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Plant selection for green infrastructure: a review of recommended species for stormwater management devices

Maria Fernanda Nóbrega dos Santos
Postdoctoral Researcher, UNESP, Brazil.
mfnsantos@yahoo.com.br

Marta Enokibara
Professor, UNESP, Brazil.
marta.enokibara@unesp.br

Maria Solange Gurgel de Castro Fontes
Professor, UNESP, Brazil.
solange.fontes@unesp.br

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ABSTRACT

Currently, one of the research gaps in the development of green infrastructure (GI) landscape projects, lies in plant selection, which are adequate to the GI existing devices and to regional characteristics. Therefore, the objective of this work was to perform a systematic literature review of GI in Brazil, focusing on stormwater management devices and their recommended species. A search was performed on Google Scholar, which identified 196 articles published in national journals by the end of 2019, which simultaneously contained the words '*espécie*' ('species') and '*infraestrutura verde*' ('green infrastructure') – and spelling variations in Portuguese. However, as GI is a wider concept and can encompass several strategies, the articles underwent an exploratory reading to verify which ones were directly related to the research objective. Seven articles fell within the scope, and 82 plant species were identified as recommended for use in the projects, some species with extensive documented experience on water treatment devices, while others only a suggestion for future use. In addition, complementary information about the species was surveyed to enable its use in landscape projects, such as: indication of use; botanical family; plant growth forms; substrate; origin; endemism; and distribution in the Brazilian Phytogeographic Domains (Amazonia, Caatinga, Cerrado, Mata Atlântica, Pampa, and Pantanal). This material was organized in a database, which can serve as a subsidy for the consolidation of a plant repertoire to be used in landscape projects with this purpose in Brazil.

KEYWORDS: Green infrastructure. Literature review. Plant species.

1 INTRODUCTION

The term urban Green Infrastructure (GI) has often been used synonymously with different integrated stormwater management practices, such as 'bioretention' techniques, 'rain gardens', among others (LI et al., 2019). However, according to Franco (2010), the term GI has different meanings, depending on the context in which it is used, and has in its genesis broader concepts, such as Landscape Ecology. In Brazil, the term GI was consolidated within Architecture, Urbanism, and Landscaping as an important research front after the publications of Benedict and McMahon (2006) and Cormier and Pellegrino (2008).

Among the main typologies of GI in Brazil raised by the study by Santos and Enokibara (2021), are the strategies for the integrated management of stormwater (such as 'rain gardens', 'bioretention' techniques, 'bioswales', etc.), in addition to 'green roofs', 'vertical gardens', and 'permeable pavements', as well as different practices, such as the 'urban afforestation', and 'urban agriculture'. Santos and Enokibara (2021) also identified that some authors still include within the scope of GI several categories of open spaces and natural areas, whether urban or not, landscaped or not.

The research on GI developed in Brazil encompasses a great diversity of themes and, according to Santos et al. (2020), the vast majority of works can be classified as case studies: both the development of GI projects for new areas, and analysis of projects already carried out. Among the topics addressed by the research, the authors point out that the main areas of interest relate to the link among GI and 'sustainability', GI and 'environmental design', GI and 'urban drainage', GI and 'urban ecology', and GI and 'urban landscape'. Another point to be emphasized concerns the interdisciplinary character of these researches, in addition to the fact that 'urban drainage' can be punctuated as a cross-sectional area of research, which touches on the other main themes within the GI (SANTOS et al., 2020). These findings certainly corroborate the strong correlation in research conducted in Brazil on GI with stormwater management strategies, a relationship that has already been pointed out in international studies reviewing the literature on the subject (LI et al., 2019).

As identified by Li et al. (2019) in their extensive review on the subject, there are many documented benefits regarding the application of GI for stormwater management – in addition to effectively enabling the mitigation of urban hydrological problems, the use of GI also provides environmental, social, and economic benefits. Furthermore, the use of vegetated GI techniques is also linked to the reestablishment of the ecological functions of the landscape and positive effects on the regulation of urban microclimates (MUNÕZ, 2019; CRUCIOL-BARBOSA, 2019).

Although the proven benefits are many, Li et al. (2019) consider that there are numerous barriers to the wide implementation of GI. Among the main ones, the authors point out the lack of technical knowledge for the development of projects as the most cited. There are important gaps in knowledge: performance evaluations over time, cost surveys, project parameters, in addition to the lack of recommendations on the maintenance routine of these structures. Without proper maintenance, there is no way to guarantee that the hydrological performance requirements of the project are being met, which can make large-scale use of GI unfeasible.

Another aspect that influences the performance of GI projects – and which Yuan and Dunnett (2018) consider to be even less explored in current research – is the issue of species selection for use in different typologies, such as ‘rain gardens’. These authors observe that the lack of technical recommendations in the manuals has led to the indication of unsuitable species for 'rain gardens' and, consequently, to the complete failure of planting. Without a well-developed layer of vegetation, the infiltration rates of the technique may differ from those specified in the project and the hydrological performance is compromised, given that the characteristics of the subsoil are its main conditioning factor.

Thus, despite the vegetation playing such an important role, there is little systematized information about the plant repertoire to be used in GI projects for areas outside Europe. Dvorak and Volder (2010), in their work on species for ‘green roofs’, point out that the selection of suitable plants for a given region is one of the most critical issues for the success of these techniques. By carrying out a literature review on the subject, the authors found 134 viable species for use in North America. In order to have an idea of the scarcity of information, only in Germany there are catalogs listing more than 3000 species for ‘green roofs’ (CANTOR, 2008).

In Brazil, a pioneering work developed by Pinheiro (2017) developed criteria for species selection in GI projects and applied it to a case study in the urban area of São Paulo. Based on the proposed methodology, the author listed 74 species for use in 3 GI typologies, with 57 species belonging to the Phytogeographic Domain of the Mata Atlântica and 14 being exotic. Confronting these data with the territorial dimensions and the richness of landscapes that Brazil has, it is possible to glimpse the possibilities of research in the area and the need to establish a plant repertoire for these projects, which is adequate to the Brazilian regional conditions.

2 OBJETIVES

The present work aimed at the identification of the plant species recommended for use in GI typologies of stormwater management through a systematic review of the literature on the subject in Brazil, in order to contribute to the creation of a plant repertoire to be used in landscaping projects of this nature in Brazil.

