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Original Paper

Flora of Ceará, Brazil: Onagraceae

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Abstract

This study aimed to provide the floristic survey of Onagraceae in Ceará state. The floristic study consisted of analyzing material deposited in the herbaria EAC, ESA, FUEL, HCDAL, HUEFS, HUVA, HVASF, INPA, K, MO, NY, P, RB, UFRN and US, as well as field work carried out between 2015 and 2017. In the study area, Onagraceae is represented by the genus *Ludwigia*, and seven species were recorded: *L. erecta*, *L. helminthorrhiza*, *L. hyssopifolia*, *L. leptocarpa*, *L. nervosa*, *L. octovalvis* and *L. tomentosa*. All seven species were also sampled in Conservation Units, with *L. erecta* recorded in six of them. *L. erecta* and *L. helminthorrhiza* have a broader distribution in the state. *L. nervosa* and *L. tomentosa* are indicated as new occurrences for Ceará, both with only one record in the south of the state, expanding their range in Northeastern Brazil. The information in this manuscript allows identification of Onagraceae representatives in Ceará state, through morphological descriptions, identification keys, taxonomic comments, illustrations, photographs and geographic distribution data.

Key words: aquatic plants, Myrtales, Northeastern Brazil, wetland.

Resumo

Este estudo teve como objetivo o levantamento florístico da família Onagraceae no estado do Ceará. O estudo florístico consistiu na análise de material depositado nos herbários EAC, ESA, FUEL, HCDAL, HUEFS, HUVA, HVASF, INPA, K, MO, NY, P, RB, UFRN e US, bem como de coletas realizadas entre 2015 e 2017. No Ceará, Onagraceae está representada apenas pelo gênero *Ludwigia*, onde foram registradas sete espécies: *L. erecta*, *L. helminthorrhiza*, *L. hyssopifolia*, *L. leptocarpa*, *L. nervosa*, *L. octovalvis* e *L. tomentosa.* Todas as sete espécies foram amostradas também em Unidades de Conservação, com *L. erecta* registrada em seis destas. *L. erecta* and *L. helminthorrhiza* têm distribuição mais ampla no estado. *L. nervosa* e *L. tomentosa* são indicadas como novas ocorrências para o Ceará, ambas com apenas um registro no sul do estado, ampliando sua amostragem no Nordeste brasileiro. As informações nesse manuscrito permitem a identificação dos representantes de Onagraceae no estado do Ceará, através das descrições morfológicas, chave de identificação, comentários taxonômicos, ilustrações, fotografias e dados de distribuição geográfica.

Palavras-chave: plantas aquáticas, Myrtales, nordeste do Brasil, áreas inundadas.

Introduction

Onagraceae Juss. belongs to the Myrtales order and its monophyly is sustained based on the sequencing of rbc*L* and ndhF genes (Levin *et al*. 2003; APG IV 2016). This family comprises 22 genera and 657 species with cosmopolitan distribution, and North America is a richness center for the group (Stevens 2001; Wagner *et al*. 2007). The family is subdivided into Ludwigioideae, which only includes the genus *Ludwigia* L., and Onagroideae, which consists of six tribes, presenting the Onagreae tribe with 13 genera (Wagner *et al*. 2007).

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In Brazil, Onagraceae is represented by four genera: *Epilobium* L., *Fuchsia* L., *Ludwigia* L. and *Oenothera* L., comprising 62 species, of which 19 are endemic (BFG 2018). Representatives of this group can be herbs, shrubs or small-to medium-sized trees, annual or perennial, often with oil cells; have simple, alternate or opposite leaves, sessile to petiolate; its flowers are usually monoclinous, ovary inferior, actinomorphic or zygomorphic, usually tetramerous, but also 2–7 merous, usually inserted in the leaf axils, solitary or arranged in racemes, sometimes in panicles, with sepals deciduous after anthesis, except in *Ludwigia*; the sepals are greenish to tones of red or purple in color; petals normally as many as sepals, of various colors and sometimes unguiculate; nectariferous disc present; androecium usually diplostemonous and heterostemonous, with episepal stamens usually larger; stigma lobulated, clavate, globose or capitate; fruits are loculicidal capsules, berries or nut-like; and seeds are numerous, free or embedded in a endocarp (Wagner *et al.* 2007).

Few floristic studies of Onagraceae were developed in Brazil, with the most comprehensive were *Flora brasiliensis* Micheli (1875) and Flora Brasílica de Munz (1947), later, some regional works were performed (Grillo & Giulietti 1998; Grigoletto *et al*. 2010; Bertuzzi *et al*. 2011; Cordeiro & Melo 2013; Lovo & Zappi 2018).

In the state of Ceará, only the genus *Ludwigia* has been reported, associated with aquatic environments, with frequent rooting in the nodes and underwater parts are usually enlarged and spongy due to aerenchyma development (Wagner *et al.* 2007; BFG 2018). Its representatives are popularly known as the "cruz-de-malta" and are economically important, as some species are used for ornamental purposes, while others may be invasive in wetland areas, which is why they are frequently seen in works carried out with the aquatic flora of Northeastern Brazil (Kissmann & Groth 2000; Bertuzzi *et al*. 2011; Cordeiro & Melo 2013).

Studies that treat the taxonomy of Onagraceae for the Ceará are nonexistent, thus, as part of the project "Flora do Ceará: conhecer para conservar", this study aims to further investigate Onagraceae representatives in Ceará, by describing the morphological characters, updating the geographic distribution of species and preparing the identification key for group representatives.

Materials and Methods

This study was carried out in the state of Ceará, located in northeastern Brazil. Comparative analysis were performed on samples obtained through collections carried out between 2015 and 2017, as well as from specimens herborized in the botanical collections EAC, ESA, FUEL, HCDAL, HUEFS, HUVA, HVASF, INPA, K, MO, NY, P, RB, UFRN and US, acronyms according to Thiers (continuously updated).

To identify and describe the taxa, specialized bibliography was used (Munz 1947; Wagner & Hoch 2005; Wagner *et al*. 2007). The names of the authors and species nomenclatures follow IPNI (2019). The morphological characters used for the descriptions follow the terminology found in Munz (1947), Font Quer (1973), Radford *et al.* (1974), Rizzini (1977) and Wagner & Hoch (2005).

The collected material was herborized following techniques (Mori *et al.* 1985) and deposited in the EAC herbarium. The occurrences of the populations were obtained by consulting herbarium data and by field work with GPS, organized in maps (Fig. 1), generated using the QGIS program, version 3.10.0 (QGIS Development Team 2019). For the classification of vegetation type we used the Manual Técnico da Vegetação Brasileira of Instituto Brasileiro de Geografia e Estatística (IBGE 2012).

Results and Discussion

In the state of Ceará, Onagraceae is represented by seven species belonging to the *Ludwigia* genera: *L. erecta* (L.) H.Hara, *L. helminthorrhiza* (Mart.) H.Hara, *L. hyssopifolia* (G.Don) Exell, *L. leptocarpa* (Nutt.) H.Hara, *L. nervosa* (Poir.) H.Hara, *L. octovalvis* (Jacq.) P.H.Raven and *L. tomentosa* (Cambess.) H.Hara. The new occurrences of *L. nervosa* and *L. tomentosa* extend their spatial distribution to Ceará.

The identification of *Ludwigia* species through vegetative traits only, such as stem and leaf morphology, was not accurate since these organs present high phenotypic plasticity, which led to mistaken identifications of several specimens deposited in the herbariums. The use of floral organs, fruits and seeds to identify and differentiate taxa proved to be more adequate and accurate, thus solving the identification problems.

