



## Untangling the tribe Coreopsiadeae (Asteraceae) beyond taxonomic concepts

Maria Liris Barbosa<sup>1,2\*</sup> , Maria Alves<sup>2</sup>  and Nádia Roque<sup>2</sup> 

Received: March 27, 2023

Accepted: September 29, 2023

### ABSTRACT

It is presented the first taxonomic study of the tribe Coreopsiadeae (Asteraceae) in Northeastern Brazil. A total of seven genera and 16 species were recorded in the region, with *Bidens* being the richest genus (8 spp.). *Bidens tenera* and *Cosmos bipinnatus* were recorded for the first time to the region, and *Heterosperma ovatifolium* represents the first record to Brazil. *Bidens*, *Chrysanthellum*, and *Dahlia* are taxonomically problematic that is reflected by several misidentifications found in the herbaria collections. *Coreopsis*, *Cosmos*, and *Dahlia* species are cultivated as ornamental but are scarcely represented in the herbaria. This study provides a checklist, an identification key to all species, in addition to discussing the importance of studying alien species for a better understanding of the Brazilian flora.

**Keywords:** Alien plants, *Bidens*, Compositae, herbarium records, Northeast of Brazil

## Introduction

The Tribe Coreopsiadeae (Asteraceae) encompasses 24 genera and ca. 600 species with a cosmopolitan distribution primarily centered in North and South America (Crawford *et al.* 2009; Susanna *et al.* 2020). In Brazil, the tribe is represented by eight genera and 38 species (12 endemics) with wide distribution in all phytogeographic domains (Bringel Jr. *et al.* 2022).

Coreopsiadeae representatives are characterized by a set of features such as an involucre with 2 (–3) series, outer bracts green and inner bracts membranous, ray flowers (when

present) neuter or female, corolla yellow, orange, white, pink or purple, disc flowers bisexual, female or functionally male, corolla yellow or orange, cypselae fusiform, terete, or dorsally flattened, brown to black, smooth or striate, wings or wingless, pappus with awns, scales or absent (Panero 2007; Crawford *et al.* 2009; Roque *et al.* 2017).

Due to the great morphological diversity in the tribe, the taxonomic delimitation of genera and species is usually complex. *Bidens* L. and *Coreopsis* L. are admittedly non-monophyletic, and their diagnostic characters overlapped, making the generic distinction difficult (Robinson 1981; Tadesse *et al.* 1995). Besides, *Bidens* also shows complex morphological circumscription by the polyploidy already

<sup>1</sup> Universidade Estadual de Feira de Santana, Depto. Ciências Biológicas, Programa de Pós-Graduação em Botânica, km 03, BR 116, 44031-460, Feira de Santana, BA, Brazil

<sup>2</sup> Universidade Federal da Bahia, Instituto de Biologia, Laboratório Flora, Rua Barão de Jeremoabo s.n., Campus Universitário de Ondina, 40170-115, Salvador, BA, Brazil

\* Corresponding author: [barbosaaliris@gmail.com](mailto:barbosaaliris@gmail.com)

recognized among its species (Ballard 1986; Tadesse *et al.* 1995; Bringel *et al.* 2017).

In addition to the taxonomic complexity, Coreopsideae stands out for its various representatives of economic interest, such as *Coreopsis*, *Cosmos* Cav., and *Dahlia* Cav. species that are widely used in gardening by their ornamental capitula (Sorensen 1969; Wiersema & León 1999; Crawford *et al.* 2009). Furthermore *Bidens*, the richest genus of the tribe (ca. 340 spp.), presents species attributed to the treatment of various diseases (Jayasundera *et al.* 2021), antifungal and antibacterial potential (Deba *et al.* 2008; Li *et al.* 2017), besides the interest in agriculture as weeds (Wiersema & León 1999; Crawford *et al.* 2009; Santos & Cury 2011).

This paper is the first taxonomic study emphasizing on the tribe Coreopsideae (Asteraceae) for Northeastern Brazil, previously only represented by floristic inventories in Bahia (Moura & Roque 2014; Amorim & Bautista 2016; Roque *et al.* 2016), Piauí (Oliveira *et al.* 2007) and Alagoas (Soares *et al.* 2022) states. We present a checklist, an identification key for the species in Northeastern Brazil, with a particular focus on alien species (naturalized and cultivated).