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3 METODOLOGY

Google Scholar was used to conduct a systematic review of the literature on plant species used in GI projects for stormwater management in Brazil. In addition to presenting a large overlap with traditional databases such as Scopus, Web of Science, and Microsoft Academic Search (ORDUNA-MALEA et al., 2015), Google Scholar is also recommended by Meho and Yang (2007) because it has the greatest coverage for non-English-speaking languages.

Thus, the occurrence of the combined terms *'espécie'* ('species') and *'infraestrutura verde'* ('green infrastructure') was evaluated – in addition to the possible spelling variations used over time (with and without a hyphen), such as *'infra-estrutura verde'* ('green infra-structure'), *'infra-estruturas verdes'* ('green infra-structures'), and *'infraestruturas verdes'* ('green infrastructures') – anywhere in the body of the text in documents available in Portuguese.

As the research was carried out in 2020, the temporal coverage of the search was defined as documents published until the end of 2019. To filter the results, only the articles published in indexed national journals were selected – in view of having been submitted to the peer review process – to compose the research corpus.

This search resulted in a total of 196 articles published in journals by the end of 2019 that simultaneously contained the terms *'espécie'* ('species') and *'infraestrutura verde'* ('green infrastructure') – and spelling variations. However, as GI is a comprehensive concept and can encompass a wide variety of typologies, the articles underwent an exploratory reading to identify which were directly related to the research objective. Thus, articles that addressed other topics within the GI, such as species indicated for 'urban afforestation' or 'green roofs', were excluded. Only articles that focused on species indicated for the GI typologies of stormwater management were selected (such as 'constructed wetlands', 'wetlands', 'rain gardens', and 'bioswales'). The selected works were: Akinaga et al. (2010); Bonzi (2013); Almeida et al. (2014); Pinheiro (2015); Guimarães et al. (2018); Souza et al. (2019) and Teixeira e Silva (2019).

Next, all the species indicated by the authors for use in Brazil were listed and grouped according to the recommended use: species for permanently flooded areas; species for seasonally flooded areas; species for margin areas, soil slopes and slope containment. This search totaled 82 plant species (76 with indication of genus and species and 6 only with identification of genus, for example *Bacopa sp*), some already with extensive documented experience for use in water treatment devices, while others only as a suggestion of use in future projects.

In order to overview these species and support the construction of a database on the subject in Brazil, it was necessary to standardize the information available in the works and update some data. First, all scientific names were updated, complemented and some corrected, according to the nomenclature accepted by the online database The Plant List (2013) at the beginning of 2021. Subsequently, the botanical family and the common name of the species were surveyed (in parentheses, always after the scientific name) in case the author had not presented this information in the article, and the explanation of the source of this information.

It was considered that more information about the species was needed to enable its use in landscape projects. Therefore, information related to the species was researched and

complemented, such as: way of growth (grass, sub-shrub, shrub, tree, liana, bamboo); substrate (aquatic, terrestrial, rupicolous); origin (native, naturalized, cultivated); endemism (whether or not it is endemic to Brazil); vegetation type and distribution. Regarding the distribution, the Phytogeographic Domains (Amazonia, Caatinga, Cerrado, Mata Atlântica, Pampa or Pantanal) where the species occurs were pointed out. All this information was extracted from the online database Flora do Brasil (2020) of the REFLORA/CNPq Program.

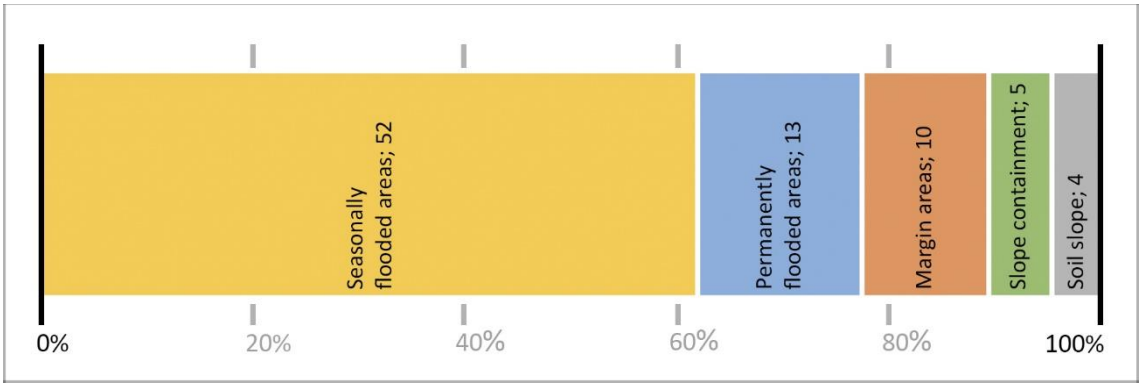
The information was organized in Microsoft Excel® software, forming a database regarding the plant repertoire indicated for the GI typologies of stormwater management in Brazil. The complete list of species cited by the articles is available in Appendix 1. All this material collected was summarized according to several reading keys, which allowed different analyses, as shown in the following results.

4 RESULTS

Initially, the plant species identified in the 7 articles (AKINAGA et al., 2010; BONZI, 2013; ALMEIDA et al., 2014; PINHEIRO, 2015; GUIMARÃES et al., 2018; SOUZA et al., 2019; and TEIXEIRA; SILVA, 2019) are presented according to the authors' recommendation for use, due to the GI typologies and the characteristics of the areas.

In Figure 1, it is possible to observe the number of species recommended for each area (values after the description of the characteristic of the area), in addition to the percentage that each indication represents in relation to the total of species (values plotted at the bottom of the chart). It is noteworthy, however, that of the total of 82 species, 2 are indicated twice (for areas with different characteristics), as recommended by the authors.

Figure 1: Number of species per indication of use, according to area characteristics



Source: Prepared by the authors (2021)

4.1 Species for seasonally flooded areas

For seasonally flooded areas, the authors Akinaga et al. (2010), Almeida et al. (2014), Pinheiro (2015), Guimarães et al. (2018), Souza et al. (2019) and Teixeira and Silva (2019) recommend 48 different species and 4 genera (*Bacopa* Aubl., *Drosera* L., *Salix* L. and *Typha* L.). Only Akinaga et al. (2010) mentions that the indication is based on a previous field survey, while

the other authors suggest species based on the literature and/or their potential for use. It is also noteworthy that among the species mentioned in the articles, only those recommended by the authors for use in Brazil were included in the results of this work.