The occurrence of *L. affinis* in Ceará was not confirmed (BFG 2018), since no samples were found with the diagnostic characters of the specie,

and the material available in the Reflora Virtual Herbarium for Ceará was mistakenly identified, as it did not present the characters of *L. affinis*, but of *L. leptocarpa*.

The records of *L. nervosa* and *L. tomentosa* in Ceará are from historical collects. Due to the lack of new records for Ceará, it becomes questionable whether or not they occur in the

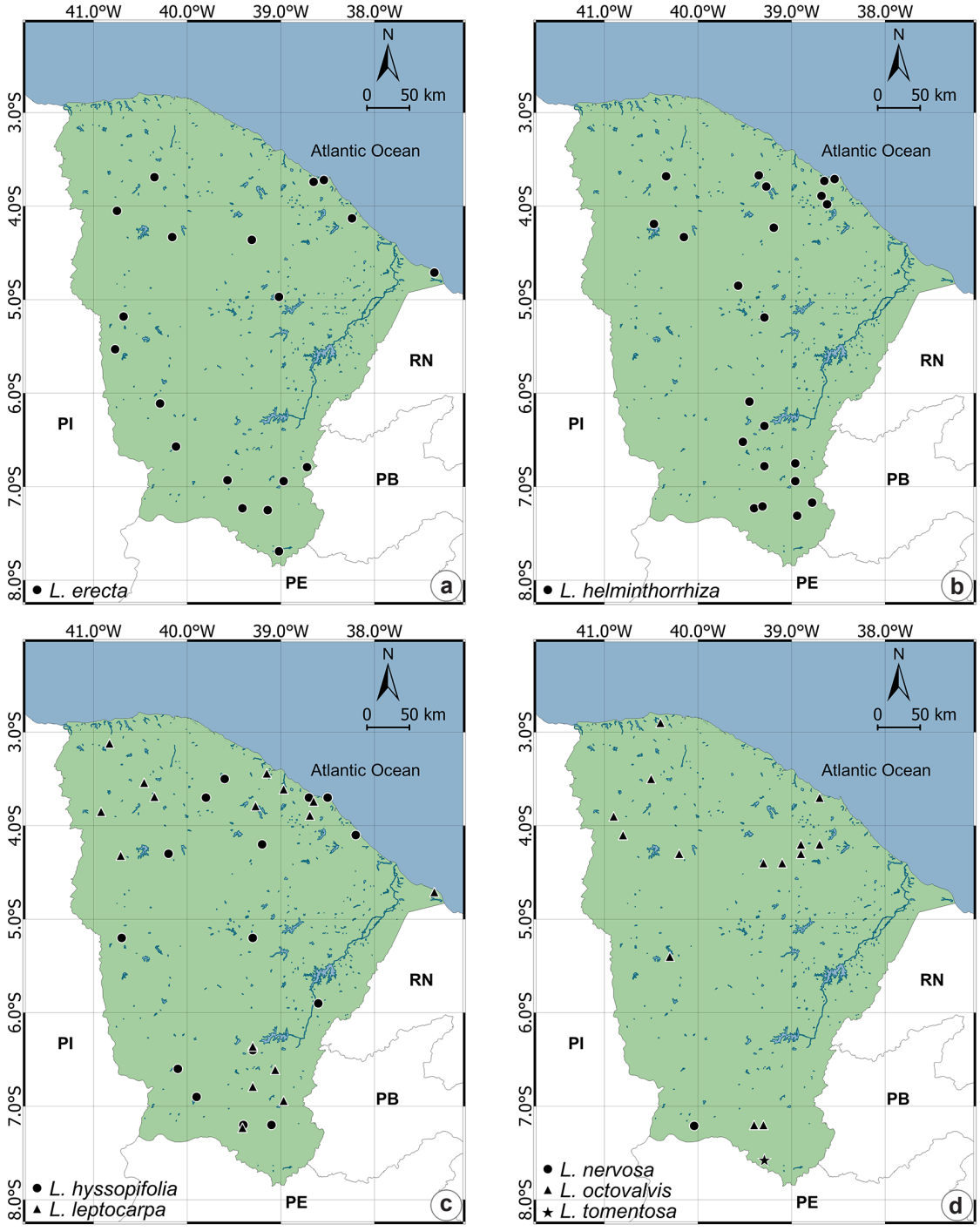

Figure 1 – Distribution of *Ludwigia erecta*, *L. helminthorrhiza*, *L. hyssopifolia*, *L. leptocarpa*, *L. nervosa*, *L. octovalvis* and *L. tomentosa* in Ceará state.

state. However, considering the existence of these collections, especially from an important collector like Gardner, it was decided to include both in this manuscript.

Regarding the occurrence, it is important to note that *L. erecta* and *L. helminthorrhiza* have a broader distribution, whereas *L. nervosa* and *L. tomentosa*, as they do not have other records in the area, are limited to the south of Ceará (Fig. 1). All seven species were found in Conservation Units, with *L. erecta* sampled in six of them.

Taxonomic treatment

Ludwigia L., Sp. Pl. 1:118 (1753).

Herbs to shrubs, helophytes. Spongy root fusiform present or not. Stem erect or prostrate, glabrous to hirsute. Leaves simple, alternate, petiole glabrous to hirsute, blade orbicular-oblong, lanceolate, elliptical or oblong, membranaceous to coriaceous, glabrous to hirsute, margin entire, apex rounded to acute, base acute. Flowers tetramerous to hexamerous, pedicel glabrous to hirsute; bracteoles in the pedicel or in the hypanthium, squamous or linear; hypanthium linear to obconic, glabrous to hirsute; sepals lanceolate-ovate, glabrous to hirsute; petals orbicular, obovate or elliptical, unguiculate, yellow or white with yellow macula at the base; nectariferous disc flat or elevated with trichomes; androecium diplostemonous and heterostemonous, the epipetals smaller than episepals; gynoecium with a stigma capitate, ovary inferior, the number of locules equal to the sepals, axial placentation. Capsule clavate or cylindrical or obconic, glabrous the hirsute. Seeds numerous, raphe inflated or not, ovoid, rounded, oblong or elliptical, embedded in pieces of endocarp or not.

Identification key for the species of *Ludwigia* in Ceará state

1. Stem prostrate; blade orbicular-oblong; petals white with yellow macula at base ..... 2. *Ludwigia helminthorrhiza*
1'. Stem erect; blade lanceolate, widely lanceolate, linear lanceolate, elliptical or oblong; petals yellow.
    2. Flowers pentamerous or hexamerous ..... 4. *Ludwigia leptocarpa*
    2'. Flowers tetramerous.
        3. Petals elliptical; seeds located in the lower region of the capsule embedded in endocarp and seeds in the upper region of the capsule not embedded in endocarp ..... 3. *Ludwigia hyssopifolia*
        3'. Petals obovate or orbicular; seeds located in the lower and upper region of the capsule not embedded in endocarp.
            4. Blade membranaceous; pedicel 1–5 mm long; petals obovate.
                5. Seeds rounded; raphe inflated to approximately the same width as the seed body. ..... 6. *Ludwigia octovalvis*
                5'. Seeds ovoids; raphe not inflated ..... 1. *Ludwigia erecta*
            4'. Blade coriaceous; pedicel 1–3 cm long; petals orbicular.
                6. Capsule clavate; seeds oblong and curved at the extremities ..... 5. *Ludwigia nervosa*
                6'. Capsule obconic; seeds elliptical ..... 7. *Ludwigia tomentosa*