## Materials and methods

### Taxonomic Study and Conceptual Terminology

Specimens of Coreopsideae were examined in the field and from collection sheets from the ALCB, BHCB, CEPEC, CEN, HUEFS, HUFU, IBGE, MAC and UB herbaria (acronyms according to Thiers (2022), continuously updated). Digital images from 16 additional herbaria (ASE, CEN, EAC, HVASE, INPA, IPA, MO, MUFAL, NY, P, RB, RBR, SP, UEC, UFRN) were also analyzed from online databases (SpeciesLink, JABOT, and Re flora). The identification key for all species was based on studying herbaria specimens, type images, and protologues available on digital platforms (JSTOR; Tropicos 2022; BHL) and specialized literature (Sherff 1932, 1937; Turner 1988; Sorensen 1969; Lizarazu & Freire 2019).

The morphological terminology used was based on Radford *et al.* (1974) and Beentje (2010) for vegetative characters and Roque & Bautista (2008) for reproductive characters. Pyšek *et al.* (2017) was used for biological invasion terminology (Tab. 1). The origin of distribution follows the Flora e Funga do Brasil (FFB) and the type of occurrence, the Global Invasive Species Database (2022a) (Tab. 2).

## Results

Coreopsideae is represented by seven genera and 16 species in Northeastern Brazil (Tab. 2). The richest genera are *Bidens* (8 spp.), *Cosmos* (3 spp.), and the remaining genera *Chrysanthellum*, *Coreopsis*, *Dahlia*, *Heterosperma*, and *Staurochlamys* are represented by a single species each. In the Northeast region, Bahia is the most representative with 11 species, followed by Pernambuco (10 spp.), Alagoas and Ceará (7 spp. each), Maranhão (6 spp.), Paraíba, Rio Grande do Norte and Sergipe (5 spp. each) and Piauí (4 spp.) (Tab. 1). *Bidens tenera* and *Cosmos bipinnatus* are recorded for the first time in the region. *Heterosperma ovatifolium* is the first record for Brazil, previously recognized for Ecuador, Peru, Chile, Bolivia, and Argentina (Ariza-Espinar & Lizarazu 2015; Barbosa *et al.* 2022).

Regarding the Coreopsideae in the Brazilian herbaria, *Bidens flagellaris* has 112 valid records but only one for the Bahia state (Viollati 271). Similarly, the native *Bidens gardneri*, widely distributed and 616 records, show only six records for Northeastern Brazil (Harley 27207; Stehmann 3840; King 8638; Conceição 169; França 3835 and Froes 34048). Likewise happens for the alien species, *Coreopsis lanceolata* and *Cosmos bipinnatus*, which have only a single record each (Silva 106; Barbosa 07, respectively), while *Dahlia coccinea* is represented by three records only in Bahia (Santos 11) and Pernambuco (Pickel 203; Guimarães, IPA 89321) states.

**Table 1.** Terminology and concepts of origin and occurrence according to Pyšek *et al.* (2017). The present manuscript is adopting the terminology in bold.

Terminology	Synonyms	Concept
<b>Alien species</b>	exotic plants; introduced plants; non-native plants; non-indigenous plant	Plant taxa in a given area (see below) whose presence there is due to intentional or unintentional human involvement, or which have arrived there without the help of people from an area in which they are alien.
<b>Native species</b>	indigenous plant	Taxa that have originated in a given area without human involvement or that have arrived there without intentional or unintentional intervention of humans from an area in which they are native.
<b>Naturalized</b>	established	Alien plants that sustain self-replacing populations for at least 10 years without direct intervention by people (or in spite of human intervention) by recruitment from seed or ramets (tillers, tubers, bulbs, fragments, etc.) capable of independent growth.
<b>Weeds</b>	pests; harmful species; problem plants; noxious plant	Plants (not necessarily alien) that grow in sites where they are not wanted, and which have detectable economic or environmental impact or both.



**Table 2.** List of Coreopsideae species for the Northeast of Brazil. The origin of distribution follows Flora e Funga do Brasil (FFB) and the occurrence, the Global Invasive Species Database (2022a). Missing information is represented by symbol (-).