On this point, it is worth noting that most of the articles are dedicated precisely to identifying the potential and recommending new species, mainly native ones, that are suitable for use in the seasonally flooded GI typologies, such as 'rain gardens' or 'bioswales'. The species *Typha* L. (taboa), also recommended for permanently flooded areas, is the only one on the list whose indication of use is corroborated in the consensus document between researchers and practitioners in the area of '*wetlands construídos*' or 'constructed wetlands' in Brazil (VON SPERLING; SEZERINO, 2018).

4.2 Species for permanently flooded areas

The authors Akinaga et al. (2010) and Bonzi (2013) cite 10 different species that can be used in permanently flooded areas, in addition to 3 genera (*Heliconia* L., *Juncus* L. and *Typha* L.), based on different sources. For Bonzi (2013), the list of species cited in the article comes from the literature, while for Akinaga et al. (2010), the species that were used in the landscape design presented in the article come from a field survey and identification of species previously existing in the intervention area.

Among the authors' recommendations, the species that stand out are *Cyperus papyrus* L. (papiro), *Eleocharis geniculata* (L.) Roem. & Schult. (junco, tiririca or junco-popoca) and *Zantedeschia aethiopica* (L.) Spreng. (copo de leite), in addition to 3 genera *Heliconia* L. (helicônia), *Juncus* L. (junco) and *Typha* L. (taboa), as they are plants widely used in the GI typology known as 'constructed wetlands' (VON SPERLING; SEZERINO, 2018).

4.3 Species for margin areas, soil slope and slope containment

Understanding that a wide range of different areas must be contemplated in a landscape design, the authors Akinaga et al. (2010) and Teixeira and Silva (2019) recommend species for use in margin areas, soil slopes and slope containment, as part of GI projects. Thus, there are 19 species in total: 10 for margin areas, 4 for soil slopes and 5 for slope containment.

The species *Cyperus papyrus* L. (papiro), also recommended for permanently flooded areas, is the only one on the list whose indication of use is supported by the document by Von Sperling and Sezerino (2018).

4.4 Species by botanical family

Among all the species listed in the articles, 41 distinct botanical families were identified. Two thirds of the total species (67%) belong to 14 families: *Poaceae* (11 species); *Cyperaceae* (9 species); *Asteraceae* (6 species); *Fabaceae* (6 species); *Malvaceae*, *Melastomataceae,* and *Onagraceae* (3 species each); *Acanthaceae*, *Araceae*, *Costaceae*, *Heliconiaceae*, *Rutaceae*, *Typhaceae,* and *Xyridaceae* (2 species each). The other third (33%) corresponds to the 27 families that have only 1 species each.

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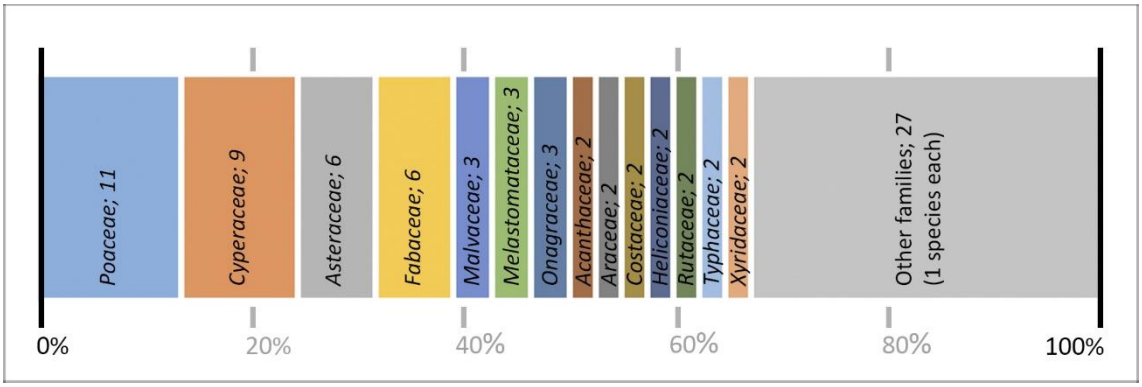
Figure 2 presents a graph with a summary of species quantities for the main botanical families (in relation to the number of species mentioned by the authors).

Figure 2: Number of species per botanical family



Source: Prepared by the authors (2021)

4.5 Species by life form

a) **Herb**: 40 species recommended by the authors have herb characteristics, in addition to the 4 genera *Heliconia* L. (helicônia); *Juncus* L. (junco); *Typha* L. (taboa) and *Drosera* L. (planta carnívora).

b) **Tree**: 14 species recommended by the authors have tree characteristics, the species *Cariniana estrellensis* (Raddi) Kuntze (jequitibá-branco); *Colubrina glandulosa* G.Perkins (saraguagi); *Cordia trichotoma* (Vell.) Arráb. ex Steud. (louro-pardo); *Erythrina crista-galli* L. (corticeira-do-banhado); *Esenbeckia leiocarpa* Engl. (guarantã); *Guarea guidonia* (L.) Sleumer (marinheiro); *Luehea divaricata* Mart. (açoita-cavalo); *Peltophorum dubium* (Spreng.) Taub. (faveiro); *Pilocarpus pennatifolius* Lem. (jaborandi); *Platymiscium floribundum* Vogel (sacambu); *Handroanthus umbellatus* (Sond.) Mattos (ipê-amarelo); *Magnolia ovata* (A.St.-Hil.) Spreng. (baguaçu); *Tibouchina sellowiana* Cogn. (quaresmeira) and *Senna bicapsularis* (L.) Roxb. (canudo-de-pito).

c) **Subshrub**: 6 species recommended by the authors have subshrub characteristics, the species *Alternanthera brasiliana* (L.) Kuntze (periquito-gigante); *Begonia reniformis* Dryand. (begônia-folha-de-videira); *Cuphea calophylla* Cham. & Schltdl. (sete-sangrias); *Ruellia jussieuoides* Schltdl. (ruélia-azul); *Spermacoce suaveolens* (G.Mey.) Kuntze (poaia, poaia do campo, vassoura de botão or vassourinha) and *Unxia suffruticosa* (Baker) Stuessy (botão-de-ouro).

