. Soc. Esp. Hist. Nat. **21:** 250-260.

— 1922: Nonsymbiotic germination of orchid seeds. – Bot. Gaz. **73:** 1-25.

Magrini, S., Barreca, D. & Zucconi, L. 2019: A rapid double-staining technique to improve seed viability testing in terrestrial orchids. – Pl. Biosyst. **153(6):** 877-882. https://doi.org/10.1080/11263504.2019.1587541.

—, De Carli, A., Onofri, S. & Scoppola, A. 2011: A comparative study of the seed germination capabilities of *Anacamptis palustris* (*Orchidaceae*), a threatened terrestrial orchid, and other more common *Anacamptis* species, by asymbiotic culture *in vitro*. – Eur. J. Environ. Sci. **1:** 71-79. https://doi.org/10.14712/23361964.2015.50

Malmgren, S. 1996: Orchid propagation: theory and practice. – Pp. 63-71 in Allen, C. (ed.) North American Native Terrestrial Orchid Conference Proceedings. – Germantown.

Oikonomidis, S., Koutsovoulou, K. & Thanos, C. A. 2020: Germination of *Neotinea maculata* (*Orchidaceae*) in nutrient media and water agar. – Fl. Medit. **30:** 394-399. https://doi.org/10.7320/FlMedit30.394

Pritchard, H. W. 1989: Modern methods in orchid conservation: The role of physiology, ecology and management. – Cambridge.

Rasmussen, H. N. 1995: Terrestrial orchids: from seed to mycotrophic plant. – Cambridge.

Zettler, L. W. & Hofer, C. J. 1998: Propagation of the little club-spur orchid (*Platanthera clavellata*) by symbiotic seed germination and its ecological implications. – Environ. Exp. Bot. **39:** 189-195. https://doi.org/10.1016/S0098-8472%2897%2900019-1

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V. Di Cecco, A. R. Frattaroli, M. Di Musciano, M. Di Santo & L. Di Martino

Seed germination reports for Policy species in the central Apennines

Abstract

Di Cecco, V., Frattaroli, A. R., Di Musciano, M., Di Santo, M. & Di Martino, L.: Seed germination reports for Policy species in the central Apennines [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 277-282. 2021. http://dx.doi.org/10.7320/FlMedit31.277

The germination ability of four policy species from the Central Apennine were studied: *Astragalus aquilanus*, *Iris marsica*, *Jacobaea vulgaris* subsp. *gotlandica*, *Klasea lycopifolia*. Mature seeds were collected in the field, within an elevation range of 365–1932 m a.s.l. Different experimental conditions were tested and the best methods with optimal germination results are provided and compared for each species. First germination records are given for the investigated taxa.

Key words: Habitat Directive, *Astragalus aquilanus, Iris marsica, Jacobaea vulgaris* subsp. *gotlandica, Klasea lycopifolia.*

Introduction

The studied species are target species of the LIFE 15 NAT/IT/946 Project “FLORANET Safeguard and valorization of the plant species of EU interest in the Natural Parks of the Abruzzo Apennine”, relating to action C.4 “Reproduction from seed”, which is focused on Directive plant species occurring in the Abruzzo protected areas such as *Adonis distorta* Ten., *Androsace mathildae* Levier, *Astragalus aquilanus* Anzal., *Cypripedium calceolus* L., *Iris marsica* I. Ricci & Colas., *Jacobaea vulgaris* subsp. *gotlandica* (Neuman) B. Nord., and *Klasea lycopifolia* (Vill.) Á. Löve & D. Löve. The work was carried out in the Maiella Seed Bank – Lama dei Peligni (CH), Italy.

The germination ecology of these target species had never been investigated so far. The experimental design was set up starting from the available literature data and germination protocols already defined for allied taxonomic units (Ellis & al. 1985; Royal Botanic Gardens Kew 2021), to identify the optimal temperature ranges and any required pre-treatments (ISTA 2012; Baskin & Baskin 2014).

Currently, fulfilling results on germination have been obtained only for 4 out of the 7 species investigated during the LIFE project. *Adonis distorta* showed a deep morpho-physiological dormancy which resulted in low final germination percentages at the conditions tested so far. Similar results occurred in *Androsace mathildae*, which revealed physiological seed dormancy and final germination percentages not exceeding 50%. Studies on the asymbiotic germination of *Cypripedium calceolus* have been carried out in a specialized laboratory for orchid germination at the Tuscia Germplasm Bank (Tuscia University). Unfortunately, the number of germinated seeds was not enough to develop a germination protocol, only the seeds from immature capsules have geminated. Since there are no literature data on the germination behaviour and propagation of these species, to date the activity is to be considered experimental.

50. ***Astragalus aquilanus*** Anzal. (*Fabaceae*) (Fig. 1a)

Accession data

It: Abruzzo. Casoli (Chieti), loc. Piano la Roma (WGS84: 42.137766°N, 14.258008°E), pascolo xerofitico, 365 m a.s.l., 27 Jul 2016, *V. Di Cecco* (MSB LIFE16A03, Maiella Seed Bank).

It: Abruzzo. L'Aquila (L'Aquila), loc. Monteluco di Roio (WGS84: 42.339791°N, 13.374163°E), bordo strada in pascolo xerofitico, 984 m a.s.l., 16 Sep 2018, *V. Di Cecco* (MSB LIFE18A22, Maiella Seed Bank).

It: Abruzzo. Gioia dei Marsi (L'Aquila), loc. Casali d'Aschi (WGS84: 41.963614°N, 13.702078°E), bordo strada sterrata in pascolo xerofitico, 950 m a.s.l., 29 Jul 2020, *L. Vitale & E. Trella* (MSB LIFE20A01, Maiella Seed Bank).

Germination data

Pre-treatments: scarification with 1) 180 grit abrasive paper for 1 minute; 2) 98% sulfuric acid for 20 min.; 3) seed piercing with a small hypodermic needle. Soaking in water for 24h, sterilization with a solution of 3% sodium hypochlorite plus Tween 20 for 1 minute followed by 3 rinses in sterile distilled water.

Germination medium: 1% agar, pH 5.75.

Sample size: 80 seeds for each test (20 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]	Accession code
100%[1]	constant 20°C	12/12h	1.8	4.7	11.8	5.3	19A02
96.0%[2]	constant 20°C	12/12h	2.0	2.6	6.8	3.6	18A22
98.8%[3]	constant 20°C	12/12h	2.0	5.0	12.0	6.2	20A01

Observations

Physical dormancy (integument impermeability, PY) was detected in many species of *Astragalus* (Miklas & al. 1987; Patanè & Gresta 2006; Eisvand & al. 2006; Keshtkar & al. 2008; Salmeri & Castrogiovanni 2020). Ten different germination protocols were tested for *A. aquilanus* at the temperature of 20°C, both in full darkness and 12/12h photoperiod, with no seed scarification or after chemical scarification with H_2SO_4 for 5 and 20 minutes, mechanical scarification with 180 grit sandpaper, and seed piercing. The viability of the non-germinated seeds at the end of each test was estimated by the cutting test. No statistically significant differences among the investigated populations were detected for all the tested conditions.

*Astragalus aquilan*us also revealed a physical dormancy, as all scarification methods proved to be helpful in interrupting seed dormancy and reaching final germination percentages close to 100%. Conversely, only low germination values (23.75% in light at 20°C) were reached in a long time without seed scarification.

51. ***Iris marsica*** I. Ricci & Colas. (*Iridaceae*) (Fig. 1b)

Accession data

It: Abruzzo. Palena (Chieti), loc. Colle di Valle Caprara (WGS84: 41.926410°N, 14.084681°E), radura in faggeta, 1541 m a.s.l., 20 Jul 2016, *G. Ciaschetti & M. Di Cecco* (MSB LIFE16A11, Maiella Seed Bank).

Germination data

Pre-treatments: sterilization with a solution of 3% sodium hypochlorite plus Tween 20 for 5 minutes followed by 3 rinses in sterile distilled water. Vernalization at 5°C for 60 days.

Germination medium: 1% agar, pH 5.75.

Sample size: 80 seeds for each test (20 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
82.9%	constant 20°C	12/12h	14.8	26.3	43.8	28.1

Observations

Many *Iris* species have morphophysiological dormancy (Curtis & Brumback 1986; Xu & al. 2003; Diboll 2004), therefore germination tests on this species were carried out based on such information. The following protocols were applied: incubation at 20°C with a 12/12 h photoperiod after 60 days of vernalization, which provided the highest germination values, at 20°C under total darkness (10.5%), 20°C with 12/12h photoperiod (34.2%), 15° C with a 12/12 h photoperiod after 60 days of vernalization (55.0%), alternating temperature 20/10°C with 12/12h photoperiod and imbibition in 800 ppm GA_3 (34.7%), 20/10°C with 12/12h photoperiod (59.4%). Germination was generally quite slow and took place staggered over time (MTG from 28.1 to 80.5), but better results were obtained after a period of vernalization at 5°C.

52. ***Jacobaea vulgaris*** subsp. ***gotlandica*** (Neuman) B. Nord. (*Asteraceae*) (Fig. 1c)

Accession data

It: Abruzzo. Rocca di Mezzo (L'Aquila), loc. Colle del Nibbio (WGS84: 42.199106°N, 13.468466°E), pascolo in cresta, 1900 m a.s.l., 13 Sep 2018, *V. Di Cecco & L. Di Martino* (MSB LIFE18A17, Maiella Seed Bank).

Germination data

Pre-treatments: sterilization with a solution of 3% sodium hypochlorite plus Tween 20 for 5 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 1% agar, pH 5.75.

Sample size: 80 seeds for each test (20 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
94.9%	constant 20°C	12/12h	1.5	2.5	5.0	3.3
80.8%	constant 20°C	0/24h	-	-	-	-

Observations

Based on Van der Meijden & Van der Waals-Kooi (1979), *J. vulgaris* does not show any seed dormancy, thus no particular method for dormancy-breaking had to be applied to favour germination. Excellent results were obtained at 20°C with a 12/12h photoperiod. Germinations under full darkness were only detected at the end of the test. The other tests have shown a germination percentage of 77.7% at 5°C under total darkness and 60.6% at 20/10°C with a 12/12h photoperiod (60.6%).

53. ***Klasea lycopifolia*** (Vill.) Á. Löve & D. Löve (*Asteraceae*) (Fig. 1d)

Accession data

It: Abruzzo. Rocca di Mezzo (L’Aquila), loc. Altopiano delle Rocche (WGS84: 42.221142°N, 13.526929°E), prato sfalciato 1276 m a.s.l., 16 Aug 2018, *V. Di Cecco* (MSB LIFE18A10, Maiella Seed Bank).

Germination data

Pre-treatments: sterilization with a solution of 3% sodium hypochlorite plus Tween 20 for 5 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 1% agar, pH 5.75.

Sample size: 80 seeds (20 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
88.4%	constant 20°C	12/12h	5.8	11.4	21.5	12.3

Observations

There is no information about seed dormancy for this species. According to Finch-Savage & Leubner-Metzger (2006), in the *Asteraceae,* both physiological dormancy and lack of dormancy can occur. A recent work by Budisavljević & al. (2021) has given 62.6% of germination for *Klasea lycopifolia* at 23°C, after a cold stratification (5°C) for 12 weeks. We obtained the highest final germination percentage at 20°C and 12/12 h photoperiod without preventive stratification (88.4%). Tests were also performed at 20°C in full darkness (40.0%), with a 12/12 h photoperiod after a vernalization period of 60 days (72.5%), and at alternating temperature 20/10°C with a 12/12 h photoperiod, but with lower results (31.6%).

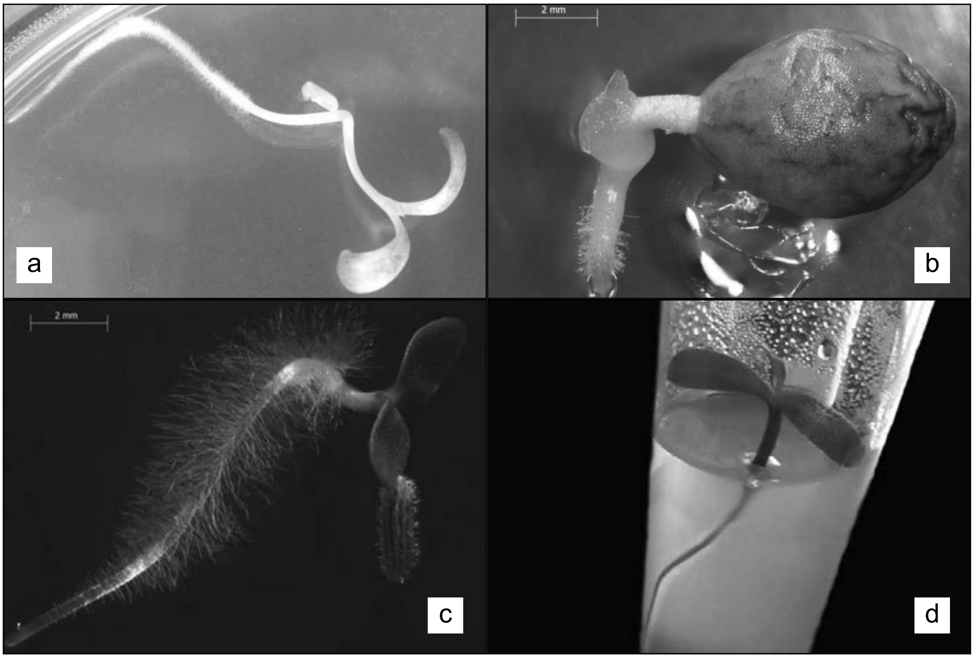

Fig. 4. Germinated seeds of: a, *Astragalus aquilanus*; b, *Iris marsica*; c, *Jacobaea vulgaris* subsp. *gotlandica*; d, *Klasea lycopifolia*.

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References

Baskin, C. C. & Baskin, J. M. 2014: Seeds. Ecology, Biogeography, and Evolution of Dormancy and Germination. – San Diego.

Budisavljević, A., Sandev, D., Randić, M., Stamenković, V. & Kovačić, S. 2021: Seed dormancy and germination of five selected NATURA-2000 plant species from Croatia showing different germination strategies. – Pl. Biosyst. **155:** 116-127. https://doi.org/10.1080/11263504.2020.1727978

Curtis, W. C. 1986: Propagation of wild flowers, Revised by Brumback W.E. – Framingham.

Diboll, N. 2004: Native wildflower and grass propagation information. – Proc. Iint. Pl. Propagator's Soc. (IPPS) **54:** 391-401.

Eisvand, H., Arefi, H. & Tavakol-Afshari, R. 2006: Effects of various treatments on breaking seed dormancy of *Astragalus siliquosus*. – Seed Sci. Technol. **34(3):** 747-752. https://doi.org/10.15258/sst.2006.34.3.22

Ellis, R. H., Hong, T. & Roberts, E. H. 1985: Handbook of seed technology for genebanks, **1.** – Rome.

Finch-Savage, W. E. & Leubner-Metzger, G. 2006: Seed dormancy and the control of germination. – New Phytol. **171:** 501-523. https://doi.org/10.1111/j.1469-8137.2006.01787.x

ISTA 2012: International rules for seed testing. – Bassersdorf.

Keshtkar, A., Keshtkar, H., Razavi, S. & Dalfardi, S. 2008: Methods to break seed dormancy of *Astragalus cyclophyllon*. – Afr. J. Biotech. **7(21):** 3874-3877. https://doi.org/10.4314/AJB.V7I21.59460

Royal Botanic Gardens Kew 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/

Miklas, P., Townsend, C. & Ladd, S. 1987: Seed coat anatomy and the scarification of *Cicer milkvetch* seed. – Crop Sci. **27:** 766-772. https://doi.org/10.2135/cropsci1987.0011183X002700040032x

Patanè, C. & Gresta, F. 2006: Germination of *Astragalus hamosus* and *Medicago orbicularis* as affected by seed-coat dormancy breaking techniques. – J. Arid Environ. **67:** 165-173. https://doi.org/10.1016/j.jaridenv.2006.02.001

Salmeri, C. & Castrogiovanni, M. 2020: Seed germination reports of high mountain species native to Mount Etna (Sicily). – Fl. Medit. **30:** 415-420. http://dx.doi.org/10.7320/FlMedit30.415

Van der Meijden, E. & Van der Waals-Kooi, R. 1979: The population ecology of *Senecio jacobaea* in a sand dune system: I. Reproductive strategy and the biennial habit. – J. Ecol. **67:** 131-153. https://doi.org/10.2307/2259341

Xu, X., Zhang, X. & Wang, H. 2003: A study on the germination of *Iris lactea* Pall. var *chinensis* Koid Z. seeds under gamma radiation. – J. Nanjing Forest. Univ. **27:** 55-58. https://doi.org/10.3969/j.jssn.1000-2006.2003.01.013

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J. A. Buhagiar, A. Lamoliere & M. Iannaccone

Seed germination reports for five coastal and inland species from the Maltese Islands

Abstract

Buhagiar, J. A., Lamoliere, A. & Iannaccone, M.: Seed germination reports for coastal and inland garrigue species from the Maltese Islands [in Magrini, S. & Salmeri, C. (eds). Mediterranean Plant Germination reports – 3] Fl. Medit. 31: 283-290. 2021. http://dx.doi.org/10.7320/FlMedit31.283

This study investigated seed germination in five indigenous species of plants in the Maltese Islands, predominantly occurring in coastal garrigue habitats but also inland, namely *Drimia maritima*, *Periploca angustifolia*, *Asparagus aphyllus*, *Myrtus communis*, and *Pancratium maritimum.* Different germination protocols were tested for one or more populations, namely: four different temperature regimes - constant 15, 20 and 25°C as well as alternating 23.5/15°C; three different photoperiods, 12/12, 16/8 and 0/24 light/dark. The best germination results for each species are provided and additional notes on the species and germination behaviour are also given.

Keywords: germination protocols, Mediterranean flora, coastal and inland garrigue.

Introduction

Based on Sommier & Caruana Gatto (1915), Borg (1927), Haslam (1969), Haslam & al. (1977), Pignatti (1982), Lanfranco (1984, 1995), Lanfranco & Schembri (1986), Anderson & Schembri (1989), Schembri (1994, 1997), Savona-Ventura (2001), Casha (2015, 2020), the flora of the Maltese islands, including the autochthonous and allochthonous ferns and spermatophytes, amounts to about 1100 taxa, species and subspecies. Several taxa described in the past are thought to have become locally extinct though there is the occasional rediscovery, often in some very localised areas and in depleted numbers (Brullo & al. 2020). Studies using karyotyping and DNA barcoding are ongoing to clarify some taxonomic doubts.

With regards to seed germination studies of the indigenous plant populations very little is known. In this paper, we present seed germination results for five different indigenous species occurring in the Maltese Islands. The five species selected are indigenous elements of the Mediterranean flora from similar coastal and more inland habitats. Three of the species considered are coastal and more inland elements and include *Drimia maritima* (L.) Stearn, *Periploca angustifolia* Labill., and *Asparagus aphyllus* L. Another species, namely

Myrtus communis L., was selected for its unique characteristics, occurring in a sheltered valley close to the sea and having white to light purple fruits. The remaining species, namely *Pancratium maritimum* L.*,* occurs on sand dunes which in the Maltese Islands are severely limited.

54. ***Drimia maritima*** (L.) Stearn (*Asparagaceae*)

Accession data

Si(M): Armier Bay, Mellieha, Malta (WGS84: 35.994250°N, 14.365611°E), 11 m a.s.l., 19 Nov 2020, *J. A. Buhagiar, M. Iannaccone & A. Lamoliere* (BDUM/20/018, Seed bank of the Department of Biology, University of Malta).

Germination data

Pre-treatments: None.

Germination medium: Seeds were germinated on 2 sheets of sterilized filter paper (Whatman™ Grade 91), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
97%	constant 15°C	0/24h	7	6.5	14	7.1
97%	constant 15°C	12/12h	7	6.6	18	7.4
93%	constant 20°C	16/8h	4	6.5	18	7.3
91%	alternating 23.5/15°C	16/8h	4	6.7	28	8.5
85%	alternating 23.5/15°C	0/24h	4	6.3	11	6.5
81%	constant 20°C	0/24h	4	6.5	25	8.3

Observations

Drimia maritima is a common element of the Maltese maritime garrigue landscape although it is also found inland. It is a geophyte, which is extremely well adapted to the Mediterranean climate, surviving the hot dry summer as semi-exposed dormant bulbs from March/April well into September. It is interesting in that it is the first flowering element towards the end of Summer (mid-to-late August) when the Maltese landscape is still very brown and dry, thereby avoiding competition for pollinators. This species tends to form sizable clumps by tillering.

Drimia maritima gave very good germination percentages at different temperatures and light/dark treatments with the highest percentage of 97% at 15°C. The maximum germination times varied between 11 and 28 days. Indeed, Marques & Draper (2012) report that fast and high germination rate is characteristic of several species of geophytes. The seeds take slightly longer to germinate at higher temperatures, and the germination percentage decreases to 77% at 25°C. It is also interesting that a diurnal cycle of 23.5/15°C combined with a 16/8h light/dark cycle also gave a good germination percentage. Comparing the germination percentages with those reported by Royal Botanic Gardens Kew (2021), the highest germination percentage of over 95% were obtained at 5, 10 and 15°C as well as a 25/10°C alternating temperature using a 16/8 light/dark cycle. However, there is high variability between different tests and germination times reported which are much longer, a good many over 40 days and one up to 105 days.

55. ***Periploca angustifolia*** Labill. (*Apocynaceae*)

Accession data

Si(M): Wied Babu, Zurrieq, Malta, (WGS84: 35.821139°N, 14.459528°E), 70 m a.s.l, 04/06/2021, *J. A. Buhagiar, M. Iannaccone & A. Lamoliere* (BDUM/21/4, Seed bank of the Department of Biology, University of Malta).

Germination data

Pre-treatments: None.

Germination medium: Seeds were germinated on 2 sheets of sterilized filter paper (Whatman™ Grade 91), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
90.0%	constant 15°C	0/24h	3	6.7	12	8.1
85.0%	alternating 23.5/15°C	0/24h	3	4.6	24	5.6

Observations

Periploca angustifolia is a common maritime garrigue element in the Maltese Islands with distribution being more common on the southwestern part of the coastline, where it forms a typical shrubby vegetation association described as *Periploco angustifoliae-Euphorbietum dendroidis* (Brullo & al. 2020). *P. angustifolia* gave the highest percentage germination at 15°C and 0/24h photoperiod. Interestingly, the germination percentage declined drastically to 60% in a 12/12h photoperiod regime for this temperature, showing photoinhibition. Higher temperatures also showed a decline in germination percentage ranging from 52 to 77% for 20°C and 25°C under light/dark conditions tested. The exception was for the diurnal cycle of 23.5/15°C combined with a 0/24h light/dark cycle which gave a germination percentage of 85%, though in the light the germination again declined to 69%. Noumi & al. (2010) reported the highest germination percentage for this species at 25°C though it must be noted that all tests were carried out in complete darkness. Abdellaoui & al. (2013) tested germination at 25°C in complete darkness for seeds collected and stored for different periods ranging from

0 to 15 years. Germination percentage was mostly below 70%, with only three- and seven-year storage being over 80%. The germination data in this report, therefore represent a notable improvement in the germination protocol for this species compared to previously published reports.

56. ***Asparagus aphyllus*** L. (*Asparagaceae*)

Accession data

Si(M): Wied Znubber, Birżebbuġa, Malta, (WGS84: 35.809167°N, 14.511278°E), March 2021, *J. A.Buhagiar, M. Iannaccone & A. Lamoliere* (BDUM/20/21, Seedbank of the Department of Biology, University of Malta).

Germination data

Pre-treatments: None.

Germination medium: Seeds were germinated on 2 sheets of sterilized filter paper (Whatman™ Grade 91), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
90.0%	alternating 23.5/15°C	0/24h	17	26.4	49	28.6
85.0%	alternating 23.5/15°C	16/8h	17	25.7	49	28.1
84.0%	constant 15°C	0/24h	17	26.1	52	26.2
83.0%	constant 15°C	12/12h	19	28.3	61	31.4

Observations

Asparagus aphyllus is present in numerous habitats of the Maltese islands (Brullo & al. 2020). It has high germination percentages at two of the thermoperiods tested, namely 15 and 23.5/15°C with no significant change between total darkness and 12/12 or 16/8 photoperiods tested. The highest percentage of 90% was at an alternating thermoperiod of 23.5/15°C under full dark conditions, though a 16/8 photoperiod also gave good germination results (85%) indicating that seeds are not negatively affected by light. Significantly lower germination rates were obtained for the other thermoperiods with the lowest being at 25°C both in complete darkness and 16/8h light/dark conditions (23% and 17% respectively). No germination data is given in the RBG Kew's Seed Information Database (https://data.kew.org/sid/) and other sources do not elaborate on germination at different temperatures. Therefore, these results provide a germination protocol for this species, with direct application in ecological restoration, but also food production.