Species	FFB	GISD	Record Northeast
<i>Bidens bipinnata</i> L.	Naturalized	Established	Weed
<i>Bidens flagellaris</i> Baker	Native - endemic	-	Native
<i>Bidens gardneri</i> Baker	Native	-	Weed
<i>Bidens pilosa</i> L.	Naturalized	Established	Weed
<i>Bidens riparia</i> Kunth	Native	-	Weed
<i>Bidens squarrosa</i> Less.	Native	-	Native
<i>Bidens subalternans</i> DC.	Native	-	Weed
<i>Bidens tenera</i> O.E.Schulz	Native	-	Native
<i>Chrysanthellum indicum</i> var. <i>afroamericanum</i> B.L.Turner	Naturalized	Established	Weed
<i>Coreopsis lanceolata</i> L.	Naturalized	Established	Cultivated
<i>Cosmos bipinnatus</i> Cav.	Naturalized	Established	Cultivated
<i>Cosmos caudatus</i> Kunth	Naturalized	Established	Cultivated and weed
<i>Cosmos sulphureus</i> Cav.	Naturalized	Established	Cultivated and weed
<i>Dahlia coccinea</i> Cav.	Cultivated	-	Cultivated
<i>Heterosperma ovatifolium</i> Cav.	-	Casual	Weed
<i>Staurochlamys burchellii</i> Baker	Native	-	Native

*Identification key for the Coreopsideae species in Northeastern Brazil (Fig. 1)*

1. Xylopodium present; outer bracts reflexed in the capitula; capitula with more than one series of ray flowers ..... ***Dahlia coccinea***
- 1'. Xylopodium absent; outer bracts patent or erect in the capitula; capitula with only a series of ray flowers ..... 2
2. Herbs or subshrubs erect; cypselae isomorphic ..... 3
- 2'. Herbs prostrate; cypselae heteromorphic ..... 15
3. Involucre 3-series; outer bracts orbiculate ..... ***Staurochlamys burchellii*** (Fig. 1N)
- 3'. Involucre 2- series; outer bracts lanceolate or ovate ..... 4
4. Leaf blade entire, elliptic; cypselae winged obovoid ..... ***Coreopsis lanceolata*** (Fig. 1H)
- 4'. Leaf blade pinnatisect, when entire, lanceolate, or ovate; cypselae fusiform or terete, wingless ..... 5
5. Filaments pilose; cypselae long rostrate (rostrum 0.5–0.7 cm) ..... 6
- 5'. Filaments glabrous; cypselae erostrate ..... 8
6. Leaf blade with lobes filiform; outer bracts ovate with apex caudate; pappus absent .... ***Cosmos bipinnatus*** (Fig. 1I)
- 6'. Leaf blade with lobes lanceolate; outer bracts lanceolate with apex acute; pappus 2-awns, with retrorsely barbelate ..... 7