d) **Herb and Subshrub**: 4 species recommended by the authors have characteristics that vary between grass and subshrub, the species *Centratherum punctatum* Cass. (perpétua-roxa); *Justicia scheidweileri* V.A.W. Graham (camarão-rosa); *Tibouchina minor* Cogn. (quaresmeira) and *Pluchea sagittalis* Less. (macela). In addition to the genus: *Bacopa* Aubl. (vick).

e) **Bamboo**: 3 species recommended by the authors have bamboo characteristics, the species *Dendrocalamus giganteus* Munro (bambu-balde or bambu-gigante); *Guadua*

angustifolia Kunth (taboca, taquaraçu, taquara or bambu-taquara) and *Guadua chacoensis* (Rojas Acosta) Londoño & P.M.Peterson (taquaraçu or taquara).

f) **Shrub**: 2 species indicated by the authors have shrub characteristics, the species *Hibiscus diversifolius* Jacq. (hibisco-do-banhado) and *Ludwigia leptocarpa* (Nutt.) H.Hara (florzeiro).

g) **Herb, Subshrub and Shrub**: 2 species recommended by the authors have characteristics that vary between grass, subshrub and shrub, the species *Aeschynomene sensitiva* Sw. (cortiça or cortiça do brejo) and *Tarenaya hassleriana* (Chodat) Iltis (mussambê de espinhos).

h) **Subshrub and Shrub**: 2 species recommended by the authors have characteristics that vary between subshrub and shrub, the species *Ludwigia peruviana* (L.) H.Hara (cruz-de-malta) and *Rhynchanthera grandiflora* (Aubl.) DC. (quaresmeira).

i) **Shrub and Liana/voluble/vine**: 2 species recommended by the authors have characteristics that vary between shrub and liana/voluble/vine, the species *Allamanda cathartica* L. (dedal-de-princesa, dedal-de-rainha or margarida) and *Fuchsia regia* (Vand. ex Vell.) Munz (brinco-de-princesa).

j) **Subshrub, Shrub and Liana/voluble/vine**: 1 species recommended by the authors has characteristics that vary between subshrub, shrub and liana/voluble/vine, the species *Ipomoea carnea* Jacq. (algodão bravo).

k) **Shrub and Tree**: 1 genus recommended by the authors has characteristics that vary between shrub and tree, the genus *Salix* L. (vimeiro).

However, it is important to point out that there is no consensus on recommending tree planting in some GI typologies. As pointed out by Baptista et al. (2015, p. 254), planting trees in typologies such as '*valas*' and '*valetas*' ('swales') can make it difficult to carry out preventive maintenance, which would impair the hydraulic function of these structures. Thus, as a general recommendation, trees can be employed as an integral part of a larger landscape design. For example, planted in places adjacent to the GI typologies with the purpose of creating multifunctional and pleasant spaces for the permanence of the users of these places, and not necessarily within these structures.

Figure 3 shows the number of species per life form.

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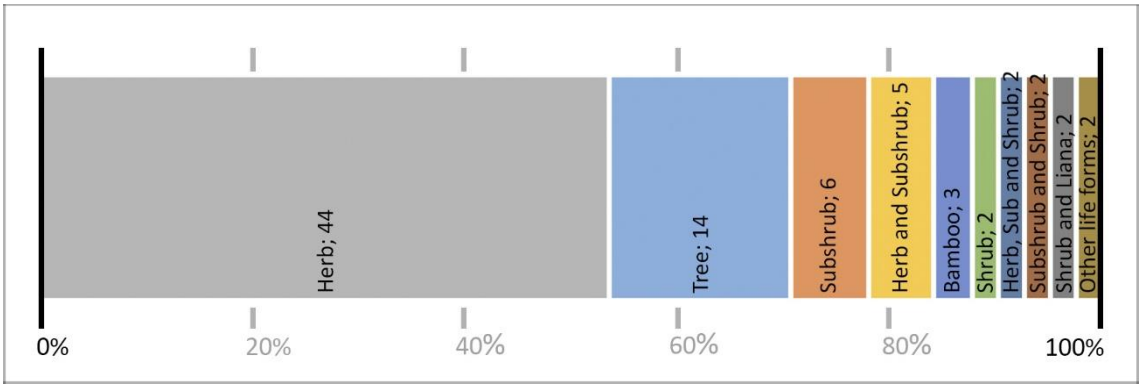
Figure 3: Number of species according to life form



Source: Prepared by the authors (2021)

4.6 Species by substrate

a) **Terrestrial**: 56 species are exclusively terrestrial. Highlight for some recommendations of species of herbs or subshrubs native and endemic to Brazil, such as: *Arachis repens* Handro (grama-amendoim); *Justicia scheidweileri* V.A.W. Graham (camarão-rosa); *Tibouchina minor* Cogn. (quaresmeira); *Xyris blepharophylla* Mart. (unidentified common name); *Rhynchospora nervosa* (Vahl) Boeckeler (capim-estrela or tiririca branca) and *Gunnera manicata* Linden ex Delchev. (urtigão). In addition to 2 exclusively terrestrial genera: *Salix* L. (vimeiro) and *Heliconia* L. (helicônia).

b) **Terrestrial and Aquatic**: 8 species are terrestrial and aquatic. Being: *Eleocharis geniculata* (L.) Roem. & Schult. (junco, tiririca or junco-popoca); *Mayaca fluviatilis* Aubl. (lodo, musgo de flor or maiacá); *Cyperus giganteus* Vahl (papiro-brasileiro); *Regnellidium diphyllum* Lindm. (samambaia-borboleta); *Sphagneticola trilobata* (L.) Pruski (mal-me-quer or vedélia); *Aeschynomene sensitiva* Sw. (cortiça or cortiça do brejo); *Cyperus mundii* (Nees) Kunth (tiririca-do-brejo) and *Rhynchospora corymbosa* (L.) Britton (capim-navalha). In addition to 3 genera: *Juncus* L. (junco); *Typha* L. (taboa) and *Bacopa* Aubl. (vick).

c) **Aquatic**: 5 species are exclusively aquatic. Of which: *Cyperus papyrus* L. (papiro); *Nymphaea caerulea* Savigny (ninféa-azul); *Nymphoides indica* (L.) Kuntze (lírio d'água); *Utricularia gibba* L. (mururé) and *Typha latifolia* L. (taboa).

d) **Terrestrial and Rupicolous**: 4 species are terrestrial and rupicolous. Being: *Chamaecostus cuspidatus* (Nees & Mart.) C.D.Specht & D.W.Stev. (cóstus-de-fogo); *Seemannia sylvatica* (Kunth) Baill. (semânia); *Philodendron renauxii* Reitz (filodendro) and *Spermacoce suaveolens* (G.Mey.) Kuntze (poaia, poaia do campo, vassoura de botão or vassourinha). In addition to 1 genus: Drosera L. (planta-carnívora).

