

# SURVEYS IN UNPROTECTED AREAS YIELD ADDITIONS TO THE NON-NATIVE FLORA OF PUERTO RICO

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## Abstract

For centuries, the Caribbean island of Puerto Rico has been subjected to the introduction of non-native plant species. Various human-related activities such as agriculture, horticulture, and ornamental landscaping have resulted in the naturalization of numerous species, some of which are now representative of the island's natural landscape. Recent floristic surveys in anthropized areas across the island yielded three new non-native plant records. We present the first reports with vouchers of *Asystasia gangetica* (L.) T. Anderson subsp. *micrantha* (Nees) Ensermu, *Emilia praetermissa* Milne-Redh., and *Acanthocereus tetragonus* (L.) Hummelinck for Puerto Rico. We review their geographic distributions, status on the island, and introduction pathways, and offer comments on the importance of surveying disturbed and unprotected areas.

**Keywords:** *Acanthocereus tetragonus*, *Asystasia gangetica* subsp. *micrantha*, *Emilia praetermissa*, naturalized plants, floristic inventories, non-native flora, Puerto Rico.

## Resumen

La isla caribeña de Puerto Rico ha estado sujeta a la introducción de especies de plantas no nativas durante siglos. Varias actividades relacionadas con el ser humano, tales como la agricultura, horticultura, y paisajismo ornamental, han resultado en la naturalización de numerosas especies de plantas, algunas de las cuales hoy en día son representativas del paisaje natural de la isla. Inventarios florísticos recientes en áreas antropizadas de la isla han arrojado tres nuevos registros de plantas no nativas. Presentamos los primeros informes con colectas de *Asystasia gangetica* (L.) T. Anderson subsp. *micrantha* (Nees) Ensermu, *Emilia praetermissa* Milne-Redh., y *Acanthocereus tetragonus* (L.) Hummelinck para Puerto Rico. Repasamos sus distribuciones geográficas, estado en la isla, vías de introducción, y ofrecemos comentarios sobre la importancia de realizar inventarios en áreas perturbadas y no protegidas.

**Palabras clave:** *Acanthocereus tetragonus*, *Asystasia gangetica* subsp. *micrantha*, *Emilia praetermissa*, flora no nativa, inventarios florísticos, plantas naturalizadas, Puerto Rico.

## INTRODUCTION

The Caribbean island of Puerto Rico has been subjected to the introduction of non-native plant species for centuries (Hill 1899; Birdsey and Weaver 1982; Dietz 1986; Miller and Lugo 2009), which now account for a significant proportion of its documented flora (Axelrod

2011; Acevedo-Rodríguez and Strong 2012; Gann et al. 2022; USDA-NRCS 2022). The majority of non-native plants in the region have been intentionally introduced (i.e., deliberately brought in and planted or dispersed by humans; Rojas-Sandoval and Acevedo-Rodríguez 2015), and their presence on the island is the result of a variety of practices, including the cultivation for agriculture,

forestry, horticulture, and ornamental landscaping (Little and Wadsworth 1964; Little et al. 1974; Schubert 1979; Francis and Liogier 1991; Rojas-Sandoval and Acevedo-Rodríguez 2015). Nevertheless, a considerable number of species have escaped from cultivation, subsequently naturalizing and conspicuously integrating into the island's natural landscape (Little and Wadsworth 1964; Little et al. 1974; Francis and Liogier 1991; Miller and Lugo 2009). On the other hand, the presence of non-native plants in the region have also been attributed to unintentional or accidental introductions to a lesser extent (i.e., inadvertent contaminants or stowaways; Rojas-Sandoval and Acevedo-Rodríguez 2015; Rojas-Sandoval et al. 2017).

We report three new non-native plant records from Puerto Rico, one of which was discovered through ongoing floristic inventories conducted on the island as part of a collaborative project (Ecological Site Descriptions-ESDs) between the USDA Natural Resources Conservation Service (NRCS) and the USDA Forest Service-International Institute of Tropical Forestry (FS-IITF). Ecological Site Descriptions (ESDs) are reports designed to assist landowners seeking to improve their land-use management activities, address conservation planning, and implement alternative practices to mitigate the effects of extreme weather events. All records correspond to plant specimens collected growing naturally in the wild during 2021 and 2022, two of which resulted from fieldwork for Ecological Site Descriptions (ESDs). The specimen vouchers and identifications were determined by SMS and are deposited at the Herbarium of the University of Puerto Rico-Río Piedras Campus (UPRRP).