7. Involucral bracts 14 (seven in each series) with yellow to orange striations; ray flowers' corolla yellow to orange ..... **Cosmos sulphureus** (Fig. 1L)
- 7'. Involucral bracts 16 (eight in each series) with vinaceous striations; ray flowers' corolla white at base and lilac or pink at the middle region to the apex ..... **Cosmos caudatus** (Fig. 1J)
8. Leaves verticillate; leaf blade membranaceous; peduncle measuring half the total length of the plant ..... **Bidens tenera** (Fig. 1F)
- 8'. Leaves opposite; leaf blade chartaceous; peduncle less than half the length of the plant ..... 9
9. Leaves pinnatisect with lobes filiform; capitulescence in corymb lax ..... **Bidens flagellaris**
- 9'. Leaves entire or pinnatisect with lobes ovate or lanceolate; capitulescence in monochasium or dichasium ..... 10
10. Subshrubs scandent; cypselae margin hirsute ..... **Bidens squarrosa** (Fig. 1D)
- 10'. Herbs erect; cypselae glabrous, strigose, or sparsely pilose ..... 11
11. Leaves dimorphic: leaf blade pinnatisect at base and bipinatissect at apex of the plant; pappus with awns unequal sizes ..... **Bidens gardneri** (Fig. 1A)
- 11'. Leaves isomorphic; pappus awns with equal sizes ..... 12
12. Leaf blade with apex acuminate; bracts outer bigger than capitulum; cypselae central glabrous, olive to light brown, cypselae peripheral strigose, dark brown; pappus formed by one awn erect and three reflexed ..... **Bidens riparia** (Fig. 1C)
- 12'. Leaf blade with apex acute; bracts outer equal or smaller than capitulum; cypselae similar in indument and colour; pappus with all erect awns ..... 13
13. Peduncle strigose; ray flowers, when present, five units, corolla white with resinous striations on the abaxial face; pappus 2–4 awns ..... **Bidens pilosa** (Fig. 1B)
- 13'. Peduncle glabrescent; ray flowers, always present, 3–4 units, corolla pale yellow without resinous striations; pappus 4–awns ..... 14
14. Capitula 1–1.5 × 1.5–3 cm; disc flowers 75; cypselae tetragonal, margin curved ..... **Bidens bipinnata**
- 14'. Capitula 0.5–0.8 × 0.8–1 cm; disc flowers 45; cypselae triquetrous, margin erect .... **Bidens subalternans** (Fig. 1E)
15. Leaf blade ovate; outer bracts 2; disc flowers 8; ray cypselae obovoid, winged, disc cypselae fusiform, pappus 2–awns ..... **Heterosperma ovatifolium** (Fig. 1M)
- 15'. Leaf blade 2–3 pinnatisect; outer bracts 4; disc flowers 13–34; ray cypselae terete, wingless, disc cypselae flattened, pappus absent ..... **Chrysanthellum indicum var. afroamericanum** (Fig. 1G)

## Discussion

### *The complex taxonomy of Coreopsideae taxa*

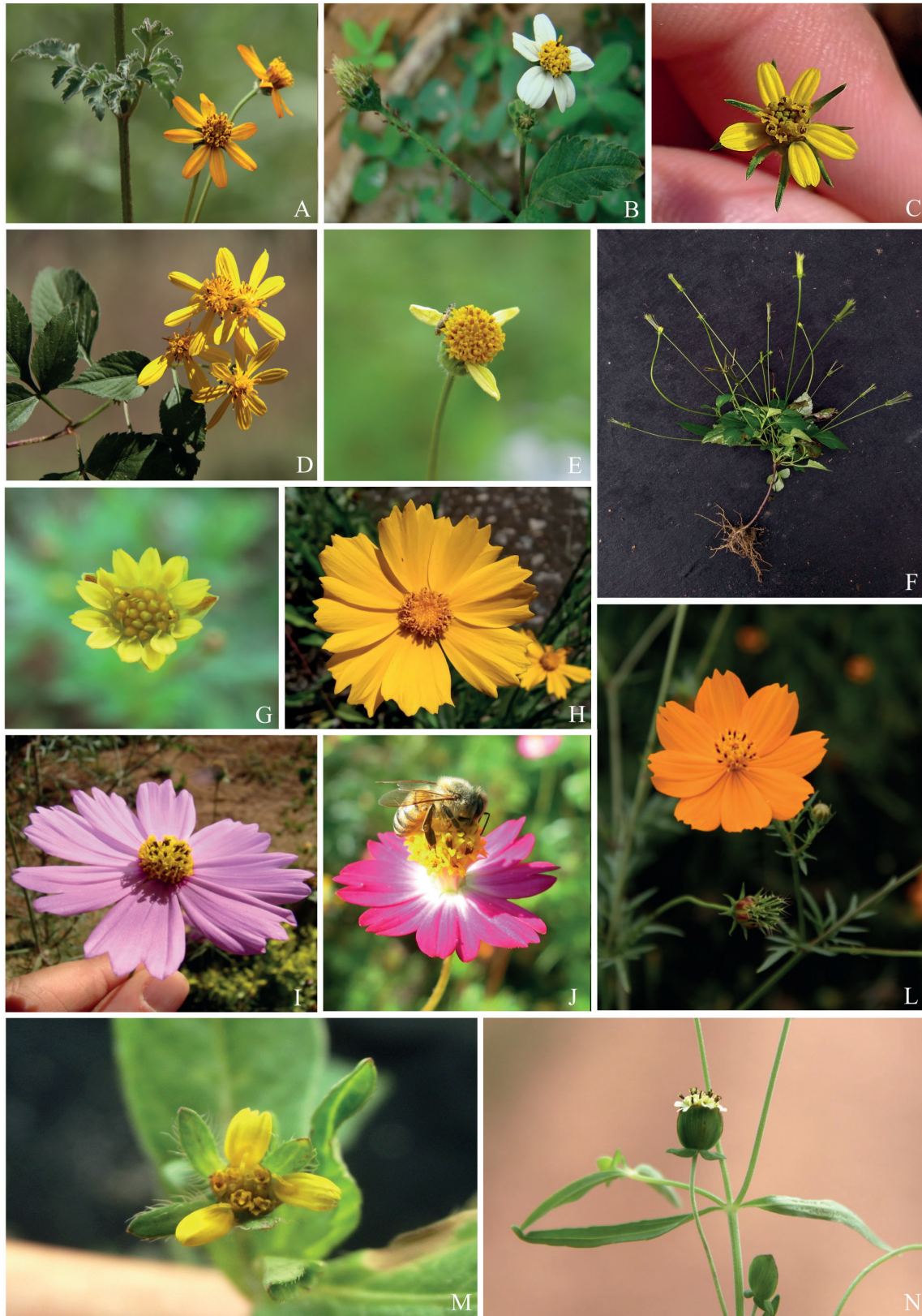
*Bidens* is the largest genus of the tribe and the most diverse in Brazil. Although the genus is easily recognized, the species are usually misidentified in herbaria; for example, *B. bipinnata*, *B. riparia*, and *B. subalternans* are primarily identified as *Bidens pilosa*. Such misunderstanding is probably caused by the absence of taxonomic studies of Brazilian species, which are cited only in floristic inventories (Oliveira *et al.* 2007; Melo *et al.* 2011; Santana *et al.* 2011; Moura & Roque 2014; Roque *et al.* 2016) and regional flora (Bringel Jr. & Cavalcanti 2009; Marques & Nakajima 2015; Amorim & Bautista 2016).