1. *Ludwigia erecta* (L.) H.Hara, J. Jap. Bot. 28: 292 (1953). Figs. 1a; 2a-c; 3a; 4a

Herb to shrub. Spongy root fusiform absent. Stem erect, glabrous to puberulus. Leaves with petiole glabrous to puberulus, 1–2 cm long; blade lanceolate to widely lanceolate, membranaceous, glabrous to puberulus, apex acute, base acute, 15–20 secondary veins, 3–13 × 1–5 cm. Flowers tetramerous; pedicel glabrous to puberulus, 1–5 mm long; bracteoles at the apex of the pedicel, squamous ca. 0.5 mm long; hypanthium linear, glabrous to puberulus, 5–6 mm long; sepals lanceolate-ovate, glabrous to puberulus, 5 veins, 3–5 × 1–1.3 mm; petals obovate, unguiculate, yellow, 2.5–3.5 × 1.2–2 mm; nectariferous disc flat, with trichomes; androecium heterostemonous, the smallest ca. 1 mm long and the largest ca. 2 mm long, anthers 0.3–0.5 mm long; gynoecium with style 1 mm long, stigma capitated, ca. 1–1.5 mm wide. Capsule cylindrical, glabrous to puberulus, ca. 13–16 × 2–3 mm. Seeds without raphe inflated, ovoid, ca. 0.5 mm long, not embedded in endocarp.

Examined material: Aiuaba, Estação Ecológica de Aiuaba, 21.IX.1982, fr., *F.A. Viana* (EAC 11956); Aurora, Açude Cachoeira, 21.XI.2013, fr., *A.J. Rangel 06* (EAC). Canindé, Iguaçú, Riacho das Bananeiras, 04°36'25"S, 39°24'08"W, 26.VI.2008, fl. and fr., *M.F. Moro & M.O.T. Menezes 486* (EAC). Cascavel, Lagoa das Melancias, 14.X.2011, fr., *H.H.S. Gonzalez et al. 41* (EAC). Caucaia, Parque Botânico do Ceará, 27.V.1998,

Figure 2 – a-c. *Ludwigia erecta* – a. habit; b. flower; c. capsule. d-f. *L. helminthorrhiza* – d. habit; e. flower; f. capsule. (a. *A. Fernandes et al.* EAC 12686; b,c. *H.P. Nascimento 07*; d,e. *A.C. Albuquerque et al.* 32; f. *A.S.F. Castro 1152*).

fl. and fr., *E.B. Souza 263* (EAC). Crateús, RPPN Serra das Almas, 05°07'37"S, 40°25'32"W, 270 m, 9.V.2002, fl. and fr., *F.S. Araújo 1540* (EAC, UFRN). Crato, Açude Thomaz Osterne de Alencar, Cariri, 19.XII.2013, fl. and fr., *C.A. Amorim 10654* (HUEFS). Farias Brito, entre Várzea Alegre e Farias Brito, 17.V.1985, fl. and fr., *A. Fernandes et al.* (EAC 13181). Fortaleza, Parque do Cocó, 17.IX.1991, fr., *A. Fernandes & E. Nunes* (EAC 17680). Graça, Planalto da Ibiapaba, Cachoeira do Belizário, 04°06'26"S, 40°45'49"W, 18.IV.2015, fr., *E.B. Souza & J.M. Monteiro 3337* (EAC, HUVA). Icapuí, Morro Pintado, 04°45'01"S, 37°18'35"W, 12.X.2011, fr., *H.H.S. Gonzalez et al. 36* (EAC). Ipaumirim, Fazenda Bananeiras, 17.II.1958, fl. and fr., *P. Bezerra & J.G. Oliveira* (EAC 1794). Jati, Açude Atalho, Final do açude sentido Milagres, 07°40'39"S, 38°58'32"W, 409 m, 15.II.2012, fl. and fr., *V.M. Cotarelli 1309* (HVASF). Missão Velha, próximo ao Geoparque Araripe, 23.V.2017, fl. and fr., *H.P. Nascimento 07* (EAC). Novo Oriente, Morro dos Três Irmãos, 26.XII.1988, fr., *F.S. Araújo* (EAC 15719). Quixadá, 24.VII.1995, fl. and fr., *A.S.F. Castro* (EAC 23114). Santa Quitéria, Fazenda Itataia, Caminho p/ Alcantil, 20.IX.1984, fr., *A. Fernandes & E. Nunes* (EAC 12790). Sobral, Fazenda Macapá, Taperuaba, 25.V.1985, fr., *A. Fernandes* (EAC 13219). Tauá, Fazenda Boa Vista, 28.IV.1981, fr., *E. Nunes & M.A. Figueiredo* (EAC 10094).

Ludwigia erecta has tetramerous flowers with obovate petals and it can be confused with the floral characters of *L. octovalvis*. However, the main features that help to differentiate *L. erecta* are related to their seeds, which are ovoid with raphe not inflated, while *L. octovalvis* has rounded seeds with inflated raphe.

This species is found in a large part of the American continent, from the south-central region of Florida, in the United States to South America, commonly found in the Guianas, Venezuela, Colombia, Ecuador, Peru and Brazil, and has been introduced in Africa and Asia (Wagner & Hoch 2005). In Brazil, it has been found in the state of Goiás, the North (except Acre and Tocantins) to the Northeast (except Piauí and Rio Grande do Norte) and throughout the Southeast and South (BFG 2018). In Ceará populations of this species are commonly associated with aquatic environments and marshy soils, as well as urban areas. Also reported for Conservation Units of Estação Ecológica de Aiuaba, Parque Estadual Botânico do Ceará, RPPN Serra das Almas, Parque Estadual do Cocó, APA Serra da Ibiapaba and APA da Chapada do Araripe. In Ceará state, *L. erecta* is found in Vegetation Complex of the Coastal Zone, Semideciduous Seasonal Forest, Dense Ombrophylous Forest, Stepic Savanna, Arboreous Stepic Savanna and Vegetation under Fluvial and/or Lacustrine Influence.

The species present flowers and fruits throughout the year.

2. *Ludwigia helminthorrhiza* (Mart.) H.Hara, J. Jap. Bot. 28: 292 (1953). Figs. 1b; 2d-f; 3b; 4b

Herb. Spongy root fusiform present. Stem prostrate floating rooted or not to the substrate, glabrous. Leaves with petiole glabrous, 1–3 cm long; blade orbicular-oblong, subcoriaceous, glabrous, apex rounded to acute, base acute, 7–10 secondary veins, 1.5–4.5 × 1.3–3.5 cm. Flowers pentamerous; pedicel glabrous, 1–5 cm long; bracteoles along the pedicel or at the apex of this, squamous or linear, 3.5–5 mm long; hypanthium linear, glabrous, ca. 1 cm long; sepals lanceolate-ovate, glabrous, 5 veins, 5–7 × 2–3 mm; petals obovate, unguiculate, white with yellow macula at the base, ca. 1–1.5 × 0.7–1.2 cm; nectariferous disc flat, with trichomes; androecium heterostemonous, the smallest 3.5–4 mm long and the largest 6–7 mm long, anthers 1.4–1.7 mm length; gynoecium with style 4–6 mm long, stigma capitate, ca. 1.5 mm wide. Capsule cylindrical, glabrous, 13–20 × 2.5–3 mm. Seeds without raphe inflated, ovoid, ca. 1 mm long; embedded in angulus endocarp fully adhered to the seeds, 1.5–2 mm long.

