

ACTA BOTANICA CROATICA

CODEN: ABCRA 25

ISSN 0365-0588

eISSN 1847-8476

ACCEPTED AUTHOR VERSION OF THE MANUSCRIPT

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DOI: 10.37427/botcro-2022-013

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Please cite this article as: Cambria S., Crisafulli A., Giusso del Galdo G., Picone R.M, Soldano A., Sciandrello S., Tavilla G.: First record of *Sida rhombifolia* L. (Malvaceae) for Italian flora: taxonomical and ecological investigation. Acta Bot Croat, DOI: 10.37427/botcro-2022-013.

This is a PDF file of a manuscript that has been accepted for publication. The manuscript will undergo language and technical editing, formatting and author proofing before it is published in its final form.

First record of *Sida rhombifolia* L. (Malvaceae) for Italian flora: taxonomical and ecological investigation

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Running title: *SIDA RHOMBIFOLIA NEW ALIEN SPECIES FOR ITALY*

Abstract – *Sida rhombifolia* L. (Malvaceae) has been reported for the first time in Italy. This species with a Paleotropics geographic origin represents a new invasive alien species in the flora of Italy. It was already reported in several European countries as invasive species, but this plant is also known for its medicinal properties in many areas of the world. The species was found in the anthropic environments of Sicily. In particular, the study area is localized in the Peloritani Mounts (NE Sicily) where the species was discovered in five stands. Our new discovery confirmed the role of anthropic activities have had in the alien species invasion in Italy. Diagnostic features, ecological and geographic data are provided. From a phytosociological viewpoint, this plant characterizes a plant community that includes various nitrophilous species such as *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn. and *Sorghum halepense* (L.) Pers. Moreover, invasiveness and impacts associated to this species were assessed by using EPPO prioritization protocol. The specimens were deposited in the herbaria of Catania and Messina University.

Keywords: anthropogenic plant, biological invasion, neophyte, Sicily, vascular flora

Introduction

Urbanization and climate change encourage the invasion and spread of exotic plant species. (Salinitro et al. 2019). In particular, several alien species have recently been reported in Italy (Sciandrello et al. 2016, Galasso et al. 2018, Musarella 2020). Among them numerous belong to the Malvaceae Juss. s.l, in fact, ca. 43% of the taxa within this family reported in Italy are non-native (Portal to the Flora of Italy 2022).

The family Malvaceae includes ca. 250 genera and 4200 species distributed mainly in the tropical regions of the world (Simpson 2019). Phylogenetic studies of this family show its division into nine subfamilies (Chase et al. 2016). Following this classification, the genus *Sida* L. fall within the tribe Malveae J. Presl belonging to the Malvoideae Burnett subfamily. The genus *Sida* L. was validly described by Linnaeus (1753), and it is one of the most diversified genera of the Malvaceae. This genus includes ca. 250 taxa, and its native array ranges from the Tropics to N America (POWO 2021), and from a taxonomical point of view, it is very complex due to its great changeability. Moreover, these species usually grow also in areas with a high

degree of human intrusions. The genus *Sida* is distinguished from other related genera by two morphological features: calyx often 10-ribbed, and schizocarp fruits with 5-14 one-seed mericarps, muticous to prominently aristate (Fryxell 1997).

During field surveys in the northeast region of Sicily, we discovered several individuals of an unknown *Sida* representative mainly associated to urban areas. The plant was identified as *Sida rhombifolia* L. through literature and herbarium research. This species, widely distributed in the tropical, sub-tropical and warm temperate regions of the world (Holm et al. 1997), was never reported for the Italian flora. Its real native range is unknown, but it is probably attributable to the Paleotropics (Verdcourt 2004). It is mainly known for its medicinal uses in tropical and subtropical areas worldwide (Ajeet et al. 2018), where it shows potential for invasiveness (Randall 2001). Generally, *S. rhombifolia* is a common weed in synanthropic stands from sea level to 2,000 m a.s.l., particularly along roadsides and urban areas, as well as in gardens, pastures, abandoned farmland and cultivated fields (Smith 1981). Sometimes, it also colonizes scrubs, open slopes, stream sides, seasonally flooded surfaces and degraded forest areas, while it does not grow in closed forests or tall scrublands (Vattakaven et al. 2016). It represents a serious nuisance for agricultural lands, pastures, and native grasslands (Reddy 2014).

Until today, the only known species belonging to this genus in Italy was *Sida spinosa* L., which is reported as a casual alien species (Galasso et al. 2018). In addition, *S. rhombifolia* is a taxonomically controversial species, which belongs to *Sida* section *Sida*. Different authors attributed many binomials and now some of them are considered as autonomous taxa within the *S. rhombifolia* complex. This new alien species to Italy was already reported in other countries of Europe and the Mediterranean area. It is reported as casual and ephemeral species in Czech Republic (Pyšek et al. 2012), France (Tison and de Foucault 2014), Great Britain (Clement and Foster 1994), Netherlands and Belgium (Verloove and Vandenberghe 1995), while it is indicated as naturalized in Croatia (Milović et al. 2010), Portugal (Webb 1968) and Spain (Pavia and Nogueira 2006). It is categorized as “not established” in Lithuania, Sweden, and Norway, while its status is unknown in Ukraine and Denmark (Valdés 2011, NOBANIS 2021). Besides, in the Mediterranean area *S. rhombifolia* is reported as native to Egypt (Boulos 2000).