*Bidens pilosa* has been the most problematic species regarding the taxonomic concept. In the first review of the genus based on morphological data, Sherff (1937)

circumscribed six varieties: *Bidens pilosa* L. var. *pilosa*, *Bidens pilosa* var. *minor* (Blume) Sherff, *Bidens pilosa* var. *radiata* Sch. Bip., *Bidens pilosa* var. *bimucronata* (Turcz.) O.E. Schulz, *Bidens pilosa* var. *alausensis* (Kunth) Sherff and *Bidens pilosa* var. *calicicola* (Greenm) Sherff. Ballard (1986) added cytogenetic, chemical, and hybridization data for the same taxa and recognized three species for *Bidens pilosa* sensu Sherff (1937): *B. alba* (L.) DC., *B. pilosa* and *B. odorata*, being only two primers occurring in Brazil (Bringel Jr. & Reis-Silva 2023). Currently, 37 names are linked as synonyms of *B. pilosa* (Tropicos.org).

Due to its invasive potential, *Chrysanthellum indicum* DC. became cosmopolitan (Turner 1988). In the revision, Turner (1988) described three subspecies and four varieties according to their geographical distributions: *C. indicum* subsp. *indicum*, with two varieties (Asia and Madagascar), *C. indicum* subsp. *Mexicanum* (Greenm.) B.L. Turner, with one variety (Mexico and Central America) and *C. indicum* subsp. *afroamericanum* B.L. Turner with 1 variety, *C. indicum*