57. ***Myrtus communis*** L. (*Myrtaceae*)

Accession data

Si(M): Gnien Ingraw, Mellieha, Malta. (WGS84: 35.959278°N, 14.358333°E), 95 m a.s.l., 09 Mar 2021, *J. A. Buhagiar, M. Iannaccone & A. Lamoliere* (BDUM/21/17, Seedbank of the Department of Biology, University of Malta).

Germination data

Pre-treatments: None.

Germination medium: Seeds were germinated on 2 sheets of sterilized filter paper (Whatman™ Grade 91), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
93.0%	constant 15°C	0/24h	3	14.0	28	15.3
93.0%	alternating 23.5/15°C	0/24h	7	10.0	19	11.0
93.0%	alternating 23.5/15°C	16/8h	7	10.8	26	12.0
92.0%	constant 15°C	12/12h	3	15.0	29	16.1
91.0%	constant 25°C	16/8h	3	7.0	24	8.4
89.0%	constant 20°C	16/8h	5	8.7	14	10.2
89.0%	constant 25°C	0/24h	3	5.7	10	6.6
88.0%	constant 20°C	0/24h	7	8.6	21	10.2

Observations

Myrtus communis is a species with high germination percentages. It does not seem to be dependent on any particular thermo- or photoperiod with all percentages being above 88% irrespective of germination in complete darkness or with a light/dark photoperiod. These results are consistent with previous results comparing blue and white morphs of *M. communis* from Mallorca (Traveset & al. 2001). For *M. communis* subsp. *communis*, the RBG Kew's Seed Information Database (Royal Botanic Gardens Kew 2021) gives comparable germination percentages from 83 to 93% for tested temperatures of 10, 15, 20 and 25°C using a 12/12h photoperiod. However, maximum germination times were much longer and range from 49 days at 25°C to 77 days for 10 and 15°C. This species does not qualify as threatened according to IUCN (Chadburn & Wilson 2018), however, this phenotype with its pale coloured and sweet fruits, but also since it is a small population restricted to few locations in the Maltese Islands, though a few specimens possibly derived from this population are present in some gardens.

58. ***Pancratium maritimum*** L. (*Amaryllidaceae*)

Accession data

Si(M): Armier Bay, Mellieha, Malta (WGS84 35.992333°N, 14.365722°E), 5 m a.s.l., 19

Nov 2020, *J. A. Buhagiar, M. Iannaccone & A. Lamoliere* (BDUM/20/13, Seed bank of the Department of Biology, University of Malta).

Germination data

Pre-treatments: None.

Germination medium: Seeds were germinated on 2 sheets of sterilized filter paper (Whatman™ Grade 91), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
94.0%	alternating 23.5/15°C	16/8h	7	19.6	68	24.0
91.0%	alternating 23.5/15°C	0/24h	5	20.9	59	23.1
89.0%	constant 15°C	0/24h	3	20.4	49	22.6
89.0%	constant 15°C	12/12h	3	22.5	61	25.4
86.0%	constant 20°C	16/8h	5	22.8	59	24.3
86.0%	constant 25°C	0/24h	7	22.3	38	23.3
86.0%	constant 25°C	16/8h	3	21.8	61	23.8
80.0%	constant 20°C	0/24h	10	19.5	52	22.2

Observations

Pancratium maritimum is another species with high germination percentages. Like the previous species, it does not seem to be dependent on any particular thermo- or photoperiod with all percentages being above 80% irrespective of germination in complete darkness or with a light/dark photoperiod. However, an alternating day and night thermoperiod of 23.5/15°C and an 18/6h photoperiod gave the highest germination percentage, 94%, followed closely by 91% for a 0/24h period. Thus, light exposure does not appear to be a crucial requirement, though in two cases, a slightly higher percentage was obtained.

These results are consistent with germination trials carried out on populations from Egypt (Mohamed & al. 2018) and Italy (Magrini & al. 2019; Salmeri & Trubia 2019), though the latter found photoinhibition at 5°C. These results represent the first documented germination data reported for this species from the Maltese archipelago, where it has a very restricted distribution and population size. Royal Botanic Gardens Kew (2021) also gives comparable results both in terms of percentages and also maximum days for germination. Together with *Eryngium maritimum* and other species, it forms a scare association in the Maltese Islands, described as a *Cypero capitati-Agropyretum juncei* (Kuhnholtz-Lordat 1923; Brullo & al. 2020).

Conclusion

Through the present research, it was possible to successfully investigate seed germination for five coastal and inland garrigue species from the Maltese Islands. Germinated seeds were eventually grown on and used for habitat restoration. It is emphasised that pre-sowing sterilisation was purposely avoided in order to preserve as much as possible the seed-associated microbiome and thereby produce more environmentally adapted and resilient seedlings. Further studies on seed conditioning, seed viability as well as fungal associations occurring during germination are envisaged.

References

Abdellaoui, R., Souid, A., Zayoud, D. & Neffati, M. 2013: Effects of natural long storage duration on seed germination characteristics of *Periploca angustifolia* Labill. – Afr. J. Biotech. **12(15):** 1760-1768. https://doi.org/10.5897/AJB10.1862

Anderson, E. W. & Schembri, P. J. 1989: Coastal zone survey of the Maltese Islands report. – Malta.

Borg, J. 1927: Descriptive flora of the Maltese Islands. – Malta.

Brullo, S., Brullo, C., Cambria, S. & Giusso del Galdo, G. 2020: The vegetation of the Maltese Islands. – Berlin.

Casha, A. 2015: Flora of the Maltese Islands. – Malta.

— 2020: Flora of the Maltese Islands. – Malta.

Chadburn, H. & Wilson, B. 2018: *Myrtus communis*. The IUCN Red List of Threatened Species 2018: e.T203365A119997141. – https://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T203365A119997141.en [Last accessed 1.11.2021]

Haslam, S. M. 1969: Malta's plant life. – Malta.

—, Sell, P. D. & Wolseley, P. A. 1977: A flora of the Maltese Islands. – Malta.

Kuhnholtz-Lordat, G. 1923: Essai de géographie botanique sur les dunes du golfe du Lion. – Paris.

Lanfranco, E. 1984: Guida alla escursioni a Malta - Aprile 1984. –Malta.

— 1995: The vegetation of the Maltese Islands. – Pp. 27-29 in: Giusti, F., Manganelli, G., Schembri, P. G. (eds), The non-marine molluscs of the Maltese Islands. – Monogr. Mus. Reg. Sci. Nat., Torino, **15.**

— & Schembri P. J. 1986: Maltese wetlands and wetland biota. – Potamon **15:**122-125.

Magrini, S., Barreca, D., Neri, L., Iacomino, A., Barbarese, F., Superchi, S. & Zucconi, L. 2019: Seed germination protocols for six dune species from the Tyrrhenian coast (central Italy). – Fl. Medit. **29:** 293-302. https://doi.org/10.7320/FlMedit29.293

Marques, I. & Draper, D. 2012: Seed germination and longevity of autumn-flowering and autumn-seed producing Mediterranean geophytes. – Seed Sci. Res. **22(4):** 299-309. https://doi.org/10.1017/S0960258512000153

Mohamed, E., Kasem, A. M. & Farghali, K. A. 2018: Seed germination of Egyptian *Pancratium maritimum* under salinity with regard to cytology, antioxidant and reserve mobilization enzymes, and seed anatomy. – Flora **242:** 120-127. https://doi.org/10.1016/j.flora.2018.03.011

Noumi, Z., Dhaou, S. O. & Chaieb, M. 2010: Seed germination characteristics of *Periploca angustifolia* Labill. and *Rhus tripartita* (Ucria) Grande: effects of temperature, salinity and water stress. – Acta Bot. Gall. **157(2):** 317-327. https://doi.org/10.1080/12538078.2010.10516209

Pignatti, S. 1982: Flora d'Italia, **1-3.** – Bologna.

Royal Botanic Gardens Kew 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/ [Last accessed November 2021]

Salmeri, C. & Trubia, M. 2019: Seed germination reports for coastal sand dune species from Sicily. – Fl. Medit. **29:** 277-287. https://doi.org/10.7320/FlMedit29.277

Savona-Ventura, C. 2001: The Maltese Islands, the natural environmental. – Malta.

Schembri, P.J. 1994: Malta's natural heritage. Pp. 105-124 in: Frendo, H. & Friggieri, O. (eds), Malta culture and identity. – Malta.

— 1997: The Maltese islands: climate, vegetation and landscape. – GeoJournal **41(2):** 115-125.

Sommier, S. & Caruana Gatto, A. 1915: Flora Melitensis nova. – Firenze.

Traveset, A., Riera, N. & Mas, R. E. 2001: Ecology of fruit-colour polymorphism in *Myrtus communis* and differential effects of birds and mammals on seed germination and seedling growth. – J. Ecol. **89(5):** 749-760. https://doi.org/10.1046/j.0022-0477.2001.00585.x

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G. Gugliuzza, G. Domina & A. Giovino

Seed germination of *Thymus richardii* subsp. *nitidus* (*Lamiaceae*)

Abstract

Gugliuzza, G., Domina, G. & Giovino, A.: Seed germination of *Thymus richardii* subsp. *nitidus* (*Lamiaceae*) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 291-293. 2021. http://dx.doi.org/10.7320/FlMedit31.291

The germination ability of the punctual endemic *Thymus richardii* subsp. *nitidus* (*Lamiaceae*) from the Island of Marettimo in W Sicily was studied. Mature seeds were collected in the field. Different experimental conditions were tested and the best methods with optimal germination results were provided. This is the first germination record for this taxon.

Key words: Marettimo, Egadi, Island flora, conservation.

Introduction

Thymus richardii Pers. (*Lamiaceae*) is a suffruticous taxon that includes five subspecies: *T. richardii* subsp. *richardii*, *T. richardii* subsp. *ebusitanus* (Font Quer) Jalas, *T. richardii* subsp. *vigoi* Riera Gümenes & Rosselló, *T. richardii* subsp. *nitidus* (Guss.) Jalas and *T. richardii* subsp. *aureopunctatus* (Beck) L.Sáez, Bogunić & Bogdanović. The first occurs in Mallorca (Balearic Islands, E Spain), the second in Ibiza (Balearic Islands, E Spain), the third in Sierra de la Safor (E Spain) the fourth in Marettimo (Egadi islands, W Sicily) and the latter in near Konjic (N Herzegovina) (Morales 2010; Sáez & al. 2021). *T. richardii* subsp. *nitidus* occurs in five localities on the island of Marettimo (Francini & Messeri 1956; Gianguzzi & al. 2006; Bartolucci & Domina 2015) and its population can be estimated at about two hundred mature individuals. This taxon can be considered among the rarest thyme in Italy, though it is listed as Near Threatened (NT) in Orsenigo & al. (2018) because no real threats affect its habitat and the population is almost stable. The best protocol for seed germination of this taxon was assessed and discussed.

59. ***Thymus richardii*** subsp. ***nitidus*** (Guss.) Jalas (*Lamiaceae*)

Accession data

Si: Isola di Marettimo (TP), Portella Ansini (WGS84: 37.962565°N, 12.062577°E), 470 m a.s.l., 14 Jun 2019, *A. Giovino & G. Gugliuzza* (SAF100040).

Germination data

Pre-treatment: seed priming with a 24 h period of imbibition in 200 ppm GA_3 water solution (200 mg/l).

Germination medium: 3 sheets of sterilized filter paper (Whatman 40), imbibed with 10 ml of distilled water under sterile conditions in Petri dishes.

Sample size: 60 seeds per treatment (20 × 3 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
82.5%	constant 20°C	0/24h	5.5	8.2	15.0	9.4

Observations

The average seed size is around 0.6-0.7 mm, dark brown in colour and oval-elliptical in shape. Thousand-seed weight: 104.7 g. The percentage of fertile seeds calculated with the flotation method is 66.8% (Fig. 1).

This is the first germination report for this taxon. Mature seeds were collected in June from wild plants and were selected by the flotation method before germination tests.

Other pre-treatments tested were seed priming with a 24 h period of imbibition in: 1) distilled water; 2) warm distilled water (35°C); 3) 0.02% boric acid aqueous solution (0.2 g/l); 4) 100 ppm GA_3 water solution (100 mg/l); 5) 300 ppm GA_3 water solution (300 mg/l).

Imbibition for 24 hours in a solution with water and gibberellic acid (200 mg/l) was the only treatment giving a percentage of germination higher than 80%. Little lower results (77.5% of germination) were achieved through the pre-treatment with 300 ppm GA_3, while simple imbibition for 24 hours in distilled water gave the worst result with just 22.5% of germination.

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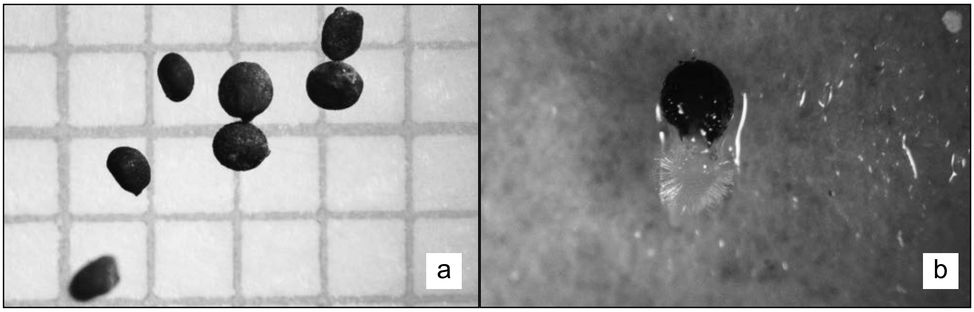

Fig. 1. *Thymus richardii* subsp. *nitidus*: **a,** seeds; **b,** germinated seed.

References

Bartolucci, F. & Domina, G. 2015: The genus *Thymus* (*Lamiaceae*) in Sicily. – Pl. Biosyst. **149:** 710-719. http://dx.doi.org/10.1080/11263504.2015.1057259

Francini, E. & Messeri, A. 1956: L'isola di Marettimo nell'arcipelago delle Egadi e la sua vegetazione. – Webbia **11:** 607-846. http://dx.doi.org/10.1080/00837792.1956.10669652

Gianguzzi, L., Scuderi, L. & Pasta, S. 2006: La flora vascolare dell'Isola di Marettimo (Arcipelago delle Egadi, Sicilia occidentale): analisi fitogeografica ed aggiornamento. – Webbia **61:** 359-402. https://doi.org/10.1080/00837792.2006.10670810

Morales, R. 2010: *Thymus* L. – Pp. 349-409 in: Castroviejo, S., Morales, R., Quintanar, A., Cabezas, F., Pujadas, A. J. & Cirujano, S. (eds), Flora Iberica, **2.** – Madrid.

Orsenigo, S., Montagnani, C., Fenu, G., Gargano, D., Peruzzi, L., Abeli, T., Alessandrini, A., Bacchetta, G., Bartolucci, F., Bovio, M., Brullo, C., Brullo, S., Carta, A., Castello, M., Cogoni, D., Conti, F., Domina, G., Foggi, B., Gennai, M., Gigante, D., Iberite, M., Lasen, C., Magrini, S., Perrino, E. V., Prosser, F., Santangelo, A., Selvaggi, A., Stinca, A., Vagge, I., Villani, M., Wagensommer, R. P., Wilhalm, T., Tartaglini, N., Duprè, E., Blasi, C. & Rossi, G. 2018: Red Listing plants under full national responsibility: Extinction risk and threats in the vascular flora endemic to Italy. – Biol. Conserv. **224:** 213-222. https://doi.org/10.1016/j.biocon.2018.05.030.

Sáez, L., Bogunić, F., Cambria, S., Riera, J., Bogdanović, S. 2021: On the identity of *Thymus humifusus* var. *aureopunctatus* (*Lamiaceae*) and taxonomic notes on the *Th. richardii* complex. – PhytoKeys **186:** 139-158. https://10.3897/phytokeys.186.75412

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A. Cucchietti, M. Lonati, B. Gallino, V. Carasso & M. Mucciarelli

Germination requirements of three segetal species of the Italian flora

Abstract

Cucchietti, A., Lonati, M., Gallino, B., Carasso, V. & Mucciarelli, M.: Germination requirements of three segetal species of the Italian flora [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 294-298. 2021. http://dx.doi.org/10.7320/FlMedit31.294

This study focuses on the germination requirements of three segetal plant species: *Agrostemma githago*, *Bupleurum rotundifolium* and *Xeranthemum inapertum*. Seeds were collected in the Western Alps, Piedmont, and conserved in a cool and dry place at room temperature for a post-maturation period of at least 30 days. Our results show a high germination response for some treatments in all the species.

Key words: *Agrostemma githago*, *Bupleurum rotundifolium*, *Xeranthemum inapertum*, weed, Western Alps.

Introduction

Segetal flora is a characteristic element of the agroecosystems, and it is important for their proper functioning; therefore, the conservation of these weed species is crucial for preserving the agrobiodiversity (Fanfarillo & al. 2020). These species are now rare in Piedmont because of the abandonment of mountain cereal cultivation. In this regard, seeds of *Agrostemma githago* L., *Bupleurum rotundifolium* L. and *Xeranthemum inapertum* (L.) Mill. (three segetal species) were collected in summer 2020, between 700 and 1000 m a.s.l., in the Western Alps, and stored in the Germplasm Bank of Chiusa di Pesio (CN, Italy). In order to introduce seed accessions to the seed bank, germination tests were carried out to establish optimum germination conditions. For each species different photo- and thermo-periods were tested.

60. ***Agrostemma githago*** L. (*Caryophyllaceae*) (Fig. 1a)

Accession data

It: Valdieri (Cuneo) (WGS84: 44.292467°N, 7.430214°E), rye field, 711 m a.s.l., 7 Aug 2020, *M. Lonati* (NA/21/2294, Piedmont Germplasm Bank).

Germination data

Pre-treatments: seed sterilization in a 70% ethanol-water solution for 3 minutes and in a 5% sodium hypochlorite water solution for 10 minutes (×2) followed by 3-4 rinses in sterilized distilled water.

Germination medium: 2 sheets of sterilized filter paper imbibed with 3 ml of filter-sterilized distilled water.

Sample size: 125 seeds for each test (25 × 5 replicates).

Germination	**Thermoperiod**	**Photoperiod [light/dark]**	**T_1 [d]**	**T_{50} [d]**	**T_{max} [d]**	**MTG [d]**
99.2%	constant 4°C	0/24h	4	2.0	11	6.9

Observations

Agrostemma githago belongs to the *Caryophyllaceae*, which have a complete embryo at the maturation of the seed and an expected simple physiological seed dormancy (Finch-Savage & Leubner-Metzger 2006). Low temperatures for a short period encourage the overcoming of seed dormancy as already described for other species within *Caryophyllaceae* (Fišer Pečnikar & al. 2018). In our experiments, seed germination was optimal (99.2%) at 4°C and under full dark conditions. Very lower germination percentages were obtained when *A. githago* seeds were incubated directly at 25/15°C in a 12/12h photoperiod (58.4%) or when the warm treatment (30 days) preceded the cold stratification (51.2%).

61. ***Bupleurum rotundifolium*** L. (*Apiaceae*) (Fig. 1b)

Accession data

It: Oulx (Torino) (WGS84: 45.032785°N, 6.832038°E), rocky debris in former terraces, 1085 m a.s.l., 6 Jul 2020, *M. Lonati* (NA/21/2292, Piedmont Germplasm Bank).

Germination data

Pre-treatments: seed sterilization in a 70% ethanol-water solution for 3 minutes and in a 5% sodium hypochlorite water solution for 10 minutes (×2) followed by several rinses in sterilized distilled water. 1) Cold stratification at 4°C for 30 days.

Germination medium: 2 sheets of sterilized filter paper imbibed with 3 ml of sterilized distilled water.

Sample size: 125 seeds for each test (25 × 5 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
92.8%	constant 4°C	0/24h	31	4.7	80	32.8
84.8%[1]	alternating 25/15°C	12/12h	31	4.5	44	32.1

Observations

Results showed that *B. rotundifolium* seed germination is improved by a short treatment at low temperatures. The highest germination percentages were obtained at 4°C (92.8%) and when a cold stratification was given before rising the incubation temperature (84.8%). Seeds have a small embryo as typical of the *Apiaceae* family (data not shown) pointing to the presence of a morphological dormancy (Finch-Savage & Leubner-Metzger 2006).

62. ***Xeranthemum inapertum*** (L.) Mill. (*Asteraceae*) (Fig. 1c)

Accession data

It: Oulx (Torino) (WGS84: 45.031864°N, 6.830746°E), rocky debris in former terraces, 1085 m a.s.l., 12 Aug 2020, *M. Lonati* (NA/21/2291 NA/21/2292, Piedmont Germplasm Bank).

Germination data

Pre-treatments: seed sterilization in a 70% ethanol-water solution for 3 minutes and in a 5% sodium hypochlorite water solution for 10 minutes (×2) followed by 3-4 rinses in sterilized distilled water.

Germination medium: 2 sheets of sterilized filter paper imbibed with 3 ml of sterilized distilled water.

Sample size: 125 seeds for each test (25 × 5 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
100.0%	alternating 25/15°C	12/12h	7	4.5	9	7.0
100.0%	constant 4°C	0/24h	7	1.4	21	11.8

Observations

Germination tests carried out on *X. inapertum* seeds provided optimal germinations (100%) under different temperatures, either in a 12/12h dark/light photoperiod or in full darkness. When a 25/15°C alternating temperature was applied, the maximum germination was reached within 9 days, while it took 21 days to the maximum germination when the seeds were incubated at 4°C. At both treatments, the germination delay was 7 days. This species responds positively, in terms of germination, to different temperatures and has no

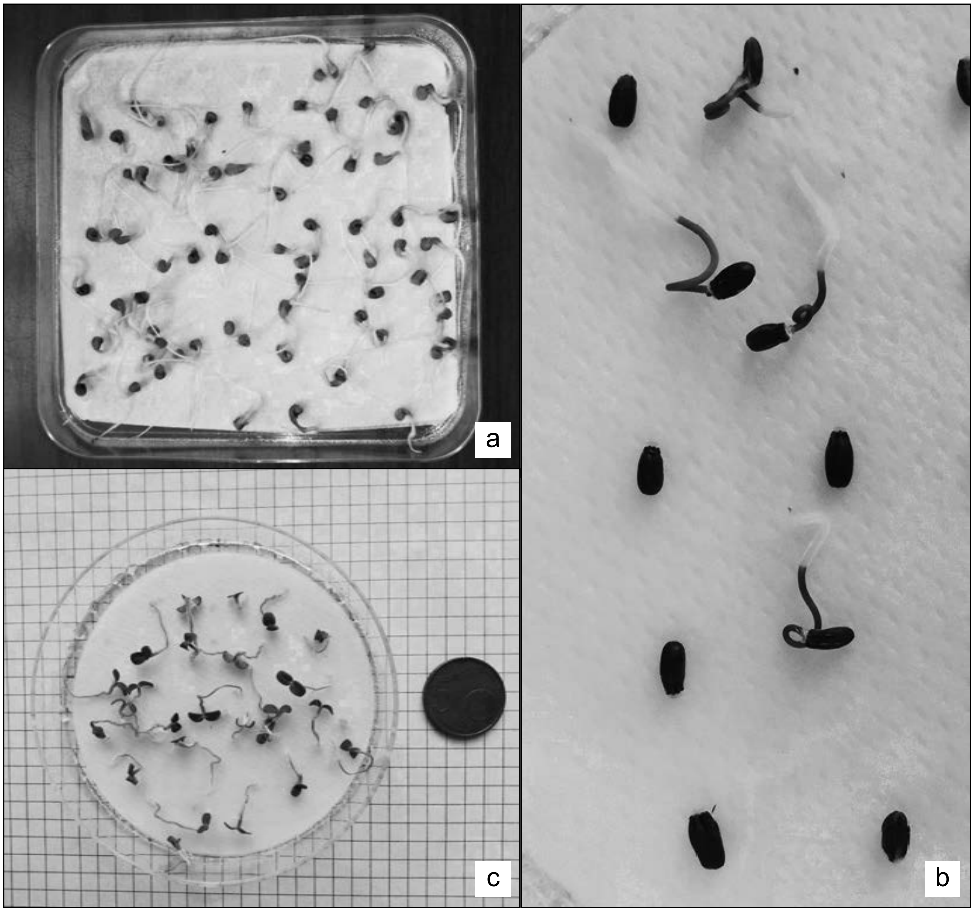

Fig. 1. a) Seedlings of *Agrostemma githago;* b) Some germinated seeds of *Bupleurum rotundifolium;* c) Seedlings of *Xeranthemum inapertum* (photos by A. Cucchietti).

seed dormancy as for many other *Asteraceae* (Baskin & Baskin 2004). The observed germination behaviour seems to be typical of an annual spring species.

