Flora of the cangas of Serra dos Carajás, Pará, Brazil: Plantaginaceae

André Vito Scatigna1,3 & Nara Furtado de Oliveira Mota2

Abstract
This is a taxonomic study of the species of Plantaginaceae from the cangas of Serra dos Carajás, Pará, Brazil. We recorded five species, all members of the tribe Gratioleae: Bacopa monnierioides, B. myriophylloides, B. reflexa, Scoparia dulcis and Stemodia verticillata. All five species are widespread in Brazil, and B. myriophylloides is here cited for the first time for the State of Pará. We present detailed descriptions, illustrations, photographs and notes on morphology, distribution and phenology of these species.

Key words: Aquatic plants, FLONA Carajás, Gratioleae, Scrophulariaceae, taxonomy.

Resumo
Este é um estudo taxonômico das espécies de Plantaginaceae das cangas da Serra dos Carajás, Pará, Brasil. Registramos cinco espécies, todas membros da tribo Gratioleae: Bacopa monnierioides, B. myriophylloides, B. reflexa, Scoparia dulcis e Stemodia verticillata. Todas as espécies apresentam ampla distribuição no Brasil, sendo B. myriophylloides referida aqui pela primeira vez para o Estado do Pará. Apresentamos descrições detalhadas, ilustrações, fotografias e comentários sobre morfologia, distribuição geográfica e fenologia destas espécies.

Palavras-chave: Plantas aquáticas, FLONA Carajás, Gratioleae, Scrophulariaceae, taxonomia.

Plantaginaceae
Plantaginaceae Juss. has a worldwide distribution, with approximately 100 genera and 2,000 species, currently comprising several genera formerly placed within Scrophulariaceae sensu lato (Wettstein 1908; Albach et al. 2005). This Lamiales family is highly heterogeneous, including specialized aquatic herbs, chasmophytic subshrubs and even carnivorous species with unique morphology (Albach et al. 2005; Souza et al. 2009; Scatigna et al. 2015). In Brazil, 25 genera and ca. 140 species are currently recognized (BFG 2015). In Serra dos Carajás, we recorded three species of Bacopa Aubl., one species of Scoparia L. and one species of Stemodia L., all representatives of the Gratioleae, a mainly Neotropical tribe (Estes & Small 2008).

Key to the genera of Plantaginaceae in the cangas of Serra dos Carajás

1. Aquatic or amphibious; calyx with unequal sepals or, if equal to sub-equal, then leaves pinnatifid ....
1. Bacopa

1’. Terrestrials; calyx with equal to sub-equal sepals and leaves entire ......................................................... 2

2. Corolla 4-lobed, rotaceous; calyx tetramerous; thecae not separated by the connective ...........

2’. Corolla 5-lobed, bilabiate; calyx pentamerous; thecae separated by the connective ...................

2. Scoparia

3. Stemodia
1. **Bacopa** Aubl.

*Bacopa* comprises aquatic or amphibian herbs with highly variable leaf morphology, blades entire, linear, elliptical, ovate or orbicular, or even pinnatifid; calyx pentamericous with free, usually unequal, rarely equal to sub-equal, sepals; corolla 5-lobed, bilabiate or slightly rotaceous; stamens 4 (rarely 2, 3 or 5) (Pennell 1946; Souza & Giulietti 2009). The genus, with ca. 50 species is one of the largest within the tribe Gratioleae, with Tropical distribution, chiefly in the New World (Souza & Giulietti 2009). In Brazil, 26 species are currently recognized (BFG 2015), three of which recorded in areas of canga of Serra dos Carajás.

**Key to the species of Bacopa in the cangas of Serra dos Carajás**

1. Leaves pinnatifid; sepals equal to sub-equal; ovary glandular-puberulent .......... 1.3. *Bacopa reflexa*

1’. Leaves entire; sepals unequal; ovary glabrous.

2. Leaves opposite, narrowly ovate to lanceolate; flowers fasciculate, sessile or short-pedicellate; corolla tube externally glabrous

1.1. *Bacopa monnierioides*

1.2. *Bacopa myriophylloides*

2’. Leaves whorled, linear-lanceolate, falcate; flowers solitary, pedicellate; corolla tube externally glandular-pubescent

1.1. **Bacopa monnierioides** (Cham.) B.L.Rob. Proc. Amer. Acad. Arts 44(21): 614. 1909.