The aim of this paper is to analyze the morphological, ecology and chorological features of the Sicilian population of *S. rhombifolia* (the only currently known in Italy). Additionally, the potential impacts and invasive behavior have been assessed for Italy.

Materials and methods

This investigation was realized between August 2014 and April 2021 in the Peloritani mounts, (Northeastern Sicily) based on literature data and morphological analysis of living material collected during fieldworks. Careful surveys of the Italian literature were carried out to find existing records of the species in Italy (Pignatti 2017-2019, Galasso et al. 2018). The specimens have been kept in the herbaria of the University of Catania and Messina (CAT and MS; herbarium acronyms follow Thiers 2020). Taxonomic identification was performed according to Pavia and Nogueira (1993), Tambde et al. (2016) and Pignatti et al. (2017-2019), while the nomenclature was compiled following Bartolucci et al. (2018), Galasso et al. (2018) and subsequent updates reported in the Portal to the Flora of Italy (2022). In addition, many herbarium sheets of *S. spinosa* and *S. rhombifolia* were carefully examined for the correct identification of the species. Morphological measurements were carried out on 10 specimens for each area using Zeiss Stemi 500 stereoscope with Zen 2.5 lite software. The stands where the species was discovered were reported in a distribution map, developed using QGIS tools (QGIS.org 2021). The vegetation in which this species was studied following the Braun-

Blanquet approach (Braun-Blanquet 1964) and the nomenclature of syntaxa follows Mucina et al. (2016). Moreover, possible impacts and invasive behavior were analyzed using the EPPO prioritization method scheme for invasive alien species (Branquart et al. 2016). This prioritization process, broadly, aims to compile a list of invasive alien plants that have grown in the assessment region, and to identify which of these should be prioritized for a Pest Risk Analysis (PRA, see EPPO 2019).

Results

Sida rhombifolia L., Sp. Pl. 2: 684, 1753 (Fig. 1)

Lectotype – Herb. Linnean No. 866.3 (LINN), designated by Rodrigo 1944.

Synonyms – *Diadesma rhombifolia* (L.) Raf., New Fl. 1: 41, 1836; *Malva rhombifolia* (L.) E.H.L.Krause, Deutschl. Fl. ed. 2, 6: 238, 1902; *Napaea rhombifolia* (L.) Moench, Methodus 621, 1794; *Sida alba* Cav., Diss. 1: 22, 1785; *Sida andicola* Gand., Bull. Soc. Bot. France 71(5–6): 632, 1924; *Sida compressa* Wall. Cat. n. 1866, 1824; *Sida hondensis* Kunth, Nov. Gen. Sp. 5: 260, 1822; *Sida insularis* Hatus, J. Jap. Bot. 35: 360, 1960; *Sida pringlei* Gand., Bull. Soc. Bot. France 71: 631, 1924; *Sida rhombifolia* subsp. *insularis* (Hatus) Hatus, Fl. Ryukyus 846, 1976; *Sida rhombifolia* subsp. *rhombifolia* Borss. Blumea 14: 195, 1966; *Sida ruderata* Macfad., Fl. Jamaica 1: 80, 1837; *Sida unicornis* Marais, Kew Bull. 38: 42, 1983.

Species description from Sicilian material

Perennial herb or semi-woody shrub up to 1–1.5 m tall. Stems erect, terete, green or purplish, many-branched, with sparse stellate hairs when younger and almost glabrous when older. Leaves alternate, slightly dimorphic, rhomboid to elliptic and with stellate hairs on both surfaces of the young branches without flowers, narrower and with stellate hairs only on the abaxial face on the flowering stems. Blade elliptic to rhomboid, 1.5–5.5 × 1–3 cm, serrate and crenate towards the top and entire towards the base, apex obtuse. Leaves with petiole 0.2–0.5 cm long, couple of stipules, 3–5 mm long, not different, linear to filiform. Calyx campanulate, pubescent, with triangular sepals, 0.4–0.7 × 0.2–0.4 cm. Flowers solitary or gathered in small groups, axillary, on slender pedicel, 2 to 3 cm long, jointed above the middle. Corolla with 5 petals partially fused together, slightly longer than calyx, pale yellow, 0.5–1 × 0.5–0.7 cm. Schizocarp, flattened or almost globular, from greenish (immature) to brownish (mature), 0.4–0.5 cm long, with peduncle 1.4–2.8 cm long; mericarps 8–10, dark brown to black, wedge-shaped, 0.3–0.4 cm long, with two vertical ribs and a pair of retrorse awns on the top, 0.5–1 mm long (Figs. 2, 3).