References

Baskin, J. M. & Baskin, C. C. 2004: A classification system for seed dormancy. – Seed Sci. Res. **14:** 1-16. https://doi.org/10.1079/SSR2003150

Fanfarillo, E., Petit, S., Dessaint, F., Rosati, L. & Abbate, G. 2020: Species composition, richness, and diversity of weed communities of winter arable land in relation to geo-environmental factors: A gradient analysis in mainland Italy. – Botany **98:** 381-392. https://doi.org/10.1139/cjb-2019-0178

Finch-Savage, W. E. & Leubner-Metzger, G. 2006: Seed dormancy and the control of germination. – New Phytol. **171:** 501-523. https://doi.org/10.1111/j.1469-8137.2006.01787.x

Fišer Pečnikar, Ž., Balant, M., Glasnović, P. & Boštjan, S. 2018: Seed dormancy and germination of the rare, high elevation Balkan endemic *Cerastium dinaricum* (*Caryophyllaceae*). – Biologia **73:** 937-943. https://doi.org/10.2478/s11756-018-0115-5

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S. Magrini, A. Alonso Simón, L. Zucconi & A. Cristaudo

Seed germination protocols in the genus *Salsola* (*Amaranthaceae*) in Italy

Abstract

Magrini, S., Alonso Simón, A., Zucconi, L. & Cristaudo, A.: Seed germination protocols in the genus *Salsola* (*Amaranthaceae*) in Italy) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 299-304. 2021. http://dx.doi.org/10.7320/FlMedit31.299

Here, successful germination protocols for the following three annual *Salsola* species are presented: *Salsola soda* (= *Soda inermis*), *S. squarrosa* subsp. *controversa*, and *S. tragus* subsp. *tragus*. It is the first report of germination data for the three species for Italy. Seeds were collected in beaches and dunes along the Tyrrhenian coasts in Sicily and south Tuscany and north Latium (central Italy). The germination ability was tested at the Catania Germplasm Bank (BGS-CT) and the Tuscia Germplasm Bank (BGT) at constant and alternating temperatures (from 5 to 40°C), under both light (with a 12/12h photoperiod) and total dark. Our results show a high germination ability and germination rate for all the tested species.

Key words: beach, coastal dunes, halophytes, Latium, psammophytes, Sicily, Tuscany.

Introduction

Annual *Salsola* L. species (*Amaranthaceae*), generally, have a relatively longer life cycle from seed germination in spring to fruit ripening in late autumn. Like other species of arid areas, they are characterized by germination heterochrony, the germination of seeds dispersed in a single season, which exhibits continuous germination during a long period (Liu & al. 2013). These species are defined as "very fast germinating species" (Parsons 2012) because seeds germinate in a very short period after the substrate is wetted. They produce seeds with a spiral embryo that is completely developed (Parsons 2012), so the cells can simply elongate after imbibition, rapidly breaking the fruit cover in just one to three days (Wallace & al. 1968). This allows a rapid response to favourable environmental conditions (Liu & al. 2013). The germination timing and rate are particularly important for species growing in stressful habitats like saline deserts (Luciani & al. 2001; Gul & al. 2013), where the establishment of a new generation depends on narrow opportunity windows. This kind of germination is the adaptive strategy of desert halophytes because the salinity of the soil is reduced by the rain only for a short duration, so rapid responses, like imbibition and rapid germination, increase their colonization ability (Luciani & al. 2001; Liu & al. 2013).

Here we present successful germination protocols for three species of *Salsola* occurring along the coasts of Sicily, *Salsola soda* L., and the Italian peninsula, *S. squarrosa* Steven ex Moq. subsp. *controversa* (Tod. ex Lojac.) Mosyakin and *S. tragus* L. subsp. *tragus*.

63. ***Salsola soda*** L. (= *Soda inermis* Fourr.) (*Amaranthaceae*)

Accession data

Si: Sicily. Paternò (Catania), Salinelle del Fiume (WGS84: 37.567984°N, 14.864458°E), mud volcanoes with emission of salt water, 108 m a.s.l., 13 Nov 1998, *A. Cristaudo* (BGS-CT, Catania Germplasm Bank).

Germination data

Pre-treatments: no treatment.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 50 seeds for each test.

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
100%	constant 30°C	12/12h	1.0	3.5	7.0	3.9
100%	constant 30°C	0/24h	1.0	4.4	9.0	4.4
100%	constant 25°C	12/12h	2.0	3.2	7.0	3.3
100%	constant 25°C	0/24h	2.0	4.0	11.0	4.4
100%	constant 15°C	0/24h	2.0	4.6	11.0	5.3
100%	alternating 15/35°C	0/24h	2.0	5.2	11.0	6.0
98%	constant 10°C	0/24h	1.0	4.7	8.0	5.3
98%	constant 20°C	12/12h	2.0	4.6	11.0	5.2
98%	constant 15°C	12/12h	2.0	5.6	11.0	6.1
98%	alternating 10/30°C	12/12h	1.0	2.3	9.0	3.2
98%	alternating 10/30°C	0/24h	1.0	4.0	9.0	3.9
98%	alternating 15/35°C	12/12h	2.0	4.6	11.0	5.5
96%	constant 10°C	12/12h	1.0	5.1	9.0	5.6
96%	constant 20°C	0/24h	2.0	4.5	11.0	5.4
94%	constant 40°C	0/24h	1.0	1.5	8.0	2.8
90%	constant 35°C	12/12h	1.0	2.4	8.0	3.5
90%	constant 35°C	0/24h	1.0	4.6	9.0	4.8
86%	constant 40°C	12/12h	1.0	2.5	9.0	3.7

Observations

Salsola soda L. is an annual herb that is native to the Mediterranean Basin. It is a succulent halophyte that typically grows in coastal regions. Here we report the first germination data for this species for Italy. Germination tests were carried out at the Catania Germplasm Bank using eight constant (5-40°C) and two alternate (10/30°C and 15/35°C) temperatures both in the light (12/12h) and in full darkness.

High germination percentages (≥ 86%) were recorded at almost all the tested temperatures, with the highest (98-100%) in the range between 10 and 30°C. At 5°C lower germination percentages were recorded in full darkness and especially in the light (66% and 38%, respectively). In particular, the fastest germination was recorded at 40°C in darkness (T_1 = 1.0 day, T_{50} = 1.5 days, and T_{max} = 8 days) with similar values also in the light. The slowest germination was recorded at 5°C under light conditions (T_1 = 8.0 days, T_{50} = 11.3 days) and full dark (T_1 = 5.0 days, T_{50} = 8.8 days).

The results are in accordance with the germination percentages reported for this species (close to 100% at 20°C) by Ferrer-Gallego & al. (2013) for Spain and by Royal Botanic Gardens Kew (2021), while they are higher than those of Royal Botanic Gardens Kew (2021) at 15°C (98% vs 89%).

64. ***Salsola squarrosa*** subsp. ***controversa*** (Tod. ex Lojac.) Mosyakin (*Amaranthaceae*)

Accession data

It: Latium. Santa Marinella (Roma), Santa Severa (WGS84: 42.018317°N 11.955122°E), spiaggia, 2 m a.s.l., 20 Opt 2021, *A. Alonso Simón & S. Magrini* (BGT-A-89521, Tuscia Germplasm Bank).

Germination data

Pre-treatments: sterilization with a solution of 5% sodium hypochlorite + Tween 20 for 5 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 1% agar.

Sample size: 100 seeds for each test (20 × 5 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
100.0%	constant 30°C	12/12h	2.8	2.8	5.2	3.4
100.0%	constant 25°C	12/12h	3.0	6.3	9.4	6.3
100.0%	constant 25°C	0/24h	3.2	3.5	10.2	4.6
100.0%	constant 20°C	0/24h	10.2	14.9	22.6	16.2
98.9%	constant 30°C	0/24h	2.6	4.1	10.8	2.9
97.8%	constant 15°C	0/24h	14.0	13.9	17.6	15.0
86.9%	constant 15°C	12/12h	14.0	14.2	17.2	14.8

Observations

Salsola squarrosa subsp. *controversa* [= *S. tragus* subsp. *pontica* (Pall.) Rilke] is an annual species typical of the sand beach drift-lines, on the Italian coasts (Acosta & Ercole 2015). Here we report the first germination data for this species for Italy. Germination tests were carried out at the Tuscia Germplasm Bank using five constant temperature regimes (10-30°C) and both light and dark conditions.

The results showed high germination percentages (≥ 79%) between 15°C and 30°C, with an optimum temperature range for this species at 20-30°C (98.9-100%), while no germination was recorded at 10°C. Further tests will be carried out to define the maximum temperature for the germination of this species.

The fastest germination was recorded at 30°C in the light (T_1 = T_{50} = 2.8 days and 5.2 days for the maximum germination) and the slowest at 20°C under light conditions (T_1 = 14.0 days, T_{50} = 20.3 days, and T_{max} = 27.0 days). While strong photoinhibition has been reported in other sand beach species, like *Cakile maritima* Scop. (Thanos & al. 1991), it has not been detected in *S. squarrosa*, like recently reported also for *Cyperus capitatus* Vand. (Salmeri & Trubia 2019) and *Matthiola sinuata* (L.) W.T. Aiton living in the same habitat (Magrini & al. 2019).

65. ***Salsola tragus*** L. subsp. ***tragus*** (*Amaranthaceae*)

Accession data

It: Tuscany. Grosseto (Grosseto), Principina a Mare (WGS84: 42,693297°N, 10,996353°E), spiaggia, 1 m a.s.l., 1 Nov 2020, *S. Magrini & A. Caldelli* (BGT-A-69620, Tuscia Germplasm Bank).

Germination data

Pre-treatments: sterilization with a solution of 5% sodium hypochlorite + Tween 20 for 5 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 1% agar.

Sample size: 100 seeds for each test (20 × 5 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
92.0%	constant 15°C	12/12h	2.8	7.5	20.8	8.4
86.7%	constant 20°C	12/12h	2.2	4.9	11.0	5.6
84.0%	constant 15°C	0/24h	2.6	7.5	14.2	7.8
83.9%	constant 20°C	0/24h	2.0	3.7	8.8	4.7

Observations

Salsola tragus (= *S. kali* L. subsp. *ruthenica* Soó) is widely spread from the Baltic Sea to the Mediterranean coasts. It is common in the annual communities of sand beaches along the Italian coasts (Acosta & Ercole 2015). Here we report the first germination data for this species for Italy. Germination tests were carried out at the Tuscia Germplasm Bank using nine constant temperature regimes (5-40°C) and both light and dark conditions.

High germination percentages (> 83%) were recorded only at 15-20°C, with slightly higher values in the light. Very lower percentages were recorded at the other temperatures, only 2-40% in the range 35-40°C, with the lowest percentages recorded at the lower temperature, 5°C, with no germination in the light and only 2% in the dark. Our results are not in accordance with Royal Botanic Gardens Kew (2021) which reported 100% germination at 5°C with an 8/16h photoperiod and 67% at 0°C, suggesting that the thermal germination behaviour may be affected by the maternal environment of seed production (De Vitis & al. 2014, 2018). As reported also for *S. squarrosa*, in a range of temperatures from 5 to 37°C, no difference in germination was observed between light conditions and full dark.

Wallace & al. (1968) reported a very short germination time (29 min) for *S. tragus* (sub *S. kali* var. *tenuifolium*), but in our tests seeds germinated within two to three days, only at 37-40°C, they germinated in one day. The fastest germination was recorded at 20-25°C in darkness (T_{50} = 3.7 and 3.5 days, respectively) and the slowest at 10°C under both light conditions and full dark (T_{50} = 21.6 and 16.4 days, respectively).

References

Acosta, A. T. R. & Ercole, S. (eds) 2015: Gli habitat delle coste sabbiose italiane: ecologia e problematiche di conservazione. – ISPRA, Serie Rapporti, 215/2015.

De Vitis, M., Mattioni, C., Mattana, E., Pritchard, H. W., Seal, C., Ulian, T., Cherubini, M. & Magrini, S. 2018: Integration of genetic and seed fitness data to the conservation of isolated subpopulations of the Mediterranean plant *Malcolmia littorea*. – Pl. Biol. **20(S1):** 203-213. https://doi.org/10.1111/plb.12637

—, Seal, C., Ulian, T., Pritchard, H. W., Magrini, S., Fabrini, G. & Mattana, E. 2014: Rapid adaptation of seed germination requirements of the threatened Mediterranean species *Malcolmia littorea* (*Brassicaceae*) and implications for its reintroduction. – S. Afr. J. Bot. **94:** 46-50. https://doi.org/10.1016/j.sajb.2014.05.008

Ferrer-Gallego, P. P., Ferrando, I., Gago, C. & Laguna, E. (eds) 2013: Manual para la conservación de germoplasma y el cultivo de la flora valenciana amenazada. – Valencia.

Gul, B., Ansari, R., Flowers, T. J. & Khan, M. A. 2013: Germination strategies of halophyte seeds under salinity. – Environ. Exp. Bot. **92:** 4-18. https://doi.org/10.1016/j.envexpbot.2012.11.006

Liu, K., Baskin, J. M., Baskin, C. C. & Du, G. 2013: Very fast-germinating seeds of desert species are cryptoviparous-like. – Seed Sci. Res. **23:** 163-167. https://doi.org/10.1017/S0960258513000135

Luciani, F., Cristaudo, A. & Aricò, D. 2001: Germination ecology of three *Plantago* L. (*Plantaginaceae*) species living in a saline environment. – Pl. Biosyst. **135(2):** 213-221. https://doi.org/10.1080/11263500112331350850

Magrini, S., Barreca, D., Neri, L., Iacomino, A., Superchi, S. & Zucconi, L. 2019: Seed germination protocols for six dune species from the Tyrrhenian coast (central Italy). – Fl. Medit. **29:** 293-302. https://doi.org/10.7320/FlMedit29.293

Parsons, R. F. 2012: Incidence and ecology of very fast germination. – Seed Sci. Res. **22:** 161-167. https://doi.org/10.1017/S0960258512000037

Royal Botanic Gardens Kew. 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/ [Last accessed 1.11.2021]

Salmeri, C. & Trubia, M. 2019: Seed germination reports for coastal sand dune species from Sicily. – Fl. Medit. **29:** 277-287. https://doi.org/10.7320/FlMedit29.277

Thanos, C. A., Douma, D. J. & Marangaki, C. J. 1991: Photoinhibition of seed germination in Mediterranean maritime plants. – Ann. Bot. **68:** 469-475. https://doi.org/10.1093/oxfordjournals.aob.a088280

Wallace, A., Rhods, W. A. & Frolich, E. F. 1968: Germination behavior of *Salsola* as influenced by temperature, moisture, depth of planting, and gamma irradiation. – Agron. J. **60:** 76-78. https://doi.org/10.2134/agronj1968.00021962006000010024x

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S. Pierce, J. Bellingardi, S. Villa, A. Ferrario, S. Armiraglio, B. E. L. Cerabolini & R. M. Ceriani

Seed germination protocols for EU Habitats Directive species from northern Italy

Abstract

Pierce, S., Bellingardi, J., Villa, S., Ferrario, A., Armiraglio, S., Cerabolini, B. E. L. & Ceriani, R. M.: Seed germination protocols for EU Habitats Directive species from northern Italy. [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 305-314. 2021. http://dx.doi.org/10.7320/FlMedit31.305

Germination protocols were developed or optimized for six northern-Italian species protected in Annexes II and IV of the European Union Habitats Directive: *Linaria tonzigii, Physoplexis comosa, Primula glaucescens, P. spectabilis, Saxifraga tombeanensis* and *Spiranthes aestivalis*. For some species (*L. tonzigii, P. glaucescens*), seeds collected in 2004 and stored at -18°C were compared with seeds collected 15 years later, and no statistically significant difference was found for final germination percentage (G), suggesting that seed banking is effective. *P. spectabilis* germinated at a high rate of G = 95.4%. *Spiranthes aestivalis* germinated extremely rapidly for an orchid, starting at just 11d (MTG = 17d), with extremely high rates (G = 97.1%).

Key words: *Linaria tonzigii, Physoplexis comosa, Primula glaucescens, P. spectabilis, Saxifraga tombeanensis, Spiranthes aestivalis*.

Introduction

The Lombardy region of northern Italy hosts a number of angiosperm species recognized by the European Council Directive 42/93/EEC of 21 May 1992 (‘on the conservation of natural habitats and of wild fauna and flora’) as either ‘species of community interest whose conservation requires the designation of special areas of conservation’ (Annex II) or ‘species of community interest in need of strict protection’ (Annex IV). For many of these species, nothing is known about seed germination and propagation requirements.

Here we present germination protocols for six ‘Habitats Directive’ species currently the object of conservation programmes in Lombardy: **Annex II:** *Linaria tonzigii* Lona (*Plantaginaceae*) and *Saxifraga tombeanensis* Boiss. ex Engl. (*Saxifragaceae*); **Annex IV:** *Physoplexis comosa* (L.) Schur (*Campanulaceae*), *Primula glaucescens* Moretti, *P. spectabilis* Tratt. (*Primulaceae*), and *Spiranthes aestivalis* (Poir.) Rich. (*Orchidaceae*).

Of these, *L. tonzigii* and *S. tombeanensis* are listed as 'Endangered' in the IUCN Red List (Armiraglio & al. 2010; Mangili & Rinaldi 2013), while the other species are 'Least Concern' (Jogan & al. 2013; Lasen & al. 2013). All species investigated here are also protected by Lombardy Regional law (n. 10, 31 March 2008) for the 'Flora and small fauna protected in Lombardy'. Specifically, they are listed as grade 'C1' rigorously protected species which cannot be damaged or removed without permission from the Lombardy Regional Government. Furthermore, Annex II species require a collection permit from the 'Ministry of the Ecological Transition' (*Ministero della Transizione Ecologica*). All material collected and used for the present study was obtained from the wild with collection permit DPN/2D/2004/13650 issued by the Ministry of the Environment to the Lombardy Seed Bank (LSB).

66. ***Physoplexis comosa*** (L.) Schur (*Campanulaceae*) (Fig. 1)

Accession data

It: Tremosine sul Garda (BS), loc. Passo Prà della Rosa (WGS84: 45.8404°N, 10.7315°E), EU habitat 8210 Calcareous rocky slopes with chasmophytic vegetation, 1679 m a.s.l., 14 Aug 2020, *V. Ghidotti* (BS999; LSB).

Germination data

Pre-treatments: Seed surface sterilization in bleach (10% v/v bleach solution, containing 0.1% Tween 20 surfactant) for 5 minutes followed by several rinses in sterilized distilled water.

Germination medium: agar 7 g L^{-1}, sucrose 20 g L^{-1}, Murashige and Skoog salts 2.15 g L^{-1} (i.e., applied at half-strength with respect to the original formulation), activated carbon 0.5 g L^{-1}, GA_3 250 mg L^{-1} (added after autoclaving via cold filter sterilization).

Sample size: 1170 seeds (n=25).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
82.8%	alternating 22/10°C	16/8 h	16.0	27.0	49.0	31.2

Observations

Addition of sucrose and half-strength Murashige & Skoog (MS) medium was performed because the work aimed to encourage seedling growth after germination in order to produce plants for conservation activities (also for the other species studied here). A relatively low concentration of agar was used because this creates a less solid gel, minimizing surface tension and maximizing contact between the substrate and seeds, but providing enough solidity to support them at the air/substrate interface.

Seed of this species has previously been germinated at high G values (> 90%; Cerabolini & al. 2004), for a population at the edge of the distributional range of the species (at Monte Barro regional park, Lecco). Here, the protocol is applied to a population from a different territory, aiming to produce plants to eventually reinforce the extremely small population at Monte Barro (Fig. 1B). Cerabolini & al. (2004) recommended a concentration of 100 mg L^{-1} GA_3. However, we conducted an initial study using this concentration, which resulted in only 20% germination for the study population (data not shown). Thus, we decided to use a higher concentration, which resulted in the final germination rate > 80%, and eventually the successful production of plants (Fig. 1B).

Fig. 1. Seedlings of *Physoplexis comosa* (A) at 32 d from sowing in a 5.5 cm Ø Petri dish, and (B) transferred to De Wit tubes at 122 d (Photos J. Bellingardi).

67. ***Primula glaucescens*** Moretti (*Primulaceae*) (Fig. 2)

Accession data

It: Monte Arera (BG), loc. Sentiero dei Fiori (WGS84: 45.927014°N, 9.802821°E), EU habitat 6170 Alpine and subalpine calcareous grasslands, 1939 m a.s.l., 20 Aug 2019, *R. M. Ceriani* (BG975; Lombardy Seed Bank), 8 Sept 2008, *Università di Pavia* (BG840; LSB), *Università di Pavia*, 18 Sept 2004 (BG336; LSB).

Germination data

Pre-treatments: Seed surface sterilization in bleach (10% v/v bleach solution, containing 0.1% Tween 20 surfactant) for 10 minutes followed by several rinses in sterilized distilled water.

Germination medium: agar 7 g L^{-1}, sucrose 20 g L^{-1}, Murashige and Skoog salts 2.15 g L^{-1} (half-strength), activated carbon 0.5 g L^{-1}, GA_3 100 mg L^{-1} (added after autoclaving via cold filter sterilization).

Sample size: 351 seeds (n=8 × each seed lot).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]	Seed lot
100.0%	alternating 22/10°C	16/8 h	3.5	10.9	21.0	13.3	BG336 (2004)
98.5%	alternating 22/10°C	16/8 h	2.0	10.8	25.0	13.2	BG840 (2008)
95.2%	alternating 22/10°C	16/8 h	1.0	8.8	14.0	13.7	BG975 (2019)

Observations

Seeds of this species have previously been germinated in our laboratories with rates of up to 100% (Cerabolini & al. 2004), but the present test provides valuable extra information because we found that high G (95-100%) was also evident for seed lots stored for up to 15 years at -18°C in the seed bank (with no statistically significant difference between lots; ANOVA: F-ratio = 0.696, *p* = 0.523). This is a new and optimistic message for the seed banking of this species. Seeds were extremely resistant to long periods of surface sterilization, which were more effective at reducing contamination. Indeed, in a separate trial using only recently collected seeds with surface sterilization for 10, 20, 30 or 60 minutes, seeds in all treatments exhibited high germination (79.6 – 89.3%) with no statistically significant differences evident (ANOVA: F = 0.618, *p* = 0.610; data not shown). However, seeds treated for 10 to 20 minutes exhibited 25-38% contamination respectively, while seeds treated for 30 to 60 minutes were completely free of contamination (data not shown).

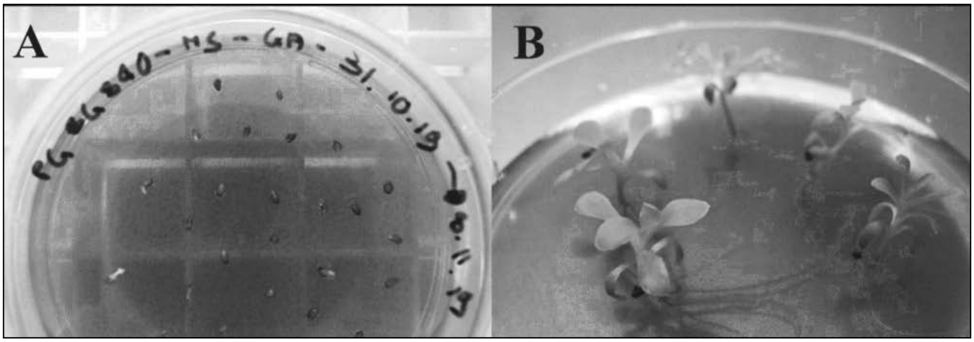

Fig. 2. *Primula glaucescens* (A) seeds germinating in a 5.5 cm Ø Petri dish, and (B). seedlings. (Photos J. Bellingardi).

68. ***Primula spectabilis*** Tratt. (*Primulaceae*) (Fig. 3)

Accession data

It: Dosso Alto (BS) (WGS84: 45.806302°N, 10.407489°E), EU habitat 6170 Alpine and subalpine calcareous grasslands, 1754 m a.s.l., 09 Aug 2019, *R. M. Ceriani* (BS996; LSB).

Germination data

Pre-treatments: Seed surface sterilization in bleach (5% v/v bleach solution, containing 0.1% Tween 20 surfactant) for 60 minutes followed by several rinses in sterilized distilled water.

Germination medium: agar 7 g L^{-1}, sucrose 20 g L^{-1}, Murashige and Skoog salts 2.15 g L^{-1} (half-strength), activated carbon 0.5 g L^{-1}, GA_3 100 mg L^{-1} (added after autoclaving via cold filter sterilization).