Herbs, aquatic or amphibious, 3–30 cm long. Stems prostrate, ascendent or erect, simple or branched, usually terete, glabrous to densely glandular-puberulent towards the apex, rarely sparsely pubescent. Leaves opposite, glabrous, markedly glandular-punctate, sessile, narrowly-ovate to lanceolate, apex acute, base truncate, sub-amplexicaul, margin entire, 2–20 × 1–5 mm. Flowers axillary, fasciculate, sessile or short-pedicellate, bi-bracteolate, emersed; pedicel ascending during anthesis, descending when fruiting, glandular-puberulent, glabrescent, 3 mm long; bracteoles 2, opposite, glandular-punctate, linear-lanceolate, ca. 0.5 mm long.

Sepals unequal, glandular-puberulent, outer ovate, apex acute, base rounded, 2–3 × 1–12 mm, inner linear-lanceolate, apex acute, 2–3 × 0.2–0.3 mm, dimensions doubling when fruiting. Corolla lilac-blue to blue; tube externally glabrous, 1–3 mm long; lobes orbicular-obovate, ca. 1 mm long. Stamens 4, reaching or slightly exserted above the throat. Ovary globose, ca. 0.75 × 0.8 mm, glabrous, style filiform, 1.2–2 mm long, stigma subglobose. Capsule ovoid ca. 2 × 1.5 mm.

**Selected material:** Canã dos Carajás, Serra Sul, S11D, 6°24’14”S, 50°18’37”W, 820 m, 18.V.2010, fl., M.O. Pivari et al. 1507 (BHCB); Serra da Bocaina, Lagoa do Buritiranal, 6°18’45”S, 49°53’21”W, 692 m, 23.VI.2015, fl. and fr., N.F.O. Mota et al. 3412 (MG, UEC). Paraúapebas, Serra Norte, N7, 6°09’16”S, 50°10’18”W, 696 m, 26.VI.2015, fl. and fr., N.F.O. Mota et al. 3432 (MG, UEC).

*Bacopa monnierioides* is highly variable regarding habit and leaf dimensions, this variability likely to be associated with water availability in the habitat. This species differs from the others in the entire leaves (*vs.* pinnatifid in *B. reflexa*), and opposite (*vs.* whorled in *B. myriophylloides*).

*Bacopa monnierioides* occurs from Panama to Argentina (Souza & Giulietti 2009). In Brazil, it is widespread (BFG 2015). Serra dos Carajás: Serra Sul: S11D, Serra da Bocaina and Serra Norte: N7. Usually found in flooded areas. More abundant blooming is observed in temporary ponds during the dry season.

1.2. **Bacopa myriophylloides** (Benth.) Wettst. in Engler & Prantl, Nat. Pflanzenfam. 4(3b): 77. 1891.

Herbs, aquatic or amphibious, 10–20 cm long. Stems ascendent, simple or branched, usually terete, submersed part glabrous, emerged, villous, trichomes adpressed. Leaves 6–12 whorled, glabrous, submersed filiform, reddish, 4–22 × 0.1–2 mm long, emersed glandular punctate, linear-lanceolate, falcate, apex acute, base connate, margin entire, 3–8 × 0.2–0.3 mm. Flowers axillary, solitary, emersed; pedicel ascending to erect during anthesis, sparsely pilose, ca. 8 mm long; bracteoles 1 or 2, sometimes absent, linear-lanceolate, ca. 1 mm long. Sepals unequal, glandular-puberulent, ciliate, outer ovate, apex acute, base rounded, 2–3 × 1–2 mm, inner linear-lanceolate, ca. 1 mm long. Stamens 4, reaching or slightly exerted above the throat. Ovary glabrous, 0.75 × 0.8 mm, style filiform, 1–2 mm long, stigma subglobose. Capsule ovoid ca. 2 × 1.5 mm.

