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Alien flora in Calabria (Southern Italy): an updated checklist

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Abstract An updated checklist of the Calabrian alien vascular flora is presented. By way of field, bibliographic, and herbarium research, we recorded 382 alien taxa (representing almost 14% of all regional flora), of which 371 are angiosperms, nine gymnosperms, and two ferns. In relation to the state of spread, the majority of alien species are casual (207 taxa; 54%), followed by naturalized (127; 33%) and invasive (48; 13%), these last include four on the list of Union Concern, *sensu* Regulation (EU) no. 1143/2014. The most represented families are Asteraceae (39 taxa) and Poaceae (39). Among genera, *Amaranthus* (nine taxa), *Prunus*, *Euphorbia*, and *Oxalis* (seven taxa) make up those with the greatest number of taxa. A total of 21 taxa were reported for the first time, three of them are new to the European flora (*Camptosema rubicundum, Musa* ×*paradisiaca* and, only for continental Europe, *Ipomoea hederacea*), two to the Italian peninsula (*Pelargonium graveolens, Schinus terebinthifolia*) and 16 to the Calabrian flora (*Aeonium arboreum, Asparagus asparagoides, Aspidistra elatior, Bidens sulphurea, Catalpa bignonioides, Citrus* ×*aurantium, Crassula ovata, Cucurbita ficifolia, Dimorphotheca ecklonis, Graptopetalum paraguayense* subsp. *paraguayense, Kalanchoë laxiflora, Nicotiana tabacum, Phytolacca dioica*, *Portulaca umbraticola, Talinum paniculatum, Tecomaria capensis*). In terms of residence status, there are 291 neophytes (76%), 73 archaeophytes (19%), and 18 regional aliens (5%); neophytes are the most represented group (45 out of 48) among invasive taxa. Concerning life forms, the two most abundant groups are therophytes (30.1%, 115 taxa) and phanerophytes (29.6%, 113 taxa). Regarding habitats, 72% of alien taxa occur in artificial (199 taxa, 52%) and agricultural habitats (75 taxa, 20%). The majority of alien taxa are native to the Americas (159; 41.6%), numerous aliens also originated in Asia (76; 19.9%) and Africa (56; 14.7%). The majority of taxa were introduced for ornamental purposes (55%). Over the past decade, alien taxa in the flora in Calabria have

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increased from 190 to the current 382 taxa. While this trend could be linked to some extent to increasing awareness of the problem of alien species and the increasing intensity of research over recent decades, it is also most probably due to new introductions resulting from the globalization that relentlessly affects the whole planet.

Keywords Alien species · Biodiversity · Exotic plant · Floristic data · Herbarium specimens · IAS · Invasiveness · New floristic records · Plant diversity

Introduction

Biological invasions are one of the greatest threats to biodiversity in the world, second only, in terms of severity, to the destruction of natural habitats (Lawler et al. 2006; Pyšek et al. 2020). The annual rate of first records worldwide has increased since 1800, and 37% of these have occurred over the last 44 years (Seebens et al. 2017). Alien species are recognized as a significant component of human-caused environmental global change, which also affects the conservation of biodiversity and the function of invaded ecosystems (Weber 2003; Pyšek et al. 2004; Richardson and Pyšek 2006). Alien species can affect the quality of habitats available to other species and consequently the ecosystem services provided Gutiérrez 2017; Vilà and Hulme 2017; Castro-Diéz et al. 2019). Many studies ascertained and documented that alien species, especially invasive ones, can also cause considerable socio-economic and health damage (Richardson et al. 2000; Bacher et al. 2017).

Alien plants are becoming an important component of wild floras and are a real challenge for current and future environmental and habitat management (Maes 2013; Pyšek et al. 2020; Gigante et al. 2018; Raposo et al. 2021).

Checklists are essential for studies on biogeography and provide an important tool for biodiversity conservation (Perrino and Signorile 2009; Perrino et al. 2013; Musarella et al. 2018; Wong and Joling 2021). Alien plant checklists are critical to understanding plant invasion in many places around the world (Celesti-Grapow et al. 2009, 2010, 2016; Galasso et al. 2018a; Lazzaro et al. 2020; Viciani et al. 2020) Datasets on the floristic state, biological attributes, and the geographic distribution of alien species are significant tools for understanding the invasiveness of alien species (Pyšek et al. 2002, 2004; Haq et al. 2021).

The total number of alien plants in the European flora, currently estimated at around 6000 taxa, has tripled in the last half-century and will continue to increase through to 2050 (Lambdon et al. 2008; Pyšek et al. 2017; Seebens et al. 2017, 2021).

Many studies on alien plants are available for Italy on a national or regional scale (Stinca et al. 2017, 2021; Rosati et al. 2020; Galasso et al. 2018a) reported 1741 alien species for the Italian territory, of which 236 are invasive; 20 of these species are included in the EU list according to Regulation 2016/1141, of 13 July 2016 and 2019/1262 of 25 July 2019 (European Commission 2019). This checklist has been updated by several other works up to the present (Galasso et al. 2018b, c, 2019a, b, 2020a, b, 2021a, b). Furthermore, Lazzaro et al. (2019) proposed a list of 96 alien species that should be included in the Italian national list according to EU Regulation 1143/2014.

Calabria, located at the southern end of the Italian peninsula in the centre of the Mediterranean Sea, has been identified by historical and environmental data as a refuge area during Quaternary for several plant taxa, very important for their conservation (Médail and Diadema 2009). Calabria is one of the regions with the highest number of endemic plant taxa (Pignatti 1994). Indeed, after the two large Italian islands of Sicily and Sardinia, Calabria is the third richest region in endemics (Peruzzi et al. 2014).

Various authors have dealt with alien flora in Calabria (Viegi et al., 1974; Celesti-Grapow et al. 2009; Galasso et al. 2018a). Moreover, information on the regional alien flora is available in certain Italian checklists and floras Pignatti 1982, 2017a,b, 2018; Conti et al. 2005; Pignatti et al. 2019). More recently, Bartolucci et al. (2021) provided an updated overview of native and alien vascular flora of Italy, with details on occurrences at national and regional administrative level.

For Calabria, there is a number of recent contributions mainly thanks to the research of this working group (Spampinato et al. 2019; Musarella et al. 2019, 2020; Musarella 2020; Rosati et al. 2020; Laface et al. 2020; Stinca et al. 2021), including many new records, that improved knowledge on alien flora in

this region. Yet, there a comprehensive analysis of the regional alien vascular flora of this region is missing.