Sample size: 807 seeds (n=8 × 4 treatments).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
95.4%	alternating 22/10°C	16/8 h	8.0	12.3	30.0	14.7

Observations

Initial germination trials were ruined by high rates of internal fungal contamination of surface-sterilized seed (data not shown). The present study determined that different exposure times to 5% bleach solution (4 treatments representing 10, 20, 30, 60 minutes of exposure) progressively and significantly diminished the contamination rate from 39.7 ± 11.7% for the 10-minute exposure, to 8.4 ± 2.8% for the 60-minute exposure (ANOVA: F = 1.292, $p = 0.296$; data not shown), while final germination rates were not significantly affected by bleach exposure times, ranging from 91.9 ± 4.17% to 95.4 ± 3.13% (ANOVA: F = 0.106, $p = 0.955$; data not shown). (Indeed, the main G value reported here represents the mean value for the 60-minute exposure time.) This suggests that fungal contamination was present throughout the seed coat, but not within the embryo.

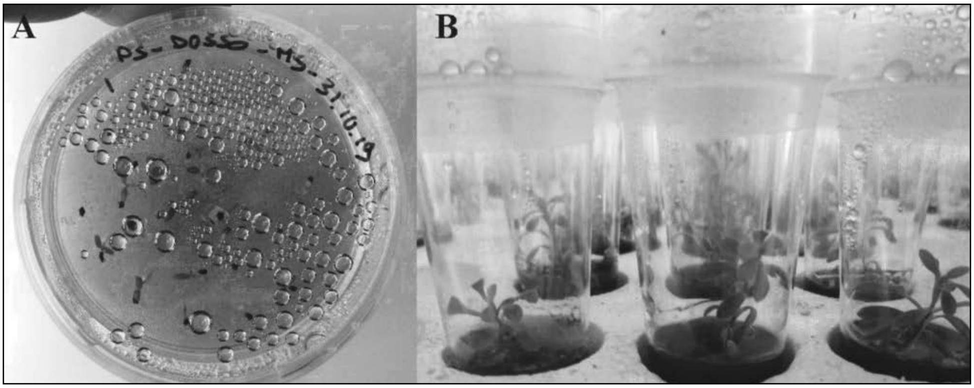

Fig.3. *Primula spectabilis* (A) seeds germinating at 5 d after sowing in a 5.5 cm Ø Petri dish, and (B) seedlings at 153 d. (Photos J. Bellingardi).

69. ***Spiranthes aestivalis*** (Poir.) Rich. (*Orchidaceae*) (Fig. 4)

Accession data

It: Soave (MN), loc. Cascina Belvedere (WGS84: 45.177087°N, 10.698333°E), population of 550 individuals in calcareous fen (EU habitat 7210* Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*), 17 m a.s.l., 23 Jul 2020, *S. Pierce* (SP/0024/2020; all seeds from this lot were sown during the current experiments, and none were stored).

Germination data

Pre-treatments: Seed surface sterilization in bleach (5% v/v bleach solution, containing 0.1% Tween 20 surfactant) for 5 minutes followed by several rinses in sterilized distilled water.

Germination medium: Malmgren (1996) terrestrial orchid medium (see Pierce & Cerabolini 2011; Pierce & al. 2015): agar 6 g L^{-1}, sucrose 10 g L^{-1}, activated charcoal powder 0.5 g L^{-1}, $MgSO_4 \cdot 7H_2O$ 75 mg L^{-1}, $(Ca)_3PO_4$ 75 mg L^{-1}, KH_2PO_4 75 mg L^{-1}, NH_4NO_3 100 mg L^{-1}, $NH_4H_2PO_4$ 150 mg L^{-1}, modified by the addition of yeast extract 75 mg L^{-1}, peptone 75 mg L^{-1} and 50 ml L^{-1} coconut milk. pH was adjusted to 5.8 using 0.1N NaOH or HCL immediately prior to autoclaving at 0.1 MPa and 121°C for 20 min.

Sample size: ~12000 seeds (n=60).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
97.1%	alternating 22/10°C	0/24 h	11.0	15.3	21.0	17.2

Observations

Germination was denoted by swelling of protocorms accompanied by the production of rhizoids (Fig. 4A). A preliminary experiment comparing the modification of the substrate using coconut milk against a coconut milk-free control showed 100% germination in both groups, but further development of protocorms occurred only with the addition of coconut milk. Rarely for an orchid, seeds started germinating within the first two weeks of sowing (shown at 21 d in Fig. 4A). Over the first 70 days from sowing, protocorms elongated into long, thin tubers, 2-3 mm in length (Fig. 4B). At around 84 days, when tubers were 3.5-4 mm in length, the first true leaves developed at the distal extremity of the tuber (Fig. 4C). At this point plantlets were transferred into De Wit culture tubes on a fresh medium differing from the sowing medium only in a higher concentration of sucrose (20 g L^{-1}); culture tubes were moved to a clean temperate greenhouse at ambient temperature and shaded from direct sunlight. By 174 d several plantlets had developed into green plants with 2 green leaves, and by 216 d plants with 4 true leaves were evident (Fig. 4D).

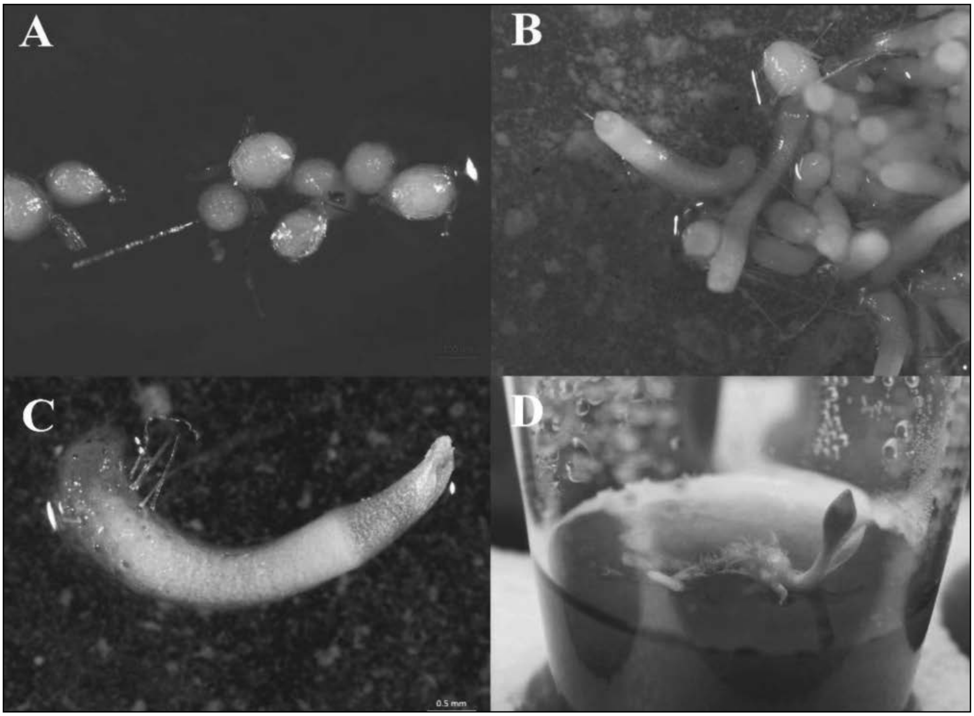

Fig. 4. Germinating seeds and plantlets of *Spiranthes aestivalis* at (A). 21 days after sowing, (B). 70 d, (C). 84 d, and (D). 216 d in a De Wit culture tube (photos by S. Pierce).

Conclusions

Germination percentages for *Linaria tonzigii* and *Saxifraga tombeanensis* were lower than 80%, thus the related protocols are not presented here as for successful protocols of other species. Nonetheless, these species are extremely rare, classified as Endangered (IUCN), listed in Annex II of the EU Habitats Directive and populations of both are so small that collecting seed involves practical and ethical difficulties, and thus any information is valuable. Indeed, it is likely that germination percentages were low precisely because these species are so rare, due to the operation of Allee effects (genetic diversity is known at least for *L. tonzigii* to be extremely low; Biella & al. 2021); germination rates of >80% may be difficult to attain for these species. The following description of experiments is briefly presented in the hope that it will be valuable for future attempts to propagate these species.

For *L. tonzigii*, the global distribution of the species is limited to particular scree slopes within a 10 km^2 area (accessibility problems also limit seed collection), and sufficient collectable seed is produced each year to allow only limited germination testing. Indeed, despite being careful to limit collection to only ~20% of the fruits observed, it is likely that even single germination studies will have a significant impact on the reproductive capacity of the entire species, and testing must be conducted cautiously. Testing in previous years has determined that seeds require cold stratification and very high concentrations of GA_3 to stimulate germination; germination *ex situ* does not occur without these conditions (Ferrario & al. 2014).

We collected seeds from Pizzo Arera (BG) [loc. Corna Piana (WGS84: 45.92875°N, 9.616018°E), EU habitat 8120 Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*), 1960 m a.s.l., 20 Aug 2019, R. M. Ceriani (BG974; Lombardy Seed Bank-LSB); 31 Aug 2004, Università di Pavia (BG193; LSB)]. Seeds should be collected when the fruits are drying and opening naturally: plants must be checked every 7-15 days during August.

Seeds were cold-humid stratified at 4˚C for 3 months (86 d) prior to sowing, wrapped in aluminium foil and placed in the refrigerator. Seeds were transferred to Petri dishes containing filter paper soaked in a solution of 250 mg L^{-1} GA_3 (pre-dissolved in 6 drops of 1N NaOH), placed in the refrigerator for 48 hours. Seeds were surface-sterilized using a bleach solution (5% v/v bleach solution, containing 0.1% Tween 20 surfactant) for 60 minutes followed by several rinses in sterilized distilled water. A range of *Linaria* species have been successfully germinated *in vitro* using either full-strength or half-strength MS medium and low (<1%) agar concentrations (e.g., Freipica & Ievinsh 2010; Matveeva & al. 2012; Pavlova & al. 2014; Vladimirov & al. 2018). Thus, the germination medium and environmental conditions (thermoperiod and photoperiod) follow the protocol for *P. comosa*, above.

Intriguingly, seeds stored for 15 years at -18˚C (seed lot BG193) showed germination percentages comparable to recently collected seeds (lot BG974; i.e. 58.5 % cf. 46.8 %, respectively), indicating that longer-term storage for this species was not problematic. Germination of dark-coloured seeds was 21.5% greater than that of light seeds (for seed lot BG974; significantly different by t-test; $t = 3.239$, $p = 0.0026$). The particularly low G of white seeds (an absolute value of 25.3 %) could reflect insufficient development at the time of capsule opening and seed dispersal. The reason for this is not known, but it is evident that *ex situ* production of plants should favour the use of dark-coloured seeds. Our germination tests led to the production of 300 seedlings which, at 48 d, were transferred to De Wit tubes (substrate modified by substituting GA_3 with 20 mg L^{-1} kinetin) for 6 months, then to a mixture of soil and Moregallo gravel (40:60), and cultivated in a temperate greenhouse.

For *Saxifraga tombeanensis*, seeds were collected during summer [from Cadria (BS) (WGS84: 45.781654°N, 10.642954°E), EU habitat 8210 Calcareous rocky slopes with chasmophytic vegetation, 1210 m a.s.l., 17 Jul 2019, S. Armiraglio (BS997; LSB) and from Corna Rossa (BS) (WGS84: 45.800582°N, 10.614543°E), 1668 m a.s.l., 23 Jun 2020, S. Armiraglio (BS998; LSB)]. Seeds were surface sterilized and sown following the protocol and environmental conditions specified for *P. comosa*, above. Using lot BS998, pretreatment by surface sterilization of seeds with various combinations of bleach concentrations (5 or 10 %) and exposure times (5, 10, 15, 30 min) did not significantly affect germination or the extent of internal fungal contamination evident as hyphae growing from within seeds (ANOVA, $p > 0.05$; data not shown). The mean germination rate for BS998 was just 12.0 %. Maximum germination was 66.7 % in a single replicate Petri of seed lot BS997 (the mean for this lot was 21.7 %). Seeds are extremely small (mean seed weight was 0.03 mg) and seedlings remain delicate, both above and below ground, during the first months of life. At 5 months from germination, some seedlings had not developed beyond the primary root plus cotyledon phase, some plants exhibiting true leaves but with underdeveloped root systems, and it is not clear if this is normal for the species. Note that additional testing using inositol to attempt further development of the root system did not significantly affect root system development or germination percentages (data not shown).

References

Armiraglio, S., Bertolli, A., Comini, B., Ghidotti, B., Prosser, F. & Gentili, R. 2010: *Saxifraga tombeanensis*. The IUCN Red List of Threatened Species 2010: e.T161993A5524958. http://dx.doi.org/10.2305/IUCN.UK.2010-1.RLTS.T161993A5524958.en

Biella, P., Akter, A., Muñoz-Pajares, A.J., Federici, G., Galimberti, A., Jersáková, J., Labra, M., Mangili, F., Tommasi, N. & Mangili, L. 2021: Investigating pollination strategies in disturbed habitats: the case of the narrow-endemic toadflax *Linaria tonzigii* (*Plantaginaceae*) on mountain screes. – Pl. Ecol. **222:** 511-523. https://doi.org/10.1007/s11258-021-01123-7

Cerabolini, B., De Andreis, R., Ceriani, R. M., Pierce, S. & Raimondi, B. 2004: Seed germination and conservation of endangered species from the Italian Alps: *Physoplexis comosa* and *Primula glaucescens*. – Biol. Conserv. **117:** 351-356. https://doi.org/10.1016/j.biocon.2003.12.011

Ferrario, A., Pierce, S., Ceriani, R. M., Villa, M. & Cerabolini, B. E. L. 2014: Germinazione, coltivazione su larga scala e rinforzamento della popolazione di *Linaria tonzigii*, una stenoendemica della Direttiva Habitat mai riprodotta prima. Poster presented at the 10th National Congress on Biodiversity (Congresso Nazionale della Biodiversità), Rome, Italy 3 September 2014.

Freipica, I. & Ievinsh, G. 2010: Relative NaCl tolerance of rare and endangered coastal plant species in conditions of tissue culture. – Environ. Exp. Biol. **8:** 35-42. https://doi.org/10.22364/eeb

Jogan, N., Gargano, D., Montagnani, C. & Bernhardt, K. G. 2013: *Physoplexis comosa*. The IUCN Red List of Threatened Species 2013: e.T162148A5549098. http://dx.doi.org/10.2305/IUCN.UK.2011-1.RLTS.T162148A5549098.en

Lasen, C., Bertolli, A. & Prosser, F. 2013: *Primula spectabilis*. The IUCN Red List of Threatened Species 2013: e.T161891A5509776. http://dx.doi.org/10.2305/IUCN.UK.2011-1.RLTS.T161891A5509776.en

Malmgren, S. 1996: Orchid propagation. Theory and practice. – Pp.63-71 in: Allen, C. (ed.) North American native terrestrial orchids. Propagation and production. North American Terrestrial Orchid Conference Proceedings. – Germantown.

Mangili, F. & Rinaldi, G. 2013: *Linaria tonzigii*. – The IUCN Red List of Threatened Species 2013: e.T162172A5553011. http://dx.doi.org/10.2305/IUCN.UK.2011-1.RLTS.T162172A5553011.en

Matveeva, T. V., Bogomaz, D. I., Pavlova, O. A., Nester, E. W. & Lutova, L. A. 2012: Horizontal gene transfer from genus *Agrobacterium* to the plant *Linaria* in nature. – Mol. Plant Microbe Interact. **25(12):** 1542-1551. https://doi.org/10.1094/MPMI-07-12-0169-R

Murashige, T. & Skoog, F. 1962: A revised medium for rapid growth and bioassays with tobacco tissue cultures. – Physiol. Pl. **15:** 473-497. https://doi.org/10.1111/j.1399-3054.1962.tb08052.x

Pierce, S. & Cerabolini, B. E. L. 2011: Asymbiotic germination of the White Mountain Orchid (*Pseudorchis albida*) from immature seed on media enriched with complex organics or phytohormones. – Seed Sci. Technol. **39:** 199-203. https://doi.org/10.15258/sst.2011.39.1.17

—, Guidi, V., Ferrario, A., Ceriani, R. M., Labra, M., Vagge, I. & Cerabolini, B. E. L. 2015: Pea seed extracts stimulate germination of the terrestrial orchid *Ophrys apifera* Huds. during a habitat restoration project. – Pl. Biosyst. **149(1):** 54-60. https://doi.org/10.1080/11263504.2013.809814

Vladimirov, I. A., Matveeva, T. V. & Lutova, L. A. 2018: The method of transformation of Moroccan Toadflax (*Linaria maroccana* Hook. F.). – Russ. J. Genet. **54(8):** 985-988. https://doi.org/10.1134/S1022795418080136

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F. Carruggio, C. Impelluso, M. Castrogiovanni & A. Cristaudo

Germination behavior in some Sicilian species of the *Euphorbia* genus

Abstract

Carruggio, F., Impelluso, C., Castrogiovanni, M. & Cristaudo, A.: Germination behavior in some Sicilian species of the *Euphorbia* genus [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 315-321. 2021. http://dx.doi.org/10.7320/FlMedit31.315

Our work concerns the requirements for germination in five *Euphorbia* species, occurring in uncultivated wet grounds, roadsides, montane pastures or deciduous broadleaf woods. The study taxa are *Euphorbia ceratocarpa*, *E. gasparrinii* subsp. *gasparrinii*, *E. hirsuta, E. meuselii,* and *E. platyphyllos*.
Seeds were collected from wild populations both in lowland and mountain areas of Eastern Sicily, at the time of natural dispersal. The germination ability was tested under constant and alternating temperatures, both in light and total dark, at the Catania Germplasm Bank (BGS-CT). The best germination protocols for each species are provided. Specifically, germination response was strongly limited by constant thermal regimes (except for *E. gasparrinii*) and, conversely, improved by fluctuating temperatures, under darkness, in all the study species. *E. gasparrinii* and *E. platyphyllos* reached high germination values also in the light.

Key words: germination protocols, constant temperature, alternating temperature, endemic species, Sicily.

Introduction

The *Euphorbia* genus is the largest one within the *Euphorbiaceae* family and includes approximately 2,000 species (Riina & al. 2013). Seed physiological dormancy has been reported for at least seventeen out of twenty *Euphorbia* species, which were reviewed by Baskin & Baskin (2014).

This work presents new germination data relating to five *Euphorbia* species of the Sicilian flora, which includes approximately thirty of them. Three of the study taxa, i.e., *E. ceratocarpa* Ten., *E. gasparrinii* Boiss. subsp. *gasparrinii*, and *Euphorbia meuselii* Geltman, are Italian endemics, whereas the other two species, *E. hirsuta* L. and *E. platyphyllos* L., have a Mediterranean distribution range. The germination traits of *E. ceratocarpa* and *E. meuselii*, together with other six congeneric species, were investigated in a recent essay (Cristaudo & al. 2019) that focused on Sicilian populations other than the current ones and obtained lower final germinated proportions in both species.

Seeds were collected between June and July 2021 and, within one month from the collection (22 ± 2°C and 50% RH storage conditions), germination trials started, except for *E. gasparrinii* (tested within two months and a half). Six different constant (from 5 to 30°C) and five alternating temperature conditions (15/10, 20/10, 20/15, 25/15, and 25/20°C) were tested, both in light/dark (12/12 h photoperiod) and darkness (0/24 h). Light and alternating temperatures were assessed because of their well-known role in breaking dormancy and promoting germination (Probert 2000; Catara & al. 2016).

70. ***Euphorbia ceratocarpa*** Ten. (*Euphorbiaceae*)

Accession data

Si: Belpasso (Catania), Madonna della Roccia (WGS84: 37.601739°N, 15.002731°E), roadside, 650 m a.s.l., 28 Jun 2021, *R. Galesi* (SiMaSeed/CT/21/777, BGS-CT).

Germination data

Pre-treatments: no treatment.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
87%	alternating 25/15°C	0/24 h	-	-	-	-
85%	alternating 20/10°C	0/24 h	-	-	-	-
83%	alternating 20/15°C	0/24 h	-	-	-	-

Observations

E. ceratocarpa is endemic to Sicily, Apulia, and Calabria, being quite common only in the first of the three Italian regions, where it is frequent, mainly up to 700 m a.s.l., in disturbed plots and along roadsides, keeping a high soil humidity.

Final germination values under constant temperatures did not exceed 10%, regardless of photoperiod conditions, except for 15°C under light/dark (ca. 40%), proving that fresh seeds of *E. ceratocarpa* have a strict requirement for alternating thermal regimes and that, additionally, light can only very slightly substitute them. Moreover, alternating temperatures provided the best performance only under dark conditions, whereas a strong photoinhibition effect appeared in light/dark conditions (final germination less than 30%). The only meaningful T_{50} value (9.5 days at 15°C, light/dark) is in agreement with what has been found in other study species.

The requirement for alternating thermal regimes had not been highlighted in the fresh seeds of this species. In addition, the present work provides the first data on the germination behavior of a further Sicilian population of *E. ceratocarpa*, in addition to that from hilly ranges of Strasatto (Palermo), for which lower germination values were obtained (Cristaudo & al. 2019).

71. *Euphorbia hirsuta* L. (*Euphorbiaceae*)

Accession data

Si: Augusta (Siracusa), Tenuta Grande-Gelsari (WGS84: 37.334078°N, 15.081472°E), uncultivated wet grounds, 1 m a.s.l., 06 Jul 2021, *R. Galesi* (SiMaSeed/CT/21/779, BGS-CT).

Germination data

Pre-treatments: no treatment.

Germination medium 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
100%	alternating 25/15°C	0/24 h	-	-	-	-
97%	alternating 20/10°C	0/24 h	-	-	-	-
93%	alternating 20/15°C	0/24 h	-	-	-	-
87%	alternating 25/20°C	0/24 h	-	-	-	-
83%	alternating 25/15°C	12/12 h	9	10.6	23	11.8

Observations

E. hirsuta is a Mediterranean species, ranging from the Macaronesian region to the Caucasus (Georgia) (POWO 2021). It grows in damp and uncultivated places, as well as along riverbanks.

The germination process in the fresh seeds of this species strictly required alternating thermal regimes, providing a germination percentage over 80% also at 25/20°C in the dark, unlike all the other study species. Photoinhibition characterized germination behavior in the light/dark conditions under alternating regimes, except at 25/15°C, where seeds showed a T_{50} value of approximately 11 days. The presence of light was not able to substitute alternating regimes under constant temperatures. Finally, *E. hirsuta* appeared as one of the two study species germinating across the widest thermal range, together with *E. platyphyllos* (see report n. 73, below), since a quite high germination value (67%) has been reached also at 15/10°C in the dark.

72. *Euphorbia meuselii* Geltman (*Euphorbiaceae*)

Accession data

Si: Messina (Messina), Pizzo Chiarino (WGS84: 38.192111°N, 15.484194°E), mixed reforestation with coniferous and broadleaf trees, 788 m a.s.l., 10 Jun 2021, *A.*

Cristaudo, F. Carruggio, M. Castrogiovanni & R. Galesi (SiMaSeed/CT/21/757, BGS-CT).

Germination data

Pre-treatments: no treatment.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
93%	alternating 20/15°C	0/24 h	-	-	-	-
85%	alternating 20/10°C	0/24 h	-	-	-	-

Observations

E. meuselii is endemic to the main Italian islands (Sicilia and Sardinia) and two southern regions, Basilicata and Calabria. It grows in deciduous oak and beech woods, at an elevation from 600 to 1500 m a.s.l.

Our tests highlighted an overall germination behavior similar to those of the other study species, i.e., an obligate requirement for alternating thermal regimes. However, a general preference for lower temperatures could be noted (79 vs. 54% final germination percentage, at 15/10 and 25/15°C, respectively, in darkness). In addition, rather high germination values have been recorded under alternating temperatures also in the light/dark (71% final germination percentage, at 20/10 and 20/15°C), although in connection with T_{50} values of 13-15 days. Our data do not confirm the requirement of mechanical manipulations and GA_3 in promoting seed germination, differently from some protocols reported by the Seed Information Database (Royal Botanic Gardens Kew 2021). Conversely, they support the results obtained by Cristaudo & al. (2019) for a different population from Madonie Mountains (Palermo), which reached the highest germination value (ca. 60%) at 8/25°C (16.5°C average) in long-stored seeds.

73. ***Euphorbia platyphyllos*** L. (*Euphorbiaceae*)

Accession data

Si: Augusta (Siracusa), Tenuta Grande-Gelsari (WGS84: 37.334078°N, 15.081472°E), uncultivated wetlands, 1 m a.s.l., 08 Jun 2021, *R. Galesi* (SiMaSeed/CT/21/751, BGS-CT).