Examined material: Acopiara, Açude em área urbana, 06°06'00"S, 39°26'00"W, 21.III.2002, fl., *A. Fernandes et al. 28788* (ESA). Aurora, Açude Cachoeira, 23.IX.2013, *A.J. Rangel 05* (EAC). Barro, km 443 da BR-116, 14.II.1985, fl., *E.M. Zardini & A.H. Gentry 2243* (US). Caridade, Fazenda Macario de Brito, 15.II.1997, fl., *M.S. Ferrucci 1143* (NY). Caucaia, Lagamar do Cauípe, 03°35'28"S, 38°46'49"W, 16.IV.2016, *H.P. Nascimento 01* (EAC). Crato, Lagoa da Cotia, 07°04'43"S, 39°29'26"W, 11.VI.2015, fl., *A.C. Albuquerque et al. 32* (EAC). Fortaleza, Parque do Cocó, 07.VIII.2011, *L.Q. Matias 607* (EAC). Iguatu, Sítio Solidão II (D13), 06°30'18"S, 39°14'02"W, 13.V.2015, fl., *L. Ibiapina-Santos et al. 83* (EAC). Juazeiro do Norte, Açude dos Carneiros, 07°08'21"S, 39°19'34"W, 13.VI.2015, fl., *A.C. Albuquerque et al. 69* (EAC). Jucás, próx. à ponte sobre o Rio Jaguaribe CE284, 05.IV.2000, fl., *P.G. Delprete et al. 507* (EAC). Lavras da Mangabeira, Açude Rosário, 07.II.2013, *A.S. Dias* (EAC 54026). Madalena, Reservatório Pau Branco, 04°53'47,5"S, 39°29'05,7"W, 30.VIII.2014, *T. Rocha 02* (EAC). Maranguape, 06.XI.1935, fl. and fr., *F.E. Drouet 2685* (NY, US). Milagres, Barragem do riacho dos Porcos, 31.III.2000, fl., *E.B. Souza et al. 492* (EAC). Pacatuba, Rod. CE-021, 04°07'00"S, 38°39'00"W, 90 m, 17.III.2002, fl. and fr., *V.C. Souza*

et al. 28665 (ESA). Pentecoste, Fazenda Vale do Curú, 03°49'15"S, 39°20'35"W, 6.X.2011, *M.I.B. Loiola 1418* (EAC). Quixeramobim, 27.VII.1995, fl. and fr., *A.S.F. Castro & L.W. Lima-Verde* (EAC 23187). Santa Quitéria, Açude Edson Queiroz, 1.VI.2011, fl., *M.E.F. Rodrigues 731* (ESA, RB). Sobral, Rio Acaraú, 8.XI.2007, fr., *L.Q. Matias et al. 569* (EAC). Umirim, 03°43'22"S, 39°22'14"W, 23.VII.2017, fl., *A.C. Albuquerque 265* (EAC). Varjota, Açude Araras, 30.VI.2010, fl., *J.R.A. Paiva & L.Q. Matias 7* (EAC). Várzea Alegre, Lagoa Azul, 06°47'27"S, 39°19'59"W, 10.VI.2015, fl., *A.C. Albuquerque et al. 19* (EAC).

Ludwigia helminthorrhiza can easily be characterized by its spongy roots fusiform (which help it float), its stem prostrate on the water blade, leaves orbicular, and its flowers with corolla white with yellow macula at the base.

Ludwigia helminthorrhiza is distributed throughout Central America, occurring in El Salvador, Belize, Honduras, Panama and southern Mexico, and throughout South America (Wagner & Hoch 2005). In Brazil, it has been reported in the Northern region (less in Acre and Roraima), in the Northeast region (except Piauí), and in the states of Mato Grosso do Sul, Mato Grosso, Rio de Janeiro and Paraná (BFG 2018). Populations of this species found in flooded environments, mainly in lentic systems, both temporary and permanent. Also reported for Conservation Units of APA do Lagamar do Cauípe and Parque Estadual do Cocó. In Ceará state, *L. helminthorrhiza* is found in Vegetation Complex of the Coastal Zone, Semideciduous Seasonal Forest, Dense

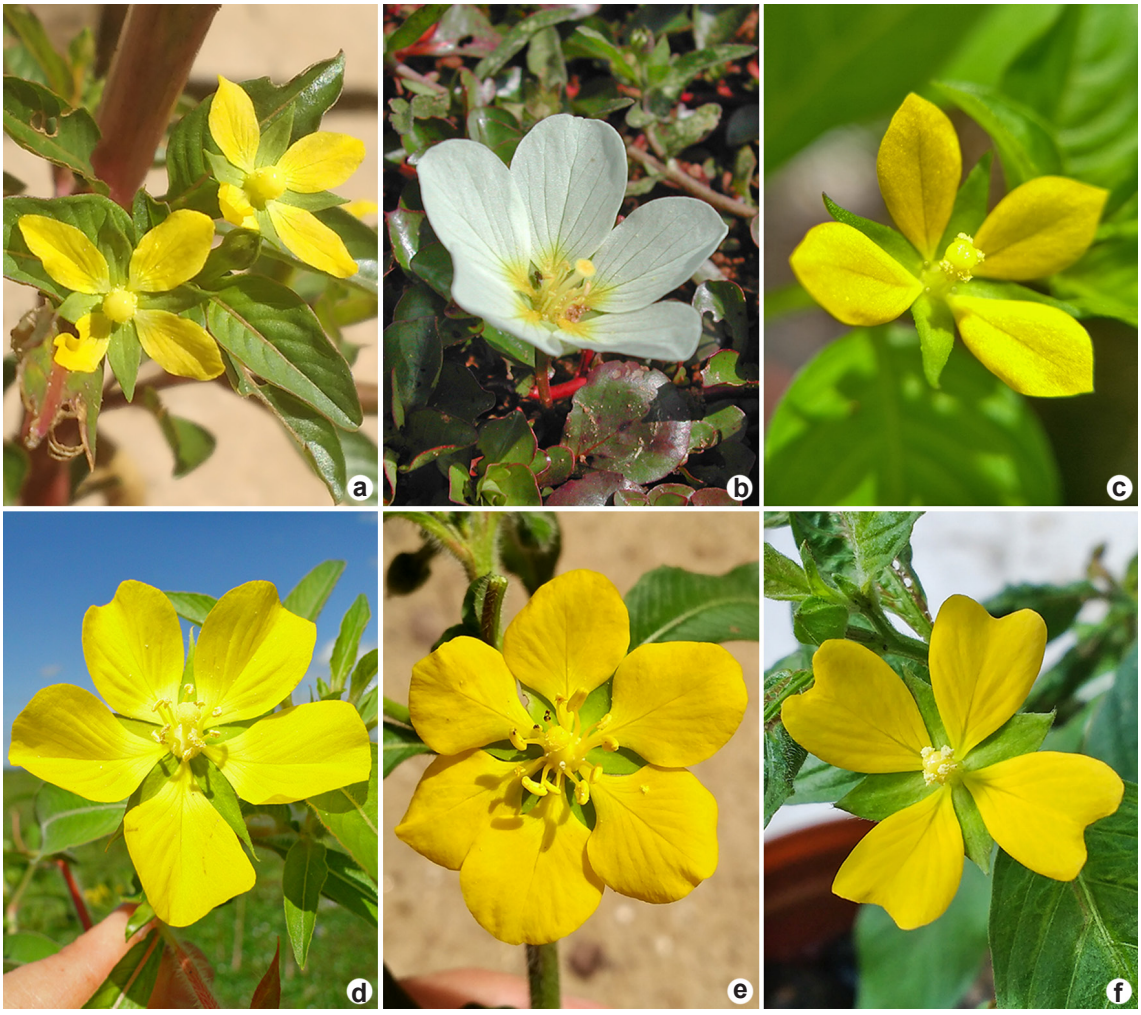

Figure 3 – a-f. Flowers of *Ludwigia* species occuring in Ceará – a. *L. erecta*; b. *L. helminthorrhiza*; c. *L. hyssopifolia*; d-e. *L. leptocarpa*; f. *L. octovalvis*.