The aim of this study is to present an updated checklist of alien vascular flora within the Calabrian region (Southern Italy), with information on the origin, distribution, and invasion status of alien taxa and their habitats. This new and updated data should contribute to filling the knowledge gap on alien species in the Mediterranean region and Southern Europe to the same degree as the better-known alien flora of Central and Northern Italy and temperate Europe.

Materials and methods

Study area

Calabria is the southernmost region of the Italian Peninsula (Fig. 1). It has an area of 15,081 km^2 with a population of 1,877,728 inhabitants (ISTAT 2021), corresponding to an average density of 126.6 inhabitants/km^2.

Calabria is a narrow peninsula in the central Mediterranean basin, approximately 250 km long, surrounded on three sides by the sea, with a coastal development of 715 km. The region is crossed from north to south by a series of mountainous reliefs at varying altitudes between 1,400 m and 2,200 m a.s.l., which together constitute the Calabrian Apennines, a continuation of the southern Apennines. The territory is mostly hilly (49% of the area), there are few

Fig. 1 Geographical position of Calabria region

plains (9%), and large areas are mountainous (42%). As regards land use in Calabria, the following Land Cover Corine categories (ISPRA 2019) are indicated: level 1-artificial surfaces (3.7%), level 2-agricultural areas (48.6%), level 3-forest and seminatural areas 48.3% (of which 31% are forested), level 4-wetlands (0.003%), level 5-inland water bodies (0.3%). Annual precipitation varies from 600 to 1800 mm, and mean annual temperature from 12 to 19 °C. The prevailing bioclimate is the Mediterranean pluviseasonal oceanic type, widespread from sea level to ~ 1000–1100 m a.s.l., at higher altitudes, it is the oceanic temperate type (Pesaresi et al. 2017).

The native flora of the Calabria region is estimated at 2,768 native taxa (species and subspecies) (Bartolucci et al. 2018, 2021), with additional 342 aliens reported by previous studies (Galasso et al. 2018a; Bartolucci et al. 2018, 2021).

Data sources and terminology

The critical analysis of bibliographic information, herbarium specimens, and observation and field collections carried out in this study made it possible to update the checklist of alien vascular flora in Calabria. The dataset for the current checklist originates from a preliminary list of Italian alien species based on Celesti-Grapow et al. (2010), Galasso et al. (2018a), and Bartolucci et al. (2018), updated with the above-mentioned literature for Italy and Calabria in particular and integrated with additional and updated information, field collections and surveys. Collected specimens are preserved at the Herbarium of the Mediterranean University of Reggio Calabria (REGGIO; acronym according to Thiers 2021). Historical records (species no longer registered for 50 years, probably casual alien that have not established), and doubtful records (doubtfully occurring in the region, probably reported by mistake or confused with other species), are listed in the Online Resource 1 but not analyzed in this study.

Each species record is supplemented with data on taxonomy, life form and growth type, presence status, invasion and residence status, habitats, and frequency. The nomenclature of taxa follows Galasso et al. (2018a) and Bartolucci et al. (2018), that of the families the APG system (Stevens 2001 onwards).

Data relating to the geographical distribution, origin, and introduction pathway come from several online databases on alien species (CABI 2021; EPPO 2021; GBIF 2021; ISSG 2021; Portal to the Flora of Italy 2021; POWO 2021). Taxonomic assignment of alien plants to genera and families to allow for comparison with native species follows Bartolucci et al. (2018, 2021). Introduction pathways were assessed by distinguishing the following categories: ornamental, forestry, agricultural and unknown (species without information on the purpose of introduction).

We classified the invasion status of alien plant species according to Richardson et al. (2000, 2011) and Pyšek et al. (2004) to distinguish casual (alien plants that may occasionally reproduce outside cultivation without forming self-replacing populations, their persistence depends on repeated introductions), naturalized (alien plants that sustain self-replacing populations and reproduce without direct human intervention from seed or vegetative parts capable of independent growth), and invasive (a subset of naturalized plants with the potential to spread over a large area in natural or man-made habitats, thanks to high reproductive efficiency and their long-distance dispersion ability from parent plants). We also recognized regional aliens that are native to other parts of Italy but alien in Calabria (according to Bartolucci et al. 2018). Plants kept only in cultivation are not included in this study.

Taxa with uncertainty as to whether they are native or alien are considered cryptogenic (Carlton 1996). They are listed in the checklist (Online Resource 1) but not considered in this study.

Alien taxa were distinguished with respect to the residence time, as archaeophytes (introduced before ~ 1500) or neophytes (introduced after ~ 1500), following the criteria suggested by Richardson et al. (2000) and Pyšek et al. (2004). Life forms, according to Raunkiaer classification (Raunkiaer 1934), followed Pignatti (2017a, b, 2018; Pignatti et al. 2019).

The following habitat groups were distinguished according to the Corine Land Cover system (CEC 1994): artificial surfaces (constructed, industrial and other artificial habitats, ruderal sites, and linear infrastructure), agricultural areas (regularly or recently cultivated agricultural, horticultural and domestic habitats), natural and seminatural habitats. The latter were divided into grasslands, riparian habitats, shrubland, wetland (including water bodies), woodland, and coast. The distribution of taxa among the different habitats was inferred from literature and from

field observations on the frequency of occurrence. When a taxon is present in more than one habitat, the prevailing one is reported.

Statistical analysis

The processed data were subjected to statistical analysis. To prove that the observed values fit the expected frequencies, the variables were arranged in the form of standardized contingency tables and the chi-square test was carried out. All analyses were performed with Microsoft Excel® spreadsheet software.

Results

Taxonomic diversity

The alien flora of Calabria includes 382 taxa (species, subspecies, and hybrids), belonging to 245 genera and 84 families (Online Resource 1). The taxa recorded belong mainly to angiosperm eudicots (68 families, 283 taxa), followed by monocots (19 families, 88 taxa), gymnosperms (two families, nine taxa), ferns and allies (two families, two taxa). When taking into account the regional vascular flora (Bartolucci et al. 2018, 2021), alien taxa represent 14% of Calabrian flora.

The distribution of alien taxa among the families is strongly unbalanced (Fig. 2). The majority of taxa are members of a few families, mainly Asteraceae (39 taxa), Poaceae (39), Fabaceae (28), and Solanaceae (23), while many families contain one or two alien taxa (Fig. 2).