Germination data

Pre-treatments: no treatment.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
100%	alternating 20/10°C	0/24 h	-	-	-	-
98%	alternating 20/10°C	12/12 h	6	6.2	8	6.8
97%	alternating 20/15°C	12/12 h	5	4.9	8	5.6
95%	alternating 25/15°C	12/12 h	5	4.8	9	5.6
92%	alternating 20/15°C	0/24 h	-	-	-	-

Observations

E. platyphyllos is an annual Euri-Mediterranean weed and has spread in both North and South America (POWO 2021).

Alternating temperatures proved to be efficient in promoting seed germination also in this species, providing good performance within a wide thermal range, as in *E. hirsuta*. Indeed, in addition to the data shown in the table above, final germination values exceeded 70% also at 15/10 and 25/15°C in the dark. Alternating temperatures and light in combination provided very high germination values, in addition to T_{50} values of 5-6 days. However, the light confirms itself as an inefficient trigger for germination under constant temperatures also in *E. platyphyllos*. The only information available on germination requirements in this species concerns the combined use of GA_3 and alternating temperatures (33/19°C, light/dark 12/12, 78% final germination; Royal Botanic Gardens Kew 2021).

74. ***Euphorbia gasparrinii*** Boiss. subsp. ***gasparrinii*** (*Euphorbiaceae*)

Accession data

Si: Alcara Li Fusi (Messina), Lago Maulazzo (WGS84: 37.942736°N, 14.672809°E), montane pastures, 1453 m a.s.l., 10 Jul 2015, *A. Cristaudo* (SO.PRO.ME/CT/15/985, BGS-CT).

Germination data

Pre-treatments: no treatment.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 6 ml of sterilized distilled water.

Sample size: 100 seeds (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T1 [d]	T50 [d]	Tmax [d]	MTG [d]
90%	alternating 20/10°C	12/12 h	7	9.7	20	10.9
85%	alternating 20/15°C	12/12 h	7	8.7	18	9.5
85%	alternating 15/10°C	12/12 h	9	10.9	15	11.5

Observations

E. gasparrinii is an Italian endemic species showing a disjunct distribution across two main mountain ranges, i.e., the central Apennines and the Calabrian-Sicilian area, growing between 800 and 1850 m a.s.l. Central Italian populations have been ascribed to the subsp. *samnitica* (Fiori) Pignatti and are rather numerous (Cresti & al. 2019). Conversely, the southern populations have been attributed to the subsp. *gasparrinii* and have become rarer over the last decades, to the point that the study population of Lago Maulazzo (Nebrodi Mountains) may be probably considered the only existing one (Cresti & al. 2019).

The germination behavior of the present population confirmed, as in the other species, the good performance of alternating temperature regimes. Our results suggested that light has an amplifying effect on germination under fluctuating temperatures, although final germination values higher than 70% were recorded also in the dark (73 and 77% at 15/10 and 20/10°C, respectively). Fresh seeds required ca. 10 days to reach 50% germination. *E. gasparrinii* strongly differed from all the other study species because of high germination values under some constant temperature regimes, regardless of the photoperiod applied. Indeed, at 15 and 20°C, values of 73 and 70% in the light/dark and 58 and 64% in the dark were recorded, respectively. This behavior showed that light partially compensated for the lack of alternating regimes.

References

Baskin, C. C. & Baskin, J. M. 2014: Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. – London.

Catara, S., Cristaudo, A., Gualtieri, A., Galesi, R., Impelluso, C. & Onofri, A. 2016: Threshold temperatures for seed germination in nine species of *Verbascum* (*Scrophulariaceae*). – Seed Sci. Res. **26:** 30-46. https://doi.org/10.1017/S0960258515000343

Cresti, L., Schönswetter, P., Peruzzi, L., Barfuss, M. H. J. & Frajman, B. 2019: Pleistocene survival in three Mediterranean refugia: origin and diversification of the Italian endemic *Euphorbia gasparrinii* from the *E. verrucosa* alliance (*Euphorbiaceae*). – Bot. J. Linn. Soc. **189(3):** 262-280. https://doi.org/10.1093/botlinnean/boy082

Cristaudo, A., Catara, S., Mingo, A., Restuccia, A. & Onofri, A. 2019: Temperature and storage time strongly affect the germination success of perennial *Euphorbia* species in Mediterranean regions. – Ecol. Evol. **9:** 10984-10999. https://doi.org/10.1002/ece3.5535

POWO 2021: Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Available from: http://www.plantsoftheworldonline.org/ [Last accessed 1/11/2021].

Probert, R. J. 2000: The role of temperature in the regulation of seed dormancy and germination. – Pp. 261-292 in: Fenner, M. (ed.), Seeds: The Ecology of Regeneration in Plant Communities. – Wallingford.

Riina, R., Peirson, J. A., Geltman, D. V., Molero, J., Frajman, B., Pahlevani, A., Barres, L., Morawetz, J. J., Salmaki, Y., Zarre, S., Kryukov, A., Bruyns, P. V. & Berry, P. E. 2013: A

worldwide molecular phylogeny and classification of the leafy spurges, *Euphorbia* subgenus *Esula* (*Euphorbiaceae*). – Taxon **62:** 316-342. https://doi.org/10.12705/622.3
Royal Botanic Gardens Kew 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/ [Last accessed 1/12/2021]

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Cristina Salmeri & Cristian Brullo

Seed germination reports for Sicilian endemic taxa of the genus *Helichrysum* (*Asteraceae*)

Abstract

Salmeri, C. & Brullo, C.: Seed germination reports for Sicilian endemic taxa of the genus *Helichrysum* (*Asteraceae*) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3]. Fl. Medit. 31: 322-333. 2021. http://dx.doi.org/10.7320/FlMedit31.322

In the present study, successful germination protocols for 11 different taxa of the genus *Helichrysum* native to Sicily are discussed. Eight of them are representative of strict endemic Sicilian taxa, 2 are Italian sub endemic and one, namely *H. stoechas*, is a widespread W Mediterranean species. Given the controversial taxonomic status and relationships of the Mediterranean *Helichrysum*, the taxonomic approach enhancing the existing diversity of Sicilian populations was herein adopted from current literature. First germination records are given for some of the investigated taxa.

Key words: germination protocols, Italian flora, native plants, seeds, Sicily.

Introduction

Helichrysum Mill. is a large and heterogenous genus of the sunflower family (*Asteraceae*), currently consisting of ca. 600 worldwide distributed species. The taxonomic and phylogenetic relationships within this genus in many ways still remain controversial and not satisfactorily resolved (Galbany-Casals & al. 2004, 2014).

As far as the Italian territory is concerned, the existing populations reveal a high rate of morphological polymorphism with some constant features often linked to strict geographical distribution and limited environmental niches (Brullo & Guarino 2018). Pignatti (1982) originally reported 11 taxa altogether (6 species plus 5 varieties). Later, Conti & al. (2005) listed 13 taxa, represented by 11 different species with 4 subspecies. Other floristic and taxonomic studies (Aghababyan & al. 2007; Giardina & al. 2007) discriminated against 15 different taxa, with 11 species and 4 subspecies, while Greuter (2006) listed only 11 taxa, namely consisting of 8 species with 5 subspecies. Phylogenetic analyses based on both morphological and molecular data (Galbany-Casals & al. 2004, 2006, 2014; Herrando-Moraira & al. 2017) recognised only 7 taxa for the Italian flora, all belonging to the section *Stoechadina* (DC.) Gren. & Godr. Additionally, contemporary interspecific hybridization is known to occur in the genus *Helichrysum* (Jeanmonod 1996; Galbany-

Casals & al. 2006), thus further complicating the taxonomic framework. More recently, Bartolucci & al. (2018) accepted for the Italian flora 12 taxa, corresponding to 7 different species and 5 subspecies, with most of the Sicilian endemic taxa treated as synonyms of *H. pendulum* (C. Presl) C. Presl in accordance with the cited phylogenetic studies. Lastly, Brullo & Guarino (2018) distinguished 14 different species with 8 subspecies, gathered in 3 main groups based on some peculiar morphological characters. Here, we applied the latter classification of the Italian *Helichrysum* since it better reflects the diversity of the Sicilian investigated populations, additionally indicating into brackets accepted names from Greuter (2006) when different.

In this work, we present successful germination protocols for eleven taxa of *Helichrysum*, nine of which are strictly endemic to Sicily and the surrounding archipelagos. All germination tests were carried out at the Catania Germplasm Bank using four constant temperature regimes (10, 15, 20 and 25°C) and both light and dark conditions.

75. *Helichrysum archimedeum* C. Brullo & Brullo ex Greuter (*Asteraceae*)

Accession data

Si: Sicily. Mts. Iblei, Ferla (Siracusa) (WGS84: 37.119167°N, 14.945834°E), calcareous rocks, 540 m a.s.l., 17 Jun 2013, *S. Brullo* (UNICT_086, BGS-CT, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
90%	constant 10°C	12/12h	9.0	13.4	32.0	15.5
90%	constant 15°C	12/12h	5.0	10.9	32.0	13.2
89%	constant 10°C	0/24h	12.0	15.4	32.0	17.5
85%	constant 20°C	12/12h	5.0	14.0	32.0	15.0
84%	constant 15°C	0/24h	5.0	9.7	32.0	11.5

Observations

Helichrysum archimedeum is a suffruticose chamaephyte endemic to the Iblei Mts. in south-eastern Sicily, where it is a member of the casmophytic vegetation (*Dianthion rupicolae*) growing on the calcareous slopes of Hyblaean canyons. Seeds of *H. archimedeum* germinated in the thermal range between 10 and 20°C, reaching the highest germination rates (90%) at 10 and 15°C under light conditions. Increasing temperature caused a significant drop in seed germination, which was only 47% at 25°C and 12/12h photoperiod. The light seems to positively affect seed germinations, because tests carried out under full darkness gave lower results with the increase in temperature, with 50% of germination at 20°C and just 9% at 25°C. As predictable, lower temperature (10°C) resulted in the slowest germination speed especially under full darkness, with a germination delay shifting from 5 to 9-12 days. Royal Botanic Gardens Kew (2021) reported for this species (provenance not specified) a germination percentage of 98% and 92% at 15°C and 20°C, respectively, under a 12/12h photoperiod, while 90% was reached with the alternating temperature 25/10°C.

76. ***Helichrysum errerae*** Tineo (*Asteraceae*)

Accession data

Si: Sicily. Pantelleria (Trapani) (WGS84: 36.73750°N, 12.001112°E), volcanic debris and basalt outcrops, 120 m a.s.l., 11 Jun 2014, *S. Brullo & L. Scuderi* (UNICT_134, BGS-CT, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
99.0%	constant 15°C	12/12h	5.0	8.3	21.0	10.1
97.0%	constant 20°C	12/12h	3.0	7.7	30.0	9.8
96.0%	constant 10°C	12/12h	9.0	14.5	30.0	16.4
96.0%	constant 10°C	0/24h	9.0	10.4	22.0	12.1
93.0%	constant 15°C	0/24h	5.0	6.4	22.0	8.4
80.0%	constant 20°C	0/24h	5.0	9.7	29.0	12.2

Observations

Helichrysum errerae is another strict Sicilian endemism, confined to the island of Pantelleria, where it is the main member of the *Matthiolo pulchellae-Helichrysum errerae* pulvinous community occurring between the internal part of the coastal cliffs and the inland vegetation all along the island. As the previous species, it also showed the highest germination rates (99-96%) in the thermal range between 10 and 20°C under a 12/12h photoperiod, with optimal results (99%) at 15°C. The seeds were not light sensitive at the lowest temperatures, reaching comparable germination percentages both in light and total dark conditions. At the highest temperature (25°C) the germination rate fell to 67% with a 12/12 h photoperiod, dropping down to 30% under dark conditions. These results somehow agree with Royal Botanic Gardens Kew (2021), reporting for this species a 100% of germination at 20°C and 12/12h photoperiod, while the alternating thermoperiod 25/10°C under light conditions gave 88% of germinated seeds.

77. *Helichrysum hyblaeum* Brullo [=? *H. hyblaeum*] (*Asteraceae*)

Accession data

Si: Sicily. Gela (Caltanissetta), Passo delle Pantanelle (WGS84: 37.047810°N, 14.386846°E), xeric steppe grasslands on limestone, 120 m a.s.l., 20 Jun 2005, *S. Sciandrello* (BGS-CT/SS109, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
80.0%	constant 15°C	12/12h	5.0	7.0	26.0	8.9

Observations

Helichrysum hyblaeum is circumscribed to south-eastern Sicily, where it grows in the xeric grasslands of the Hyblean Plateau on calcareous and marly slopes. This is the first germination report for this taxon. The highest germination percentage (80%) was obtained at 20°C and 12/12h photoperiod. The other tested temperature regimes provided similar results, with germination percentages just a little lower (78% and 76% at 20 and 25°C, respectively), except for 10°C which provided only 47% of germinated seeds. Seeds did not show a photoperiod sensitivity, because germination percentages were comparable at both light and dark conditions, except at 10°C where the full darkness improved seed germination to 68%.

78. ***Helichrysum italicum*** subsp. ***siculum*** (Jord. & Fourr.) Galbany, L. Sáez & Benedí

Accession data

Si: Sicily. Mt. Etna, Nicolosi (Catania) (WGS84: 37.650556°N, 14.988889°E), volcanic rocks, 1060 m a.s.l., 26 Jul 2013, *S. Bogdanovic, C. Brullo, S. Brullo & G. Giusso* (UNICT_087, BGS-CT Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
85.0%	constant 15°C	0/24h	5.0	7.4	22.0	9.8

Observations

This is a sub endemic taxon, also reported for Calabria (S Italy) and Tunisia, which grows both on calcareous and volcanic substrata, in different habitats, ranging from sea cliffs to sand dunes, rocky places and even roadsides, in a wide altitudinal range (0-1330 m a.s.l.). The investigated population from Mt. Etna reached 85% of germination at 15°C under full dark conditions, while the other tested temperatures (10 and 20° C) provided lower results (77% and 66% respectively), falling to no more than 50% under light conditions. High temperature (25°C) strongly affected seed germination which ranged between 18% and 29% in 12/12h photoperiod and full darkness respectively. Seeds of *H. italicum* subsp. *siculum* are clearly negatively photosensitive, as darkness significantly improved germination response at all temperature regimes. Royal Botanic Gardens Kew (2021) indicates a 95% of germination at 20°C, 79% at 15°C and 77% at the alternating 25/15°C thermoperiod. Given the wide altitudinal range and the variety of habitats and substrata, it is likely that different populations may exhibit different germination behaviour as an adaptive response to distinct environmental factors. Further studies on a larger sample of populations will contribute to better define the germination requirements for this taxon.

79. ***Helichrysum litoreum*** Guss. (*Asteraceae*)

Accession data

Si: Sicily. Is. Eolie, Filicudi (Messina) (WGS84: 38.560834°N, 14.579723°E), coastal cliffs, 60 m a.s.l., 01 Jul 2012, *P. Minissale* (UNICT_062, BGS-CT Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
99.0%	constant 15°C	12/12h	9.0	12.4	27.0	14.3
94.0%	constant 20°C	12/12h	5.0	8.6	26.0	10.2
92.0%	constant 10°C	12/12h	5.0	9.0	27.0	10.6
81.0%	constant 20°C	0/24h	5.0	8.1	26.0	10.8
81.0%	constant 10°C	0/24h	12.0	12.1	30.0	14.0
80.0%	constant 15°C	0/24h	5.0	7.4	33.0	9.9

Observations

Helichrysum litoreum is an Italian Tyrrhenian endemic, occurring on sea cliffs, both on limestone and volcanic soils, and permanently affected by sea salt aerosol. The investigated population from Is. Eolie showed the highest germination response (> 90%) in the thermal range between 10°C and 20°C, with the maximum value (99%) at 15°C under 12/12h light conditions. The alternate exposure to 12 h photoperiod improved seed germination, while under full dark conditions the germination percentage was around 80%. A higher temperature (25°C) did not favour seed germination, which reached 74% with light exposure and only 47% with total darkness. Our results were significantly higher than those reported by Royal Botanic Gardens Kew (2021) at 15°C and 12/12 h (99% *vs*. 80%).

80. ***Helichrysum nebrodense*** Heldr. [= ? *H. nebrodense*] (*Asteraceae*)

Accession data

Si: Sicily. Madonie Mts., Polizzi Generosa (Palermo), Strada per Vallone Madonna degli Angeli (WGS84: 37.841902°N, 14.011112°E), 1047 m a.s.l., 21 Jul 2005, *S. Pasta & L. Scuderi* (BGS-CT/127LS/SP/05 Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
80.0%	constant 15°C	0/24h	7.0	8.3	36.0	10.5

Observations

Helichrysum nebrodense is an orophilous Sicilian endemic species, confined to the mountain belt of Madonie Mts., on breccias and debris-flow deposits. The germination tests carried out at different constant temperatures under both light and dark conditions did not provide successful results, with a maximum of 80% of germinated seeds at 15°C and 0/24 h photoperiod. The worst response was at the highest temperature (25°C) with 47% and 19% of germination under light and full dark conditions respectively. Similarly, the lowest temperature (10°C) also gave a low germination rate, around 60%, both with and without light exposure. Overall, seeds of *H. nebrodense* do not seem to be significantly affected by light, except for higher temperatures when under 0/24 photoperiod germination dropped from 71% to 57% at 20°C and from 47% to 19% at 25°C. As far as we know from the literature, this is the first germination report for this taxon.

81. ***Helichrysum panormitanum*** Tineo ex Guss. subsp. ***panormitanum*** (*Asteraceae*)

Accession data

Si: Sicily. Castellammare del Golfo (Trapani), Mt. Inici (WGS84: 38.020834°N, 12.871389°E), 280 m a.s.l., 30 Jun 2013, *S. Brullo* (UNICT_087, BGS-CT Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
90.0%	constant 15°C	12/12h	5.0	6.8	28.0	9.9
88.0%	constant 20°C	12/12h	5.0	7.6	33.0	11.2
87.0%	constant 10°C	12/12h	9.0	14.3	29.0	16.4
87.0%	constant 10°C	0/24h	13.0	14.9	33.0	18.1

Observations

Helichrysum panormitanun is a complex species endemic to NW Sicily and the Egadi islands, growing on sea cliffs not directly affected by sea splashes, which is characterized by a certain morphological variability among geographically distinct subtaxa (Iamonico & al. 2016). The typical form only occurs alongside the NW Sicilian coast, from Termini Imerese and Trapani (Brullo & Guarino 2018). Successful germination response was obtained (≥ 87%) in the thermal range between 10°C and 20°C, with the highest percentage (90%) at 15°C and 12/12 h photoperiod. Seeds resulted as both thermal- and light-sensitive because tests carried out under full dark conditions provided lower germination percentages (but not at 10°C), while at 25° C the germination rate dropped down to 9% and 0% in light and total dark conditions, respectively. Our results differ from those of Royal Botanic Gardens Kew (2021), which reports (provenance unknown) 98% and 96% of germination at 20°C and 15°C, respectively, and 90% of germination with alternating temperature 25/10°C, all with a 12/12 h photoperiod. Further studies on a larger sample of populations and other experimental combinations will contribute to better define the germination requirements for this taxon.

82. ***Helichrysum panormitanum*** subsp. ***stramineum*** (Guss.) C. Brullo & Brullo (*Asteraceae*)

Accession data

Si: Sicily. Sferracavallo (Palermo), Capo Gallo (WGS84: 38.213056°N, 13.291667°E), rupi costiere, 280 m a.s.l., 31 May 2012, *C. Brullo, S. Brullo, M. Patanè & D. Torrisi* (UNICT_063, BGS-CT Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
90.0%	constant 15°C	12/12h	6.0	6.6	30.0	8.7
81.0%	constant 15°C	0/24h	6.0	9.1	33.0	10.3
80.0%	constant 20°C	12/12h	4.0	5.9	22.0	8.1

Observations

According to Brullo & Guarino (2018), this taxon is confined to Capo Gallo, just northwest of Palermo. Seeds showed the best germination percentage (90%) at 15° C and 12/12 h photoperiod. Lower results, around 80%, were obtained at 15°C under full dark conditions and at 20°C with light exposure. The other tested temperatures provided further lower germination percentages, which ranged between 76% and 65% at 10°C under light and full dark conditions, respectively, while 63% was reached at 20°C and 0/24 photoperiod. The highest temperature (25°C) negatively affected the germination response (59% with 12/12 h photoperiod), as the absence of light also seems to do, given that seed germination was significantly lower under dark conditions, with the worst value at 25° C (17%). Our data disagree with those from Royal Botanic Gardens Kew (2021), giving on a sample of 19 seeds sown a 100% of germination at 15°C and 12/12 h.

83. ***Helichrysum panormitanum*** subsp. ***messeriae*** (Pignatti) C. Brullo & Brullo [*H. panormitanum*] (*Asteraceae*)

Accession data

Si: Sicily. Is. Egadi, Marettimo (Trapani), Punta Libeccio (WGS84: 37.959277°N, 12.046662°E), 17 m a.s.l., 21 Oct 2004, *S. Pasta & L. Scuderi* (BGS-CT 056GR5/04, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
99.0%	constant 15°C	12/12h	7.0	9.8	29.0	11.8
94.0%	constant 20°C	12/12h	4.0	11.4	30.0	13.2
93.0%	constant 15°C	0/24h	7.0	11.2	30.0	14.0

Observations

Due to the little availability of seeds and in accordance with the best germination results from allied taxa, the germination tests for this taxon, geographically limited to Marettimo (Egadi Is.), were performed at 15 and 20°C, under both 12/12h and 0/24h photoperiod, all giving successful germination results (≥ 93%), with the maximum rate (99%) at 15°C and light exposure. Seed germination seems to be somehow improved by light exposure, because the germination percentages were lower under dark conditions, with major divergence at 20°C (69% *vs*. 94%).

84. ***Helichrysum preslianum*** C. Brullo & Brullo subsp. ***compactum*** (Guss.) Maggio & al. [*H. stoechas* subsp. *barrelieri* (Ten.) Nyman] (*Asteraceae*)

Accession data

Si: Sicily. Mazara del Vallo (Trapani), Torretta Granitola (WGS84: 37.599977°N, 12.631203°E), 1 m a.s.l., 13 Jun 2005, *S. Pasta & L. Scuderi* (BGS-CT 101LS/SP/05, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
81.0%	constant 15°C	12/12h	6.0	7.4	29.0	9.6

Observations

The population occurring on calcarenite outcrops alongside the sea cost of Mazara del Vallo, namely in the area of Torretta Granitola, were originally described as *H caespitosum* var. *compactum* Guss. and recently revalued by Maggio & al. (2016) as *H. preslianum* C. Brullo & Brullo subsp. *compactum* (Guss.) Maggio, Bruno, Guarino, Senatore & Ilardi, also based on secondary metabolite patterns. The germination tests carried out on this population provided satisfactory results (81%) only at 15°C and 12/12h photoperiod. Conversely, at the other tested temperatures, seed germination ranged between 74% and 79% at 15 and 25°C, respectively, with light conditions, and between 72% (15°C) and 75% (20 and 25°C) under total darkness. The worst germination response was obtained at 10°C, with only 14% of germinated seed under light exposure and 59% with 0/24 photoperiod. Light just little improved the germination rate, except for the lowest temperature which seems to have benefited by total darkness.

85. ***Helichrysum stoechas*** (L.) Moench [*H. stoechas* subsp. *stoechas*] (*Asteraceae*)

Accession data

Si: Sicily. Gela (Caltanissetta), Passo delle Pantanelle (WGS84: 37.047810°N, 14.386846°E), xeric steppe grasslands on limestone, 120 m a.s.l., 20 Jun 2005, *S. Sciandrello* (BGS-CT SS107/05, Catania Germplasm Bank).

Germination data

Pre-treatments: sterilization with a 1% sodium hypochlorite water solution for 3 minutes followed by 3 rinses in sterile distilled water.

Germination medium: 3 sheets of sterilized filter paper (Whatmann No. 1), imbibed with 5 ml of sterilized distilled water.

Sample size: 100 seeds for each test (25 × 4 replicates).

Germination	Thermoperiod	Photoperiod [light/dark]	T_1 [d]	T_{50} [d]	T_{max} [d]	MTG [d]
82.0%	constant 15°C	0/24h	6.0	5.6	29.0	7.8
81.0%	constant 15°C	12/12h	6.0	7.4	29.0	9.6

Observations

This is the most widespread taxon among the Mediterranean group, which in Italy is native along the Tyrrhenian coasts of Liguria, Tuscany and Latium, and in in the south-eastern coast of Sicily, where it can be found in the retrodunal areas, fixed dunes, and coastal cliffs, between 0 and 1000 m. The studied Sicilian population showed good germination percentages (> 80%) at 15°C, both under 12/12 h and 0/24 h photoperiod. The other tested temperatures provided lower germination percentages, ranging between 65% (20°C, 12/12h) and 76% (10°C, 0/24h). No significant difference was detected between the different applied photoperiods, but little lower germination percentages were obtained at 10° C (56% *vs*. 76%) and 20°C (65% *vs.* 74%) under light exposure. Our results are in accordance with Royal Botanic Gardens Kew (2021), giving a similar germination percentage (83%) at 15°C and 12/12h condition (unknown provenance).