Taxonomic remarks of *S. rhombifolia*

According to several authors (Fryxell 1988, Tambde et al. 2016), *S. rhombifolia* represents a species complex with a great morphological variation, including many taxa treated at a specific, subspecific or varietal level. Indeed, the taxonomy of this complex species is quite disputed (Aguilar et al. 2003), and the proposed classification is often very different according to the various geographical areas, lacking an overall treatment of the entire group in all its range. The specimens collected in the northeast of Sicily can be referred to *S. rhombifolia* L., showing leaves with an indumentum of minute sessile stellate hairs, and serrate margins at the apex, as well as dehiscent mericarps provided with 2 prominent apical awns. Finally, it must be highlighted that the only other species of the *Sida* genus present in Italy is *S. spinosa*, first reported for western Sicily by Romano (2004). These two species are easily distinguished for

several features, and based on our measurements and bibliographic data, the following analytical key is provided:

1a. Plant 2–6 (–10) dm tall, stems with 1 or 2 spines at the base of petioles, leaf blades narrow-ovate to oblong or elliptic, 5–7 mericarps with 2 awns 1–1.5 mm long *Sida spinosa*

1b. Plant 10–15 dm tall, stems without spines at the base of petioles, leaf blade elliptic to rhomboid, 8–14 mericarps with 2 awns 0.5–1 mm long *Sida rhombifolia*

Distribution and ecology of *S. rhombifolia* in Italy

Sida rhombifolia was found in five localities of the Peloritani mounts (Northeastern Sicily), along the coastal belt between Furnari and Rometta, near from Messina (Fig. 4). It colonizes mainly disturbed sites not far from the sea, at an altitude of 0–140 m a.s.l., such as roadsides, abandoned quarries and uncultivated areas, which are characterized by high levels of nitrates and certain moisture. From a phytosociological point of view, this species plays a dominant role in the community characterized by several nitrophilous annual species with a summer-autumn cycle, as *Digitaria sanguinalis* (L.) Scop., *Eleusine indica* (L.) Gaertn., *Euphorbia prostrata* Aiton, *Setaria verticillata* (L.) P.Beauv., *Dittrichia viscosa* (L.) Greuter, *Foeniculum vulgare* Mill. subsp. *vulgare*, *Rubus ulmifolius* Schott, *Geranium molle* L., *Malva sylvestris* L., *Oxalis pes-caprae* L., *Portulaca oleracea* L., *Sixalix atropurpurea* (L.) Greuter & Burdet, *Sonchus tenerrimus* L., *Sorghum halepense* (L.) Pers., *Symphotrichum squamatum* (Spreng.) G.L.Nesom, *Verbena officinalis* L., *Vicia villosa* Roth, *Xanthium strumarium* L. (Tab. 1).

Therefore, these aspects should be referred to the *Amarantho-Digitarietum sanguinalis* Pignatti 1953 (*Digitario sanguinalis-Eragrostietea minoris* Mucina, Lososová & Šilc 2016), anthropogenic vegetation described by Pignatti (1953) for the Venetian plain and recently reported by Viciani et al. (2020) in the checklist of the alien-dominated communities in Italy. Besides, *S. rhombifolia* sometimes forms dense monodominant vegetation or mixed community with *R. ulmifolius*, unlike other parts of continental Europe where it is very ephemeral and mature individuals are seldom seen (Verloove and Vandenberghe 1995, Milović et al. 2010). In Sicily, it is locally well established and exhibits high coverage with a growing number of individuals based on our observations in the period 2014–2020 (Fig. 5). The stands of *S. rhombifolia* distributed in the northeast of Sicily are represented by several individuals (ca. 50–100 for each stand), and due to awned seeds, the species mainly spreads by adhering to clothing and animals (Smith 2002). The introduction of *S. rhombifolia* in Sicily was almost certainly accidental, probably due to seeds carried on vehicles in an area of trade such as the Messina Strait or it could have come from the nursery activity specialized in the trade of exotic species, since the first finding was made in an area with a high human presence.

According to Pyšek et al. (2004), the invasion status of the species can be considered in Italy as naturalized. Besides, the EPPO protocol (Branquart et al. 2016) was performed on *S. rhombifolia*. The result of the assessment (evaluation of spread, impacts, and uncertainty degree) is shown in the Tab. 2.

Discussion

This new record of *S. rhombifolia* for Italy seems to not show a high invasive potential of the species, despite its increasing spread in the Mediterranean Europe territories in the last years. Until now, this species in Sicily has not yet colonized habitats with a significant ecological value. However, in the future, based on its ecological requirements and ongoing climate changes occurring in Italy, it might invade natural environments of this area, as grasslands (Habitat code 6220), and the wide pebbly bottoms of seasonal waterways locally known as “fiumare” (Habitat code 3290). *Sida rhombifolia* together with other invasive species reported from the Northeastern part of Sicily, such as *Euphorbia hypericifolia* L., *Ailanthus altissima* (Mill.) Swingle., *Lantana camara* L., *Boerhavia coccinea* Mill., *Digitaria ciliaris* (Retz.) Koeler, *Opuntia ficus-indica* (L.) Mill. (Sciandrello et al. 2016, Galasso et al. 2020), could represent a serious threat for many natural habitats in this area, hosting narrow endemic species (Sciandrello et al. 2019, Brullo et al. 2021).

Furthermore, the occurrence of numerous other sites with similar ecological characteristics makes foreseeable its growing expansion in the coming years not only in the Messina area, but also in other parts of Sicily, considering the high invasive potential of this species observed in numerous geographical areas (Rejmánek 2016, Kuswanto et al. 2020). As highlighted by Steel et al. (2008), based on mathematical models, global warming could lead to a significant invasive potential of the species, even in non-tropical areas and in those with a Mediterranean climate.