The genera with the highest number of alien taxa are *Amaranthus* (nine taxa), *Prunus*, *Euphorbia* and *Oxalis* (seven), *Bidens* (six), *Vitis*, *Cyperus*, and *Solanum* (five taxa). Most genera include only one taxon. The richest genera include weed species or species of agronomic interest.

New aliens to calabrian flora

The field research carried out in this study has identified several new alien vascular taxa for the flora of Calabria. A complete list of these taxa is given in Online Resource 2 with complete information on collection locations and their environmental conditions. Three taxa are new to the European alien flora

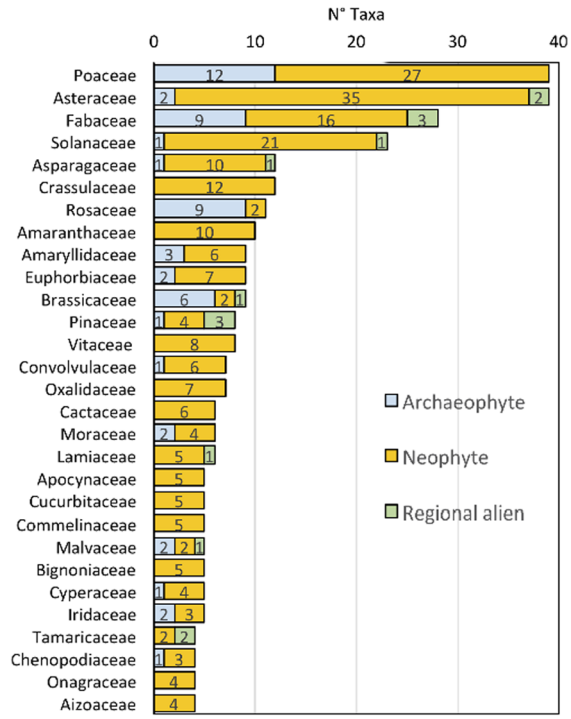

Fig. 2 The families most represented in Calabrian alien flora (≥4 taxa). Residence status is indicated

(*Camptosema rubicundum, Musa* ×*paradisiaca* and, only for continental Europe, *Ipomoea hederacea*), two to the Italian peninsula (*Pelargonium graveolens*, *Schinus terebinthifolia*) and 16 to the Calabrian flora (*Aeonium arboreum*, *Asparagus asparagoides, Aspidistra elatior*, *Bidens sulphurea, Catalpa bignonioides, Citrus* ×*aurantium, Crassula ovata, Cucurbita ficifolia, Dimorphotheca ecklonis, Graptopetalum paraguayense* subsp. *paraguayense, Kalanchoë laxiflora, Nicotiana tabacum, Phytolacca dioica*, *Portulaca umbraticola, Talinum paniculatum, Tecomaria capensis*).

Species status

In relation to invasion status (Fig. 3), casuals (207 taxa) account for 54% of the flora, naturalized (127 taxa) for 33% and invasive (48 taxa) for 13%. Four invasive species of these are included in the European Union list: *Acacia saligna, Cenchrus setaceus, Ailanthus altissima*, and *Hydrocotyle ranunculoides* (European Commission 2019). The latter species represents new record for the region.

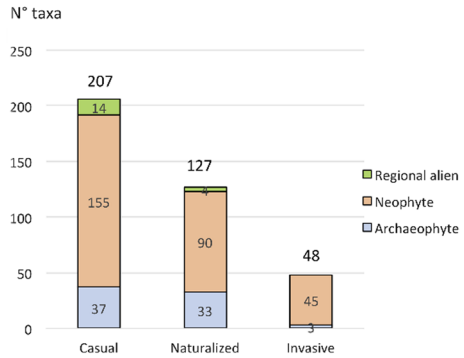

Fig. 3 Number of taxa by invasion (casual, naturalized and invasive) and residence status (archaeophytes, neophytes, regional aliens)

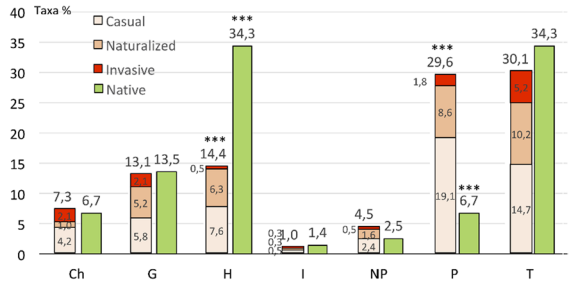

Fig. 4 Distribution of life forms among casual, naturalized and invasive alien taxa compared with native flora in the Calabria region. Significant differences in the distribution of alien and native flora in particular life-history groups, based on chi-square test, are indicated above the bars (* < 0.05, ** < 0.01, *** < 0.001). Ch–chamaephyte, G–geophyte, H–hemicryptophyte, I–hydrophytes, NP–nanophanerophyte, P–phanerophyte, T–therophyte

Regarding residence status, 76% of Calabrian alien taxa are neophytes (291), 19% are archaeophytes (73) and 5% are regional aliens (18). When comparing residence status and invasion status, neophytes are over-represented among invasive aliens, where they make 94% (45 out of 48 taxa). Archeophytes are over-represented among naturalized taxa (26%), followed by casuals (18%) and invasives (6%). In general, regional aliens are poorly represented in Calabrian flora, being more present among casuals (7%), followed by naturalized (3%) and completely absent among invasives.

Life forms

The life forms spectrum (Fig. 4) highlights that therophytes (30.1%, 115 taxa) and phanerophytes (29.6%, 113 taxa) are the dominant life forms among Calabrian alien flora, followed by hemicryptophytes (14.4%, 55 taxa), geophytes (13.1%, 50 taxa). Other life forms such as chamaephytes (7.6%, 29 taxa), nanophanerophytes (4.5%, 17 taxa), and hydrophytes (1%, four taxa) are less represented.

Compared to native flora, alien taxa are over-represented among phanerophytes and under-represented among hemicryptophytes, the differences being highly significant ($P < 0.001$). There were no significant differences for the other categories of life forms (Fig. 4). The higher frequency of phanerophytes results from the introduction and widespread use of trees and shrubs for ornamental purposes, such as *Acer negundo, Amorpha fruticosa, Austrocylindropuntia subulata*, *Schinus molle, Sesbania punicea*, but also in forestry (*Acacia saligna, Robinia pseudacacia, Populus* ×*canadensis, Eucalyptus camaldulensis, E. occidentalis*) and in agriculture (i.e., crops such as *Ricinus communis, Vitis rupestris, Opuntia ficus-indica*).