## METHODS

### Review of Literature, Digital Herbarium Collections, Online Databases, and Social Platforms

We reviewed the island's most comprehensive and recent botanical checklists (e.g., Liogier and

Martorell 2000; Axelrod 2011; Acevedo-Rodríguez and Strong 2012), as well as literature from journal articles and other sources (e.g., books, government reports), and conducted a search on local collection records in the digital databases of the following herbaria: MAPR (<https://herbaria.plants.ox.ac.uk/bol/MAPR>), NY (<http://sweetgum.nybg.org/science/vh/>), UPR and UPRRP (<http://herbario.uprrp.edu/>), and US (<https://collections.nmnh.si.edu/search/botany/>) to determine whether our contributions herein represent taxa not previously reported from or collected in Puerto Rico. For the same purpose, we also searched the following online checklists and databases: Flora of the West Indies by the Smithsonian National Museum of Natural History (<https://naturalhistory2.si.edu/botany/WestIndies/catalog.htm>), Plants of the Island of Puerto Rico by The Institute for Regional Conservation (IRC; <https://www.regionalconservation.org/ircs/database/site/IntroPR.asp>; cited in this article as Gann et al. 2022), and the PLANTS Database (<http://plants.usda.gov>; cited in this article as USDA-NRCS 2022). Furthermore, the species checklists portal of the Global Biodiversity Information Facility (GBIF; <https://www.gbif.org/>) and The Plants of the World Online database by Kew Science (POWO; <https://powo.science.kew.org/>) were used to obtain additional information on current taxonomic statuses and geographic distributions. Lastly, the citizen science platform iNaturalist (<https://www.inaturalist.org/>) and local social media groups (e.g., Biodiversidad de Puerto Rico, <https://www.facebook.com/groups/PRNatural/?fref=nf>; Plantas en Puerto Rico / Plants in Puerto Rico, <https://www.facebook.com/groups/AmigosDePlantasDeBoriken>) were also accessed for insights on unconfirmed reports and natural history observations. Based on our review, the records below represent the first reports with vouchers of *Asystasia gangetica* subsp. *micrantha*, *Emilia praetermissa*, and *Acanthocereus tetragonus* for Puerto Rico.

## RESULTS AND DISCUSSION

### ACANTHACEAE

*Asystasia gangetica* (L.) T. Anderson subsp. *micrantha* (Nees) Ensermu in J. H. Seyani & A. C. Chikuni (eds.), Proc. XIII Plenary Meet. AETFAT, Zomba, Malawi. 1: 343. 1994. Native to Africa, India, and Sri Lanka (Hsu et al. 2005). Introduced in Malaysia (Kiew and Vollesen 1997), Singapore (Pandit et al. 2006), Taiwan (Hsu et al. 2005), Indonesia, Australia, Papua New Guinea, and the Pacific Islands (CRC Weed Management 2003), including the Solomon Islands (Westaway et al. 2016), Hawaii (Starr and Starr 2016), and French Polynesia (Vitrac et al. 2019). It is also introduced in Central and South America (Mocharla and Aluri 2021), including Venezuela (Luján et al. 2011), as well as North America (Florida, U.S.A.; Wunderlin et al. 2022). In addition, it has been observed (i.e., unconfirmed reports) in the Caribbean islands of Cuba (iNaturalist.org/observations/136175544; iNaturalist.org/observations/136722917, both accessed 21 October 2022), and Trinidad and Tobago (iNaturalist.org/observations/65532537, accessed 21 October 2022), but has not been reported in the literature for the Caribbean region. It is widely regarded as a serious invasive weed, particularly in Southeast Asia and Australia.

**New report for Puerto Rico.** Initially observed by SMS and JDCZ on June 23, 2021. Naturalized herb on the grounds of the Lajas Agricultural Experimental Station in the southwestern town of Lajas. Discovered and later collected in the understory of a *Swietenia macrophylla* plantation, near a grazing field intermittently used by cattle for shade and resting. It was probably introduced inadvertently through the sowing of forage grasses, which is a common practice at the location. It is distinguished from the widely distributed and abundant *Asystasia gangetica* (L.) T. Anderson in Puerto Rico by having broadly lanceolate or elongated acuminate leaves, and a white corolla that is generally under 25 mm long with purple blotches or spots on the

lower lip. The distinctive purple markings of the bottom petal lobe have been remarked by several authors as a notable feature to distinguish this taxon (see Kiew and Vollesen 1997; Hsu et al. 2005; Luján et al. 2011; Danthanawanit et al. 2015) (Figure 1A).