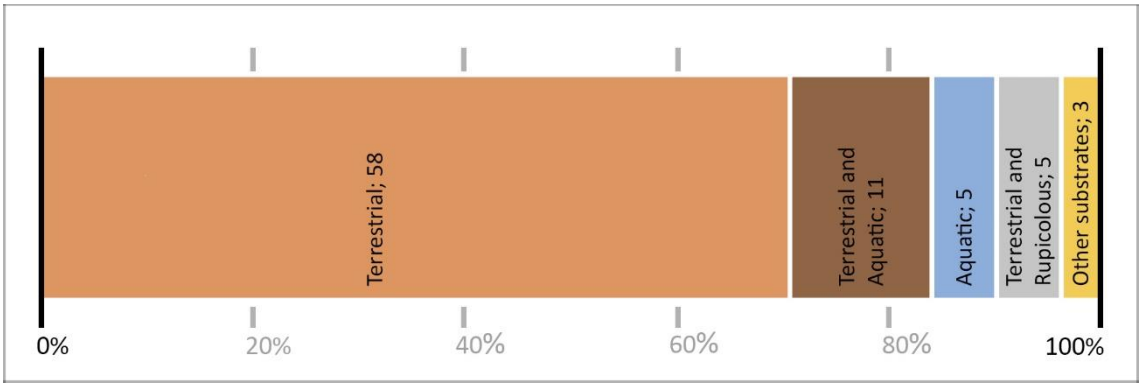
e) **Rupicolous**: Only 1 species, *Begonia reniformis* Dryand. (begônia-folha-de-videira) is exclusively rupicolous.

f) **Terrestrial and Epiphytic**: Only 1 species, *Fuchsia regia* (Vand. ex Vell.) Munz (brinco-de-princesa) is terrestrial and epiphytic.

g) In addition, there is no information about the substrate for 1 of the species, according to information extracted from the Flora do Brasil database (2020).

Figure 4 shows the number of species by type of substrate. It is also important to highlight that, despite the authors presenting different recommendations on the types of substrates in which the species can be planted, the classification of the Flora do Brasil database (2020) was adopted for the purpose of standardizing the results.

Figure 4: Number of species by type of substrate



Source: Prepared by the authors (2021)

4.7 Species by origin

a) **Native**: The vast majority of the species recommended by the authors is native, with 60 species, in addition to the 6 genera *Heliconia* L. (helicônia); *Juncus* L. (junco); *Typha* L. (taboa); *Bacopa* Aubl. (vick); *Drosera* L. (planta-carnívora) and *Salix* L. (vimeiro). This finding is certainly in line with the objective of the selected articles: to explore and suggest new species for use in GI typologies, suited to the characteristics of Brazil.

b) **Naturalized**: 7 species recommended by the authors are naturalized, that is, exotic species that can reproduce in the place where they were introduced without the need for direct human intervention. Of which: *Cyperus papyrus* L. (papiro); *Nymphaea caerulea* Savigny (ninféa-azul); *Brassica juncea* (L.) Czern. (mostarda marrom); *Festuca arundinacea* Schreb. (festuca-alta or festuca); *Hedychium coronarium* J.Koenig (lírio-do-brejo); *Lolium perenne* L. (azevém-perene) and *Cyperus mundii* (Nees) Kunth (tiririca-do-brejo).

c) **Cultivated**: 5 species recommended by the authors are cultivated, that is, exotic species that cannot survive without human cultivation. Being: *Dendrocalamus giganteus* Munro (bambu-balde or bambu-gigante); *Guadua angustifolia* Kunth (taboca, taquaraçu, taquara or bambu-taquara); *Zantedeschia aethiopica* (L.) Spreng. (copo de leite); *Daucus carota* L. (cenoura) and *Panicum virgatum* L. (*switchgrass*).

d) In addition, there is no information about the origin for 4 of the species, according to information extracted from the Flora do Brasil database (2020).

Figure 5 shows the number of species by origin.

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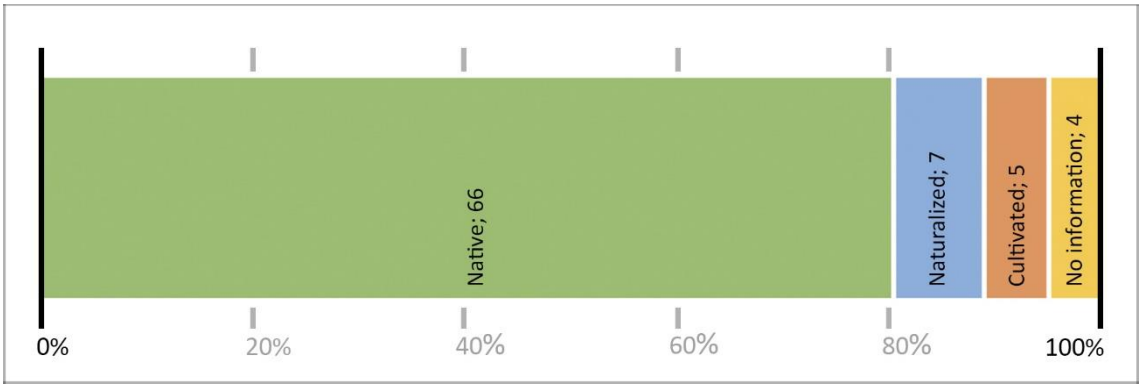
Figure 5: Number of species by origin