The distribution of phanerophytes and nanophanerophytes compared for casual vs. naturalized taxa, including invasive, was significantly different; taxa of this life form were recorded as casuals with lower frequency than expected and with higher than expected among naturalized. For the other life form categories the differences were not significant (Fig. 5).

Habitat

In Calabria, alien taxa grow mostly on artificial surfaces (199 taxa, 52%), especially in the urban and suburban territory. There is also significant representation for taxa growing on agricultural surfaces (75 taxa, 20%) such as crops and orchards. As many as 108 taxa (28%) occur in natural and seminatural habitats, especially in riparian places (6%), wetlands (6%), scrublands (5%), and grasslands (5%). Finally, woodlands and coasts are less represented with 3% each.

Geographical origin

Most of the alien taxa (159) are native to the Americas with 41.6% (97 from South America: 25.4%; 62 from North America: 16.2%). The second most important source region is Asia, providing 76 alien

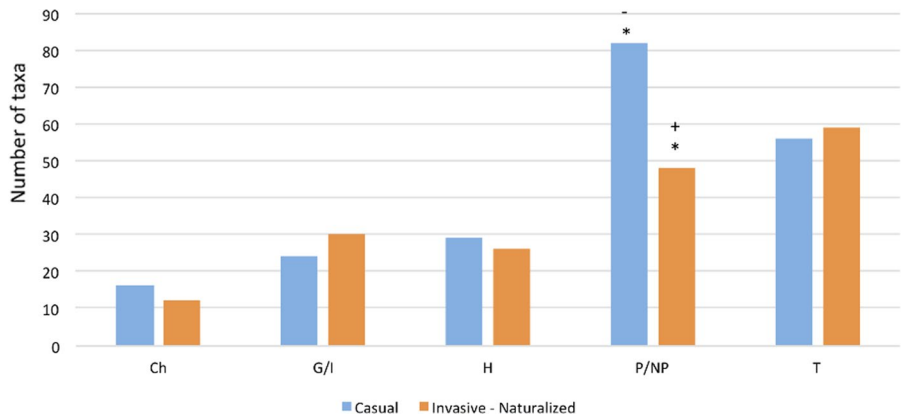

Fig. 5 Alien taxa in Calabria classified according to life forms, shown for casual and naturalized taxa (including invasive). Significant differences, based on the chi-square test, among these two invasion status groups are indicated for each life form above the bars (-, lower than expected; +, higher than expected, *: $P < 0.05$). Ch–chamaephyte, G–geophyte, H–hemicryptophyte, I–hydrophytes, NP–nanophanerophyte, P–phanerophyte, T–therophyte

taxa (19.9%); Africa follows with 56 (14.7%). Fewer species are native to the Mediterranean region (8.9%), Europe (4,7%), and Eurasia (3.9%). Finally, 2.4% are currently spread over a large distribution area (cosmopolitan), 2.1% come from Australia, and another 1.8% are of uncertain origin (Fig. 6).

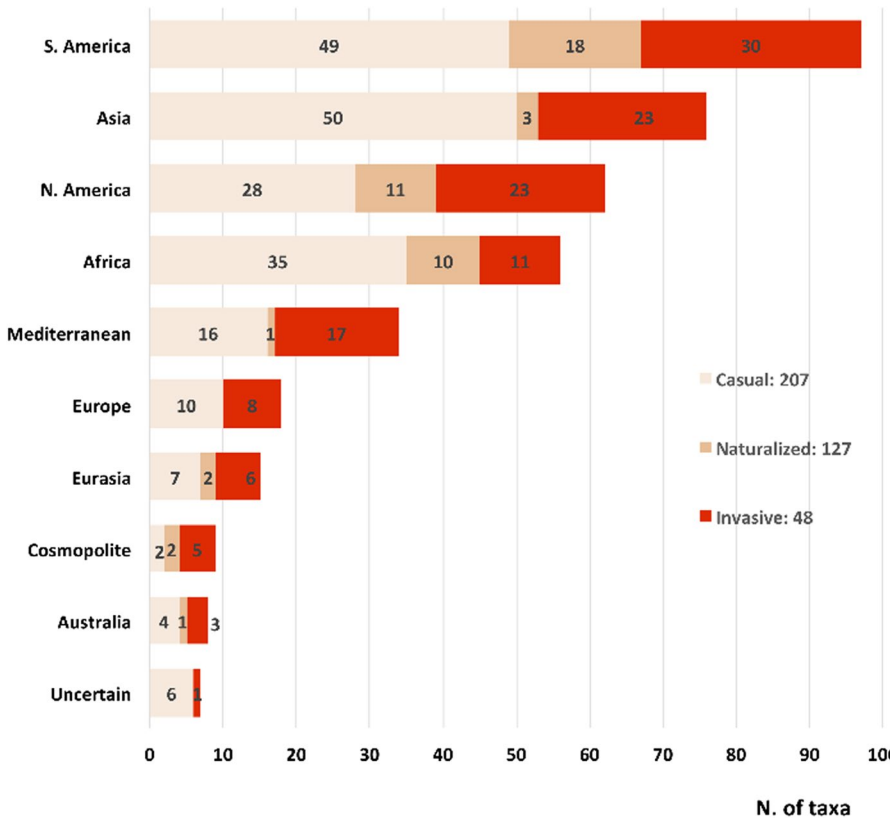

Fig. 6 Geographical origin of alien vascular flora of Calabria. The numbers of taxa are shown, with residence status indicated

Introduction pathways

Most alien species were introduced intentionally as ornamental plants (55.2%), for agriculture (19.1%) and forestry (3.4%). Unintentional introductions account for 22.3%, often as contaminated seed supply or with soils.