References

Aghababyan, M., Greuter, W., Mazzola, P. & Raimondo, F. M. 2007: Typification of Sicilian *Helichrysum* (*Compositae*) revisited. – Taxon **54(4):** 1285-1288. https://doi.org/10.2307/25065922

Bartolucci, F., Peruzzi, L., Galasso, G., Albano, A.., Alessandrini, A,, Ardenghi, N. M. G., Astuti, G., Bacchetta, G., Ballelli, S., Banfi, E., Barberis, G., Bernardo, L., Bouvet, D., Bovio, M., Cecchi, L., Di Pietro, R., Domina, G., Fascetti, S,, Fenu, G,, Festi, F,, Foggi, B,, Gallo, L,, Gottschlich, G., Gubellini, L., Iamonico, D., Iberite, M., Jiménez-Mejías, P., Lattanzi, E,, Marchetti, D., Martinetto, E., Masin, R. R., Medagli, P., Passalacqua, N. G., Peccenini, S., Pennesi, R., Pierini, B., Poldini, L., Prosser, F., Raimondo, F. M., Roma-Marzio, F., Rosati, L., Santangelo, A., Scoppola, A., Scortegagna, S., Selvaggi, A., Selvi, F., Soldano, A., Stinca, A., Wagensommer, R. P., Wilhalm, T. & Conti, F. 2018: An updated checklist of the vascular flora native to Italy. – Pl. Biosyst. **152(2):** 179-303. https://doi.org/10.1080/11263504.2017.1419996

Brullo, S. & Guarino, G. 2018: *Helichrysum* Mill. Pp. 778-784 in: Pignatti, S., Guarino, R. & La Rosa, M. (eds) Flora d'Italia, 2° Ed., & Flora digitale, **3.** – Milano

Conti, F., Abbate, G., Alessandrini, A. & Blasi, C. (eds) 2005: An annotated checklist of the Italian vascular flora. – Rome.

Galbany-Casals, M., Garcia-Jacas, N., Susanna, A., Sáez, L. & Benedí, C. 2004: Phylogenetic relationships in the Mediterranean *Helichrysum* (*Asteraceae, Gnaphalieae*) based on nuclear rDNA ITS sequence data. – Austral. Syst. Bot. **17:** 241-253. http://dx.doi.org/10.1071/SB03031

—, Garcia-Jacas, N., Susanna, A., Saez, L. & Benedì, C. 2006: A taxonomic revision of *Helichrysum* Mill. sect. *Stoechadina* (DC.) Gren. & Godr. (*Asteraceae, Gnaphalieae*). – Canad. J. Bot. **84:** 1203-1232. https://doi.org/10.1139/b06-082

—, Unwin, M., Garcia-Jacas, N., Smissen R.D., Susanna, A. & Bayer, R. J. 2014: Phylogenetic relationships in *Helichrysum* (*Compositae: Gnaphalieae*) and related genera: Incongruence implications for generic delimitation. – Taxon **63:** 608-624. https://doi.org/10.12705/633.8

Giardina, G., Raimondo, F. M. & Spadaro, V. 2007: A catalogue of the vascular plants growing in Sicily. – Bocconea, **20:** 5-582.

Greuter, W. (2006+): *Compositae* (pro parte majore). In: Greuter, W. & Raab-Straube, E. von (eds): *Compositae*. Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. Published at http://www.europlusmed.org [Last accessed 1/11/2021].

Herrando-Moraira, S., Carnicero, P., Blanco-Moreno, J. M., Sáez, L., Véla, E., Vilatersana, R. & Galbany-Casals, M. 2017: Systematics and phylogeography of the Mediterranean *Helichrysum pendulum* complex (*Compositae*) inferred from nuclear and chloroplast DNA and morphometric analyses. – Taxon **66(4):** 909-933. https://doi.org/10.12705/664.7

Iamonico, D., Guarino, R., Ilardi, V. & Pignatti, S. 2016: A revision of *Helichrysum panormitanum* s.l. (*Asteraceae*) in the Italian and Maltese floras. – Phytotaxa **286:** 207-210. https://doi.org/10.11646/phytotaxa.286.3.10

Jeanmonod, D. 1996: *Xanthium* subg. *Xanthium* et *Helichrysum italicum*, deux cas taxonomiques ardus. – Candollea **53:** 435-457.

Maggio, A., Bruno, M., Guarino, R., Senatore, F. & Ilardi, V. 2016: Contribution to a Taxonomic Revision of the Sicilian *Helichrysum* Taxa by PCA Analysis of Their Essential-Oil Compositions. – Chem. Biodivers. **13:** 151-159. https://doi.org/10.1002/cbdv.201500052

Pignatti S. 1982: *Helichrysum* – Pp. 41-43 in: Flora d'Italia, **3.** – Bologna.

Royal Botanic Gardens Kew. 2021: Seed Information Database (SID). Version 7.1. – http://data.kew.org/sid/ [Last Accessed 1/11/2021].

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Mediterranean plant karyological data – 31

edited by G. Kamari, C. Blanché & S. Siljak-Yakovlev

Abstract

Kamari, G., Blanché, C. & Siljak-Yakovlev, S. (eds): Mediterranean plant karyological data – 31. — Fl. Medit. 31: 335-354. 2021. — ISSN: 1120-4052 printed, 2240-4538 online.

This is the thirty-one of a series of karyological data from Mediterranean area, peri-Alpine communities and the Atlantic Islands, in English or French language. It comprises contributions on 11 taxa: *Hieracium* from Sicily and S Italy by E. Di Gristina, G. Domina, & A. Geraci (Nos 1997-1999); *Allium*, *Drimia*, *Oncostema* and *Pancratium* from Tunisia by G. Barone, E. Di Gristina, R. El. Mokni & G. Domina (Nos 2000-2003); *Allium*, *Cyclamen*, *Cynara* and *Ornithogalum* from Greece, Crete and East Aegean Islands by E. Liveri, D. Phitos & G. Kamari (Nos 2004-2007).

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E. Di Gristina, G. Domina & A. Geraci

Karyological data of three *Hieracium* (*Asteraceae*) from Sicily and South Italy

Abstract

Di Gristina, E., Domina, G. & Geraci, A. 2021: Karyological data of three *Hieracium* (*Asteraceae*) from Sicily and South Italy [In Kamari, G., Blanché, C. & Siljak-Yakovlev, S. (eds), Mediterranean plant karyological data-31]. – Fl. Medit. 31: 336-340. http://dx.doi.org/10.7320/FlMedit31.336

Chromosome numbers are given for three endemic *Hieracium* taxa from Sicily and Campania (Southern Italy). All the examined taxa resulted triploid ($2n = 3x = 27$). The triploid chromosome set found in the population of *H. pallidum* from Rocche dell'Argimusco (Peloritani Mountains, NE-Sicily) differs from the previous counts ($2n = 4x = 36$) reported for the same species from its *locus classicus* (Mt. Etna).

Keywords: Agamospermy, chromosome number, endemism, polyploidy, distribution, rediscovery.

Introduction

The genus *Hieracium* L. s. str. (*Asteraceae*) is well known as one of the most species-rich plant group in the world. It includes perennial herbs distributed predominantly in temperate regions of Europe, Asia and North America (Chrtek & al. 2006). In the past, *Hieracium* also included *Pilosella* Vaill. but now they are treated as two separate genera, based on a whole range of morphological, biochemical, cytological and genetical characteristics (Braütigam & Greuter 2007; Di Gristina & al. 2013). *Hieracium* belongs to a group of genera in which diplosporous agamospermy and polyploidy seem to prevail. Hybridization also appears as a very rare phenomenon and is most likely confined to crosses between diploid sexual species (Chrtek & al. 2006). The primitive basic chromosome number for most of the *Asteraceae* and especially for *Hieracium* is $x = 9$ (Babcock 1947). However, the great majority of *Hieracium* taxa are triploid ($2n = 27$) or tetraploid ($2n = 36$) due to the species being sexual or apomictic or both (Mraz & al. 2001; Niketic & al. 2003). Sexuality is extremely rare and confined to a few diploid species, mostly distributed in South Europe (Merxmüller 1975; Chrtek & al. 2004). Agamospermy, together with sexuality and hybridization, in the past have given rise to a very large number of variants that have been described as subspecies, as has traditionally been the case in Central Europe or at rank of species in British Isles, Scandinavia, East Europe (Mraz & al. 2001; Chrtek & al. 2006).

In order to define the phylogenetic and systematic relationships among the endemic *Hieracium* taxa in Southern Italy, a cytogeographical analyses at population level, is in progress. In this frame, we here report the chromosome number of two *Hieracium* from Sicily and one from Campania.

1997. *Hieracium hypochoeroides* subsp. *lucanicum* (Arv.-Touv.) Di Grist., Gottschl. & Raimondo **—** $2n = 3x = 27$ (Fig. 1a).

It: Salerno, Parco Nazionale del Cilento e Vallo di Diano, Mt. Sacro, 40° 12' 56,88" N, 15° 20' 08,8" E, granitic conglomerate and sandstone rocks, 1.655 m a.s.l., 06 Jul 2013, *E. Di Gristina s.n.* (PAL).

Hieracium hypochoeroides subsp. *lucanicum* (Arv.-Touv.) Di Grist., Gottschl. & Raimondo is a little known taxon described from Mt. Sacro (Parco Nazionale del Cilento e Vallo di Diano, South Italy). It is a rosulate hemicryptophyte published by Guadagno under *H. sartorianum* var. *lucanicum* Arv.-Touv. and recently reclassified as a subspecies of *H. hypochoeroides* (Di Gristina & al. 2015a). The collective species *H. hypochoeroides* s.l. is a young aggregate of many apomictic microtaxa which have evolved probably during the post-glacial period (Di Gristina & al. 2015b). Many of the taxa described so far have a very restricted distribution and are very narrow endemics (Di Gristina & al. 2015b). In southern Europe there are only local populations and most of them seem to be relict (Di Gristina & al. 2016a).

The chromosome number $2n = 3x = 27$ (Fig. 1a), found here for the first time on material from its *locus classicus* (Mt. Sacro, Salerno) is included in the variability ($2n = 3x = 27$, $2n = 4x = 36$) reported for the collective species *H. hypochoeroides* by Sell & West (1976).

1998. *Hieracium pallidum* Biv. **—** $2n = 3x = 27$ (Fig. 1b).

Si: Messina, Peloritani Mountains, Rocche dell'Argimusco, 37° 59' 19,70" N, 15° 02' 26,24" E, quartzarenitic rocks, 1.225 m a.s.l., 17 Jun 2012, *E. Di Gristina s.n.* (PAL).

Hieracium pallidum Biv. is a rosulate chasmophyte recently considered as an intermediate species between *H. schmidtii* and *H. racemosum* ("*schmidtii* > *racemosum*") (Gottschlich & al. 2013). It was included as a local endemic species of Sicily in *H.* sect. *Grovesiana* which comprehends a complex of similar morphotypes resulting from hybridization processes of *H. grovesianum* Belli and *H. racemosum* Willd. (Di Gristina & al. 2014a). Other records given for *H. pallidum* from various European countries and regions belong to other subspecies of *H. schmidtii* complex, and need a critical revision (Gottschlich & al. 2013). In Sicily, *H. pallidum* has so far been known only from Mt. Etna (E-Sicily). A new population has recently been discovered from Rocche dell'Argimusco (Peloritani Mountains, NE-Sicily).

The chromosome number 2*n* = 3x = 27 (Fig. 1b), found here on material from Rocche dell'Argimusco does not agree with the number reported for the same species (2*n* = 4x = 36) from the *locus classicus* (Mt. Etna) by Brullo & al. (2005) and Di Gristina & al. (2005); it also differs with that detected for *H. pallidum* subsp. *aetnense* (2*n* = 4x = 36) (Di Gristina & al. 2014b). These observations suggest that the *H. pallidum* population of Rocche dell'Argimusco needs critical treatment.

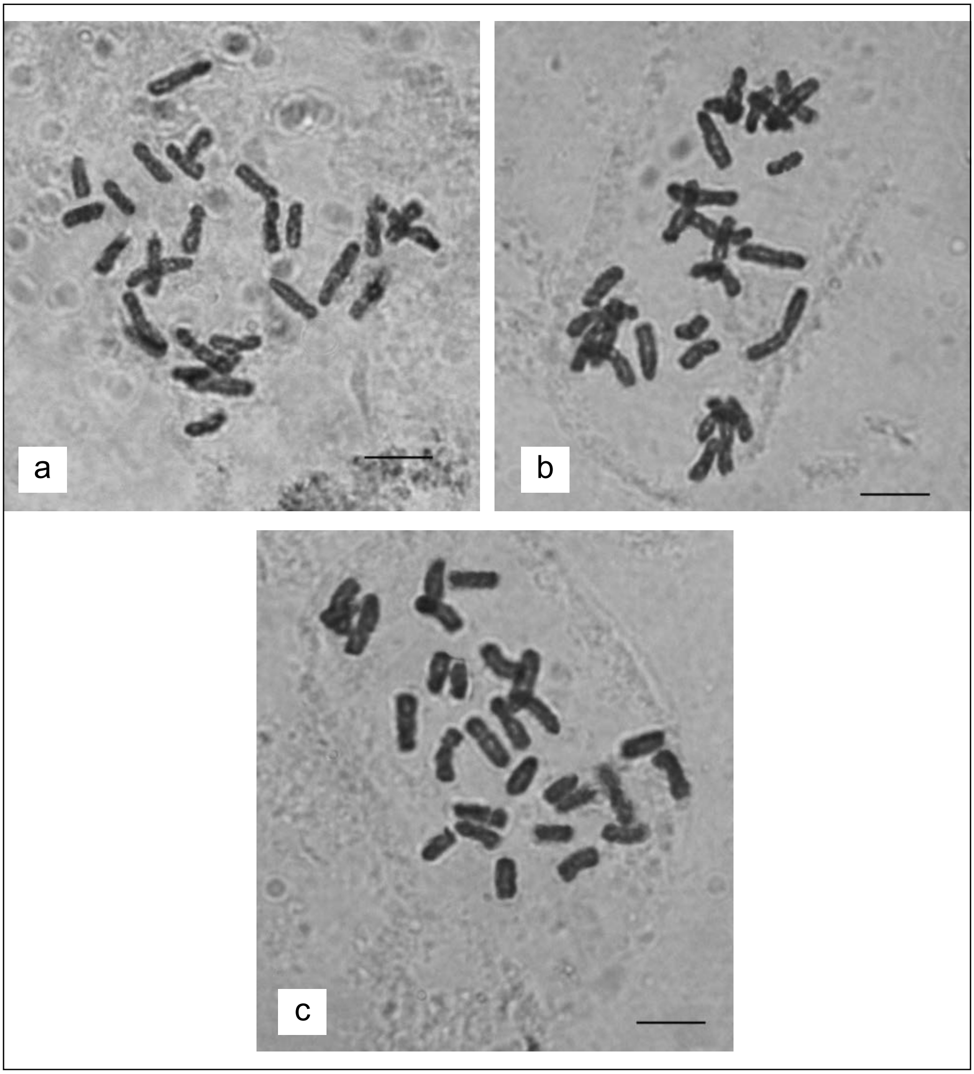

Fig. 1. Microphotographs of mitotic metaphase plates of: **a,** *Hieracium hypochoeroides* subsp. *lucanicum*, 2*n* = 3x = 27; **b,** *H. pallidum*, 2*n* = 3x = 27; **c,** *H. schmidtii* subsp. *nebrodense*, 2*n* = 3x = 27. – Scale bars = 10 µm.

1999. *Hieracium schmidtii* subsp. *nebrodense* (Tineo ex Lojac.) Di Grist., Gottschl. & Raimondo **—** 2*n* = 3x = 27 (Fig. 1c).

Si: Palermo, Madonie Mountains, Mt. Cavallo, 37° 49' 41,75" N, 14° 01' 56,60" E, quartzarenitic rocks, 1.474 m a.s.l., 27 Jun 2012, *E. Di Gristina s.n.* (PAL).

Hieracium schmidtii subsp. *nebrodense* (Tineo ex Lojac.) Di Grist., Gottschl. & Raimondo is a little-known endemic to Sicily and it has been recently rediscovered from the type locality after almost two centuries since its first and only collection made in 1830 in the Madonie Mountains (NC-Sicily) (Di Gristina & al. 2016b). It is a rosulate chasmophyte belonging to the collective species *H. schmidtii* (*H.* sect. *Oreadea*), which includes perennial plants, characterized by glaucous-green leaves in a basal rosette with long and rigid simple hairs at least on the leaf margins or on the surface.

The aggregate includes also the Sicilian endemic subspecies of the Madonie Mountains, *H. schmidtii* subsp. *madoniense* (syn. *H. madoniense*, see Raimondo & Di Gristina 2007).

The chromosome number 2*n* = 3x = 27 (Fig. 1c), found here for the first time on material from its *locus classicus* (Mt. Cavallo, Madonie Mountains) is included in the variability (2*n* = 3x = 27, 2*n* = 4x = 36) reported for the collective species *H. schmidtii* by Sell & West (1976), and it corresponds with the one found for *H. schmidtii* subsp. *madoniense* by Raimondo & Di Gristina (2007).

References

Babcock, E. B. 1947: The genus *Crepis*. Part One. – Univ. Calif. Publ. Bot. **21:** 1-197.

Braütigam, S. & Greuter, W. 2007: A new treatment of *Pilosella* for the Euro-Mediterranean flora. Notulae ad floram euro-mediterraneam pertinentes No. 24. – Willdenowia **37:** 123-137.

Brullo, S., Campo, G. & Romano, S. 2005: Indagini citotassonomiche sul genere *Hieracium* L. (*Asteraceae*) in Sicilia. – Inform. Bot. Ital. **36(2):** 481-485.

Chrtek J. jr., Mráz P. & Severa M. 2004: Chromosome numbers in selected species of *Hieracium* s.str. (*Hieracium* subgen. *Hieracium*) in the Western Carpathians. – Preslia **76:** 119-139.

—, — & Sennikov, A. 2006. *Hieracium ×grofae*, a rediscovered diploid hybrid from the Ukrainian Carpathians. – Biologia **61:** 365-373. https://doi.org/10.2478/s11756-006-0066-0

Di Gristina, E., Geraci, A. & Raimondo, F. M. 2005: Osservazioni citotassonomiche su popolazioni siciliane afferenti a *Hieracium pallidum* (*Asteraceae*). – Inform. Bot. Ital. **37(1):** 26-27.

—, Domina, G., Gottschlich, G., Mazzola, P. & Geraci, A. 2013: Morphological and genetic diversity within *Pilosella hoppeana* aggr. (*Asteraceae*) in Italy and taxonomic implications. – Pl. Biosyst. **147(3):** 788-799. https://doi.org/10.1080/11263504.2013.829880

—, Gottschlich, G. & Raimondo, F. M. 2014a: *Hieracium terraccianoi* (*Asteraceae*), a new species endemic to the Pollino National Park (Southern Italy). – Phytotaxa **188(1):** 55-60. https://doi.org/10.11646/phytotaxa.188.1.8

—, Domina, G. & Geraci, A. 2014b: Report 1837. In: Kamari, G., Blanché, C. & Siljak-Yakovlev, S. (eds), Mediterranean chromosome numbe rereports - 24. – Fl. Medit. **24:** 283-284. https://doi: 10.7320/FlMedit24.273

—, Gottschlich, G. & Raimondo, F. M. 2015a: Taxonomic remarks on *Hieracium sartorianum* var. *lucanicum* (*Asteraceae*), a little known taxon of Cilento (Campania, southern Italy). – Nordic J. Bot. **33:** 465-468. http://dx.doi.org/10.1111/njb.00755

—, — & — 2015b: *Hieracium hypochoeroides* subsp. *peracutisquamum* (*Asteraceae*), a new taxon from Basilicata, southern Italy. – Ann. Bot. Fennici **52:** 376-380. http://dx.doi.org/10.5735/085.052.0519

—, — & — 2016a: *Hieracium hypochoeroides* subsp. *cilentanum* (*Asteraceae*), a new taxon from S Italy. – Phytotaxa **246(3):** 192-197. https://doi.org/10.11646/phytotaxa.246.3.3

—, — & — 2016b: Rediscovery of *Hieracium nebrodense* (*Asteraceae*), a little-known endemic of Sicily (Italy). – Phytotaxa **265(1):** 59-66. https://doi.org/10.11646/phytotaxa.265.1.5

Gottschlich, G., Raimondo, F. M. & Di Gristina, E. 2013: *Hieracium pallidum* subsp. *aetnense* (*Asteraceae*), a new subspecies from Sicily (Italy), with notes on the taxonomy of *H. pallidum* Biv. – Pl. Biosyst. **147(3):** 826-831. https://doi.org/10.1080/11263504.2013.829882

Niketic M., Bareka P. & Kamari G. 2003: Karyosystematic study of selected *Hieracium* (*Compositae*) taxa from Mt. Durmitor (Montenegro). – Bot. Chron. **16:** 23-45.

Merxmüller, H. 1975. Diploide Hieracien. – Anal. Inst. Bot. Cavanilles **32:** 189-196.

Mráz P., Chrtek J. jr. & Kirschner J., 2001. Genetic variation in the *Hieracium rohacsense* Group. (*Hieracium* sect. Alpina). – Phyton **41:** 269-276.

Raimondo, F. M. & Di Gristina, E. 2007: *Hieracium madoniense* (*Asteraceae*), a new species from Sicily. – Pl. Biosyst. **141(1):** 86-92. https://doi.org/10.1080/11263500601153982

Sell, P. D. & West, C. 1976: *Hieracium* L. – Pp. 358-410 in: Tutin, T. G., Heywood, V. H., Burges, N. A., Moore, D. M., Valentine, D. H., Walters, S. M., Webb, D. A. (eds), Flora Europaea, **4.** – Cambridge.

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G. Barone, E. Di Gristina, R. El Mokni & G. Domina

Karyological data of four geophytes native to Tunisia

Abstract

Barone, G., Di Gristina, E., Mokni, R. El. & Domina, G. 2021: Karyological data of four geophytes native to Tunisia [In Kamari, G., Blanché, C. & Siljak-Yakovlev, S. (eds), Mediterranean plant karyological data-31]. – Fl. Medit. 31: 341-345. http://dx.doi.org/10.7320/FlMedit31.341

Chromosome numbers were studied in four geophytes collected in Tunisia. *Allium pallens* was collected from Zembra island, N of Tunisia, while *Drimia purpurascens*, *Oncostema peruvianum* and *Pancratium foetidum* from continental Tunisia. The chromosome numbers found for *Allium pallens*, *Drimia purpurascens*, and *Oncostema peruvianum* coincides with the previous reports obtained from other Mediterranean populations. The chromosome number 2*n* = 22, found on material from Toujane is the first reported for *Pancratium foetidum.*

Keywords: Chromosome number, North Africa, *Allium pallens*, *Drimia purpurascens*, *Oncostema peruvianum*, *Pancratium foetidum*.

Introduction

In the course of floristic and biological investigations on the flora of Tunisia in the last 10 years, geophyte seeds and bulbs have been collected and cultivated at the Botanical Garden of Palermo. The karyological investigations on the cultivated plants enriches the knowledge on this peculiar flora. Monocotyledonous geophytes make up about 6 percent of the entire flora (cfr. El Mokni & al. in press). Of these, 25 are endemic to Tunisia or to Tunisia and the surrounding countries (Domina & El Mokni 2018). Although monocotyledonous geophytes are among the most investigated plants from the cariological point of view, the knowledge on this component of the flora of Tunisia is limited to a few contributions (Battaglia 1957; Hong 1982; García-Barriuso & al. 2010; Ferjani & al. 2015).

2000. ***Allium pallens*** L. — 2*n* = 4x = 32 (Fig. 1a).

Tn: Island of Zembra, hills above the village, 50 m a.s.l., 37.120615° N, 10.809218° E, 10 May 2013, *G. Domina* (Hort. coll. PAL).

Allium pallens L. (sect. *Codonoprasum* Rchb.) is a geophyte widespread in the Mediterranean area, in particular Portugal, Spain, Baleares, France, Italy, Sicily, Greece, Aegean Islands, Cyprus, W and S Turkey, Syria, Lebanon, Israel, Egypt, Tunisia, Algeria and Morocco. It is a synanthropic species, occurring in nitrophilous habitats as cultivated or abandoned fields (vineyards, olive-grove), roadsides, sometimes in natural environments as garigues, maquis and meadows where it flowers in early summer. *A. pallens* is a critical species, often taxonomically misidentified in the European and Mediterranean Floras. It is closely related to *A. convallarioides* Grossh., a diploid species linked to natural habitats, which can be considered its probable ancestor (Brullo & al. 2003).