Source: Prepared by the authors (2021)

4.8 Endemic species

Among the species recommended by the authors, 14 are endemic to Brazil, that is, they occur exclusively in the country: *Arachis repens* Handro (grama-amendoim); *Begonia reniformis* Dryand. (begônia-folha-de-videira); *Chamaecostus cuspidatus* (Nees & Mart.) C.D.Specht & D.W.Stev. (cóstus-de-fogo); *Esenbeckia leiocarpa* Engl. (guarantã); *Justicia scheidweileri* V.A.W. Graham (camarão-rosa); *Philodendron renauxii* Reitz (filodendro); *Platymiscium floribundum* Vogel (sacambu); *Handroanthus umbellatus* (Sond.) Mattos (ipê-amarelo); *Magnolia ovata* (A.St.-Hil.) Spreng. (baguaçu); *Tibouchina minor* Cogn. (quaresmeira); *Xyris blepharophylla* Mart. (unidentified common name); *Rhynchospora nervosa* (Vahl) Boeckeler (capim-estrela or tiririca branca); *Tibouchina sellowiana* Cogn. (quaresmeira) and *Gunnera manicata* Linden ex Delchev. (urtigão).

4.9 Species by Phytogeographic Domain

Regarding the occurrence of species, it is noteworthy that the same species can occur in different Phytogeographic Domains (and even in all), as is the case of species such as *Eleocharis geniculata* (L.) Roem. & Schult. (junco, tiririca or junco-popoca) or *Sphagneticola trilobata* (L.) Pruski (mal-me-quer or vedélia). Among the 82 species, 18 fit this situation, that is, they occur in all six Domains. This explains the difference between the value resulting from the sum of the number of species that occur in each Domain (268 species), and the total number of species mentioned by the articles (82 species).

a) **Mata Atlântica**: There are 71 species that occur in the Mata Atlântica Domain. Of these, 10 species occur exclusively in this Domain: *Guadua chacoensis* (Rojas Acosta) Londoño & P.M.Peterson (taquaraçu or taquara); *Chamaecostus cuspidatus* (Nees & Mart.) C.D.Specht & D.W.Stev. (cóstus-de-fogo); *Festuca arundinacea* Schreb. (festuca-alta or festuca); *Justicia scheidweileri* V.A.W. Graham (camarão-rosa); *Lolium perenne* L. (azevém-perene); *Philodendron renauxii* Reitz (filodendro); *Cyperus mundii* (Nees) Kunth (tiririca-do-brejo); *Senecio pinnatus* Poir. (unidentified common name); *Tibouchina*

sellowiana Cogn. (quaresmeira) and *Gunnera manicata* Linden ex Delchev. (urtigão).

b) **Cerrado (*lato sensu*):** It was observed that, of the total number of species recommended by the authors, 54 occur in the Cerrado Domain and of these, 2 species occur exclusively in this Domain, being *Seemannia sylvatica* (Kunth) Baill. (semânia) and *Xyris blepharophylla* Mart. (unidentified common name).

c) **Pampa**: Among the species recommended by the authors, 39 species occur in the Pampa Domain and of these, no species occurs exclusively in this Domain.

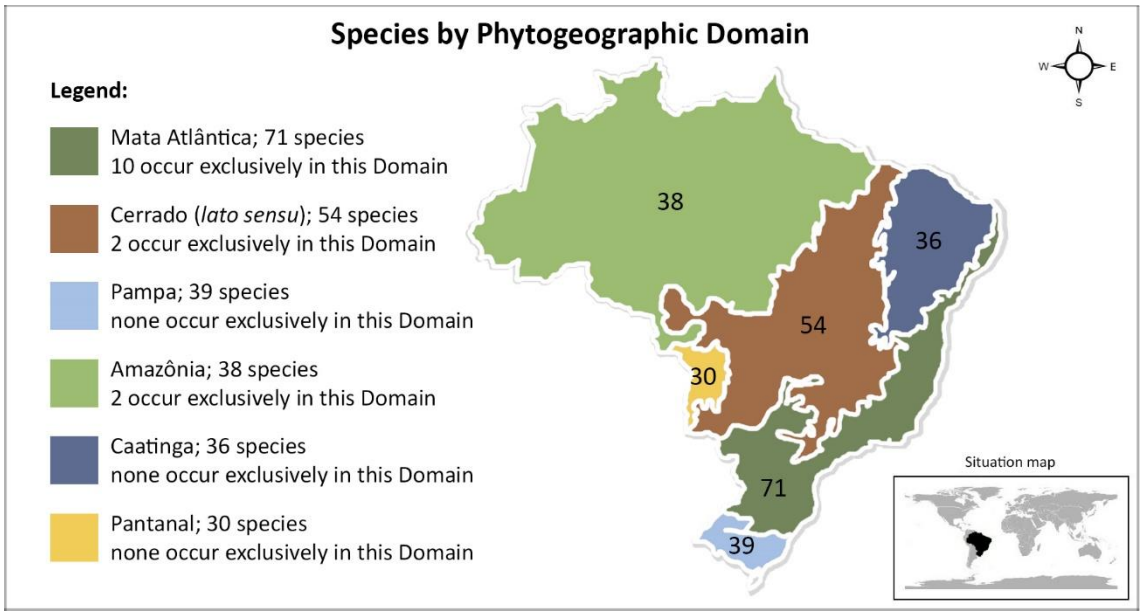
d) **Amazonia**: As found in the survey, 38 of the species recommended by the authors occur in the Amazon Domain. Of these, 2 species occur exclusively in this Domain: *Spermacoce suaveolens* (G.Mey.) Kuntze (poaia, poaia do campo, vassoura de botão or vassourinha) and *Unxia suffruticosa* (Baker) Stuessy (botão-de-ouro).

e) **Caatinga**: Among the recommended species, 36 species occur in the Caatinga Domain and of these, no species occurs exclusively in this Domain.

f) **Pantanal**: To conclude, among the species recommended by the authors, 30 species occur in the Pantanal Domain and of these, no species occurs exclusively in this Phytogeographic Domain.

Figure 6 shows a map of the location of the six Phytogeographic Domains in Brazil and the number of species mentioned in the articles that occur in each of them.