Discussion

The data reported by several scholars highlights a hyperbolic increase of alien species in Calabria, especially in recent years. The records of alien plant taxa to Calabrian flora increased from just 12 in 1974 (Viegi et al. 1974), to 163 (Pignatti 1982), 190 in 2009 by Celesti-Grapow et al. (2009), 267 of Galasso et al. (2018a), 284 (Pignatti 2017a,b; Pignatti et al. 2019), and, finally, 342 taxa were recorded by Bartolucci et al. (2021). Moreover, Conti et al. (2005) reported 119 invasive and naturalized taxa for Calabrian flora, excluding casual ones, as previously recorded by other authors. Our survey yielded 382 taxa for alien Calabrian vascular flora. According to Bartolucci et al. (2018, 2021), the native regional flora of Calabria includes 2,786 taxa (including species, subspecies and hybrids), therefore, approximately 14% of the regional flora is made up of alien taxa. The rapid increase in alien taxa is due to new introductions, as a result of globalization, which affect the entire planet, producing biotic homogenization (Stohlgren et al. 2011). However, there is an awareness of the problem of alien species and an increase of studies in recent decades.

The comparison with other Mediterranean countries, such as Algeria (211 alien plant taxa) (Meddour et al. 2020), Turkey (340 taxa) (Uludağ et al. 2017) or Greece (343) (Arianoutsou 2010a), highlights the abundance of alien taxa (including casual, naturalized and invasive aliens) in Calabrian flora, considering that these Mediterranean territories are much larger. This data is confirmed by the density of alien taxa in Calabria (log taxa/log km^2 of area), which is 0.62, and ranks Calabria among the Mediterranean territories with the highest levels of invasion; the corresponding value for Greece is 0.50, for Algeria 0.36 and Turkey 0.43. Compared to other Italian regions, the number of alien taxa in Calabria corresponds to other less populated agricultural regions, such as Puglia (202.2 inhabitants/km^2; 361 alien taxa) and Abruzzo (117.6 inhabitants/km^2; 350), far from the industrialized and densely populated regions of the north of Italy, such as Lombardy (417.6 inhabitants/km^2; 776) and Veneto (264.6 inhabitants/km^2; 618) (ISTAT 2021; Galasso et al. 2018a).

The richest families of Calabrian alien flora are Asteraceae, Poaceae, Fabaceae, and Solanaceae, which are also dominant in other European alien floras (Pyšek et al. 2002; Lambdon et al. 2008; Galasso et al. 2018a) and globally (Pyšek et al. 2017). Poaceae, Fabaceae, and Asteraceae are also the largest families in the native Mediterranean flora (Heywood et al. 2007). On the other hand, the Solanaceae family is less represented in native Calabrian flora but is mainly an extra-European plant family with many taxa introduced as cultivated plants (Tutin et al. 1972).

The genus *Amaranthus* is the most representative in Calabrian alien flora, among other genera, as well as in several countries of the world (Pyšek et al. 2017; Galasso et al. 2018a; Weber et al. 2008; Lambdon et al. 2008). In addition to this genus of North American origin, there are also others, such as *Bidens*, *Cyperus*, and *Solanum*, comprising mainly urban and agricultural weeds (Lambdon et al. 2008).

The prevailing life form among aliens in Calabria are therophytes and phanerophytes that have approximately the same percentage; overall, woody species (phanerophytes and nanophanerophytes) are more abundant than therophytes. This pattern is different from the native flora of Calabria, where the most represented groups are therophytes and hemicryptophytes (Fig. 4). The preponderance of phanerophytes/nanophanerophytes among aliens is a common character in invasive floras in various territories due to the preference of gardeners for ornamental trees (Crawley et al. 1996). In the alien flora of other Mediterranean territories, such as Greece (Arianoutsou et al. 2010b) and Sardinia (Podda et al. 2012), a common feature is the dominance of phanerophytes/nanophanerophytes and therophytes that appear best suited to overcome the long dry seasons typical of the Mediterranean bioclimate (Wagner et al. 2017). They occupy different niches, and their success in colonizing new territories is based on them possessing different strategies – phanerophytes cope with water scarcity through their architecture, while therophytes avoid the dry season (Allen 2001).

Alien taxa are present in Calabria in artificial, comprising human-disturbed and urban sites, and agricultural habitats, but a significant percentage occur in natural and seminatural habitats. This is quite alarming because it shows that about a third of alien taxa grow in natural environments that are vulnerable due to the anthropic pressure linked to urbanization.

Most Calabrian alien taxa are of neotropical origin. These are thermophilous taxa coming from South America that are favoured by the Mediterranean bioclimate that affects a large part of the region, up to about 1000 m of altitude. An important group of alien plants also comes from Asia; these are plants of warm environments, too, that easily spread in the Mediterranean territories. Some studies show that global warming favours the spread of alien tropical or subtropical taxa in Europe, mainly introduced into gardens for ornamental purposes (Dullinger et al. 2017). The majority of alien taxa are introduced as ornamental plants, including in Calabria, and especially in urban areas, which represent preferential routes for invasive taxa; favoured by global warming, such species can easily spread to the surrounding areas (Géron et al. 2021).

Conclusions

This study highlights a progressive and constant increase in alien taxa in the vascular flora of Calabria and provides a baseline for further studies on the management of invasive species and invasion ecology. The habitats located at lower altitudes (0–200 m a.sl.m.) are most threatened by the spread of alien taxa; road and railway infrastructures are the main ways of spreading alien plants. On the other hand, waterways and disturbed humid environments also contribute to the maintenance and invasions of alien taxa (See ESM 2). Further investigations are needed to better quantify the damage caused by invasive species to natural ecosystems and habitats.

Most of the new entries are represented by plants that have escaped from gardens, confirming the importance of ornamental plant cultivation as a source of such introductions.

Any future solutions to contain the problem depend not only on the tools made available by the legislator and on the interventions implemented by the administrators of local authorities but also on the ability of researchers and administrators to find technical solutions and make citizens aware of the rules and behaviour needed, especially in nursery fields (Caddeo et al. 2020).