Ombrophylous Forest, Savanna, Stepic Savanna, Arboreous Stepic Savanna and Vegetation under Fluvial and/ or Lacustrine Influence.

The species present flowers and fruits throughout the year.

3. *Ludwigia hyssopifolia* (G.Don) Exell, Garcia de Orta v. 471 (1957). Figs. 1c; 3c; 4c; 5a-b

Herb to shrub. Spongy root fusiform absent. Stem erect, glabrous. Leaves with petiole glabrous, 0–0.5 mm long; blade lanceolate, membranaceous, glabrous, apex acute, base acute, 13–16 secondary veins, 4–10 × 1–3 cm. Flowers tetramerous; pedicel glabrous, 3–5 mm long; bracteoles at the top of the hypanthium, squamous, ca. 0.6 mm long; hypanthium linear, glabrous, 2.5–5 mm long; sepals lanceolate-ovate, glabrous, 3 veins, ca. 4 × 1.5 mm; petals elliptical, unguiculate, yellow, ca. 5 × 1.5 mm; nectariferous disc flat, with trichomes; androecium heterostemonous, the smallest ca. 1.5 mm long and the largest ca. 2 mm long, anthers ca. 0.3–0.5 mm long; gynoecium with style 1.5 mm long, stigma capitate, ca. 0.8 mm wide. Capsule cylindrical slightly enlarged in the upper region, glabrous, 1.8–2.6 × 0.1 cm at the base of the capsule and 0.2 cm at the apex of the capsule. Seeds without raphe inflated, those located in the lower region of the capsule ovoid, ca. 1 mm long; embedded in angulus endocarp, ca. 1 mm long; seeds located in the upper region of the capsule ovoid, ca. 0.7 mm long; not embedded in endocarp.

Examined material: Assaré, 06°50'24"S, 39°57'35,9"W, 31.V.2014, fl. and fr., *M. Mayer 272* (EAC). Aiuaba, Estacão Ecológica de Aiuaba, Riacho do Caldeirão, 06°35'00"S, 40°07'00"W, 400 m, 6.VIII.1996, fr., *E.L. Paula-Zárate et al. 269* (EAC, HUEFS). Amontada, Distrito de Salgadinho, 03°19'22"S, 39°49'29"W, 7.IX.2013, fl. and fr., *M.I.B. Loiola et al. 2086* (EAC). Caridade, Rio Coreaú, 21.VI.2008, fl. and fr., *D.J.L. Sousa et al.* (EAC 43582). Cascavel, Choró vaquejador, 17.V.1998, fl. and fr., *M.S. Lopes* (EAC 27696). Caucaia, Parque Botânico de Caucaia, 17.IV.1998, fl. and fr., *L.Q. Matias 85* (EAC). Crateús, Grajaú, Serra das Almas, VII.2004, fr., *K.M.E. Linhares 51* (EAC). Crato, Açude Umari, 07°06'58"S, 39°28'58"W, 12.VI.2015, fl. and fr., *A.C. Albuquerque et al. 61* (EAC). Fortaleza, Campus do Pici - UFC, 14.VI.2016, fr., *F.G. Santos 337* (EAC). Iguatu, Sítio Zé Firmo (E20), 06°25'29"S, 39°08'53"W, 14.V.2015, fl. and fr., *L. Ibiapina-Santos et al. 107* (EAC). Irauçuba, VII.2007, fr., *C.D.S. Pessoa 84* (EAC). Jaguaribe, Pitombeira, 13.VIII.1994, fl. and fr., *D. Macêdo & E.L. Paula-Zárate 10* (EAC). Missão Velha, próximo ao Geoparque Araripe, 23.V.2017, fl. and fr., *H.P. Nascimento 08* (EAC). Quixeramobim, estrada de Bonfim para Quixeramobim, 05°13'00"S, 39°14'00"W, 6.VI.1984, fl. and fr., *J.E.R. Collares & L. Dutra 185* (NY, RB). Santa Quitéria, 2,8 km NW (em linha reta) da sede da fazenda Itataia, arredores de açude, 04°33'30,2"S, 39°48'48,3"W, 25.IV.2012, fl. and fr., *J. Paula-Souza et al. 10974* (EAC, RB).

The presence of flowers with elliptical petals, seeds embedded in endocarp in the lower part of the capsule and seeds not embedded in endocarp in the upper part are the main characteristics that distinguishes *Ludwigia hyssopifolia* from the other species in Ceará state.

Ludwigia hyssopifolia is a pantropical species of unknown origin (Wagner *et al*. 2007) and its populations are found throughout Brazil, except in the states of Rio Grande do Norte, Sergipe, Mato Grosso do Sul, Espirito Santo, Santa Catarina and Rio Grande do Sul (BFG 2018). For Ceará, *L. hyssopifolia* has been collected in 15 municipalities, present in a large portion of the state, also reported for Conservation Units of Estação Ecológica de Aiuaba, Parque Estadual Botânico do Ceará, RPPN Serra das Almas and APA da Chapada do Araripe. Occurring in marshy environments or those that flood at a certain time of the year. In Ceará state, *L. hyssopifolia* is found in Vegetation Complex of the Coastal Zone, Semideciduous Seasonal Forest, Dense Ombrophylous Forest, Stepic Savanna, Arboreous Stepic Savanna and Vegetation under Fluvial and/ or Lacustrine Influence.

The species present flowers and fruits throughout the year.

4. *Ludwigia leptocarpa* (Nutt.) H.Hara, J. Jap. Bot. 28: 292 (1953). Figs. 1c; 3d-e; 4d; 5c-e

Herb to shrub. Spongy root fusiform absent. Stem erect, hirsute. Leaves with petiole glabrous to hirsute, 0–2 mm long; blade lanceolate to linear lanceolate, membranaceous, glabrous to hirsute mainly in the central vein, apex acute, base acute, 15–25 secondary veins, 4–14.5 × 1–2.3 cm. Flowers pentamerous to hexamerous; pedicel hirsute, 1–1.5 cm long; bracteoles at the apex of the pedicel, linear, ca. 3 mm long; hypanthium linear, hirsute, 1.5–1.8 cm long; sepals lanceolate–ovate, hirsute, 5 veins, 10–13 × 3–3.2 mm; petals obovate, unguiculate, yellow, ca. 1.5 × 1.2 cm; nectariferous disc elevated, with trichomes; androecium heterostemonous, the smallest 4–5 mm long and the largest 6–7 mm long, anthers 2–3 mm long; gynoecium with style 4.5–5 mm long, stigma capitated, ca. 1. 3–1.5 mm wide. Capsule cylindrical, hirsute, ca. 25–55 × 2.5–3 mm. Seeds

without raphe inflated, ovoid, ca. 1 mm long; embedded in horseshoe-shaped endocarp, ca. 1–1.5, mm long.