**Record voucher:** PUERTO RICO. Lajas, Bo. Sabana Yeguas, Estación Experimental Agrícola de Lajas, 42 m, 10 Sept. 2021, *Steve Maldonado Silvestrini & Johann D. Crespo* 937 (UPRRP). **Note:** This taxon has been incorrectly referred to as *Asystasia intrusa* (Forssk.) Blume; this issue has been previously noted by different authors (see Kiew and Vollesen 1997; Thye 1997).

### ASTERACEAE

*Emilia praetermissa* Milne-Redh., Kew Bull. 5: 375. 1951. Native to Africa (Olorode and Olorunfemi 1973; Chung et al. 2009). Introduced in China (He et al. 2020), Taiwan (Chung et al. 2009; Wu et al. 2010; Wang and Wang 2018), North America (Florida, U.S.A.; Wunderlin et al. 2022), and the Caribbean islands of Saint Lucia, Saint Vincent, and Martinique (Dumbardon-Martial and Delblond 2019). Nonetheless, it has also been observed (i.e., unconfirmed reports) in multiple countries of Central America and northern South America (e.g., Panamá, Ecuador, Venezuela, among others; iNaturalist.org/observations/114475270; iNaturalist.org/observations/66471567; iNaturalist.org/observations/126720029, all accessed 21 October 2022). Also found on several other Caribbean islands such as Hispaniola (iNaturalist.org/observations/116718578, accessed 26 October 2022), Montserrat (iNaturalist.org/observations/125607427, accessed 21 October 2022), and Trinidad and Tobago (iNaturalist.org/observations/108173978; iNaturalist.org/observations/73765145; iNaturalist.org/observations/91408437, all accessed 21 October 2022).

**New report for Puerto Rico.** Initially observed by SMS on May 12, 2020, as a naturalized herb in the mountainside town of Adjuntas. Nevertheless,