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References

Allen HD (2001) Mediterranean ecogeography. Pearson Education Limited, Edinburgh

Arianoutsou M, Bazos I, Delipetrou P, Kokkoris Y (2010a) The alien flora of Greece: taxonomy, life traits and habitat preferences. Biol Invasions 12:3525–3549. https://doi.org/10.1007/s10530-010-9749-0

Arianoutsou M, Delipetrou P, Celesti-Grapow L, Basnou C, Bazos I, Kokkoris Y, Blasi C, Vilà M (2010b) Comparing naturalized alien plants and recipient habitats across an east–west gradient in the Mediterranean Basin. J Biogeogr 37:1811–1823

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkilä J (2017) Socio-economic impact classification of alien taxa (SEICAT). Methods Ecol Evol 9:159–168. https://doi.org/10.1111/2041-210x.12844

Bartolucci F, Peruzzi L, Galasso G, Albano A, Alessandrini A et al (2018) An updated checklist of the vascular flora native to Italy. Plant Biosyst 152:179–303

Bartolucci F, Galasso G, Peruzzi L, Conti F (2021) Report 2020 on plant biodiversity in Italy: native and alien vascular flora. Nat History Sci 8(1):41–54. https://doi.org/10.4081/nhs.2021.520

CABI (2021) Retrieved 30 June 2021

Caddeo A, Cogoni A, Iiriti G, Loi MC, Marignani M et al (2020) Dai balconi ai parchi urbani: buone pratiche per un giardinaggio consapevole. Life ASAP Pubblicazione realizzata nell'ambito dell'azione B4 del progetto LIFE15 GIE/IT/001039 "Alien Species Awareness Program" (ASAP).

Carlton JT (1996) Biological invasions and cryptogenic species. Ecology 77:1653–1655

Castro-Díez P, Vaz AS, Silva JS, Loo M, Alonso A et al (2019) Godoy Global effects of non-native tree species on multiple ecosystem services. Biol Rev 94(4):1477–1501. https://doi.org/10.1111/brv.12511

CEC (1994) CORINE land cover. Technical guide. Luxembourg (Office for Official Publications of European Communities

Celesti-Grapow L, Alessandrini A, Arrigoni PV, Banfi E, Bernardo L et al (2009) The inventory of the non-native flora of Italy. Plant Biosyst 143(2):386–430. https://doi.org/10.1080/11263500902722824

Celesti-Grapow L, Pretto F, Carli E, Blasi C (eds) (2010) Non-native and invasive vascular flora of the regions of Italy. Casa Editrice Università La Sapienza, Roma. (in Italian)

Celesti-Grapow L, Bassi L, Brundu G, Camarda I, Carli E et al (2016) Plant invasions on small Mediterranean islands: an overview. Plant Biosyst 150(5):1119–1133. https://doi.org/10.1080/11263504.2016.1218974

Conti F, Abbate G, Alessandrini A, Blasi C, Bonacquisti S, Scassellati E (2005) La flora vascolare italiana: ricchezza e originalità a livello nazionale e regionale. In: Scoppola A, Blasi C (eds) Stato delle conoscenze sulla flora vascolare d'Italia: 18–22. Palombi & Partner, Roma

Crawley MJ, Harvey PH, Purvis A (1996) Comparative Ecology of the Native and Alien Floras of the British Isles. Philosophical Transactions: Biological Sciences, 351(1345): 1251–1259. Retrieved August 3, 2021, from http://www.jstor.org/stable/56200

Dullinger I, Wessely J, Bossdorf O, Dawson W, Essl F, Gattringer A, Klonner G, Kreft H, Kuttner M, Moser D, Pergl J, Pyšek P, Thuiller W, van Kleunen M, Weigelt P, Winter M, Dullinger S (2017) Climate change will increase the naturalization risk from garden plants in Europe. Global Ecol Biogeogr 26:43–53. https://doi.org/10.1111/geb.12512

EPPO (2021) Retrieved 30 June 2021

European Commission (2019) Regulation (EU) No 1143/2014 of the European Parliament and of the Council of 22 October 2014 on the Prevention and Management of the Introduction and Spread of Invasive Alien Species. Off J Eur Union 2014, 317, 35–55

Galasso G, Conti F, Peruzzi L, Ardenghi NMG, Banfi E et al (2018a) An updated checklist of the vascular flora alien to Italy. Plant Biosyst 152(3):556–592. https://doi.org/10.1080/11263504.2018.1441197

Galasso G, Domina G, Adorni M, Ardenghi NMG, Bonari G et al (2018b) Notulae to the Italian alien vascular flora: 5. Ital Bot 5:45–56. https://doi.org/10.3897/italianbotanist.5.25910

Galasso G, Domina G, Alessandrini A, Ardenghi NMG, Bacchetta G et al (2018c) Notulae to the Italian alien vascular flora: 6. Ital Bot 6:65–90. https://doi.org/10.3897/italianbotanist.6.30560

Galasso G, Domina G, Ardenghi NMG, Aristarchi C, Bacchetta G et al (2019a) Notulae to the Italian alien vascular flora: 7. Ital Bot 7:157–182. https://doi.org/10.3897/italianbotanist.7.36386

Galasso G, Domina G, Andreatta S, Angiolini C, Ardenghi NMG et al (2019b) Notulae to the Italian alien vascular flora: 8. Ital Bot 8:63–93. https://doi.org/10.3897/italianbotanist.8.48621

Galasso G, Domina G, Adorni M, Angiolini C, Apruzzese M et al (2020a) Notulae to the Italian alien vascular flora: 9. Ital Bot 9:47–70. https://doi.org/10.3897/italianbotanist.9.53401

Galasso G, Domina G, Azzaro D, Bagella S, Barone G et al (2020b) Notulae to the Italian alien vascular flora: 10. Ital Bot 10:57–71. https://doi.org/10.3897/italianbotanist.10.60736

Galasso G, Domina G, Andreatta S, Argenti E, Bacchetta G et al (2021a) Notulae to the Italian alien vascular flora: 11. Ital Bot 11:93–119. https://doi.org/10.3897/italianbotanist.11.68063

Galasso G, Domina G et al (2021b) Notulae to the Italian alien vascular flora: 12. Italian Botanist 12:105–121. https://doi.org/10.3897/italianbotanist.12.78010

Géron C, Lembrechts J, Borgelt J et al (2021) Urban alien plants in temperate oceanic regions of Europe originate from warmer native ranges. Biol Invasions 23:1765–1779. https://doi.org/10.1007/s10530-021-02469-9

GBIF.org (2021) GBIF Home Page. Available from: https://www.gbif.org [13 July 2021]

Gigante D, Acosta ATR, Agrillo E, Armiraglio S, Assini S et al (2018) Habitat conservation in Italy: the state of the art in the light of the first European red list of terrestrial and freshwater habitats. Rend Lincei Sci Fis Nat 29:251–265