**Selected material:** Canã dos Carajás, Serra Sul, S11D, 6°24’14”S, 50°18’37”W, 820 m, 18.V.2010, fl., M.O. Pivari et al. 1507 (BHCB); Serra da Bocaina, Lagoa do Buritiranal, 6°18’45”S, 49°53’21”W, 692 m, 23.VI.2015, fl. and fr., N.F.O. Mota et al. 3412 (MG, UEC). Paraúapebas, Serra Norte, N7, 6°09’16”S, 50°10’18”W, 696 m, 26.VI.2015, fl. and fr., N.F.O. Mota et al. 3432 (MG, UEC).
Figure 1 – a-b. Bacopa monnieroides – a. aerial branch showing leaves and flower insertion; b. open calyx with unequal sepals. c-d. Bacopa myriophylloides – c. aerial branch showing leaves and flower insertion; d. open calyx with unequal sepals. e-f. Bacopa reflexa – e. submerse branch showing leaves and flower insertion; f. open calyx with equal sepals. g-h. Scoparia dulcis – g. branch showing leaf arrangement; h. open calyx with equal sepals. i-k. Stemodia verticillata – i. branch showing leaves and fruits; j. open calyx with equal sepals; k. open corolla showing anthers with separated thecae. (a-b. N.F.O. Mota 3432; c-d. N.F.O. Mota et al. 3407; e-f. N.F.O. Mota et al. 2989; g-h. A. Cardoso et al. 2002; i-k. N.F.O. Mota et al. 1164). Illustrations: Alex Pinheiro Araújo.
ca. 0.7 × 0.5 mm, glabrous, surrounded by linear bristles, style filiform, ca. 2.2 cm long, stigma bi-globose. Fruit not observed. **Selected material:** Canaã dos Carajás, Serra da Bocaina, Lagoa do Buritiranal, 6°18'43"S, 49°52'21"W, 692 m, 23.VI.2015, fl., *N.F.O. Mota et al.* 3407 (MG, UEC). Parauapebas [Marabá], Serra Norte, N1, 14.V.1982, fl., *R. Secco et al.* 191 (MG).

*Bacopa myriophylloides* is easily recognized by its linear-lanceolate aerial leaves, that are often falcate and 6–12 whorled (Figs. 1c; 2d-f). It also presents submerged, reddish, filiform, whorled leaves (Fig. 2d). Heterophyll is well documented in several aquatic plant species (Sculthorpe 1985; Cook 1990; Bell 2008), but is a rare feature among the Gratioleae, being found in the Old World aquatic genera *Limmophila* R.Br. and *Hydrotriche* Zucc. (Cook 1990), and referred by Pott & Pott (2000) for South American *B. myriophylloides*. Whether the leaves of *B. myriophylloides* are actually whorled or opposite and palmatifid is still controversial, and developmental studies are needed to clarify this matter (Pennell 1946; Barroso 1952; Souza & Giulietti 2009).

*Bacopa myriophylloides* is restricted to South America (Brazil, Venezuela, and Colombia) (Souza & Giulietti 2009). In Brazil, the species are found in Amapá, Mato Grosso, Mato Grosso do Sul, Minas Gerais, Paraná, and Rondônia (BFG 2015); its occurrence in Pará is here recorded for the first time. Serra dos Carajás: Serra da Bocaina and Serra Norte: N1. Usually found in flooded areas. More abundant blooming is observed in temporary ponds during the dry season.

1.3. *Bacopa reflexa* (Benth.) Edwall, Bolm. Commiss. Geogr. Estado de São Paulo 13: 176. 1897. *Benjaminia reflexa* (Benth.) D’Arcy, Ann. Miss. Bot. Gard. 66: 194. 1979. Figs. 1e-f; 2g-i

Herbs, aquatic, submerged or amphibious, 10–35 cm long. Stems ascendent, simple or branched, terete, submersed glabrescent, emersed villous. Leaves (6–)8-whorled, glabrous, sometimes verrucose, pinnatifid, 4–26 mm long, segments filiform, 1–10 mm long. Flowers axillary, solitary, emersed, pedicel erect during anthesis, glabrous to sparsely glandular-puberulent, ca. 10–12 mm long during anthesis, up to 25 mm long when fruiting; bracteoles absent, linear-lanceolate, ca. 1 mm long. Sepals equal to sub-equal, glandular-puberulent, ciliate, apex acute, base truncate, 2.5–4 × 0.8–1 mm. Corolla lilac, with yellow patch on throat; tube externally glabrous, 2–3 mm long; upper lobes connate, erect, ca. 2 × 1 mm, lower lobe slightly keeled 3–6 mm long. Stamens 4, didynamous, inserted. Ovary ovoid, ca. 0.5 × 0.3 mm, glandular-puberulent, surrounded by linear bristles, style filiform, ca. 1.5 mm long, stigma flattened. Capsule sub-globose, 2.5 × 1.5 mm. **Selected material:** Canaã dos Carajás, Serra Sul, S11B, 6°21’22”S, 50°23’26”W, 703 m, 29.IV.2015, fl., *N.F.O. Mota et al.* 2972 (MG); S11D, 6°21’23”S, 50°23’26”W, 729 m, 2.XII.2015, fl., *B.R.S. Silva et al.* 3 (MG); Serra do Tarzan, 6°20’2”S, 50°39’45”W, 735 m, 27.III.2015, fl., *P.L. Viana et al.* 5687 (MG). Parauapebas [Marabá], Serra Norte, N3, 6°2’34”S, 50°12’33”W, 678 m, 27.IV.2015, fl., *N.F.O. Mota et al.* 2954 (MG); N4, 6°6’8”S, 50°11’14”W, 718 m, 26.III.2016, fl., *R.M. Harley et al.* 57494 (MG); N4WS, 6°6’36”S, 50°11’11”W, 675 m, 23.IV.2012, fl., *A.J. Arruda et al.* 1058 (BHCB); N5, Trilha da Lagoa da Mata, 6°22’6”S, 50°5’18”W, 674 m, 30.IV.2015, fl., *N.F.O. Mota et al.* 2989 (MG).