Examined material: Aurora, Açude Cachoeira, 24.II.2014, fl. and fr., *A.J. Rangel 07* (EAC). Caucaia, Lagamar do Cauípe, na lagoa costeira do Cauípe, 03°35'28,4"S, 38°46'49,5"W, 16.IV.2016, fl., *H.P. Nascimento 02* (EAC). Cedro, Sítio Solidão III (D14), 06°30'02"S, 39°13'02"W, 13.V.2015, fl., *L. Ibiapina-Santos et al. 75* (EAC). Crato, 11.VIII.1993, fr., *M.A. Figueiredo & M.F. Mata* (EAC 20047). Granja, barragem Lima Brandão, em frente ao memorial D.C. Prado, 19.VII.2014, fl. and fr., *M.I.B. Loiola & E.A. Lima Junior 2396* (EAC). Icapuí, Morro Pintado, 04°45'01,4"S, 37°18'35,8"W, 12.X.2011, fl. and fr., *H.H.S. Gonzalez et al. 40* (EAC). Iguatu, Lagoa do Baú, 06°24'17,4"S, 39°10'32,7"W, 6.IX.2009, fl. and fr., *L.Q. Matias et al. 581* (EAC). Ipu, Bica do Ipu, 19.XII.1979, fl. and fr., *P. Martins & E. Nunes* (EAC 7875). Maranguape, 31.X.1935, fl. and fr., *F.E. Drouet 2654* (MO, NY). Meruoca, Sítio santo Antonio, 25.II.1981, fl. and fr., *A. Fernandes & P. Martins* (EAC 9712). Paraipaba, Lagoinha (APA), 16.VIII.2003, fr., *D.V. Azevedo 24* (EAC). Pentecoste, Rio Curu, 27.IX.2012, fl. and fr., *L. Ibiapina-Santos et al. 01* (EAC). São Gonçalo do Amarante, Pecém, 11.XI.2007, fl. and fr., *M.F. Moro et al. 308* (EAC). Sobral, Rio Acaraú, base Cagece, 8.XI.2007, fl., *L.Q. Matias et al. 569* (EAC). Ubajara, Quênio do frade, 7.XI.2008, fl. and fr., *L.Q. Martins et al. 549* (EAC). Várzea Alegre, Lagoa Azul, 06°47'27"S, 39°19'59"W, 10.VI.2015, fl., A.C. *Albuquerque et al. 24* (EAC).

The presence of a horseshoe-shaped endocarp surrounding its seeds and its flowers

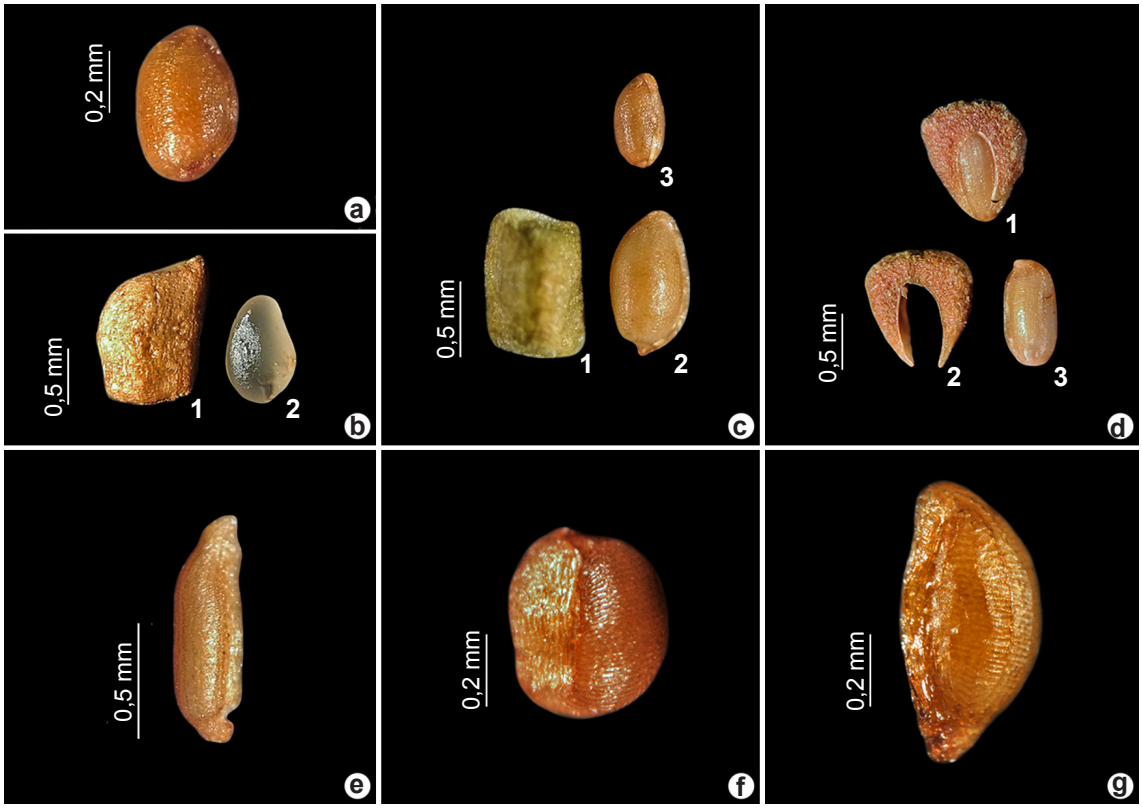

Figure 4 – a-g. Seeds and endocarps of *Ludwigia* species occuring in Ceará – a. *L. erecta* seed not embedded in endocarp; b. *L. helminthorrhiza* (1 = seed embedded in endocarp; 2 = seed withdrawn from endocarp); c. *L. hyssopifolia* (1 = seed embedded in endocarp located in lower region of the capsule; 2 = seed of lower region of the capsule withdrawn from endocarp; 3 = seed located in upper region of the capsule not embedded in endocarp); d. *L. leptocarpa* (1 = seed embedded in endocarp; 2 = horseshoe-shaped endocarp; 3 = seed withdrawn from endocarp); e. *L. nervosa* seed not embedded in endocarp; f. *L. octovalvis* seed not embedded in endocarp; g. *L. tomentosa* seed not embedded in endocarp. (a. *E.B. Souza & J.M. Monteiro 3337*; b. *L.Q. Matias et al. 569*; c. *L. Ibiapina-Santos et al. 107*; d. *L. Ibiapina-Santos et al. 22*; e. *A.S.F. Castro 261*; f. *A. Fernandes et al.* EAC 5086; g. *A. Fernandes & Matos* EAC 11304).

pentamerous or hexamerous with yellow corolla are the main characteristics that differentiate *Ludwigia leptocarpa* from the other species in Ceará. The shape of the blade and the width of the raphe in relation to the seed are the main characters that differentiate it from *L. affinis*, because *L. leptocarpa* has blade lanceolate to lanceolate linear and raphe from 1/6 to 1/8 of the seed width, while *L. affinis* has blade oval or elliptical and raphe from 1/3 to 1/4 of the seed width (Munz 1947; Wagner & Hoch 2005). No analyzed material presented the diagnostic characteristics of *L. affinis*, discarding its occurrence in Ceará.

Ludwigia leptocarpa presents records for Africa and America, and on the American continent occurs from the United States to South America, also reported throughout the Brazilian territory (Wagner & Hoch 2005; BFG 2018). The populations that occur in Ceará may present branches older glabrous, so in order to show the indument of the stem it is important to observe the younger branches. It is usually associated with other species of the family, occurring at the edge of aquatic environments or in humid soils, throughout the extension of the study area. Also reported for Conservation Units of APA do Lagamar do Cauípe, APA da Bica do Ipú, APA das Dunas da Lagoinha and Parque Nacional de Ubajara. In Ceará state, *L. leptocarpa* is found in Vegetation Complex of the Coastal Zone, Semideciduous Seasonal Forest, Dense Ombrophylous Forest, Stepic Savanna, Arboreous Stepic Savanna and Vegetation under Fluvial and/ or Lacustrine Influence.