In conclusion, it would be desirable to monitor the species in the Sicilian territory, in order to supervise the expected spread in the above mentioned habitats to limit the alteration of the floristic and structural composition of these environments.

Specimina visa:

Sida rhombifolia L.–Portugal: Azores, 1846, *T. Hunt s.n.* (BR0000013473679); India: Tamil Nadu Peninsula Indiae Orientalis Madras, 1867, *Wight 166* (K000659356); Cameroon: Koum, 25 August 1974, *MM Bosch Geerling & L.V.P. Lavieren 5169* (YA0053739); Usa: Sumter County, S Side of Cane Savannah, 5 air mi SE of downtown Wedgefield, 23 August 2019, *J.B. Nelson & D.P. Ferral s.n.* (USCH0053519); Fairfield County, 2.8 road miles N of downtown, Ridgeway, 6 September 2019, *J.B. Nelson s.n.* (USCH0058773); Italy: Sicily: Barcellona Pozzo di Gotto, lungo il margine dei Caselli autostradali, 12 m, 22 August 2014, *A. Crisafulli & A. Soldano s.n.* (MS); Rometta, 5 m, 21 February 2016, *A. Crisafulli s.n.* (MS); *ibid.*, 20 December 2020, *S. Cambria & G. Tavilla s.n.* (CAT); Valdina nel lago grande, 16 m, 3 January 2017, *A. Crisafulli s.n.* (MS); *ibid.*, 16 m, 13 November 2020, *S. Cambria s.n.* (CAT).

Sida spinosa L.–Italy: Sicily: Misilmeri, contrada Incorbina (Palermo), September 2001, *S. Romano s.n.* (PAL); Brazil: Monte Corcorado, January 1818, without collector (W00693489); Sergipe, Capela, RVS Mata do Junco, Mata Atlantica, May 2012, *L.A. Gomes et al. s.n.* (NY); São Sebastião da Vitória, 10 May 2014, *M.T.R. Costa s.n.* (RB00947655); Colombia: Tocaima, November 1932, *E. Pérez Arbeláez 2447* (COL000141171); Usa: North Carolina, Poplar Branch Township, 21 September 2018, *T. Holdsclaw s.n.* (NCU659548);

Acknowledgements

The authors wish to thank Salvatore Casella for having realized the drawing included in the text. We would also like to thank Giulia Giangravè, English native speaker, for the linguistic improvements to the manuscript.

Author contributions

Conceptualization: S.C., G.T.; Data gathering and curation: S.C., A.C., R.M.P., A.S. G.T.; Methodology: S.C., G.T.; Documentation review: S.C., A.C., R.M.P., G.T., S.S.; Data Analysis: S.C., G.T.; stereomicroscope Images: S.C., G.T.; Writing-original Draft: S.C., G.T.; Writing-revision and editing: S.C., G.G.d.G., G.T., S.S.; Cartography: G.T. All authors have read and agreed to the published version of the manuscript.

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Tab. 1. Phytosociological relevés of plant community with *S. rhombifolia* carried out in Messina province (NE Sicily, Italy). Place and date of relevés: Rels. 1-4: Rometta, 13. 11. 2020, Rels. 5-6: Valdina, 15 .4. 2021, Rels. 7-8: Furnari, 16. 4. 2021, Rel. 9: Terme Vigliatore, 16. 4. 2021, Rels. 10-12: Barcellona Pozzo di Gotto, 16. 4. 2021.