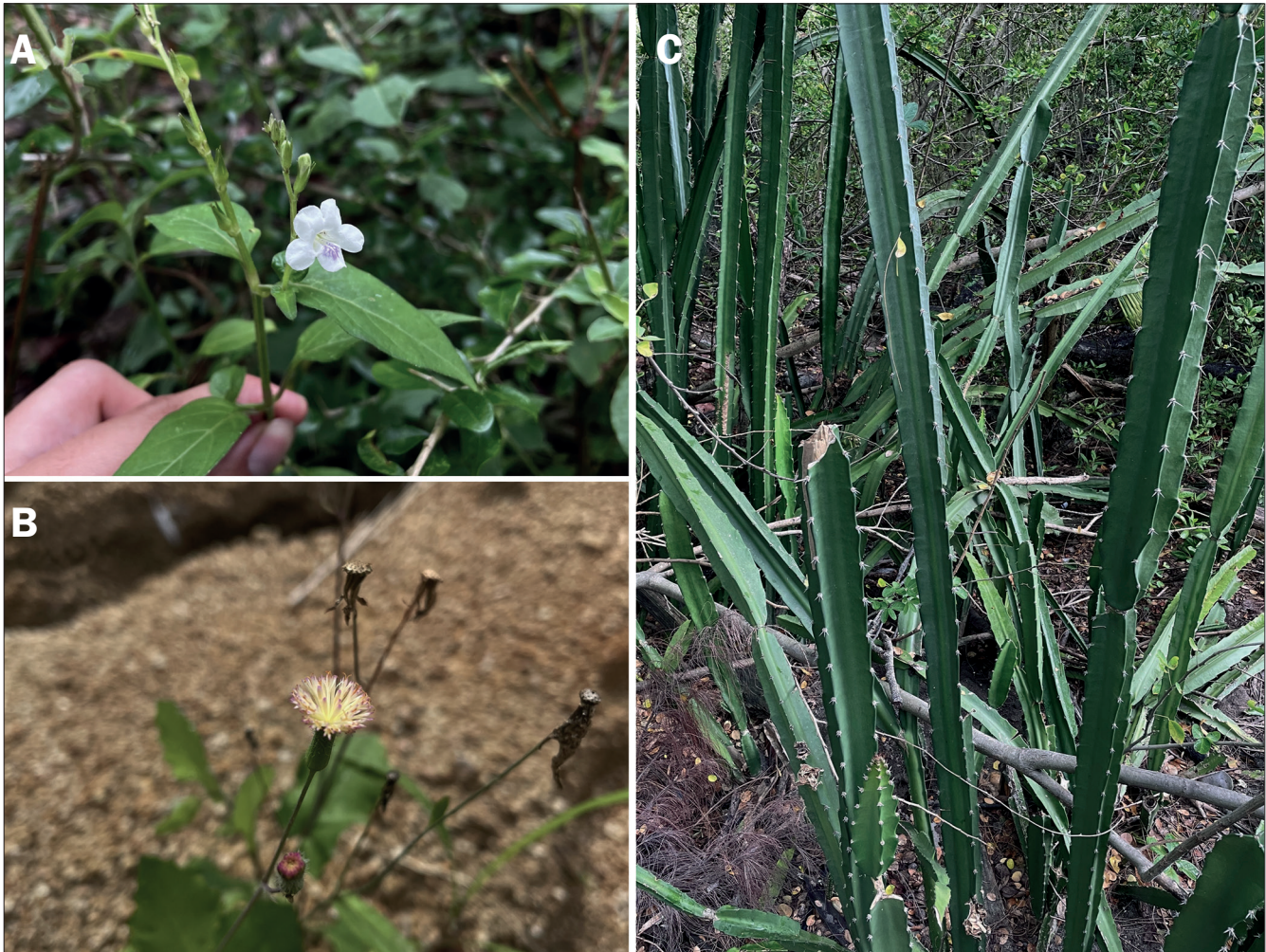


Figure 1. A) *Asystasia gangetica* ssp. *micrantha* flowering in the shaded understory of a *Swietenia macrophylla* plantation (Lajas, southwestern Puerto Rico); B, *Emilia praetermissa* growing on sandy soils in a private agricultural farm (Utuaado, Central Puerto Rico); C, *Acanthocereus tetragonus* growing among mangroves and other coastal vegetation (Isabela, northwestern Puerto Rico). Photos: SMS.

previous photographic documentation of the species from the neighboring town of Lares, dating back to 2019 and 2017, was found on social platforms, but it was not properly identified at the time the photos were posted online ([iNaturalist.org/observations/24835453](https://www.inaturalist.org/observations/24835453); [facebook.com/photo/?fbid=10213074430242551&set=gm.1916491575302278](https://www.facebook.com/photo/?fbid=10213074430242551&set=gm.1916491575302278), both accessed on October 26, 2022). It is widely naturalized on disturbed sites in the Cordillera Central and other mountainous areas of Puerto Rico (e.g., Adjuntas, Ciales, Comerío, Naranjito, Patillas, and Utuaado; SMS and JDCZ, personal observations), but also occurs in lesser disturbed natural areas in the northern karst region and coastal lowlands (e.g., Arecibo, Florida, Isabela, and Vega Alta;

SMS, personal observation). Collected in an open field growing among sedges and grasses, primarily *Andropogon bicornis*. It is morphologically similar to *Emilia fosbergii* Nicolson and *Emilia sonchifolia* (L.) DC., both of which also occur on the island across different elevations and habitats but are distinguished by having paler capitula that range from light orange or yellow to cream-white colors, with darker-colored anthers, as well as deeply-dentate leaf margins (Nicolson 1980; Lisowski 1997; Chung et al. 2009; Mapaya and Cron 2016; Dumbardon-Martial and Delblond 2019) (Figure 1B). It has been remarked that when dried, specimens lose their florets' distinctive color and become "nearly indistinguishable" from *E. fosbergii* (Chung et

al. 2009). Nonetheless, when examined under a microscope, dried specimens of *E. praetermissa* appear best distinguished by having persistent papillose to pilose involucre (SMS, personal observation).

The resemblance of *Emilia* species has been widely acknowledged by researchers for decades, leading to numerous cytological studies on the genus, with *E. praetermissa* being proposed and generally accepted as originating from hybridization between the palaeotropical natives *Emilia coccinea* (Sims) G. Don and *E. sonchifolia* (Olorode 1973; Olorode and Olorunfemi 1973). However, recent phenetic and phylogenetic works have addressed and debated the subject (see Mapaya and Cron 2016; Mapaya 2017).