The chromosome number $2n = 4x = 32$ (Fig. 1a), found here on material from the island of Zembra (Tunisia) coincides with the previous reports obtained in Italy (Marchi & al 1974; Brullo & al. 2003) and other Mediterranean countries (Tanker & Kurucu 1979; Pastor 1985; Tzanoudakis 1999; Brullo & al. 2003). Also the chromosome number $2n = 16$ is known for *A. pallens* (Pastor 1982; Ruíz Rejón & al. 1986).

2001. ***Drimia purpurascens*** J. Jacq. — $2n = 2x = 20$ (Fig. 1b).

Tn: Djebel Boukornine, 300 m a.s.l., 36.697365° N, 10.340933° E, 24 Mar 2014, *G. Domina* (Hort. coll. PAL).

Drimia purpurascens J. Jacq. is a critical species, often taxonomically misidentified in the Mediterranean Floras. The species was published by Jacquin (1812) on plants cultivated in Vienna (Austria), received by the Botanical Garden of Milan (Italy) with the name "*Drimia undulata*". The origin of those plants was unknown, but they were placed at the Vienna Botanical Garden along with South African bulbous plants, and it was implicitly assumed that they were native to southern Africa. From that time, *D. purpurascens* is widely accepted to be a synonym of *D. elata* Jacq., a species widespread from Sudan to South Africa. However, a nomenclatural and taxonomic study on the taxa of the *Drimia undata* group (Crespo & al. 2020) made it possible to clarify the taxonomic position of *D. purpurascens*. In fact, a close examination of the illustration in the protologue of *D. purpurascens* (the only extant original material of that name) revealed important morphological differences that make the synonymization with *D. elata* incorrect. On the contrary, main morphological characteristics of *D. purpurascens* closely relate it to *D. undata* Stearn (Crespo & al. 2020).

The chromosome number $2n = 2x = 20$ (Fig. 1b), found here on material from Bou Kournine (Tunisia) does not agree with the number reported for *Drimia elata* ($2n = 18$) by Cave (1957) and Fedorov (1974) but it coincides with the one reported by Martinoli (1949), Battaglia (1957) and Bartolo & al. (1984).

2002. ***Oncostema peruvianum*** (L.) Speta — $2n = 2x = 16$ (Fig. 1c).

Tn: Matmatat-Al-Qadimal, 400 m a.s.l., 33.539738° N, 9.989747° E, 29 Apr 2019, *G. Domina & R. El Mokni* (Hort. coll. PAL).

Oncostema peruvianum (L.) Speta is a geophyte whose distribution extends from South Africa, into Europe and Asia (Azizbekova & al. 1997). It is an attractive floral species with excellent commercial potential. *O. peruvianum* have different chromosome numbers due to changes in the nucleolar chromosomes and polyploidy (Carmona & al. 1984).

The chromosome number 2*n* = 2x = 16 (Fig. 1c), found here on material from Matmatat-Al-Qadimal (Tunisia) is included in the variability (2*n* = 14, 2*n* = 15, 2*n* = 16, 2*n* = 28, 2*n* = 32) reported for the *Oncostema peruvianum* group (Battaglia 1949, 1950; Carmona & al. 1984; Luque 1988).

2003. *Pancratium foetidum* Pomel **—** 2*n* = 2x = 22 (Fig. 1d).

Tn: Toujane, 550 m a.s.l., 33.460248° N, 10.139170° E, 29 Apr 2019, *G. Domina & R. El Mokni* (Hort. coll. PAL).

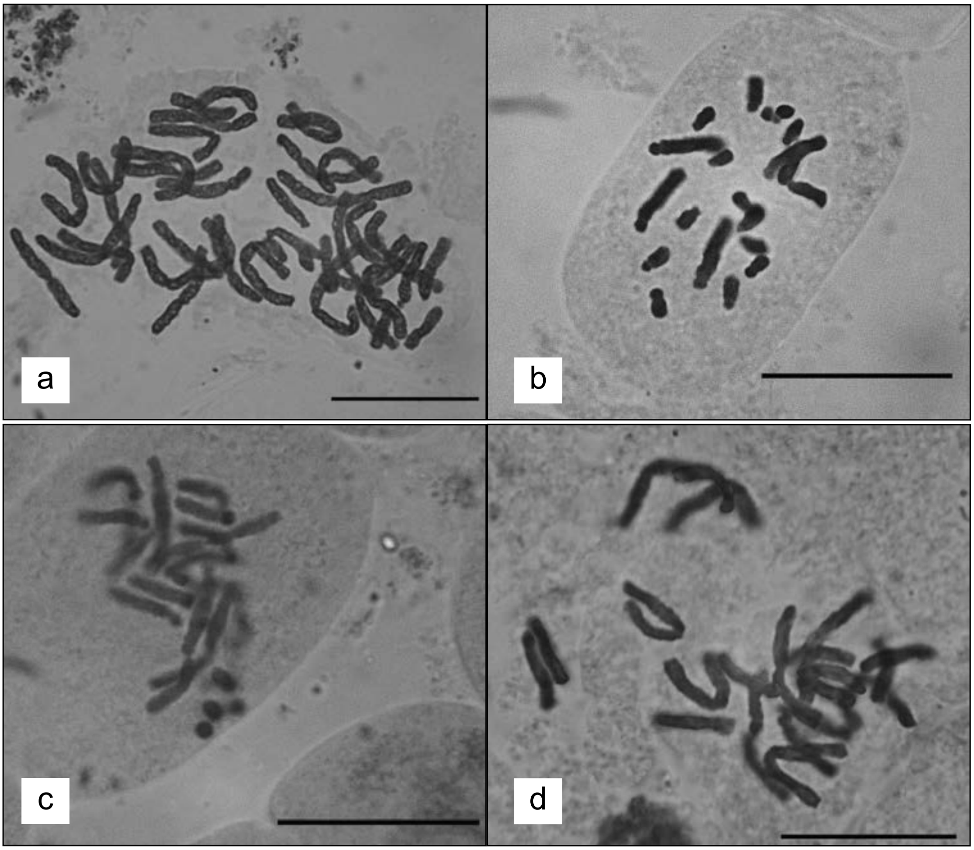

Fig. 1. Microphotographs of mitotic metaphase plates of: **a,** *Allium pallens*, 2*n* = 32; **b,** *Drimia purpurascens*, 2*n* = 20; **c,** *Oncostema peruvianum*, 2*n* = 16; **d,** *Pancratium foetidum*, 2*n* = 22. – Scale bars: 10 µm.

Pancratium foetidum Pomel is a geophyte native of NW-Africa, occurring from Morocco to Libya (El Gadi 1978). It was also found in Malta by Lanfranco & Spiteri (2001). *P. foetidum* is vegetatively similar to *P. maritimum* to such an extent that the two species are indistinguishable in the field when not in flower or fruit. However, they can be easily separated during flowering or fruiting. In fact, the flowers of *P. foetidum* are considerably smaller compared to those of *P. maritimum* and furthermore, its flowers are foul-smelling in contrast to the fragrant flowers of *P. maritimum*. *P. foetidum* flowers mainly in Late September and October while *P. maritimum* flowers mainly in summer with only a brief overlap in the flowering period between the two species. *P. foetidum* has stamens about equal to the coronal teeth while in *P. maritimum* these are longer. The fruit in *P. foetidum* is oblong in contrast to the subglobular fruit of *P. maritimum* and carries much smaller seed (Lanfranco & Spiteri 2001).

The chromosome number $2n = 2x = 22$ (Fig. 1d), found here on material from Toujane (Tunisia) is the first report for this species.

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References

Azizbekova, N., Roberts, C. M., Butland, S. & Ellis B. 1997: Annual Growth and Development of *Scilla peruviuana*. – Hort. Sci. **32(3):** 467-467.

Bartolo, G., Brullo, S., Pavone, P. & Terrasi, M. C. 1984: Cytotaxonomical notes on some *Liliaceae* of N. Cyrenaica. – Webbia **38:** 601-622.

Battaglia, E. 1949: Mutazioni cromosomiche in *Scilla peruviana* L. – Caryologia **1(2):** 144-174.

— 1950: Mutazioni cromosomiche in *Scilla peruviana* L. – Caryologia **3(1):** 126-147.

— 1957: Filogenesi del cariotipo nel genere *Urginea*. I–III: *U. maritima* (L.) Baker, *U. fugax* (Moris) Steinh. ed *U. undulata* (Desf.) Steinh. – Caryologia **9:** 234-273.

Brullo, S., Guglielmo, A., Pavone, P. & Salmeri, C. 2003: Cytotaxonomical remarks on *Allium pallens* and its relationships with *A. convallarioides* (*Alliaceae*). – Bocconea **16(2):** 557-571.

Carmona, M. J., De Dominicis, R. I., Salvi, G. & Maggini, F. 1984: Ribosomal RNA genes in biotypes of *Scilla peruviana* (*Liliaceae*). – Pl. Syst. Evol. **146:** 1-11.

Cave, M. S. 1957: Index to Plant Chromosome Numbers for 1957. – Berkeley.

Crespo, M. B., Martínez-Azorín, M. & Alonso, M. Á. 2020: The identity of *Drimia purpurascens*, with a new nomenclatural and taxonomic approach to the "*Drimia undata*" group (*Hyacinthaceae=Asparagaceae* subfam. *Scilloideae*)**.** – Pl. Syst. Evol. **306:** 67. https://doi.org/10.1007/s00606-020-01689-1

Domina, G. & El Mokni, R. 2018: An inventory of the names of vascular plants endemic to C Mediterranean and described from Tunisia. – Phytotaxa **409(3):** 105-128. https://doi.org/10.11646/phytotaxa.409.3.1

—, Greuter, W., Elyes Kchouk, M., El Mokni, R., Smaoui, A., Vitek, E., Bazan, G., Escobar, P. & Raimondo, F. M. 2015: The 12th "Iter Mediterraneum" in Tunisia, 24 March – 4 April 2014. – Bocconea **27(1):** 5-11

El Gadi, A. 1978: *Amaryllidaceae*, Flora of Libya, **51.** – Tripoli.

El Mokni, R., Barone, G., Maxted, N., Kell, S. & Domina, G. in press: A Prioritised Inventory of Crop Wild Relatives and Wild Harvested Plants of Tunisia. – Genet. Res. Crop Evol.

Fedorov, A. A. (ed.) 1974: Chromosome numbers of flowering plants. – Leningrad.

Ferjani, H., Haouala, F. & Mars, M. 2015: Morphological and karyological studies in two wild iris species (*Iridaceae*) of Tunisia. – Europ. Sci. J. **11(3):** 175-185.

García-Barriuso, M., Sonia Bernardos, S. & Amich, F. 2010: Chromosomal evolution in Mediterranean species of *Ophrys* sect. *Pseudophrys* (*Orchidaceae*): An analysis of karyotypes and polyploidy. – Taxon **59:** 525-537.

Hong, D. 1982: Cytotype variation and polyploidy in *Scilla autumnalis* L. (*Liliaceae*). – Hereditas **97:** 227-235.

Jacquin, J. F. 1812: Eclogae plantarum rariorum aut minus cognitarum, **1(3-4).** – Vindobonae [Wien].

Lanfranco, E. & Spiteri, H. J. 2001: New records for the Maltese flora: *Pancratium foetidum* Pomel (Family *Amaryllidaceae*). – Central Medit. Naturalist **3(3):** 147-148.

Luque, T., Mejas, J. A. & Daz Lifante, Z. 1988: Números cromosómicos para la flora española: 544-550. – Lagascalia **15(1):** 130-133.

Marchi, P., Carpineri, R. & D'Amato, G. 1974: Numeri cromosomici per la flora italiana: 182-189. – Inform. Bot. Ital. **6(3):** 303-312.

Martinoli, G. 1949: Ricerche citotassonomiche sui generi *Urginea* e *Scilla* della flora sarda. – Caryologia **1(3):** 329-357.

Pastor, J. 1982: Karyology of *Allium* species from the Iberian Peninsula. – Phyton **22(2):** 171-200.

— 1985: Karyology of *Allium stearnii* and *A. reconditum*, two new species from the Iberian Peninsula. – Phyton **25(1):** 73-76.

Ruíz Rejón, C., Lozano, R. & Ruíz Rejón, M. 1986: Números cromosómicos para la flora española, 479-484. – Lagascalia **14(2):** 292-296.

Tanker, N. & Kurucu, S. 1979: Cytotaxonomical researches on some species of *Allium* naturally growing in Turkey. – J. Fac. Pharm. Ankara Univ. **9:** 64-80.

Tzanoudakis, D. 1999: The genus *Allium* in Cyprus: a preliminary cytotaxonomical study. – Bocconea **11:** 105-115.

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E. Liveri, D. Phitos & G. Kamari

Karyological study of some plant taxa from Greece

Abstract

Liveri, E., Phitos, D. & Kamari, G. 2021: Karyosystematic study of some plant taxa from Greece. [In Kamari, G., Blanché, C. & Siljak-Yakovlev, S. (eds), Mediterranean plant karyological data - 31]. – Fl. Medit. 31:346-354. http://dx.doi.org/10.7320/FlMedit31.346

Chromosome numbers and karyotype morphology are given for four taxa of the Greek flora together with distributional and taxonomic notes. The chromosome number ($2n = 16$) and karyotype morphology of *Allium sphaerocephalon* subsp. *arvense* is reported for the first time in material from Kithnos island (Kiklades). The studied population of *Cyclamen graecum* subsp. *graecum* shows the chromosome number $2n = 84$, which is in accordance with previous reports from Greek material of unknown origin. A new subpopulation of *Cynara cyrenaica* from E Crete is presented and karyologically investigated confirming the previous chromosome number ($2n = 34$), whereas microphotograph of the karyotype is provided here for the first time. Furthermore, chromosome data for *Ornithogalum fimbriatum* subsp. *fimbriatum* reveal a diploid karyotype ($2n = 12$), which constitute the first karyological contribution from a Greek population belonging to the typical subspecies.

Keywords: *Allium sphaerocephalon* subsp. *arvense*, *Cyclamen graecum* subsp. *graecum*, *Cynara cyrenaica*, *Ornithogalum fimbriatum* subsp. *fimbriatum*, chromosome number, karyotype morphology, Greek flora.

Introduction

Greece represents one of the biodiversity hotspots in the Mediterranean Basin (Médail & Quezél 1999). The high plant diversity in combination to its extent places the Greek flora among the richest compared to other European countries (Phitos & al. 2009).

In this paper, we present new karyological data for four phytogeographically interesting taxa from Greece together with distributional and taxonomic comments, in the framework of accumulating karyological data of plants from the Mediterranean region and especially Greece (Bareka & al. 2008: "PhytoKaryon database").

2004. ***Allium sphaerocephalon*** subsp. ***arvense*** (Guss.) Arcang. — $2n = 2x = 16$ (Figs 1a & 1b).

Gr: Isl. Kithnos, Kiklades Islands (Kik): Above Merichas port, alt. ca. 50 m., 37° 23’ 20.81” N, 24° 23’ 37.11” E, 12 Jul 2013, *E. Liveri & V. Ketsilis-Rinis 99* (Herb. Phitos & Kamari in UPA).

Allium sphaerocephalon L. (*Alliaceae*) is a Mediterranean-European element, which presents great morphological variability. Four subspecies of *A. sphaerocephalon* have been recognized in Greece: a) subsp. *sphaerocephalon*, widely distributed across the entire area of the species; b) subsp. *aegaeum* (Heldr. & Halácsy) Karavok. & Tzanoud., endemic to Greece, restricted in Kiklades Islands (ins. Naxos) (Kik) and East Aegean Islands (EAe) (Karavokyrou & Tzanoudakis 1990; Karavokyrou 1994; c) subsp. *arvense* (Guss.) Arcang., which occurs in C & E Mediterranean region (Sicily, Malta, Albania, Greece, Anatolia) (Kollmann 1984); d) subsp. *trachypus* (Boiss. & Spruner) K. Richt., growing in Greece and Turkey (Karavokyrou 1994; Govaerts 2005; Dimopoulos & al. 2017+).

Allium sphaerocephalon subsp. *arvense*, which is characterized by white or green-whitish tepals, has been placed in several taxonomic ranks, ie. *arvense* type (Bothmer 1972), variety (Fiori 1923), subspecies (Arcangeli 1882; Stearn 1980; Mathew 1996) and species (Garbari 1982; Marcucci & Tornadore 1997).

The basic chromosome number for the whole *A. sphaerocephalon* complex, is x = 8 (Bothmer 1970). The karyological studies for *A. sphaerocephalon* subsp. *arvense* reveal two chromosome numbers: 2*n* = 2x =16 in material from Sicily and Italy (Maggini & Garbari 1977; Bartolo & al. 1978; Tornadore 1989; Johnson & Özhatay 1996; Marcucci & Tornadore 1997), Malta (Brullo & al. 1997), Greece (Bothmer 1970; Tzanoudakis 1985) and 2*n* = 4x = 32 in material from Egypt (Hamoud & al. 1990). Marcucci & Tornadore (1997) observed additionally 0-2 B-chromosomes in populations from Sicily and Italy.

The chromosome number and the karyotype morphology presented here are given for the first time in material from Kithnos island (Kik). The karyotype of diploid *A. sphaerocephalon* subsp. *arvense* is symmetrical, consisting of 2*n* = 2x = 16 metacentric hromosomes (Figs 1a & 1b). The size ranges from 8.0 to 10.5 µm. The given chromosome number hereby is in accordance with previous references from different localities in Greece but some differences in karyotype morphology are noted. Bothmer (1970) reported for *A. sphaerocephalon* in material from the Prov. Arkadia (Peloponnisos) a karyotype consisting of 2*n* = 16 metacentric chromosomes with a large satellite in one pair. One more population from Kea island (Kik) investigated by the same author, who found 16 metacentric and metacentric/submetacentric chromosomes and 1 submetacentric B-chromosome (2*n* = 16+1B). In this karyotype, two pairs are bearing large satellites. Bothmer (1970) did not mention the subspecific level for the above mentioned populations. However, in his subsequent article Bothmer (1972) showed a distribution map of *A. sphaerocephalon* in Greece and indicated the populations from Kiklades as *arvense* type, whereas the populations from Arkadia as *trachypus* type. Thus, we assume that the population from Kea most possibly belongs to subsp. *arvense* and the other one to subsp. *trachypus*. Tzanoudakis (1985) examined karyologically three populations of *A. sphaerocephalon* subsp. *arvense* from Prov. Achaia (Peloponnisos) and also resulted to 2*n* = 16 metacentric and submetacentric chromosomes with large satellites in two pairs. In our studied material, no B-chromosomes were observed but some variation in satellited chromosomes was noted (Figs 1a & 1b).

2005. *Cyclamen graecum* Link subsp. ***graecum*** **—** 2*n* = 84 (Fig. 1c).

Gr: Prov. Messinia, Peloponissos (Pe): close to Stoupa village, uncultivated fields, alt. ca. 20 m, 36° 50' N, 22° 15' E, 30 Oct 2017, *E. Liveri & V. Ketsilis-Rinis 364* (Herb. Phitos & Kamari in UPA).

Cyclamen L. (*Primulaceae*) is an important horticultural genus, native to the Mediterranean Basin, including more than 20 species (Grey-Wilson 2003; Compton & al. 2004; Yesson & Culham 2006; Marhold 2011; Curuk & al. 2016). One of the most common species in Greece is *Cyclamen graecum*, which also occurs in Cyprus and Turkey (Moore & Jope 2011). Three subspecies of *C. graecum* are currently recognized based mainly on flower and leaf morphology as well as geographic distribution: a) subsp. *graecum*, found in mainland Greece and islands; b) subsp. *anatolicum* Grey-Wilson, which occurs in Rodos island (East Aegean Islands), Cyprus and coastal areas of S Turkey; c) subsp. *candidum* Grey-Wilson, endemic to Crete (Moore & Jope 2011; Mathew 2013; Culham & Konyves 2014; Dimopoulos & al. 2017+). However, some doubts for the status of *C. graecum* subsp. *anatolicum* have been raised (Culham & Konyves 2014).

Several chromosome numbers have been given for *C. graecum*, but the number 2*n* = 84 is the most common. Glasau (1939) gives an approximate chromosome number, ie. 2*n* = 78-80, as well as De Haan & Doorenbos (1951), who give 2*n* = 84-85 in material from Greece without mentioning the exact localities. Legro (1959) additionally reports several chromosome numbers (2*n* = 84, 85, 86, 136) but based mainly on cultivars. However, Ishizaka (1996, 2003) gives the chromosome number 2*n* = 84 for wild form of *C. graecum* obtained from the Cyclamen Society in UK.

Two interesting hypotheses about the basic number and the origin of 2*n* = 84 in *C. graecum* have been suggested so far. Anderberg (1994) assumes that the basic chromosome number of *C. graecum* is x = 12 and the origin of 2*n* = 84 could be the result of hybridization between the morphologically related *C. hederifolium* Aiton and *C. persicum* Mill. Ishizaka (2003) considers *C. graecum* as autoploid based on cytogenetic experiments stating though that diploids plants became extinct since they have never been found in either wild or cultivated form.

The studied population of *C. graecum* subsp. *graecum* shows chromosome number 2*n* = 84 (Fig. 1c), which is in accordance with the previous references (De Haan & Doorenbos 1951; Legro 1959; Ishizaka 1996, 2003). The karyotype consists of mostly metacentric (m), small chromosomes varying in size (1.0-2.0 µm).

2006. *Cynara cyrenaica* Maire & Weiller **—** 2*n* = 2x = 34 (Fig. 1d).

Cr: Isl. Crete (KK): Prov. Lasithiou: At the road between the village Kalo Chorio and the city of Ag. Nikolaos, in place named Xerokambi, alt. 100-150 m, 35° 07' N, 25° 43' E, 13 Jun 2020, *G. Afordakos s.n.* (Herb. Phitos & Kamari in UPA).

The genus *Cynara* L. (*Asteraceae*) is a Mediterranean genus comprised of 10 species, which are characterized by restricted distribution in most cases (Greuter 2006). A disjunct distribution pattern is found in *Cynara cyrenaica*, native to E Crete (Greece) and Cyrenaica (NE Libya) (Boulos 1979; Ali & Jafri 1983; Wiklund 1992; Jahn & Schönfelder 1995; Greuter 2006; Turland 2009). The presence of *C. cyrenaica* in Cyprus (Robba & al. 2005) proved to be an error (Makris 2007; Hand & Hadjikyriakou 2009). The species, which is included in the Red Data Book of the flora of Cyprus categorized as Vulnerable (VU) under the name *C. cyrenaica* (Makris 2007) refers to *C. makrisii* Hand & Hadjik., a morphologically similar species, described a few years later (Hand & Hadjikyriakou 2009). *Cynara cyrenaica* is included in Red Data Book of Rare and Threatened Plants of Greece (Phitos & al. 2009) as Endangered (EN) since it was known only from two small subpopulations in E Crete (Turland 2009). Recently, a new third small subpopulation was discovered by G. Afordakos (in Jun 2020), cultivated and karyologically studied here.

The chromosome number 2*n* = 34 has been reported for *C. cyrenaica* in material from Crete (Turland 2009). All the other species for the genus counted so far have the same chromosome number except one single report for *C. tournefortii* Boiss. & Reut., which has 2*n* = 22 chromosomes (for references see Chromosome Counts Database - Rice & al. 2015).

The chromosome number 2*n* = 2x = 34, which is presented here from the new subpopulation of *C. cyrenaica*, is in accordance with the previous unpublished reference cited in the Red Data Book of Greece (Phitos & al. 2009). The karyotype is diploid and symmetrical, consisting of metacentric (m) and submetacentric (sm) chromosomes varying in size from 1.1 to 2.4 μm. The karyotype and microphotograph for *Cynara cyrenaica* are provided here for the first time.

2007. *Ornithogalum fimbriatum* Willd. subsp. ***fimbriatum* —** 2*n* = 2x = 12 (Figs 1e & 1f).

Gr: Thraki, Prov. Evrou (NE): At the river Evros, close to the village Gemisti, alt. ca. 30 m, 40° 58’ N, 26° 19’ E, 10 Mar 2017, *G. Mitsainas 29254* (Herb. Phitos & Kamari in UPA).

Ornithogalum fimbriatum (*Hyacinthaceae*) is a variable species of a taxonomically difficult genus, which contains ca. 35 species in Greece (Dimopoulos & al. 2017+). The species occurs in SE Europe and NW Turkey forming two subspecies: a) the widespread subsp. *fimbriatum* and b) the Greek endemic subsp. *gracilipes* (Zahar.) Landström, which differs in several morphological characters, geographic distribution and chromosome number (Landström 1989). Zahariadi (1983) defined the Greek populations from Sterea Hellas (StE) as different species, ie. *O. gracilipes* Zahariadi, whilst distinguished the populations from Samothraki island (North Aegean Islands – NAe) placing them in var. *ciliatum* (Boiss.). Subsequently, Landström (1989) studied populations from Sterea Hellas and Peloponnisos, recognized as *O. fimbriatum* subsp. *gracilipes* but mentioned that the material from Samothraki (NAe) and Chios (EAe) islands may represent the typical subspecies.

