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## **Additional data on the ongoing naturalization of the non-native woody plant *Duranta erecta* (Verbenaceae) in Sicily, Italy**

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Running title: ONGOING NATURALIZATION OF THE ALIEN PLANT *DURANTA ERECTA*

**Abstract** – We recorded the occurrence of *Duranta erecta* L. in the Aeolian Islands (Sicily, Italy), where it currently behaves as a casual alien. At the global scale, however, this woody species has shown highly invasive behaviour in different island ecosystems. On the basis of this evidence, we have investigated which ecological and biological traits may have allowed its establishment and spread, and could trigger its further expansion in the Aeolian Islands in the near future. Several factors seem to have favoured its success on a global scale, such as the wide edaphic and climatic range, the tolerance to anthropogenic disturbance, and the production of toxic metabolites that protect it from herbivore browsing and from competition with other plants. The study of the organisms that perform pollination and seed dispersal is probably the key to understanding the local naturalization of this plant, introduced about three centuries ago in Europe and the Mediterranean, here discussed in detail for the first time.

**Keywords:** alien woody plants, early detection, golden dewdrop, hedge plant, invasion biology

### **Introduction**

The management of invasive plants is quite difficult, especially in the case of widespread species. Indeed, early detection and prompt actions are considered to be the most effective tools for the control of invasive species and for limiting their negative impacts on native species and ecosystems (Regulation EU 1143/2014, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R1143>). In the framework of field observations and literature search aimed at updating the vascular flora of the Aeolian Islands (Sicily, Italy), we report here the record of *Duranta erecta* L., a new alien plant species occurring in the archipelago. *D. erecta* is a spreading, sometimes climbing, evergreen shrub; on nutrient-rich and deeper soils, it can reach the size of a small tree (up to 7 m tall) (Arengo 2015). Naturally, it mostly occurs in dry coastal areas (yearly annual precipitation between 800 and 1800 mm: Arengo 2015) from sea level up to more than 1600 m a.s.l. (populations growing at 3500 m a.s.l. occur on some of the Caribbean Islands). Notwithstanding its tropical origins, *D. erecta* proved to be a hardy plant, being able to withstand even short frost events (Arengo 2015).

Moderately shade-intolerant, *D. erecta* does not compete well with taller woody plants and, consequently, is usually not found in dense plant communities. Within its natural distribution range, it commonly grows in well-lit areas, mostly on rocky or sandy soils, and prefers low and discontinuous herb- and grass-rich plant communities and thickets (PIER 2013). Under moister conditions, it may also occur in inland areas prone to anthropogenic disturbance (e.g., roadsides: Adams 1972).

The karyological studies on *D. erecta* pointed out a high variability throughout the native distribution range (from  $2n = 16$  to  $2n = 36$ , Munir 1995). Hence, the extremely wide climatic and edaphic amplitude of the golden dewdrop; its remarkable adaptability to man-made habitats may depend on the varied response to disturbance of different populations bearing different genetic traits. The ecological plasticity of this plant is paralleled by the high variability of many of its morphological traits, encompassing the growth form (shrub, liana or small tree), the habit (erect vs. prostrate), the leaf margin shape (entire vs. dentate), the leaf size (large or small). These features, together with the presence of axillary thorns (on mature individuals only), explain the plethora of specific epithets given to the very same species during the last 250 years (see <http://www.theplantlist.org/tpl/record/kew-65221>); the most commonly featured synonyms are *Duranta repens* L., *D. ellisia* Jacq., and *D. plumieri* Jacq. Reported to be native to the Americas, *D. erecta* grows along the Pacific rims of central and southern America (from Texas, Arizona and California south to Peru) as well as along the Atlantic coast from Florida, Louisiana to Puerto Rico south to Brazil and Argentina (POWO 2024). The secondary range encompasses many tropical and subtropical countries in South America, Africa and East Asia (POWO 2024). Due to the wide spectrum of traditional usages within its native range and its widespread cultivation outside it, dozens of vernacular names have been given to *D. erecta* across Asia (India, Indonesia, China, etc.), south and central America, W-Africa and the Pacific islands (Missouri Botanic Garden 2018, Srivastava and Shanker 2022).

Although frequently cultivated in Mediterranean Europe, and being generically reported for Türkiye (Uludağ et al. 2017), no record of naturalization has been hitherto reported (Raab-Straube von 2022+). Hence, this paper also aims to provide an updated picture of knowledge on the ecology and distribution of this species on a global scale as well as to give some clues to interpreting the meaning of the new record within the peculiar biogeographical context of the Aeolian Islands.

## Material and methods

We made an in-depth bibliographic search on the two most popular databases of scientific literature, namely Scopus (<https://www.scopus.com/search/form.uri?display=basic#basic>) and Web of Science (<https://www.webofscience.com/wos/woscc/basic-search>) to find out additional information on *Duranta erecta*. To this aim, we cross-checked papers and reports using the above-reported binomial epithets and the keywords “allelopathy”, “chemical compounds”, “climate”, “cultivation”, “dispersal”, “distribution range”, “ecological amplitude”, “genetics”, “introduction”, “invasiveness”, “metabolites”, “pollination”, “niche”, “soil”, “substrate”, “typification” and “vegetation”.