The species present flowers and fruits throughout the year.

5. *Ludwigia nervosa* (Poir.) H.Hara, J. Jap. Bot. 28: 293 (1953). Figs. 1d; 4e; 5f-g

Herb to shrub. Spongy root fusiform absent. Stem erect, hirsutulous. Leaves with petiole hirsutulous, 0–2 mm long; blade lanceolate to oblong, coriaceous, hirsutulous, apex acute to obtuse, base acute, 9–11 secondary veins, 4–4.5 × 0.6–0.9 cm. Flowers tetramerous; pedicel hirsutulous, ca. 1–1.5 cm long; bracteoles at the apex of the pedicel, linear, ca. 2 mm long; hypanthium obconic, hirsutulous, 7 mm long; sepals lanceolate-ovate, hirsutulous, 5 veins, ca. 8.5 × 3 mm; petals orbicular, short unguiculate, yellow, ca. 8.5 × 9 mm; nectariferous disc elevated, with trichomes; androecium heterostemonous, the smallest ca. 5 mm long and the largest ca. 7 mm long, anthers ca. 2–6 mm long; gynoecium with style 2 mm long, stigma capitate, ca. 1.3 mm wide. Capsule clavate, hirsutulous, ca. 1–1.5 × 0.3–0.5 cm. Seeds without raphe inflated, oblong and lightly curved at the extremities, ca. 1 mm long; not embedded in endocarp.

Examined material: Serra de Araripe, 1838, fl. and fr., *Gardner 1598* (NY, P).

Additional material: BRASIL. MARANHÃO: BR-230, entre Butirama e São Domingos, 22.IV.1980, fl. and fr., *A. Fernandes & E. Nunes* (EAC 8490). Timon, 17.X.1996, fl. and fr., *A.S.F Castro 261* (EAC).

Ludwigia nervosa has coriaceous blade and tetramerous flowers with orbicular petals and it can be confused with *L. tomentosa*. However, *L. nervosa* has capsules singularly clavate and oblong seeds characteristically curved at the extremities. On the other hand, the capsules of *L. tomentosa* are obconic with elliptical seeds.

Ludwigia nervosa occurs from Central America, in Mexico, to South America, associated with Cerrado wetlands (Wagner & Hoch 2005). In Brazil, it has not been confirmed in the states of Acre, Rio Grande do Sul, Santa Catarina, Sergipe, Alagoas, Paraíba, Rio Grande do Norte and Ceará (BFG 2018). Therefore, this occurrence of *L. nervosa* is new for the state of Ceará, with only one record by Gardner in 1838, which were collected in the Serra de Araripe, without exact locations. Since then, no records have been obtained for the state, indicating a more restricted occurrence of *L. nervosa* in southern Ceará, probably in Conservation Unit of APA da Chapada do Araripe.

The species present flowers and fruits throughout the year.

6. *Ludwigia octovalvis* (Jacq.) P.H.Raven, Kew Bull. 15(3): 476. (1962). Figs. 1d; 3f; 4f; 5h-i

Herb to shrub. Spongy root fusiform absent. Stem erect, glabrous to hirsute. Leaves with petiole glabrous to hirsute, 0–2 mm long; blade lanceolate to linear lanceolate, membranaceous, glabrous to hirsute mainly in the central vein, apex acute, base acute, 10–22 secondary veins, 4.3–20 × 0.5–4 cm. Flowers tetramerous; pedicel glabrous to hirsute, 3–5 mm long; bracteoles at the apex of the pedicel or along the hypanthium, squamous, ca. 1 mm long; hypanthium linear, glabrous to hirsute, 1.7–2 cm long; sepals lanceolate–ovate, glabrous to hirsute, 5 veins, ca. 7 × 3 mm; petals obovate, unguiculate, yellow, ca. 7–8 × 5–6 mm; nectariferous disc flat, with trichomes; androecium heterostemonous, the

smallest ca. 3 mm long and the largest ca. 3.5 mm long, anthers ca. 0.5 mm long; gynoecium with style 2–2.6 mm long, stigma capitate, 1–2 mm wide. Capsule cylindrical, glabrous to hirsute, ca. 25–35 × 2–3 mm. Seeds with raphe inflated, rounded, 0.5–0.7 mm long; not embedded in endocarp.

Examined material: Aratuba, Sítio Pindora, 18.X.1979, fr., *E. Nunes & A.J. Castro* (EAC 7128). Baturité, Serra de Baturité, 27.VIII.1989, fr., *A. Fernandes et al.* (EAC 16031). Canindé, Iguaçu, 04°36'25,3"S, 39°24'08"W, 27.VI.2008, fl. and fr., *M.F. Moro & M.O.T. Menezes 502* (EAC). Caucaia, Lagamar do Cauípe, na lagoa costeira do Cauípe, 03°35'28,4"S, 38°46'49,5"W,