Relevé number	1	2	3	4	5	6	7	8	9	10	11	12
Altitude (m a.s.l.)	10	10	10	10	18	18	17	17	65	14	14	14
Plot size (m ²)	40	40	40	40	50	50	50	50	50	50	50	40
Vegetation cover (%)	80	80	90	90	80	80	90	90	80	90	80	90
<i>Sida rhombifolia</i> L.	3	2	2	2	3	2	2	1	2	3	4	3
<i>Digitario sanguinalis-Eragrostietea minoris</i>												
<i>Achyranthes sicula</i> (L.) All.	.	.	.	.	.	.	.	.	.	+	+	+
<i>Amaranthus retroflexus</i> L.	.	.	.	.	.	.	.	.	.	+	+	+
<i>Bidens pilosa</i> L.	.	.	.	.	.	.	.	.	3	2	+	1
<i>Boerhavia coccinea</i> Mill.	.	.	.	.	.	.	.	.	.	.	1	1
<i>Digitaria sanguinalis</i> (L.) Scop.	2	+	+	.	.	1	+	+	.	+	+	.
<i>Eleusine indica</i> (L.) Gaertn.	.	+	+	1	.	.	+	.	.	.	.	.
<i>Erigeron bonariensis</i> L.	.	.	.	.	.	.	1	+	.	.	+	+
<i>Euphorbia prostrata</i> Aiton	.	.	.	+	+	+	.	.	+	.	.	.
<i>Setaria verticillata</i> (L.) P. Beauv.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Sorghum halepense</i> (L.) Pers.	+	+	.	+	.	.	.	.	.	.	.	.
<i>Symphotrichum squamatum</i> (Spreng.) G.L. Nesom	1	.	.	.	1	1	2	2	.	.	.	.
<i>Rhamno-Prunetea</i>												
<i>Rubus ulmifolius</i> Schott	+	3	.	.	1	2	.	+	+	.	.	+
Other species												
<i>Arundo plinii</i> Turra	.	.	.	.	.	.	.	1	.	.	.	.
<i>Bituminaria bituminosa</i> (L.) C.H. Stirt.	.	.	.	.	.	.	+	+	.	+	.	.
<i>Convolvulus sepium</i> L.	.	.	1	+	.	.	.	.	.	.	.	+
<i>Dittrichia viscosa</i> (L.) Greuter subsp. <i>viscosa</i>	.	+	.	.	1	2	+	+	.	.	.	.
<i>Equisetum arvense</i> L.	.	.	.	+	+	.	.	.	.	.	.	.
<i>Foeniculum vulgare</i> Mill. subsp. <i>vulgare</i>	.	+	.	.	+	.	.	.	.	.	.	.
<i>Galactites tomentosus</i> Moench	.	.	.	.	.	.	+	.	.	.	.	+
<i>Geranium molle</i> L.	1	.	.	.	+	.	.	.	.	+	.	.
<i>Hyparrhenia hirta</i> (L.) Stapf subsp. <i>hirta</i>	.	.	.	.	.	.	1	+	.	.	+	+
<i>Lathyrus annuus</i> L.	.	.	.	.	.	.	+	.	.	+	.	.
<i>Malva sylvestris</i> L.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Melilotus</i> sp.	+	.	+	+	.	.	.	.	.	.	.	.
<i>Oxalis pes-caprae</i> L.	.	.	3	3	.	.	+	+	+	.	.	.
<i>Portulaca oleracea</i> L.	.	+	.	.	+	.	.	.	.	.	.	.
<i>Reichardia picroides</i> (L.) Roth	.	1	.	.	.	.	.	.	.	.	.	.
<i>Rhus coriaria</i> L.	.	.	.	.	.	.	.	.	+	.	.	.
<i>Ricinus communis</i> L.	.	.	.	.	.	.	.	.	.	.	.	+
<i>Rumex pulcher</i> L.	+	.	.	.	.	.	.	.	.	.	+	+
<i>Sixalix atropurpurea</i> (L.) Greuter & Burdet	+	.	.	.	+	+	.	.	.	.	.	.
<i>Sonchus tenerrimus</i> L.	.	+	.	.	+	.	.	.	.	.	.	.
<i>Verbena officinalis</i> L.	.	.	+	+	+	.	.	.	.	.	.	.
<i>Vicia sativa</i> L.	.	.	.	.	.	.	+	+	.	.	.	.
<i>Vicia villosa</i> Roth	.	+	.	.	+	+	+	.	+	+	.	.
<i>Xanthium strumarium</i> L.	.	.	.	+	.	+	.	.	.	.	.	.

Tab. 2. Conclusions from the prioritization (stage 1: risk assessment): *Sida rhombifolia* L. was categorized in the European List of Minor Concern (ELMC). Abbreviations: Aus – Australia, Am – America, Pal – Paletropical. Country abbreviations correspond to ISO codes. Under questions A8 and A9, uncertainty is represented by (L) low, (M) medium or (H) high

Species	<i>Sida rhombifolia</i> L.
A.1. Clear taxonomy	Yes
A.2. Alien in the EU	Yes (Pal)
A.3. Quality of information sufficient	Low
A.4. Established in the EU	Yes (BE, CZ, ES, FR, GB, HR, NL, PT)
A.5. Invasive outside the EU	Yes (Aus, Am)
A.6. Potential establishment in the EU	Yes (DK, IT, LT, NO, SE, UA)
A.7. Spread	Medium
A.8. Impact on native plant species	Low (L): forms dense stands, not spread rapidly to the surrounding area
A.9. Impact on ecosystem functions and services	Low (L): until now, it spread only in urban areas
Conclusion of stage 1	ELMC