In the meantime, we carried out regular field surveys across the whole Aeolian Archipelago between 1994 and 2024.

## Results

In November 2019, a few decimetres tall individual of an unknown woody species was observed growing on the inner edge of a sidewalk at the limit of a building in the centre of the town of Lipari (the largest island of the Aeolian archipelago), at about 20 m a.s.l. A more accurate observation allowed us to classify the plant as *Duranta erecta* L. (Verbenaceae J.St.-Hil.), a small shrub native to the Americas and also known by the English names of golden dewdrop, pigeon berry, and skyflower. The putative parents grew about 20 meters off, *i.e.*, on the terrace of an apartment located just above the sidewalk. Probably, some berries fell from the terrace through the gutter, from which rainwater drains to just where the individual grows. Within the last four years, the plant probably enjoyed additional water coming from the gutter: in fact, it was able to grow steadily (it now exceeds 2 metres, see Fig. 1) and two years ago it began to bloom and regularly fructify.



**Fig. 1.** The self-sown individual of *Duranta erecta* found growing wild in the centre of Lipari (Aeolian Islands, Sicily, Italy). It is more than two meters high and has started fruiting (see the small picture taken from the same plant, up on the left) (photo: Pietro Lo Cascio).

*D. erecta* was introduced in the private garden of one of the authors (PLC) in at least the 1970s. However, no bibliographic information is available about an earlier introduction of this

species on Lipari Island, where it was first observed under cultivation only recently by Domina and Mazzola (2008). This individual can be considered fully established but the species should be considered as a casual alien plant, due to the uniqueness of the finding and the current lack of self-sustaining populations.

The golden dewdrop is not featured in the list of the alien plants naturalized in Sicily (Raimondo et al. 2005a,b). Despite having been reported as spontaneously occurring in the urban areas of Palermo (Domina et al. 2019), *D. erecta* is not featured either in the Euro+Med PlantBase (Raab-Straube 2022+) or in the last inventory of the Italian non-native flora (Galasso et al. 2024). Hence, our data represent the first clear indication of its ongoing naturalisation both at the national and the Euro-Mediterranean scale, and the first concerning Mediterranean small islands. Moreover, this paper provides a detailed picture of its spatio-temporal invasion process at the global scale, as well as the future implications of a likely further spread in the Mediterranean.

## Discussion

### Introduction history: from the global scale to Sicily

*Duranta erecta* was introduced far from its native range very early, probably many centuries ago, *i.e.*, long before being described by botanists, when the Europeans learnt from native Americans about its properties. This may explain the remarkably wide spectrum of medicinal “traditional” uses of this plant in countries like Nigeria, India, China, and the Philippines (see Srivastava and Shanker 2022 and references therein).

A second impetus to the spread of the species on a global scale was given by its massive use as a popular hedge plant. In fact, from the 18<sup>th</sup> century, its showy flowers and fruit made it one of the most commonly cultivated ornamental plants in tropical and subtropical gardens worldwide, not only in most of the islands and archipelagos of the Pacific and Indian Ocean but even in the Mediterranean Basin (Missouri Botanical Garden 2018).

During his stay in Leiden, Linnaeus (1753, p. 637) probably based his description of *Duranta erecta* on the original drawings of Charles Plumier (who was cited in the protologue), a French botanist who probably was the first to observe the plant growing in the wild during one of his three voyages to the Caribbean islands between 1689 and 1697 (Moroni et al. 2018). We can therefore assume that the golden dewdrop was imported into Europe shortly after, perhaps by Plumier himself, who described this species using the polynomial epithet “*Castorea racemosa, flore caeruleo, fructu amaro*” (Plumier 1703, p. 30). His choice to dedicate the species to the Italian botanist Castore Durante (1529-1590) was followed by Linnaeus (1753), who decided to assign it within the genus *Duranta*.

A careful search for mentions of *D. erecta* (and of its synonyms) in Europe led to a reference by Sims (1815), who clearly stated that Philip Miller cultivated it in London even before 1739. As far as Italy is concerned, the oldest record is featured in the catalogue of plants cultivated at the Royal Botanical Garden of Mantua (Anonymous 1785). In the first half of the nineteenth century, the species was also cultivated in the botanical gardens of Bologna and Ferrara, as mentioned in letters by the Italian botanist Antonio Bertoloni (Buldrini et al. 2017).

As for Sicily, it can be assumed that *D. erecta* was first introduced in Palermo during the last decade of the 18<sup>th</sup> century. In fact, it did not appear in either the Ucria (1789) or the Tineo (1790) checklists of cultivated plants, while, just a few years later, it was listed among the plants cultivated at the Botanical Garden of Palermo in the lists of Tineo (1799, 1802). Since then, *D. erecta* has been massively used in Sicily: in fact, it is featured among the forty most frequent ornamental non-native plant species occurring in the island’s historic gardens (Bazan et al. 2005).