Figure 6: Number of species that occur in each Phytogeographic Domain



Source: Prepared by the authors (2021) based on IBGE (2021)

5 CONCLUSION

In Brazil, experimental data on species recommended for GI projects are still scarce. Considering only the species indicated for seasonally flooded areas, which is the case of typologies such as 'rain gardens', 'bioswales' or 'bioretention' techniques, the authors Akinaga

et al. (2010), Almeida et al. (2014), Pinheiro (2015), Guimarães et al. (2018), Souza et al. (2019) and Teixeira and Silva (2019) mention a total of 48 different species and 4 genera. As for permanently flooded areas, which include the typologies of 'constructed wetlands' or 'wetlands' the authors Akinaga et al. (2010) and Bonzi (2013) cite 10 different species, and 3 genera.

However, only Akinaga et al. (2010) is based on a previous field survey, while the other authors suggest species based on the literature and/or on their potential for use, considering the vegetation characteristics. On this point, it is worth noting that most of the previously mentioned national publications are dedicated precisely to suggesting new species for GI projects, especially native species. But it is concerning that of this universe of 82 species, only a small part (3 species and 3 genera) are species whose indication of use is corroborated in the consensus document between researchers and practitioners in the area in Brazil (VON SPERLIN; SEZERINO, 2018).

Thus, the present work was dedicated to exploring this gap, by compiling the plant species indicated in the national literature for use in GI projects, focusing on the recommended species for the GI typologies of stormwater management. The result of this survey is a database containing information on 82 plant species, which may serve for future research in the area that aims at the validation of the use of native species through experimental data, subsidizing the elaboration of a plant repertoire to be used in landscape projects of this nature in Brazil.

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Appendix 1. List of species recommended for green infrastructure: stormwater management typologies

Species for permanently flooded areas Typologies such as 'constructed wetlands' or 'wetlands'			
Species (current scientific name)	**Species (name according to article)**	**Common name**	**Source**
Cyperus papyrus L.	*Cyperus papyrus*	Papiro	Bonzi (2013)
Dendrocalamus giganteus Munro	*Dendrocalamus giganteus*	Bambu-balde; Bambu-gigante	Bonzi (2013)
Eleocharis geniculata (L.) Roem. & Schult.	*Eleocharis geniculata*	Junco; Tiririca; Junco-popoca	Akinaga et al. (2010)
Guadua angustifolia Kunth	*Guadua augustifolia*	Taboca; Taquaraçu; Taquara; Bambu-taquara	Bonzi (2013)
Guadua chacoensis (Rojas Acosta) Londoño & P.M.Peterson	*Guadua chacoensis*	Taquaraçu; Taquara	Bonzi (2013)
Heliconia L.	*Heliconia spp*	Helicônia	Bonzi (2013)
Juncus L.	*Juncus spp*	Junco	Bonzi (2013)
Mayaca fluviatilis Aubl.	*Mayaca fluviatilis*	Lodo; Musgo de flor; Maiacá	Akinaga et al. (2010)
Nymphaea caerulea Savigny	*Nymphaea caerulea*	Ninféa-azul	Akinaga et al. (2010)
Nymphoides indica (L.) Kuntze	*Nymphoides indica*	Lírio d'água	Akinaga et al. (2010)
Typha L.	*Typha spp*	Taboa	Bonzi (2013)
Utricularia gibba L.	*Utricularia gibba*	Mururé	Akinaga et al. (2010)
Zantedeschia aethiopica (L.) Spreng.	*Zantedeschia aethiopica*	Copo de leite	Bonzi (2013)
Species for seasonally flooded areas Typologies such as 'rain gardens', 'bioswales' or 'bioretention' techniques			
Species (current scientific name)	**Species (name according to article)**	**Common name**	**Source**
Agrostis montevidensis Spreng. ex Nees	*Agrostis montevidensis*	Capim-mimoso	Teixeira e Silva (2019)
Allamanda cathartica L.	*Allamanda catártica*	Dedal-de-princesa; Dedal-de-rainha; Margarida	Guimarães et al. (2018)
Alternanthera brasiliana (L.) Kuntze	*Alternanthera brasiliana* (L.) Kuntze	Periquito-gigante	Almeida et al. (2014)
Arachis repens Handro	*Arachis repens* (Handro)	Grama-amendoim	Almeida et al. (2014)
Bacopa Aubl.	*Bacopa sp*	Vick	Akinaga et al. (2010)
Begonia reniformis Dryand.	*Begonia reniformis* Hook.	Begônia-folha-de-videira	Almeida et al. (2014)
Brassica juncea (L.) Czern.	*Brassica juncea* (L.) Czern	Mostarda marrom	Pinheiro (2015)
Cariniana estrellensis (Raddi) Kuntze	*Cariniana estrellensis* (Raddi) Kuntze	Jequitibá-branco	Souza et al. (2019)
Centratherum punctatum Cass.	*Centratherum punctatum* Cass.	Perpétua-roxa	Almeida et al. (2014)
Chamaecostus cuspidatus (Nees & Mart.) C.D.Specht & D.W.Stev.	*Chamaecostus cuspidatus* (Nees & Mart.) C.Specht & D.W.Stev.	Cóstus-de-fogo	Almeida et al. (2014)
Colubrina glandulosa G.Perkins	*Colubrina glandulosa* (Perkins)	Saraguagi	Souza et al. (2019)