Gutiérrez JL (2017) Modification of habitat quality by non-native species. In: Vilà M, Hulme P (eds) Impact of biological invasions on ecosystem services, vol 12. Springer, Cham. https://doi.org/10.1007/978-3-319-45121-3_3

Haq SM, Hamid M, Lone FA, Singh B (2021) Himalayan hotspot with Alien Weeds: a case study of biological spectrum, phenology, and diversity of weedy plants of high altitude mountains in District Kupwara of J&K Himalaya, India. Proc Natl Acad Sci India Sect B Biol Sci 91:139–152. https://doi.org/10.1007/s40011-020-01219-6

Heywood VH, Brummitt RK, Culham A, Seberg O (2007) Flowering plant families of the world. Royal Botanic Gardens, Kew

ISPRA (2019) Annuario dei dati ambientali 2019. https://annuario.isprambiente.it/ada/downreport/html/7037#C7037 Retrieved 30 June 2021

ISSG (Invasive Species Specialist Group (2021) ISSG 20152021. The Global Invasive Species Database. Version 2015.1. Retrieved 30

ISTAT (2021) http://dati.istat.it/Index.aspx?QueryId=18565. Retrieved January 30 June 2021

Karamura DA (1998) Numerical Taxonomic Studies of the East African Highland Bananas (Musa AAA-East Africa) in Uganda. The University of Reading

Laface VLA, Musarella CM, Cano Ortiz A, Quinto Canas R, Cannavò S, Spampinato G (2020) Three new Alien Taxa

for Europe and a chorological update on the Alien vascular Flora of Calabria (Southern Italy). Plants 9:1181. https://doi.org/10.3390/plants9091181

Lambdon PW, Pyšek P, Basnou C, Hejda M, Arianoutsou M et al (2008) Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. Preslia 80:101–149

Lawler JJ, Aukema JE, Grant JB, Halpern BS, Kareiva P et al (2006) Conservation science: a 20-year report card. Front Ecol Environ 4(9):473–480

Lazzaro L, Bolpagni R, Barni E, Brundu G, Blasi C et al (2019) Towards alien plant prioritization in Italy: methodological issues and first results. Plant Biosyst 153(5):740–746. https://doi.org/10.1080/11263504.2019.1640310

Lazzaro L, Bolpagni R, Buffa G, Gentili R, Lonati M et al (2020) Impact of invasive alien plants on native plant communities and Natura 2000 habitats: state of the art, gap analysis and perspectives in Italy. J Environ Manage 274:111140. https://doi.org/10.1016/j.jenvman.2020.111140

Lorenzi H, Souza HM (2008) Plantas ornamentais no Brasil: arbustivas, herbáceas e trepadeiras, 4th edn. Nova Odessa, Instituto Plantarum, p 1088

Maes J (2013) A model for the assessment of habitat conservation status in the EU. JRC scientific and policy report. European Commission Joint Research Centre Institute for Environment and Sustainability. Publication Office of the European Commission, Luxembourg

Médail F, Diadema K (2009) Glacial refugia influence plant diversity patterns in the Mediterranean Basin. J Biogeogr 36:1333–1345. https://doi.org/10.1111/j.1365-2699.2008.02051.x

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 167(4):453–470. https://doi.org/10.1080/23818107.2020.1802775

Molina AB, Roa VN (eds) (2000) Advancing banana and plantain R&D in Asia and the Pacific. In: Proceedings of the 9th INIBAP-ASPNET Regional Advisory Committee meeting held in South China Agricultural University, Guangzhou, China, 2–5 November 1999

Musarella CM (2020) *Solanum torvum* Sw. (Solanaceae): a new alien species for Europe. Genet Resour Crop Evol 67(2):515–522. https://doi.org/10.1007/s10722-019-00822-5

Musarella CM, Laface VLA, Morabito A, Cano-Ortiz A, Cannavò S, Spampinato G (2019) Aggiornamenti sulla flora alloctona calabrese: Novità e conferme. Notiz Soc Bot Ital 3:39–40

Musarella CM, Mendoza-Fernández AJ, Mota JF, Alessandrini A, Bacchetta G, Brullo S, Caldarella O, Ciaschetti G, Conti F, Di Martino L et al (2018) Checklist of gypsophilous vascular flora in Italy. PhytoKeys 103:61–82. https://doi.org/10.3897/phytokeys.103.25690

Musarella CM, Stinca A, Cano-Ortíz A, Laface VLA, Petrilli R, Esposito A, Spampinato G (2020) New data on the alien vascular flora of Calabria (southern Italy). Ann Bot 10:55–66

Perrino EV, Signorile G (2009) Costa di Monopoli (Puglia): check-list della flora vascolare. Inf Bot Ital 41(2):263–279

Perrino EV, Signorile G, Marvulli M (2013) A first checklist of the vascular flora of the ''Polignano a Mare'' coast (Apulia, Southern Italy). Nat Croat 22(2):295–318

Peruzzi L, Conti F, Bartolucci F (2014) An inventory of vascular plants endemic to Italy. Phytotaxa 168:1–75. doi:https://doi.org/10.11646/phytotaxa.168.1.1

Pesaresi S, Biondi E, Casavecchia S (2017) Bioclimates of Italy. J Maps 13(2):955–960. https://doi.org/10.1080/17445647.2017.1413017

Pignatti S (1982) Flora d'Italia; 1–3; Edagricole. Bologna, Italy

Pignatti S (1994) Ecologia del paesaggio. UTET Editore, Torino

Pignatti S (2017a) Flora d'Italia: In 4 Volumi. Volume 1: Flora d'Italia & Flora Digitale, 2nd ed.; Edagricole-Edizioni Agricole di New Business Media srl: Milano, Italy. ISBN 978-88-506-5242-6

Pignatti S (2017b) Flora d'Italia: In 4 Volumi. Volume 2: Flora d'Italia & Flora Digitale, 2nd ed.; Edagricole-Edizioni Agricole di New Business Media srl: Milano, Italy. ISBN 978-88-506-5243-3

Pignatti S (2018) Flora d'Italia: In 4 Volumi. Volume 3: Flora d'Italia & Flora Digitale, 2nd ed.; Edagricole-Edizioni Agricole di New Business Media srl: Milano, Italy. ISBN 978-88-506-5244-0

Pignatti S, Guarino R, La Rosa M (2019) Flora d'Italia: In 4 Volumi Volume 4: Flora d'Italia & Flora Digitale, 2nd ed.; Edagricole-Edizioni Agricole di New Business Media srl: Milano, Italy. ISBN 978-88-506-5245-7