### **Why the Aeolian Islands?**

The synergic effect of mild winters, abundant overnight dew accumulation during the dry season, and good soil quality make Mediterranean volcanic islands an ideal place for alien plant cultivation, frequently followed by fast naturalisation events and unwanted spread (Pretto et al. 2012, Blackburn et al. 2016, Celesti-Grappo et al. 2016, Pasta et al. 2017, Guarino et al. 2021, Minissale et al. 2023). Not surprisingly, the Aeolian archipelago has long been the perfect scenario for the introduction and establishment of many ornamental non-native plants (Domina and Mazzola 2008, Di Gristina et al. 2021, Barone et al. 2023). In fact, these islands were home to the first or the only Italian or Sicilian naturalization cases of plants coming from all over the world: for instance, *Curio talinoides* (DC.) P.V. Heath, first reported on Vulcano under the name *Kleinia mandraliscae* by Tineo (1855) which escaped from private gardens in the 19<sup>th</sup> century (Pasta 2003), *Arctotheca calendula* (L.) Levyns (Madon 1994) and *Pelargonium graveolens* (Thunb.) L'Hér. (Di Gristina et al. 2021) from S-Africa, *Paraserianthes lophanta* (Willd.) I.C. Nielsen (Domina and Spallino 2007) and *Cotula australis* (Sieber ex Spreng.) Hook. f. (Guarino et al. 2018) from S-Australia, *Salvia leucantha* Cav. (Pasta et al. 2008) from central America and *Passiflora incarnata* L. from N-America (Di Gristina et al. 2021).

### **Why *Duranta erecta* is a successful invader worldwide?**

*Duranta erecta* may behave as an invasive, prolific, fast-growing plant spread by birds from man-made habitats to natural areas. In such cases, conservation practitioners may have serious problems in keeping it under control. For instance, it has been identified as an invasive alien species in most of the Pacific islands and archipelagos like Tonga, Fiji, Hawai'i, French Polynesia, Micronesia (PIER 2013), in South Africa (Foxcroft et al. 2008), SE Australia (Mulvaney 1991), Mayotte Islands in the Indian Ocean (IUCN-France 2013), and Taiwan (Wu et al. 2004). In many other areas where it was introduced a long time ago, like E and SE Africa (Witt and Luke 2017), Mauritius, India, Indonesia, China and Japan, it is fully naturalized but not invasive (Missouri Botanical Garden 2018). However, as a consequence of its wide cultivation and favourable biological traits, *D. erecta* was listed in the most comprehensive and recent checklist of invasive trees and shrubs at the global scale (Rejmánek and Richardson 2013).

### **How concrete is the risk of *Duranta erecta* spreadings over the Mediterranean Basin?**

On the one hand, when selecting exotic ornamental plants, horticulturists are used to prefer species characterized by a broad climatic and edaphic amplitude, *i.e.*, capable of growing in environmental conditions that are as diverse as possible. On the other hand, invasion biologists are increasingly aware of the strong correspondence between these traits and those increasing the likelihood that "candidate invasive plants" will become successfully established in the introduced range, as well as showing a fast spread and invasive behaviour (Pasta 2022). This evidence makes it hard to manage non-native ornamental plants, which account for a major portion of the global naturalized plant database (van Kleunen et al. 2018). As for *D. erecta*, another favourable trait may be related to its chemical weapons. In fact, *D. erecta* produces several allelopathic compounds (Tur et al. 2010) and has even been used against mosquitos (Dacko et al. 2020). These toxic substances represent a very effective defence against herbivores, that mainly work outside its native distribution range, according to the novel weapons hypothesis (Callaway and Ridenour 2004). In fact, the leaves and the unripe (yellow-orange) berries are toxic, and are confirmed to have killed children in the past (Wheeler 1895) and domestic animals more recently (Thompson 2007).

During the last decade, numerous exotic ornamental plants of tropical and subtropical origin, introduced several centuries ago in the Mediterranean, have been the protagonists of apparently sudden cases of naturalization in Sicily (e.g., Pasta et al. 2014, Speciale et al. 2015, Badalamenti 2021, Collesano et al. 2021). In most cases, their success probably depended on their entry as a functional element in the trophic networks of the recipient ecosystems. In fact, these species have managed to create stable interactions with other organisms that allow them to carry out two crucial phases such as pollination and seed dispersal. Hence, the study of the organisms that perform pollination and seed dispersal will probably provide the key to understanding the local naturalization of *D. erecta*. As far as we know, in its home range pollination is performed by hummingbirds (Byragi Reddy and Subba Reddi 1996). Nonetheless, as the blooming period of this species is almost all year long, different groups of insects such as butterflies and moths, bees and wasps (Byragi Reddy and Subba Reddi 1996) may be effective as well.

Based on literature data, the berries may be dispersed by pigeons and songbirds (Missouri Botanical Garden 2018). During the last two years, one of the authors (PLC) repeatedly observed blackbirds (*Turdus merula* Linnaeus 1758) feeding on the fruits. Hence, given the presence of birds that could facilitate its seed dispersal, the possible spread of the golden dewdrop requires careful monitoring.

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