Most karyological studies for the species revealed the chromosome number 2*n* = 12 in material from Turkey (Cullen & Ratter 1967; Dalgiç & Özhatay 1997; Johnson & Brandham 1997), Bulgaria (Markova & al. 1972, 1974), Crimea (Van Loon & Oudemans 1976) and also in cultivated material of unknown origin (Zhukova 1967). Agapova

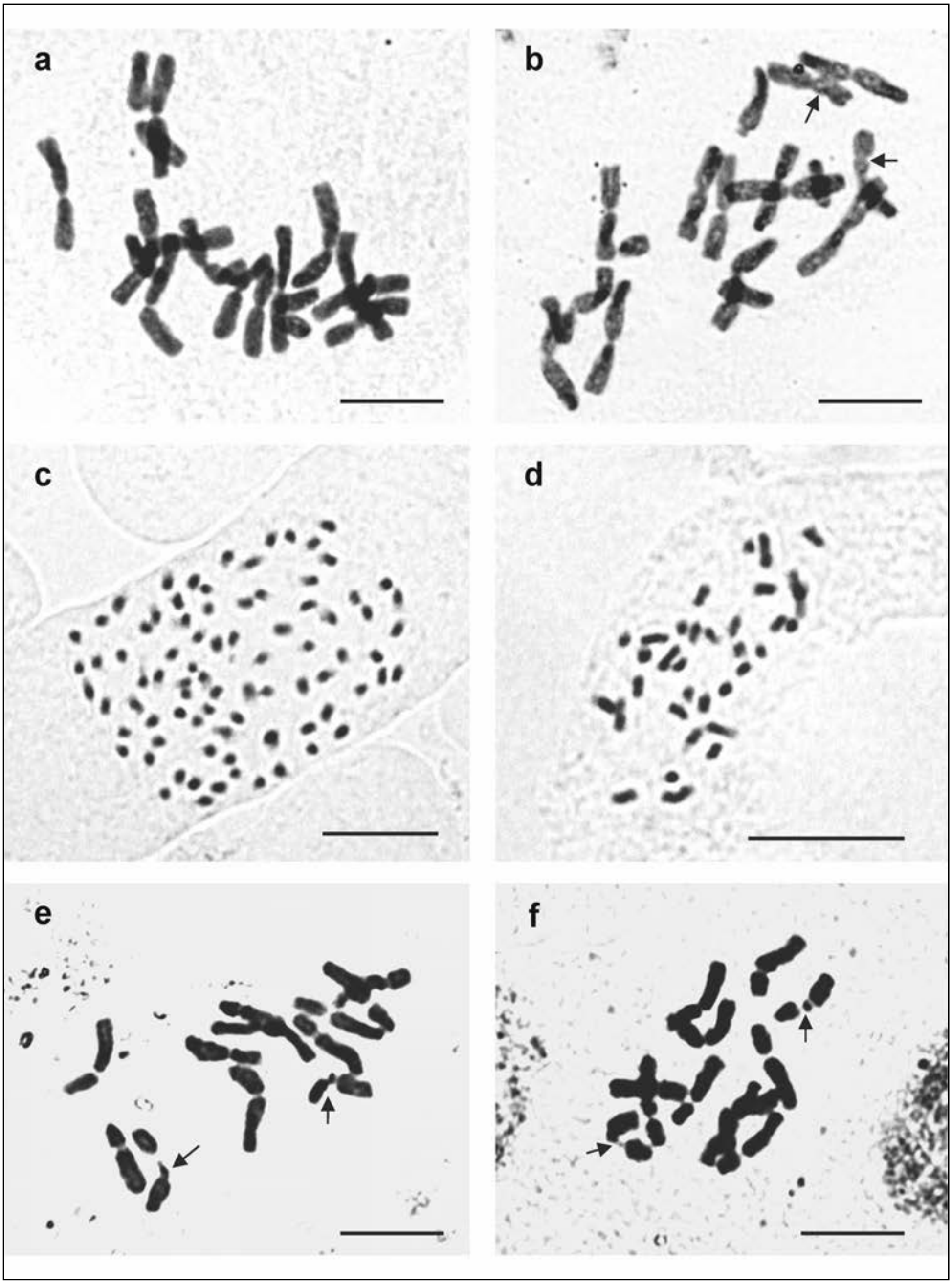

Fig. 1. Microphotographs of mitotic metaphase plates of: **a, b,** *Allium sphaerocephalon* subsp. *arvense*, 2*n* = 2x = 16; **c,** *Cyclamen graecum* subsp. *graecum*, 2*n* = 84; **d,** *Cynara cyrenaica*, 2*n* = 2x = 34; **e, f,** *Ornithogalum fimbriatum* subsp. *fimbriatum*, 2*n* = 2x = 12. – Arrows indicate secondary constrictions and/or SAT-chromosomes; Scale bars = 10 µm.

(1980) reports the same chromosome number with 0-3 B-chromosomes ($2n = 12+0\text{-}3B$) in plants from the former USSR. Johnson & al. (1991) indicated trisomy ($2n = 2x+1 = 13$) and polyploidy with one B-chromosome ($2n = 20+1B$) in material from Turkey. The chromosome number $2n = 35+0\text{-}2B$ reported in Turkish populations of *O. fimbriatum* by Cullen & Ratter (1967) probably belong to *O. umbellatum* group according to Landström (1989). For all the above mentioned references, the subspecific level is not mentioned but most probably belongs to the typical subspecies. In addition, Landström (1989) gives the chromosome number $2n = 14$ for *O. fimbriatum* subsp. *gracilipes* in material from Sterea Hellas.

The examined population of *O. fimbriatum* subsp. *fimbriatum* shows the diploid chromosome number $2n = 2x = 12$ (Figs 1e & 1f). The karyotype is symmetrical and consists of $2n = 8m + 4sm = 12$ chromosomes, varying in size from 6.0 to 9.5 μm. One pair of metacentric chromosomes has a secondary constriction close to the centromere, while no B-chromosomes have been observed. To our knowledge, the chromosome number and karyotype morphology given here in Greek material of the typical subspecies are reported for the first time. The same chromosome number has been reported for *O. fimbriatum* originated from other countries (see references above).

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References

Agapova, N. D. 1980: Cytosystematic studies of the European representatives of the genus *Ornithogalum* (*Liliaceae*) of the flora of the USSR. 11 Subgenus *Ornithogalum*. – Bot. Zhurn. **65(6):** 783-794. [In Russian]

Ali, S. I. & Jafri, S. M. H. 1983: Flora of Libya, **107.** – Tripoli.

Anderberg, A. A. 1994: Phylogeny and subgeneric classification of *Cyclamen* L. (*Primulaceae*). – Kew Bull. **49(3):** 455-476.

Arcangeli, G. 1882: Compendia della Flora Italiana, ossia Manuale per Ia Determinazione delle Piante che trovansi selvatiche od inselvatichite nell'Italia e nelle Isole adiacenti. – Torino.

Bareka, P., Mitsainas, G. P., Constantinidis, Th. & Kamari, G. 2008: PhytoKaryon a karyological database of European and Mediterranean plants. – Fl. Medit. **18**: 109-116.

Bartolo, G., Brullo S. & Pavone, P. 1978: Numeri cromosomici per la Flora Italiana: 484-493. – Inform. Bot. Ital. **10:** 267-277.

Bothmer, R. von 1970: Cytological Studies in *Allium* I. Chromosome Numbers and Morphology in *Allium* sect. *Allium* from Greece. – Bot. Not. **123(4):** 518-550.

— 1972: Four species of *Allium* sect. *Allium* in Greece. – Bot. Not. **125(1):** 62-76.

Boulos, L. 1979: A check-list of the Libyan flora 3. *Compositae* (by C. Jeffrey) – Candollea **34:** 307-332.

Brullo, S., Guglielmo, A., Pavone, P. & Terrasi, M. C. 1997: Reports (885-898). [In Kamari, G., Felber, F. & Garbari, F. (eds), Mediterranean chromosome number reports - 7]. – Fl. Medit. **7:** 267-274.

Compton, J. A., Clennett, J. C. B. & Culham, A. 2004: Nomenclature in the dock. Overclassification leads to instability: a case study in the horticulturally important genus *Cyclamen* (*Myrsinaceae*). – Bot. J. Linn. **146(3):** 339-349.

Culham, A. & Konyves, K. 2014: The *Cyclamen graecum* group, how many species? – Cyclamen **38 (2):** 70-76. https://centaur.reading.ac.uk/38956/

Cullen, J. & Ratter, J. A. 1967: Taxonomic and cytological notes on Turkish *Ornithogalum* L. – Notes RBG, Edinburgh **27:** 293-339.

Curuk, P., Sogut, Z., Bozdogan, E., Izgu, T., Sevindik, B., Tagipur, E. M., Teixeira da Silva, J. A., Serce, S., Kacar, Y. A. & Mendi, N. Y. Y. 2016: Morphological characterization of *Cyclamen* sp. grown naturally in Turkey: Part I. – Acta Sci. Pol. Hortorum Cultus **15(5):** 205-224.

Dalgiç, G. & Özhatay, N. 1997: The genus *Ornithogalum* (*Liliaceae*) and its karyotype variation in European Turkey. – Bocconea **5:** 743-747.1997.

De Haan, I. & Doorenbos, J. 1951: The cytology of the genus *Cyclamen*. – Meded. Land.-bouwhogeschool te Wageningen **51(7):** 151-166.

Dimopoulos, P., Raus, T. & Strid, A. 2017 onwards: Flora of Greece Website. –
http://portal.cybertaxonomy.org/flora-greece/ [Last accessed December 2021]

Fiori, A. 1923: *Allium* L. – Pp. 269-275 in: Nuova Flora Analitica d'Italia, **1.** – Firenze.

Garbari, F. 1982: *Allium* L. – Pp. 379-394 in: Pignatti, S. (ed.), Flora d'Italia, **3**. – Bologna.

Glasau, F. 1939: Monographie der Gattung Zyklamen auf Morphologisch-cytologischer Grundlage. – Planta **30:** 507-549.

Govaerts, R. 2005: World Checklist of *Alliaceae*. Facilitated by the Royal Botanic Gardens, Kew. – http://wcsp.science.kew.org/ Retrieved [Last accessed December 2021]

Greuter, W. 2006: *Compositae* (pro parte majore) – In: Greuter, W. & Raab-Straube, E. von (eds): *Compositae*. Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. – https://ww2.bgbm.org/EuroPlusMed/PTaxonDetail.asp?NameCache=Cynara%20 cyrenaica&PTRefFk=7000000 [Last Accessed December 2021]

Grey-Wilson, C. 2003: *Cyclamen*: a guide for gardeners, horticulturalists and botanists. –London.

Hamoud, M. A., Badr, A. & Turki, Z. 1990: Cytotaxonomic Relationships of Some Taxa of Egyptian *Allium* L. – Cytologia (Tokyo) **55:** 161-167. https://doi.org/10.1508/cytologia.55.161

Hand, R. & Hadjikyriakou, G. 2009: *Cynara makrisii* (*Asteraceae*, *Cardueae*), a new artichoke species in Cyprus. – Willdenowia **39:** 77-81. https://doi.org/10.3372/wi.39.39108

Ishizaka, H. 1996: Chromosome association and fertility in the hybrid of *Cyclamen persicum* Mill. and *C. hederifolium* Aiton and its amphidiploid. – Breed. Sci. **44**: 367-371.

— 2003: Cytogenetic studies in *Cyclamen persicum*, *Cyclamen graecum* (*Primulaceae*) and their hybrids. – Pl. Syst. Evol. **239:** 1-14. https://doi.org/10.1007/s00606-002-0261-6

Jahn, R. & Schönfelder, P. 1995: Exkursionsflora für Kreta. – Stuttgart.

Johnson, M. A. T., Garbari, F. & Mathew, B. 1991: A cytotaxonomical approach to species delimitation of a group of early-flowering Turkish *Ornithogalum* species (*Hyacinthaceae*). – Bot. Chron. (Patras) **10:** 827-839.

— & Özhatay, O. 1996: Cytology of *Allium* sect. *Allium.* – Pp. 17-40 in: Mathew, B. (ed.), A review *of Allium* sect. *Allium.* – Kew.

— & Brandham P. E. 1997: New chromosome numbers in petaloid monocotyledons and in other miscellaneous angiosperms. – Kew Bull. **52:** 121-138.

Karavokyrou, E. 1994: Study of the plant genus *Allium* in Eastern Greece. – PhD Thesis, University of Patras, Patras, Greece [In Greek with English summary].

— & Tzanoudakis, D. 1990: The genus *Allium* in Greece: II. A cytogeographical study of the E Aegean species. – Bot. Chron. (Patras) **10:** 777-784.

Kollmann, F. 1984: *Allium.* – Pp. 98-211 in: Davis, P. H. (ed.), Flora of Turkey and the East Aegean Islands, **8.** – Edinburgh.

Landström, T. 1989: The species of *Ornithogalum* L. subg. *Ornithogalum* (*Hyacinthaceae*) in Greece. – PhD Thesis, University of Lund, Lund, Sweden.

Legro, R. A. H. 1959: The cytological background of *Cyclamen* breeding. – Meded. Land.-bouwhogeschool te Wageningen **59(8):** 8-51.

Maggini, F. & Garbari, F. 1977: Amounts of Ribosomal DNA in *Allium* (*Liliaceae*). – Pl. Syst. Evol. **128:** 201-208.

Makris, C. 2007: *Cynara cyrenaica* Maire & Weiller. – Pp. 192-193 in: Tsintides, T., Christodoulou, C. S., Delipetrou, P. & Georghiou, K. (eds), The Red Data Book of the flora of Cyprus. – Lefkosia.

Markova, M., Radenkova, J., & Ivanova, P. 1972: Reports. [In Löve, Á. (ed.), IOPB chromosome number reports XXXVI]. – Taxon **21:** 333-346.

—, Popova, M., Radenkova, J. & Ivanova, P. 1974: Karyologischen Untersuchungen der in Bulgarien wildwachsenden Vertreter der Gattung *Ornithogalum*. – Bull. Inst. Bot. **25:** 63-92.

Marcucci, R. & Tornadore, N. 1997: Cytological and taxonomical notes on *Allium arvense* Guss. (*Alliaceae*) in Italy. – Webbia **51(2):** 189-199. http://dx.doi.org/10.1080/00837792.1997.10670620

Marhold, K. 2011: *Primulaceae* – In: Euro+Med Plantbase - the information resource for Euro-Mediterranean plant diversity. – https://ww2.bgbm.org/EuroPlusMed/PTaxonDetail.asp?NameCache=Cyclamen%20graecum&PTRefFk=7200000 [Last accessed December 2021]

Mathew, B. 1996: A review of *Allium* section *Allium.* – Royal Botanic Gardens, Kew.

— 2013: Genus *Cyclamen* in: Science, Cultivation, Art and Culture. – Kew, Camberley.

Médail, F. & Quezél, P. 1999: Biodiversity Hotspots in the Mediterranean. – Conserv. Biol. **13(6):** 1510-1513.

Moore, P. & Jope, M. 2011: The cyclamen of Greece: a guide to the species of *Cyclamen* growing in Greece. – Camberley.

Phitos, D., Constantinidis, T. & Kamari, G. 2009: The Red Data Book of Rare and Threatened Plants of Greece, **1(A-D).** – Patras.

Rice, A., Glick, L., Abadi, S., Einhorn, M., Kopelman, N. M., Salman-Minkov, A., Mayzel, J., Chay, O. & Mayrose, I. 2015: The Chromosome Counts Database (CCDB) - a community resource of plant chromosome numbers. – New Phytol. **206(1):** 19-26. http://dx.doi.org/10.1111/nph.13191

Robba, L., Carine, M. A., Russell, S. J. & Raimondo, F. M. 2005: The monophyly and evolution of *Cynara* L. (*Asteraceae*) *sensu lato*: Evidence from the Internal Transcribed Spacer region of nrDNA. – Pl. Syst. Evol. **253:** 53-64. http://dx.doi.org/10.1007/s00606-004-0259-3.

Stearn, W. T. 1980: *Allium* L. – Pp. 49-69 in: Tutin, T. G., Heywood V. H., Burges N. A., Valentine D. H., Walters S. M., Webb D. A. (eds), Flora Europaea, **5.** – Cambridge.

Tornadore, N. 1989: Population variability in *Allium sphaerocephalon* L. – Atti Soc. Tosc. Sc. Nat. Mem. ser B., **96:** 53-62.

Turland, N. 2009: *Cynara cyrenaica* – Pp. 345-347 in: Phitos, D., Constantinidis, Th. & Kamari, G. (eds), The Red Data Book of Rare and Threatened Plants of Greece, **1(A-D).** – Patras.

Tzanoudakis, D. 1985: Chromosome studies in some species of *Allium* sect. *Allium* in Greece. – Ann. Mus. Goulandris **7:** 233-247.

Van Loon, J. C. & Oudemans, J. J. M. 1967: Chromosome numbers of some angiosperms of the southern U.S.S.R. – Acta Bot. Neerl. **25(5):** 329-336.

Wiklund, A. 1992: The genus *Cynara* L. (*Asteraceae-Cardueae*). – Bot. J. Linn. **109:** 75-123.

Yesson, C. & Culham, A. 2006: A phyloclimatic study of *Cyclamen*. – BMC Evolutionary Biology **6(72):** 23. https://doi.org/10.1186/1471-2148-6-72

Zahariadi, C. A. 1983: Quelques taxons nouveaux du genre *Ornithogalum* (*Liliaceae*) recemment trouves dans les Balcans et dans le Proche-Orient. – Ann. Mus. Goulandris **6:** 171-197.

Zhukova, P. G. 1967: Karyology of some plants, cultivated in the Arctic-Alpine Botanical Garden. – Pp. 139-149 in: Avrorin, N. A. (ed.), Plantarum in Zonam Polarem Transportatio. II. – Leningrad. [In Russian]

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Obituary

Fl. Medit. 31: 355-357
https://doi.org/10.7320/FlMedit31.355

Stephen L. Jury

R. D. Meikle 1923–2021

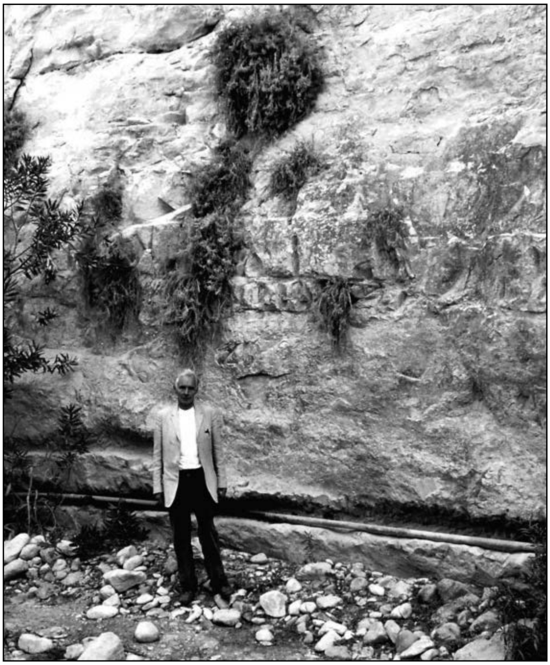

Fig. 1. Desmond Meikle in Cyprus in c. 1990 on Mount Akamas with the endemic *Centaurea akamantas* T.Georgiadis & Hadjik. on the limestone rocks (photo by Jeanne Webb).

Robert Desmond Meikle (known as Desmond) was born 18th May 1923 in Newtonards, County Down, Northern Ireland and although always greatly interested in nature and especially plants, read law at Trinity College, Dublin. After graduation, he moved to London to work in the Civil Service and started visiting The Royal Botanic Gardens, Kew in his spare time. The staff were obviously very impressed with his botanical knowledge as they offered him a job in the Herbarium. After working on the flora of West Africa, he became head of the Middle Eastern section and in 1950 started work on his *Flora of Cyprus*.

His *Times* obituary (*The Times*, Wednesday 24 March 2021) records that he first worked for Summerhayes, Kew's celebrated orchid specialist who featured in Ian Flemming's James Bond novel *On Her Majesty's Secret Service* and when expounding to Meikle on the subject, stepped back and fell through an open trap door. (No Health and Safety Officer in those days!) Meikle reported "Summerhayes was shaken, but not stirred", his favourite of many Kew tales.

I visited Kew as a research student working on the genus *Torilis* in 1972 when I encountered Mr Meikle in the *Umbelliferae* bay in the Herbarium working on the Cypriot specimens. We had a great and valuable discussion and he offered to take me to lunch in his regular haunt, Newens–the Original Maids of Honour, on Kew Road, but not until 2 p.m. I survived until then with the help of a 'Mars' chocolate bar. After the meal, the lateness was revealed as the waitress came out with the remains of luncheon, foil wrapped with instructions for how to heat it up for supper in his nearby apartment! He lived at weekends in his Somerset home and garden in Wootton Courtenay and used up his annual leave in half days commuting there at weekends.

Meikle became known for a very useful Kew publication in 1980: *Draft Index of Author Abbreviations compiled at The Herbarium Royal Botanic Gardens, Kew* which grew into *Authors of Plant Names* edited by R. K. Brummitt and C.E. Powell and published again by Kew in 1992. It is Meikle's work that is the foundation for the abbreviation of botanists' names and taken on by IPNI.org, the on-line International Plant Names Index and recognised by The Taxonomic Databases Working Group and now rebranded as Biodiversity Information Standards (TDWG) as a standard to use in all databases to facilitate data exchange.

Meikle used his legal mind to great effect in his comprehension of the laws of botanical nomenclature and was appointed to the Editorial Committee of the International Code of Botanical Nomenclature at Seattle in 1969, re-appointed in Leningrad in 1975 and again at Sydney in 1981. He was the clear choice for all Kew botanists to go to with their nomenclatural problems.

At home he made Willows and Poplars his special subject and published a Botanical Society of Britain and Ireland (BSBI) Handbook (number 4, *Willows and Poplars of Great Britain and* Ireland) on them in 1984 and kept in print and still available from the Society's book agent. He kept his interest in these and remained a BSBI referee for many years receiving specimens from members for identification. However, his catholic interest in plants meant that he published a great many papers on a huge range of taxa, but his 30-year research and study on the Cyprus flora gave rise to his magnum opus. He paid many visits to the island for fieldwork and recognised eight phytogeographical regions listing a specimen for each of the regions of occurrence. His nomenclature with full synonymy and complete botanical descriptions set the standard for all subsequent Floras. He methodically worked his way around the Kew Herbarium examining, not just all the material from Cyprus but checking this for any variation in other areas. He gave a final seminar at Kew: "The Flora of Cyprus: a Completed Project".

His scientific publications are listed by Belyaeva & Brough (2021) along with a local appreciation. Sadly, before moving to live in a care home, he burnt all his papers, correspondence and photographs in the belief that nobody would want them.

He was a popular member of his local Somerset community and freely gave support and advice, and thus it was no surprise that they organised a memorial luncheon for him which raised funds for the Somerset Wildlife Trust to provide trees to plant to increase local biodiversity. Guests were also asked to bring a flower from their garden to the luncheon to create a memorial vase on the day. However, a legacy of the Desmond Meikle Award features in the Koestler Awards and has enabled prisoners to engage in and demonstrate botanical art. The winner of the 2021 Meikle Award is entitled ‘Delicate Flowers’ by a prisoner, Stephen, in HM Prison, Albany on the Isle of Wight. How pleased Desmond would have been by this.

References

Belyaeva, I. V. & Brough, C. 2021: Scientific heritage of Robert Desmond Meikle (1923–2021). – Skvortsovia **7(3):** 24-43. http://dx.doi.org/10.51776/2309-6500_2021_7_3_24

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Errata-Corrige. Fl. Medit. 31-2021

Salmeri, C. & Brullo, C.: Seed germination reports for Sicilian endemic taxa of the genus *Helichrysum* (*Asteraceae*) [In Magrini, S. & Salmeri, C. (eds), Mediterranean plant germination reports – 3].

Pag. 328, line 20: “(UNICT_087, ….)” **should read** “(UNICT_088, ….)”
Pag 329, line 20 : “280 m a.s.l.,” **should read** “10 m a.s.l.,”
Pag 330, line 25, last line of Table: “11.2 30.9 14.0” **should read** “9.2 26.0 11.3”
Pag. 331, line 14, Table: “constant 15°C” **should read** “constant 20°C”
Pag. 331, line 21: “only at 15°C” **should read** “only at 20°C”

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