Podda L, Lazzeri V, Mascia F, Mayoral O, Bacchetta G (2012) The checklist of the Sardinian exotic flora: an update. Not Bot Horti Agrobo 40(2):14–21. https://doi.org/10.15835/nbha4028225

Portal to the Flora of Italy (2021) Available at http:/dryades.units.it/floritaly. Retrieved 30 June 2021

POWO (2019) Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; http://www.plantsoftheworldonline.org/ Retrieved 30 June 2021

Pyšek P, Hulme PE, Simberloff D, Bacher S, Blackburn TM, Carlton JT, Dawson W, Essl F, Foxcraft LC, Genovesi P, Jeschke JM, Kühn I, Liebhold AM, Mandrak NE, Meyerson LA, Pauchard A, Pergl J, Roy HE, Seebens H, van Kleunen M, Vilà M, Wingfield MJ, Richardson DM (2020) Scientists' warning on invasive alien species. Biol Rev 95:1511–1534. https://doi.org/10.1111/brv.12627

Pyšek P, Jarošík V, Kucera T (2002) Patterns of invasion in temperate nature reserves. Biol Cons 104:13–24

Pyšek P, Richardson DM, Rejmánek M, Webster G, Williamson M et al (2004) Alien plants in checklists and floras: towards better communication between taxonomists and ecologists. Taxon 53(1):131–143. https://doi.org/10.2307/4135498

Pyšek P, Pergl J, Essl F, Lenzner B, Dawson W et al (2017) Naturalized alien flora of the world: species diversity, taxonomic and phylogenetic patterns, geographic distribution and global hotspots of plant invasion. Preslia 89:203–274. https://doi.org/10.23855/preslia.2017.203

Raposo MAM, Pinto Gomes CJ, Nunes LJR (2021) Evaluation of species invasiveness: a case study with Acacia dealbata link on the slopes of Cabeça (Seia-Portugal). Sustainability 13(20):11233. https://doi.org/10.3390/su132011233

Raunkiaer C (1934) The life-forms of plants and statistical plant geography. Clarendon Press, Oxford

Richardson DM, Pyšek P (2006) Plant invasions: merging the concepts of species invasiveness and community invasibility. Prog Phys Geogr 30:409–431

Richardson DM, Pyšek P, Rejmánek M, Barbour MG, Panetta FD et al (2000) Naturalization and invasion of alien plants: concepts and definitions. Divers Distrib 6:93–107

Richardson DM, Pyšek P, Carlton JT (2011) A compendium of essential concepts and terminology in biological invasions. In: Richardson DM (ed) Fifty years of invasion ecology: the legacy of Charles Elton. Blackwell Publishing, Oxford, pp 409–420

Rosati L, Fascetti S, Romano VA, Potenza G, Lapenna MR et al (2020) New chorological data for the Italian vascular Flora. Diversity 12:22. https://doi.org/10.3390/d12010022

Seebens H, Blackburn TM, Dyer EE, Genovesi P, Hulme PE et al (2017) Nat Commun 8:14435. https://doi.org/10.1038/ncomms14435

Seebens H, Bacher S, Blackburn T, Capinha C, Dawson W et al (2021) Projecting the continental accumulation of alien species through to 2050. Glob Chang Biol 27:970–982

Sell P, Murrell G (2009) Flora of Great Britain and Ireland 3: Mimosaceae –Lentibulariaceae. Cambridge University Press, Cambridge, pp 342–348

Spampinato G, Cannavò S, Cano-Ortiz A, Caruso G, Laface VLA et al (2019) Invasività di *Cenchrus setaceus* (Forssk.) Morrone in Italia. Notiz Soc Bot Ital 3:1–10

Stevens PF (2001) onwards) Angiosperm Phylogeny website. Version 14, July 2017. http://www.mobot.org/MOBOT/research/APweb/

Stinca A, Chianese G, D'Auria G, Del Guacchio E, Fascetti S et al (2017) New alien vascular species for the flora of southern Italy. Webbia 72(2):295–301. https://doi.org/10.1080/00837792.2017.1349236

Stinca A, Musarella CM, Rosati L, Laface VLA, Licht W, Fanfarillo E et al (2021) Italian Vascular Flora: new findings and updates. Diversity 13:600. https://doi.org/10.3390/d13110600

Stohlgren TJ, Pyšek P, Kartesz J et al (2011) Widespread plant species: natives versus aliens in our changing world. Biol Invasions 13:1931–1944. https://doi.org/10.1007/s10530-011-0024-9

Thiers B (2021) Index herbariorum: a global directory of Public Herbaria and Associated Sta. New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/science/ih/. Accessed 30 June 2021

Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA (1972) Flora Europaea, 3. Cambridge University Press, Cambridge

Uludağ A, Aksoy N, Yazlık A, Arslan ZF, Yazmış E et al (2017) Alien flora of Turkey: checklist, taxonomic composition and ecological attributes. NeoBiota 35:61–85. https://doi.org/10.3897/neobiota.35.12460

Viciani D, Vidali M, Gigante D, Bolpagni R, Villani M et al (2020) A first checklist of the alien-dominated vegetation in Italy. Plant Sociol 57:29–54

Vilà M, Hulme PE (2017) Impact of biological invasions on ecosystem services. Springer. https://doi.org/10.1007/978-3-319-45121-3

Weber E, Sun SG, Li B (2008) Invasive alien plants in China: diversity and ecological highlights. Biol Invasions 8:1411–1429. doi:https://doi.org/10.1007/s10530-008-9216-3

Wagner V, Chytrý M, Jiménez-Alfaro B et al (2017) Alien plant invasions in European woodlands. Divers Distrib 23:969–981. https://doi.org/10.1111/ddi.12592

Weber E (2003) Invasive plant species of the world: a reference guide to environmental weeds. CAB Int Publ, Wallingford

Wong SY, Joling J (2021) Checklist of aroids (Alismatales, Araceae) from Sabah (Malaysian Borneo). Check List 17(3):931–974. https://doi.org/10.15560/17.3.931

Wood JRI, Williams BRM, Mitchell TC, Carine MA, Harris DJ et al (2015) A foundation monograph of *Convolvulus* L. (Convolvulaceae). PhytoKeys 51:1–278. https://doi.org/10.3897/phytokeys.51.7104