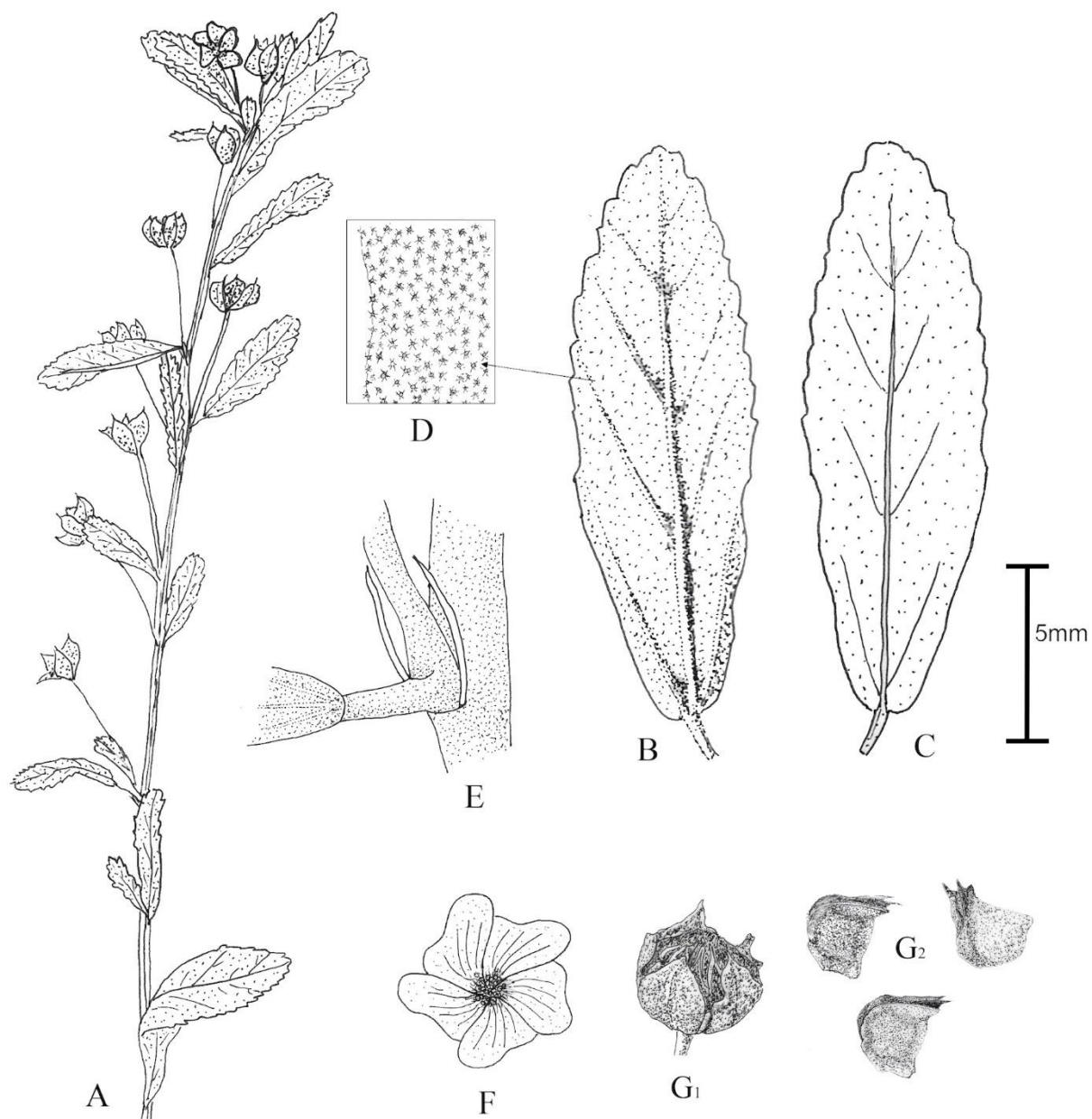


Fig. 1. Drawing of *Sida rhombifolia* L. (Malvaceae) from living Sicilian specimens (by S. Casella): A – flowering stem, B – leaf abaxial surface, C – leaf adaxial surface, D – close-up to stellate hairs, E – stipules, F – flower, G₁ – schizocarp, G₂ – mericarps.