*Bacopa reflexa* is easily differentiated from the other species of the genus by its pinnatifid leaves (Fig. 1e) and equal to sub-equal sepals (Figs. 1f; 2i). It is commonly confused with *Cabomba* Aubl., differing in the simply pinnatifid leaves (vs. double-pinnatifid). The taxonomic position of *Bacopa reflexa* is still controversial, it has been treated as *Benjaminia reflexa* (Benth.) D’Arcy by some authors (D’Arcy 1979; Velasquez 1994; Burger & Barringer 2000). It is hoped that molecular studies may help to resolve this issue (Souza & Giulietti 2009).

*Bacopa reflexa* occurs from Central to northern South America (Souza & Giulietti 2009). In Brazil, this species is found in Acre, Amapá, Amazonas, Goiás, Maranhão, Mato Grosso, Pará, and Roraima (BFG 2015). Serra dos Carajás: Serra Sul: S11B, S11D, Serra do Tarzan and Serra Norte: N3, N4, N4WS, N5. Usually found in flooded areas. Very abundant blooming is observed in temporary ponds during the dry season.

2. *Scoparia* L.

*Scoparia* comprises terrestrial herbs or subshrubs with linear, lanceolate, elliptical or pinnatifid leaves; calyx tetramerous or pentamerous, with free, equal sepals; corolla 4-lobed, rotaceous, with a tuft of trichomes at center; and 4 stamens with thecae not separated by its linear-lanceolate aerial leaves, that are often falcate and 6–12 whorled (Figs. 1c; 2d-f). It also presents submerged, reddish, filiform, whorled leaves (Fig. 2d). Heterophyll is well documented in several aquatic plant species (Sculthorpe 1985; Cook 1990), but is a rare feature among the Gratioleae, being found in the Old World aquatic genera *Limmophila* R.Br. and *Hydrotriche* Zucc. (Cook 1990), and referred by Pott & Pott (2000) for South American *B. myriophylloides*. Whether the leaves of *B. myriophylloides* are actually whorled or opposite and palmatifid is still controversial, and developmental studies are needed to clarify this matter (Pennell 1946; Barroso 1952; Souza & Giulietti 2009).

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Figure 2 – a-c. *Bacopa monnieroides* – a. specimens in flooded habitat; b. flowering branches; c. frontal view of the flower. d-f. *Bacopa myriophylloides* – d. specimens in flooded habitat showing red submerse leaves; e. flowering branch in apical view; f. flowering branch in lateral view showing linear, curved leaves and unequal sepals. g-i. *Bacopa reflexa* – g. specimens in flooded habitat; h. flowering specimens; i. flower in lateral view. j. *Scoparia dulcis* – flower in lateral view showing tuft of trichomes. k-l. *Stemodia verticillata* – k. fruiting branch with leaves in lateral view. l. flowering branch in apical view. Photos: a-f, h. N.F.O. Mota; g, i. P.L. Viana
Souza & Giulietti 2009), occurring in southern Neotropics, especially in Argentina, Paraguay, Uruguay and southern Brazil, where six species are currently recognized (Souza & Giulietti 2009; BFG 2015).

2.1. *Scoparia dulcis* L. Sp. pl.: 116. 1753.