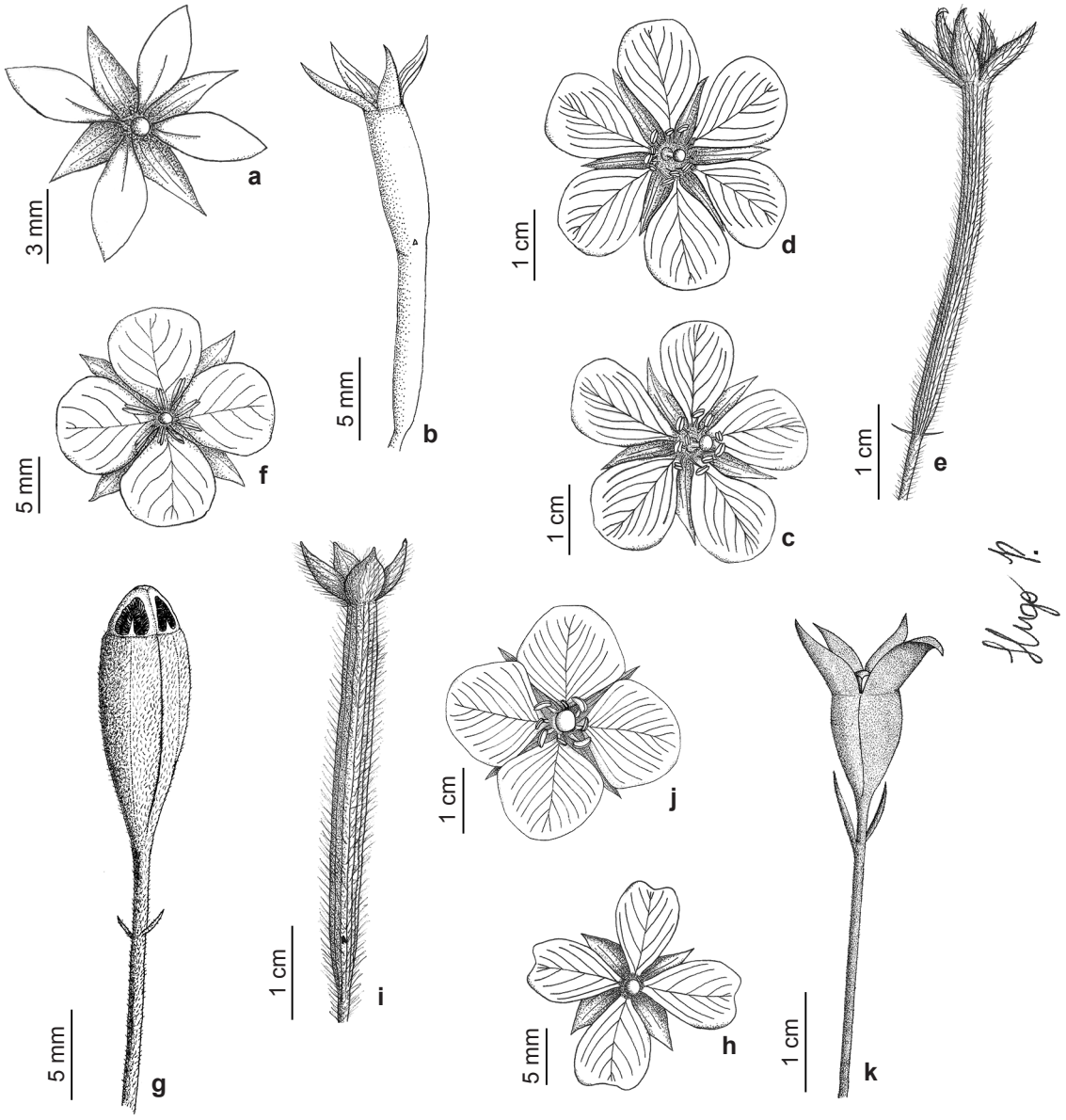

Figure 5 – a-b. *Ludwigia hyssopifolia* – a. flower; b. capsule. c-e. *L. leptocarpa* – c. flower pentamerous; d. flower hexamerous; e. capsule. f-g. *L. nervosa* – f. flower; g. capsule. h-i. *L. octovalvis* – h. flower; i. capsule. j-k. *L. tomentosa* – j. flower; k. capsule. (a,b,c,d,h. *H.P. Nascimento 04, 06, 08*; e. *A.J. Rangel 07*; f. *A. Fernandes & E. Nunes* EAC 8490; g. *Gardner 1598*; i. *A. Fernandes et al.* EAC 5086; j. *A. Fernandes & Matos* EAC 11304, *Gardner 2571*; k. *Gardner 1949*).

16.IV.2016, fl., *H.P. Nascimento 03* (EAC). Crato, Macaíbas, 27.VII.2001, fr., *E. Silveira.* (EAC 30840). Graça, Planalto da Ibiapaba, Cachoeira do Belizário, 04°06'26"S, 40°45'49"W, 18.IV.2015, fl. and fr., *E.B. Souza & A. Cunha* (EAC 58636, HUVA). Guaramiranga, Serra de Baturité, IX.1897, fl. and fr., *J.E. Huber HG208* (INPA). Independência, BR-226, 05°24'13,5"S, 40°19'23,4"W, 12.V.2011, fl. and fr., *L.Q. Matias et al. 616* (EAC). Jijoca de Jericoacoara, 5.V.2000, fl. and fr., *L.Q. Matias 261* (EAC). Juazeiro do Norte, Lagoa próxima ao Açude dos Carneiros, 07°09'32"S, 39°19'53"W, 13.VI.2015, fl. and fr., *A.C. Albuquerque et al. 81* (EAC). Meruoca, Serra da Meruoca, 12.XI.2002, fl. and fr., *A. Fernandes* (EAC 32218). Pacoti, Sítio Pirajá, 20.XII.1940, fl., *B. Landim 34* (EAC). Redenção, 14.IX.1935, fr., *F.E. Drouet 2466* (US). Santa Quitéria, 16.IV.2011, fl. and fr., *M.E.F. Rodrigues 698* (ESA). Ubajara, Perto do Riacho Cafundó, 2.XI.1978, fr., *A. Fernandes et al.* (EAC 5086).

The main feature to identification of *L. octovalvis* is their rounded seeds with inflated raphe, not embedded in endocarp. Although the flowers of *L. octovalvis* are similar to *L. erecta* flowers, its seeds are morphologically different (see comments above).

Ludwigia octovalvis has pantropical distribution and in Brazil has been recorded in all states (Wagner & Hoch 2005; BFG 2018). Its populations are distributed in various aquatic and wetland environments in Ceará, also reported for Conservation Units of APA da Serra de Baturité, APA do Lagamar do Cauípe and Parque Nacional de Ubajara, usually occurring with other representatives of the group. In Ceará state, *L. octovalvis* is found in Vegetation Complex of the Coastal Zone, Semideciduous Seasonal Forest, Dense Ombrophylous Forest, Stepic Savanna, Arboreous Stepic Savanna and Vegetation under Fluvial and/or Lacustrine Influence.

The species present flowers and fruits throughout the year.

7. *Ludwigia tomentosa* (Cambess.) H.Hara, J. Jap. Bot. 28: 294 (1953). Figs. 1d; 4g; 5j,k

Shrub. Spongy root fusiform absent. Stem erect, hirsutulous. Leaves with petiole hirsutulous, 0.2–0.3 cm long; blade elliptical to oblong, coriaceous, hirsutulous, apex acute, base acute, 18–23 secondary veins, 5.5–10 × 3.3 cm. Flowers tetramerous; pedicel hirsutulous, 2–3 cm long; bracteoles at the apex of the pedicel, linear, ca. 7 mm long; hypanthium obconic, hirsutulous, ca. 5 mm long; sepals lanceolate-ovate, hirsutulous, 5 veins, 10–13 × 3–4 mm; petals orbicular, unguiculate, yellow, ca. 1.7 × 1.8 cm; nectariferous disc elevated, with trichomes; androecium heterostemonous, the smallest ca. 2.5 mm long and the largest ca. 3.5 mm long, anthers 2–3 mm long; gynoecium with style 2 mm long, stigma capitate, ca. 3 mm wide. Capsule obconic, hirsutulous, ca. 13 × 8 mm. Seeds without raphe inflated, elliptical, ca. 1 mm long; not embedded in endocarp.

Examined material: Jardim, 1838, fl. and fr., *Gardner 1949* (K).

Additional material: BRASIL. BAHIA: Boninal, Povoado Furados, 28.XII.2014, fr., *N.X.M. Sousa 71* (HUEFS). Formosa do Rio Preto, Fazenda Embiraçu, 15.V.1982, fl. and fr., *A. Fernandes & Matos* (EAC 11304, MO 3324947). PIAUÍ: Parnaguá, 1841, fl. and fr., *Gardner 2571* (K).

Ludwigia tomentosa is characterized by its capsules obconic and also by its seeds elliptical, not embedded in endocarp. *L. tomentosa* and *L. nervosa* have similar flowers, but their capsules and seeds are very different (see comments above).

The species has been reported only in South America, from the Eastern Bolivia to Brazil (Wagner & Hoch 2005). In Brazil, it occurs in Tocantins, Bahia, Distrito Federal, Goiás, Mato Grosso do Sul, Mato Grosso, Minas Gerais and São Paulo (BFG 2018). *L. tomentosa* is commonly found in Cerrado wetlands (Wagner & Hoch 2005).

Analyzing the material collected by Gardner, deposited in Kew, we found a sample of *L. tomentosa* collected in Ceará in 1838 in the municipality of Jardim (formerly Barra do Jardim), constituting a new occurrence for the state. Its occurrence is restricted to the south of the study area, probably in Conservation Unit of APA da Chapada do Araripe.

The species present flowers and fruits throughout the year.

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List of exsiccates

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