**Record voucher:** PUERTO RICO. Vega Alta, Bo. Sabana, Ciénaga Prieta, 5 m, 7 Oct. 2021, *Steve Maldonado Silvestrini & Amelia Merced 971* (UPRRP). **Note:** This herb has been most recently collected in the mountain town of Utuado (23 Mar. 2022) (*Acevedo-Rodríguez, P. 17425* [US]).

## CACTACEAE

*Acanthocereus tetragonus* (L.) Hummelinck, Succulenta (Netherlands) 20: 165. 1938. Native to the Caribbean islands of Cuba, Dominica, Grenada, Guadeloupe, Martinique, Saint Lucia, Trinidad and Tobago, Aruba, Curaçao, and Margarita, as well as northern South America, Central America (Acevedo-Rodríguez and Strong 2012), and North America (Mexico; Acevedo-Rodríguez and Strong 2012; Gann et al. 2022; also Florida and Texas, U.S.A.; Gann et al. 2022; Wunderlin et al. 2022). It is introduced in India (Karthigeyan et al. 2013; Patel et al. 2016; Subitha et al. 2016), Australia (Randall et al. 2007; McFadyen 2012), New Caledonia (Beauvais et al. 2006; Hequet et al. 2009), Hawaii (Lorence et al. 1995), and the Caribbean islands of Saint Croix and Saint Thomas (Acevedo-Rodríguez and Strong 2012). It is also reportedly introduced in Europe (e.g., Sicily and Malta; Tela Botanica 2018; Mifsud 2022).

**New report for Puerto Rico.** Initially observed by SMS in 2017 under cultivation near Jobos Beach in the northwestern town of Isabela, and subsequently on August 31, 2019, also cultivated in the eastern town of Fajardo. Discovered naturalized by SMS on April 11, 2021, in the same location where it was initially observed, at the edge of a disturbed mangrove forest dominated by *Avicennia germinans* before being severely damaged by Hurricane Maria in 2017. Collected on August 15, 2022, at the same location, where it is propagating vegetatively and growing naturally among wild coastal vegetation (e.g., *Avicennia germinans*, *Coccoloba uvifera*, *Cocos nucifera*, *Conocarpus erectus*, *Pithecellobium dulce*, *Terminalia catappa*, *Thespesia populnea*, among others). This cactus was originally planted as an ornamental in the front patios of properties bordering the mangroves, and it most certainly escaped from cultivation, possibly after the hurricane's disturbance. It is distinguished from similar Cactaceae on the island (e.g., *Leptocereus* spp. and *Selenicereus* spp.) by being columnar with stems up to 3 m long, usually four-winged and flanked by spines, prone to arching and occasionally scandent (Figure 1C).

This species was most likely present on the island earlier and had not been properly reported or documented. It is absent from Puerto Rico's most recent floristic summaries but is listed as "cultivated" in the online records (digital checklist version) of the *Catalogue of Seed Plants of the West Indies* (cited in this article as Acevedo-Rodríguez and Strong 2012). The species' entry in the digital checklist is noted as last edited on May 28, 2009 ([https://naturalhistory2.si.edu/botany/WestIndies/getonerecord\\_Emu.cfm?ID=2284](https://naturalhistory2.si.edu/botany/WestIndies/getonerecord_Emu.cfm?ID=2284)), three years prior to the date of publication (2012). Two references pertaining to Puerto Rico are cited only in the digital records: Britton and Wilson (1923-1926) and Otero et al. (1945), of which the former lists the species as *Acanthocereus pentagonus* (L.) Britton & Rose (a taxonomic synonym) for the Caribbean islands of Saint Croix and Saint Thomas. The basis for the inclusion, however, relies on the second reference (see Otero et al.



1945) due to the assumption that the species was present in Puerto Rico as it was included with the common name '*Dildo espinoso*' (P. Avacedo-Rodríguez, personal communication with SMS).

After Britton and Wilson (1923-1926) and Otero et al. (1945), another catalog checklist was published on the common and scientific names of the island's flora (Martorell et al. 1981), in which the species was included based on the latter reference. It is noted that José I. Otero based his checklists and reports partly on his collections deposited at the former herbarium of the Experimental Agronomic Station in Río Piedras, which have been integrated into the UPR herbarium. Nonetheless, no collections by J. I. Otero or anyone else referable to this species were found in our search. Moreover, the primary authors in Martorell et al. (1981) published a systematic synopsis of the island's flora nineteen years later (Liogier and Martorell 2000), in which the species is absent.