   Figs. 1g-h; 2j

Herbs or subshrubs, terrestrial, 10–50 cm tall. Stems erect, usually branched, quadrangular, glabrous, sparsely glandular-punctate. Leaves opposite or 3-whorled, glabrous, markedly glandular-punctate, obscurely petiolate, obovate to narrowly elliptical, apex acute to rounded, base attenuated, margin entire, sub-entire to serrate, 3–13 × 1–3 mm. Flowers axillary; pedicel glandular-puberulent, 1–3 cm long; bracteoles absent. Calyx tetramerous; sepals ovate to obovate, apex roudend, margin ciliate, 3–4 × 1–2 mm. Corolla white to pale lilac, with a tuft of pale lilac trichomes; lobes elliptic, 1–4 × 1–2 mm long. Stamens 4. Ovary ellipsoid, style filiform, usually persistent. Capsule globose, 2–4 × 1–3 mm.

**Selected material:** Canã dos Carajás, S11D, 30.III.2015, fr., A. Cardoso et al. 2002 (MG). Parauapebas [Marabá], Serra Norte, N4, 17.III.1984, fl. and fr., A.S.L. Silva et al. 1862 (INPA, MG, NY).

*Scoparia dulcis* is characterized by the tetramerous calyx and rotaceous corolla with a tuft of trichomes at center (Fig. 2j).

*Scoparia dulcis* is one of the most widespread species of Plantaginaceae in the world, with pantropical distribution (Souza & Giulietti 2009). In Brazil, it occurs in all states and in the Distrito Federal (BFG 2015). Serra dos Carajás: Serra Sul: S11D; Serra Norte: N4. Usually found in disturbed areas, such as N4 and S11D mine areas.

3. *Stemodia* L.

*Stemodia* presents wide morphological variation, from creeping annual herbs to perennial erect subshrubs; leaves sessile, with clasping base, or clearly petiolate; flowers sessile or pedicellate, with or without bracteoles; calyx pentamerous, with free, equal to subequal sepals; corolla 5-lobed, bilabiate; and stamens 4, with two thecae separated by a connective in each anther. The genus, as currently delimited, comprises ca. 50 species distributed in the tropics, especially in the New World, usually occurring in open areas with moist soil (Turner & Cowan 1993a, 1993b; Souza & Giulietti 2009). In Brazil, 17 species are recognized (Scatigna et al. 2017), with a group of species concentrated in the wet lowlands of southern Brazil and another in the mountains of southeastern to northeastern Brazil, while some species have broader distribution (Souza & Giulietti 2009).

3.1. *Stemodia verticillata* (Mill.) Hassl., Trab. Mus. Farmacol. 21: 110. 1909. Figs. 1i-k; 2k-l

Herbs, terrestrial, creeping, ca. 5 cm tall. Stems procumbent, usually branched, quadrangular, villous. Leaves 3-whorled, rarely opposite, sparsely villous, glandular punctate; petals villous, 1–3 mm long; blades ovate, apex acute, base obtuse, margin serrate to double-serrate, 3–13 × 1–3 mm. Flowers axillary, solitary, sessile or sub-sessile; pedicil villous, up to 2 mm long when fruiting; bracteoles absent. Sepals sub-equal, villous, lanceolate, apex acute, base acute, ca. 2.5 × 0.6 mm. Corolla lilac, throat yellow, tube internally yellow; tube externally glabrous, ca. 2.5 mm long; lobes orbicular, 0.5 mm diam. Stamens 4, didynamous, inserted, thecae separated by the connective. Capsule globose, ca. 2.5 × 2 mm.

**Selected material:** Parauapebas, Serra Norte, N1, 6°2’38”S, 50°16’56”W, 666 m, 12.XII.2007, fl., N.F. O. Mota et al. 1164 (BHCB, ESA); N3, 6°2’44”S, 50°13’09”W, 692 m, 27.III.2012, fl., A.J. Arruda et al. 882 (BHCB).

*Stemodia verticillata* is characterized by sub-equal sepals and anthers with separated thecae (Fig. 1k).

*Stemodia verticillata* is the most widespread species of the genus, occurring in the Neotropics and West Africa (Souza & Giulietti 2009). In Brazil, this species occurs in all states and in the Distrito Federal (BFG 2015). Serra dos Carajás: Serra Norte: N1, N3. Usually found in disturbed areas.

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