**Figure 1.** Representatives of the tribe Coreopsideae (Asteraceae). (A) *Bidens gardneri* Baker, (B) *Bidens pilosa* L., (C) *Bidens riparia* Kunth, (D) *Bidens squarrosa* Less., (E) *Bidens subalternans* DC., (F) *Bidens tenera* O.E.Schulz, (G) *Chrysantellum indicum* var. *afroamericanum* B.L.Turner, (H) *Coreopsis lanceolata* L., (I) *Cosmos bipinnatus* Cav., (J) *Cosmos caudatus* Kunth, (L) *Cosmos sulphureus* Cav., (M) *Heterosperma ovatifolium* Cav., (N) *Staurochlamys burchellii* Baker. Photos: A, D, L, N. H.J.C. Moreira; B, E. L. Moura; C. K. Michel; F. L.F. Pinheiro; G, J. M.L. Barbosa; H. C.O. Gussoni; I. N. Roque; M. R.F. Almeida.



var. *afroamericanum* B.L. Turner (Africa and South America). Considering this classification, *Chrysanthellum indicum* var. *afroamericanum* is the only species accepted for Brazil. For the other names of *Chrysanthellum* found in the Brazilian herbaria collections we pointed out *C. procumbens* is an illegitimate name, *C. americanum* is endemic to the Caribbean (Turner 1982), and *C. tuberculatum* is a heterotypic synonym of *C. indicum* (Turner 1988).

Crucial for commercializing ornamental plants, some species of *Dahlia* are described as hybrids (Hansen & Hjerting 1996), and the genus studies are focused on horticulture, making the taxonomic delimitation between species complex since little is known about native species (Sorensen 1969). Considering the coloration of ray flowers, Sorensen (1969) differentiated *D. pinnata* by white, lilac-whitish, pink, or purple corolla, while *D. coccinea* by yellow, orange, reddish-orange or deep red corolla. Although there are identifications of *D. pinnata* in the Northeast herbaria, only specimens with ray corolla flowers predominantly red were found.

### Why study alien plant species?

In most floristic, taxonomic, and phytosociological studies in Brazil, alien plants (cultivated, invasive, or naturalized) are excluded (e.g., Barbosa *et al.* 2006; Stehmann *et al.* 2009; Wanderley *et al.* 2011), making it impossible to discuss the environmental impacts they cause in their areas of occurrence (e.g., Ehrenfeld 2003; Levine *et al.* 2003; Rejmánek *et al.* 2005; Richardson & Pyšek 2012). Furthermore, botanists fail to collect alien species in the field, which can be evidenced by the low number of these specimens recorded in herbaria (e.g., *Cosmos bipinnatus* and *Heterosperma ovatifolium*).

Although Flora e Funga do Brasil (2023) included the cultivated (6%) and naturalized (2%) species in the list, the taxonomic treatment has not been carried out in 80.6% and 22.3% of the species, respectively. In Asteraceae, the family with the largest number of alien species in the world (Pyšek *et al.* 2017), 35.2% of the cultivated species do not have taxonomic treatment.

Although the naturalized species identified in this study (Tab. 2) do not present the potential of invasive species in the country, there is a need to indicate in taxonomic studies the occurrence of these species in which the dispersion and possible damage of them in natural environments can be investigated, especially for species that are already indicated as invasive in other countries, such as *Bidens pilosa* (Global Invasive Species Database 2022b). In addition, taxonomic studies that include alien species may contribute to the knowledge of diversity (e.g., *Bidens* species) and understanding of new taxa (such as the new occurrence of *Heterosperma ovatifolium*) in the Brazilian flora.

The results of this study showed the subsampling of the tribe Coreopsideae representatives in the Northeast region. Although it is the third largest region in the country, its representativeness of general botanical collections is only

18.5% (specieslink.net), with Bahia and Pernambuco being the states with the highest number of herbaria (18 herbaria out of 40 for the region). On the other hand, the Southeast and South regions, which represent 18% of the national territory, have 54% of the botanical collections in Brazil (specieslink.net). These results can be attributed to the historical presence of research institutions and universities, totaling 61% of Brazilian herbaria in these two regions (Gasper *et al.* 2020). There is a need for more investment in floristic and taxonomic studies in regions or areas that are poorly sampled to mitigate the situation and contribute directly to forming more specialists in the Brazilian flora.

## Acknowledgements

We thank the Post Graduate Program at the State University of Feira de Santana for supporting in the development of this research. This study was partially financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brasil (CAPES) — Finance Code 001. MLB and NR are grateful to CNPQ for their granted fellowships (133498/2019-0) and (PQ- 311379/2022-2), respectively.

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