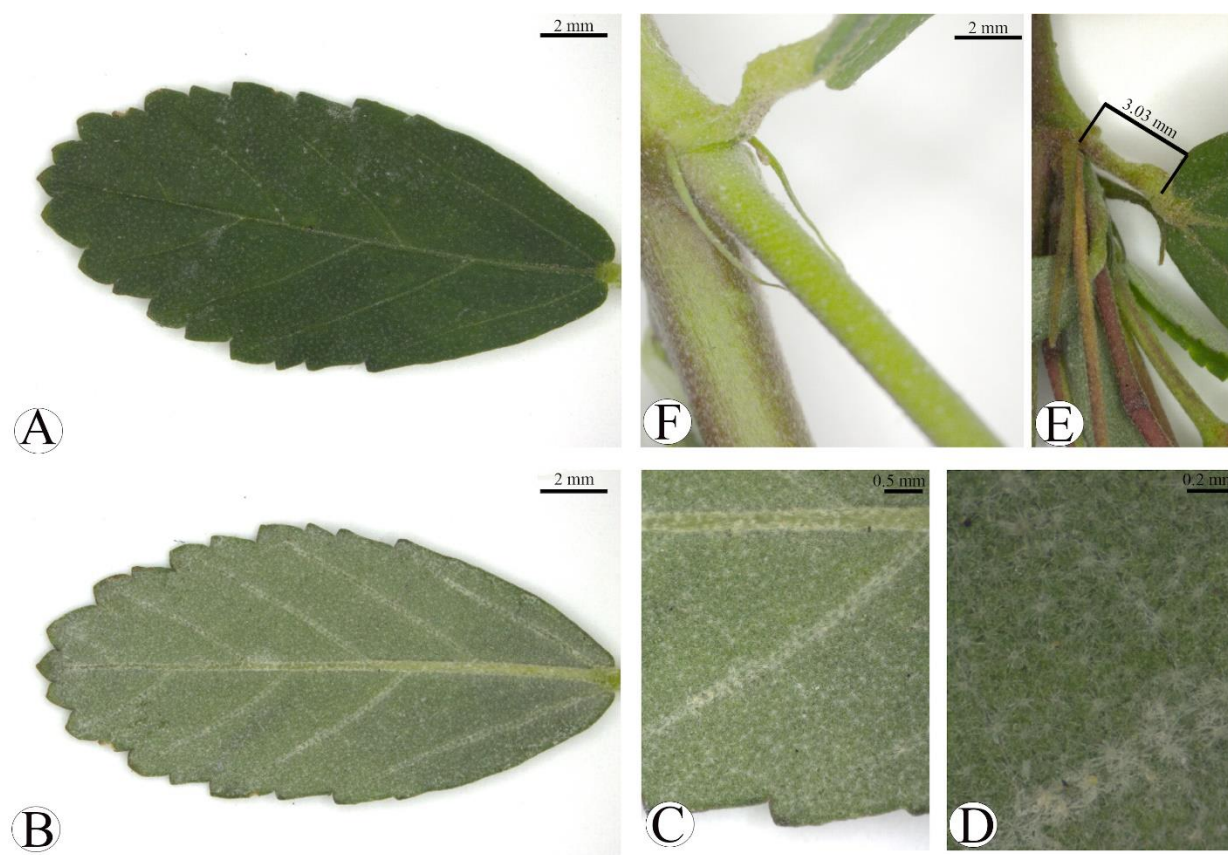


Fig. 2. Morphological features of leaves of *Sida rhombifolia* L. (Malvaceae): A – leaf adaxial surface, B – leaf abaxial surface, C – detail of the leaf edge, D – stellate hairs, E, F – stipules.

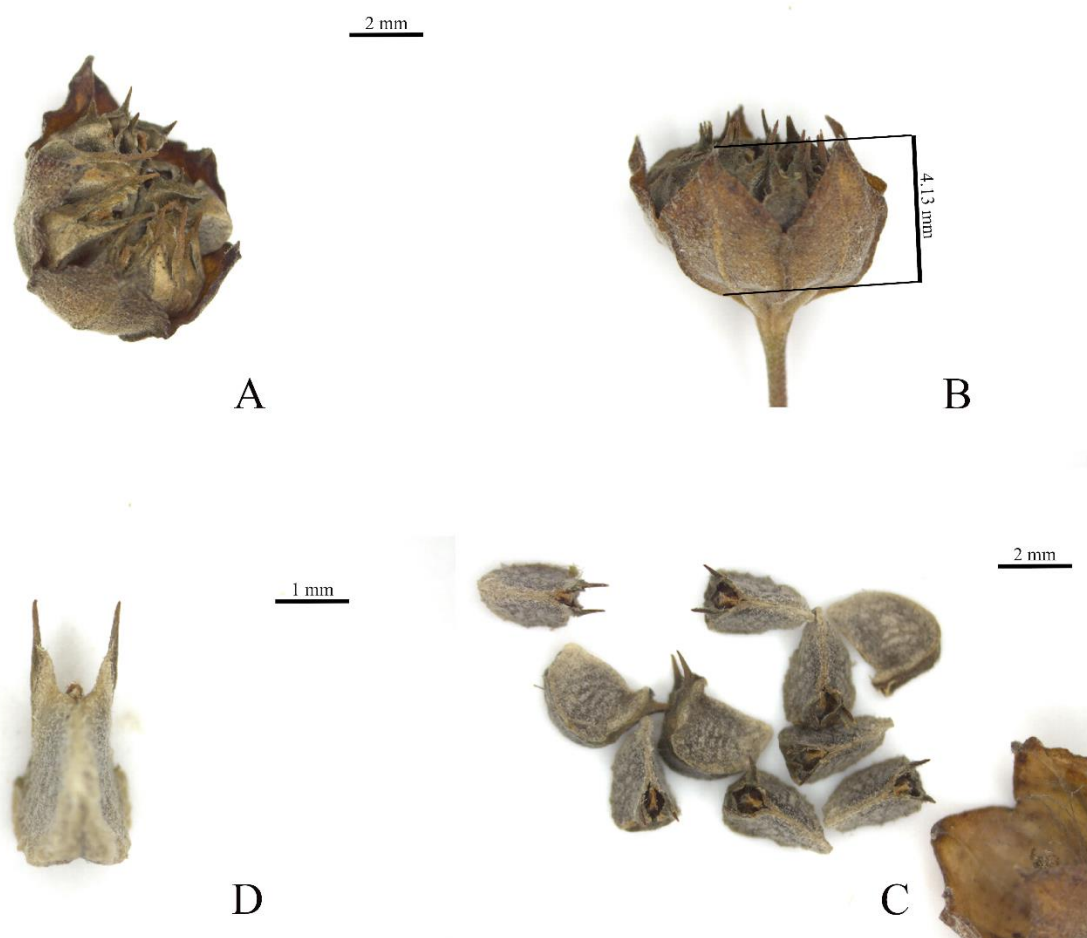


Fig. 3. Fruit of *Sida rhombifolia* L. (Malvaceae): A – frontal view of schizocarp B – lateral view of schizocarp, C – detaching mericarps, D – frontal view of mericarp.