We think that the original inclusion of this species to the Puerto Rican flora was an error in Otero and Toro (1931) (the first edition version of Otero et al. 1945), which relied on Britton and Wilson (1923-1926) as the primary reference for species inclusion, thus being added based on its presence in the U.S. Virgin Islands and not Puerto Rico. The species was eventually listed in references that cited Otero et al. (1945) (see above paragraphs for examples). However, it was probably not included in most of the subsequent botanical summaries and checklists due to the dubious nature of the report and the absence of a record voucher. We confirm its presence on the island with a photograph (Figure 1C) and specimen voucher of a naturalized population.

**Record voucher:** PUERTO RICO. Isabela, Bo. Bajura, PR-466: Km 7.9, 6 m, 15 Aug. 2022, *Steve Maldonado Silvestrini & Johann D. Crespo 1244* (UPRRP).

## CONCLUDING REMARKS

Recent studies and reports on the spread and naturalization of non-native plants in Puerto Rico show

that the flow of such species into the island is ongoing (e.g., Ackerman and González-Orellana 2021). Other recent, local studies and assessments on the topic, including urban and protected natural areas (e.g., Meléndez-Ackerman and Rojas-Sandoval 2021; Zimmerman et al. 2021), support the assertion that human-related activities strongly influence their introduction and naturalization. While some may not persist, others might establish and eventually become invasive, potentially causing negative impacts on multiple factors, including the local biodiversity, natural resources, and economy. For instance, in recent years, *Salvinia molesta*, an aquatic fern listed as one of the IUCN's 100 most invasive species (Luque et al. 2013), established in Lago Las Curias (a waterbody in the metropolitan area of San Juan) and caused detrimental effects locally for several years (Wahl et al. 2020).

Some of the taxa herein reported have already been recorded or confirmed in neighboring Caribbean islands (see Results). We are confident that the local naturalization of one species, *Acanthocereus tetragonus*, is of horticultural origin, whereas the others may have arrived naturally or unintentionally by different pathways. The latter is most likely the case of *Asystasia gangetica* subsp. *micrantha*, a naturalized herb on the grounds of an agricultural experiment station that conducts a variety of farming activities, thus probably entering by accident through the sowing of a contaminated seed batch or another similar source, which is an introduction method previously suggested for other African-native plants recorded near the location (e.g., McKenzie et al. 1993). It is a highly invasive weed that primarily affects oil-palm plantations in Southeast Asia and adjacent countries (CRC Weed Management 2003; Wahyuni et al. 2015).

In contrast, a presumption on the arrival and naturalization of *Emilia praetermissa* is more challenging and involves other possibilities. For example, *Emilia* spp. and other similar Asteraceae rely primarily on wind currents as their main dispersal mechanism (Sorensen 1986; Adedeji 2005; De-Paula et al. 2015), which

significantly facilitates their ability to spread over long distances and expand their geographic distributions. Notably, other African-native species of Asteraceae similar to *Emilia* have been added to the Puerto Rican flora in the last decades (e.g., *Crassocephalum crepidioides*; Axelrod and Taylor 1993). It is also worth noting that Asteraceae is the third taxonomic family with the largest number of non-native plant species in Puerto Rico and the Virgin Islands, surpassed by Fabaceae and Poaceae (Rojas-Sandoval and Acevedo-Rodríguez 2015). The expansion and naturalization success of non-native Asteraceae on the island appears to be best explained by the advantages of dispersal adaptations they possess, which may explain why some of these species are expanding naturally via wind through the Caribbean region.

The records presented herein were discovered initially in highly disturbed areas near urban development and notably distant from protected nature reserves. Even though several floristic surveys in natural protected areas of Puerto Rico have previously yielded notable contributions to its native and non-native flora (e.g., Monsegur-Rivera 2009; Padrón-Vélez and Ricart-Pujals 2015), the most recent discoveries of endemic species have taken place in non-protected areas (Ackerman and Ortíz-Jordan 2021; Gdaniec et al. 2022). Consequently, farms, neglected terrains, and other anthropized vegetated areas without a protection designation and with a history of agriculture or other land uses may yield significant discoveries of native and non-native plant species and should also be considered in conservation and management efforts. Also, local farmers and residents can be valuable for identifying areas that require such attention and evaluation, and citizen scientists should be included in this process. More efforts should be made to explore and research outside of protected areas, including those with ongoing disturbance by human land use, because it may result in botanical additions to the region, ultimately enriching our understanding of plant biogeography, species diversity, natural history, and conservation.

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