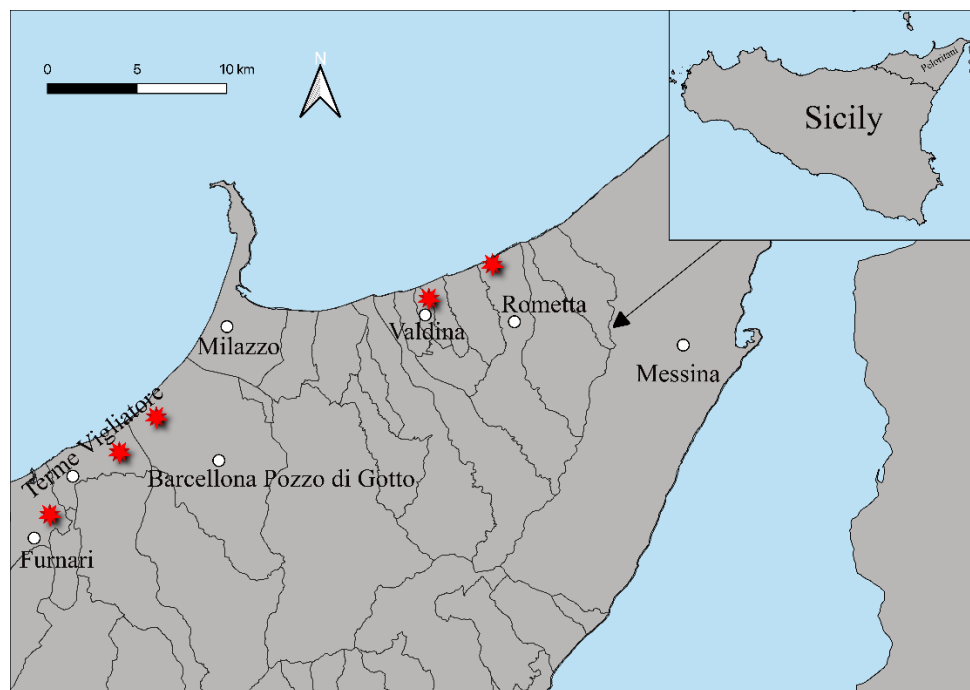


Fig. 4. Distribution map of *Sida rhombifolia* L. (Malvaceae) in Sicily, Italy.

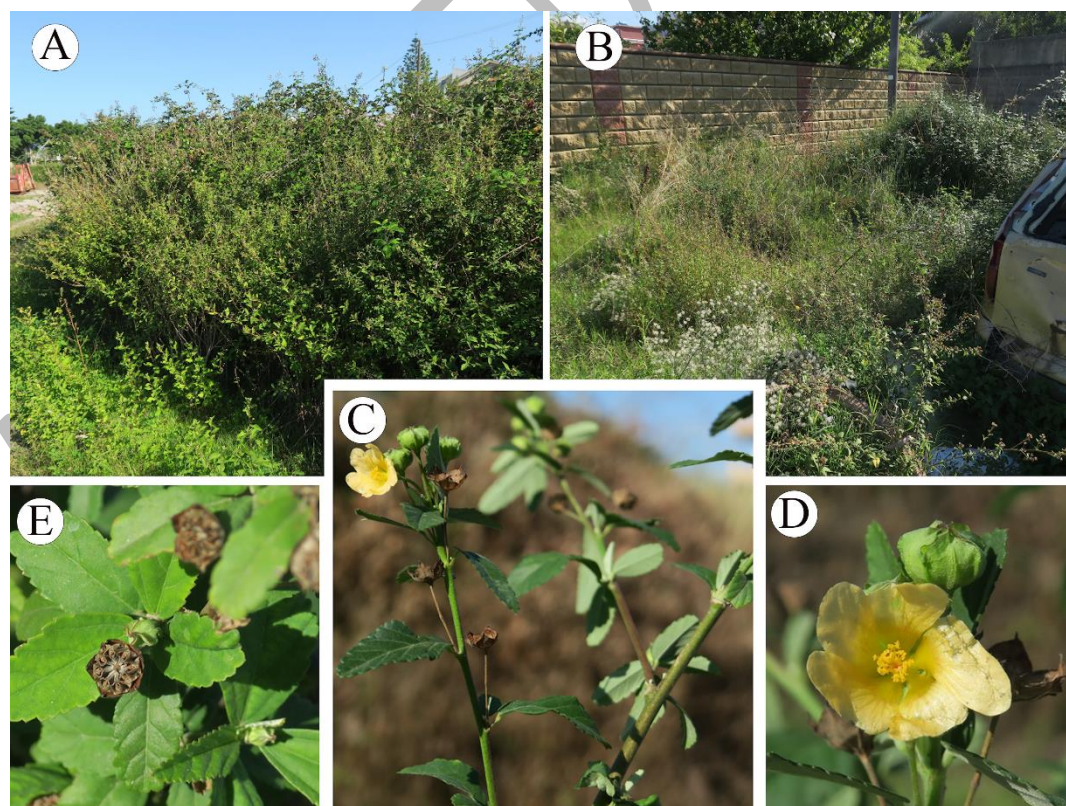


Fig. 5. Habit (A, B) of *Sida rhombifolia* L. (Malvaceae) (Sicily) with morphological details of the leaves (C), flower (D), and schizocarps (E)