Cordia trichotoma (Vell.) Arráb. ex Steud.	*Cordia trichotoma* (Vell.) Arrab. Ex Steud.	Louro-pardo	Souza et al. (2019)
Costus spiralis (Jacq.) Roscoe	*Costus spiralis* (Jacq.) Roscoe	Cana-de-macaco	Souza et al. (2019)
Cuphea calophylla Cham. & Schltdl.	*Cuphea calophylla*	Sete-sangrias	Akinaga et al. (2010)
Cyperus giganteus Vahl	*Cyperus giganteus* Vahl	Papiro-brasileiro	Souza et al. (2019)
Daucus carota L.	*Daucus carota* L.	Cenoura	Pinheiro (2015)
Drosera L.	*Drosera sp*	Planta-carnívora	Akinaga et al. (2010)
Erythrina crista-galli L.	*Erythrina crista-galli*	Corticeira-do-banhado	Teixeira e Silva (2019)
Esenbeckia leiocarpa Engl.	*Esenbeckia leiocarpa* Engl.	Guarantã	Souza et al. (2019)
Festuca arundinacea Schreb.	*Festuca arundinacea*	Festuca-alta; Festuca	Pinheiro (2015)
Guarea guidonia (L.) Sleumer	*Guarea guidonia (*L.) Sleumer	Marinheiro	Souza et al. (2019)
Handroanthus umbellatus (Sond.) Mattos	*Tabebuia umbellata*	Ipê-amarelo	Teixeira e Silva (2019)
Hedychium coronarium J.Koenig	*Hedychium coronarium*	Lírio-do-Brejo	Akinaga et al. (2010)
Heliconia psittacorum L.f.	*Heliconia psittacorum* L. f.	Heliconia-papagaio	Souza et al. (2019)
Hibiscus diversifolius Jacq.	*Hibiscus diversifolius*	Hibisco-do-banhado	Teixeira e Silva (2019)
Ischaemum minus J.Presl	*Ischaemum minus*	Grama-de-folha-larga	Teixeira e Silva (2019)
Justicia scheidweileri V.A.W. Graham	*Justicia scheidweileri* V.A.W.Graham	Camarão-rosa	Almeida et al. (2014)
Lolium perenne L.	*Lolium perenne* L.	Azevém-perene	Pinheiro (2015)
Ludwigia peruviana (L.) H.Hara	*Ludwigia peruviana*	Cruz-de-malta	Akinaga et al. (2010)
Luehea divaricata Mart.	*Luehea divaricate* Mart.	Açoita-cavalo	Souza et al. (2019)
Magnolia ovata (A.St.-Hil.) Spreng.	*Talauma ovata*	Baguaçu	Teixeira e Silva (2019)
Panicum virgatum L.	*Panicum virgatum* L.	*Switchgrass*	Pinheiro (2015)
Peltophorum dubium (Spreng.) Taub.	*Peltophorumdubium* (Spreng.) Taub.	Faveiro	Souza et al. (2019)
Philodendron renauxii Reitz	*Philodendron renauxii* Reitz	Filodendro	Souza et al. (2019)
Pilocarpus pennatifolius Lem.	*Pilocarpus pennatifolius* Lem	Jaborandi	Teixeira e Silva (2019)
Platymiscium floribundum Vogel	*Platymiscium floribundum* Vogel	Sacambu	Souza et al. (2019)
Regnellidium diphyllum Lindm.	*Regnellidium diphyllum*	Samambaia-borboleta	Teixeira e Silva (2019)
Rhynchanthera grandiflora (Aubl.) DC.	*Rhynchanthera limosa*	Quaresmeira	Akinaga et al. (2010)
Ruellia jussieuoides Schltdl.	*Ruellia puri* Mart.ex Nees	Ruélia-azul	Almeida et al. (2014)
Salix L.	*Salix* L.	Vimeiro	Pinheiro (2015)

Schizachyrium scoparium (Michx.) Nash	*Schizachyrium scoparius*	*Little bluestem*	Pinheiro (2015)
Seemannia sylvatica (Kunth) Baill.	*Gloxinia sylvatica* (Kunth) Wiehler	Semânia	Almeida et al. (2014)
Senecio bonariensis Hook. & Arn.	*Senecio bonariensis*	Margarida-do-banhado	Teixeira e Silva (2019)
Sorghastrum nutans (L.) Nash	*Sorghastrum nutans*	*Indian grass*	Pinheiro (2015)
Spermacoce suaveolens (G.Mey.) Kuntze	*Spermacoce suaveolens*	Poaia; Poaia do campo; Vassoura de botão; Vassourinha	Akinaga et al. (2010)
Sphagneticola trilobata (L.) Pruski	*Sphagneticola trilobata* (L.) Pruski	Mal-me-quer	Almeida et al. (2014)
Sphagneticola trilobata (L.) Pruski	*Wedelia paludosa* DC.	Vedélia	Souza et al. (2019)
Tibouchina minor Cogn.	*Tibouchina minor*	Quaresmeira	Akinaga et al. (2010)
Typha L.	*Typha spp*	Taboa	Souza et al. (2019)
Typha latifolia L.	*Typha latifólia*	Taboa	Guimarães et al. (2018)
Unxia suffruticosa (Baker) Stuessy	*Unxia suffruticosa* (Baker) Stuessy	Botão-de-ouro	Almeida et al. (2014)
Xyris blepharophylla Mart.	*Xyris blepharophylla*		Akinaga et al. (2010)
Xyris macrocephala Vahl	*Xyris laxifolia*	Botão-de-ouro; Jupiedi	Akinaga et al. (2010)
Species for margin areas, soil slope and slope containment			
Species (current scientific name)	**Species (name according to article)**	**Common name**	**Source**
Aeschynomene sensitiva Sw.	*Aeschynomene sensitiva*	Cortiça; Cortiça do brejo	Akinaga et al. (2010)
Bulbostylis capillaris (L.) Kunth ex C.B.Clarke	*Bulbostylis capillaris*	Alecrim-da-praia	Akinaga et al. (2010)
Cyperus mundii (Nees) Kunth	*Pycreus decumbens*	Tiririca-do-brejo	Akinaga et al. (2010)
Cyperus meyenianus Kunth	*Cyperus meyenianus*	Junquinho; Tiririca-mansa	Akinaga et al. (2010)
Cyperus papyrus L.	*Cyperus papyrus*	Papiro	Akinaga et al. (2010)
Cyperus sesquiflorus (Torr.) Mattf. & Kük.	*Cyperus sesquiflorus*	Capim Cheiroso	Akinaga et al. (2010)
Fuchsia regia (Vand. ex Vell.) Munz	*Fuchsia regia*	Brinco-de-princesa	Teixeira e Silva (2019)
Gunnera manicata Linden ex Delchev.	*Gunnera manicata*	Urtigão	Teixeira e Silva (2019)
Ipomoea carnea Jacq.	*Ipomoea carnea*	Algodão Bravo	Akinaga et al. (2010)
Ludwigia leptocarpa (Nutt.) H.Hara	*Ludwigia leptocarpa*	Florzeiro	Akinaga et al. (2010)
Panicum racemosum (P.Beauv.) *Spreng.*	*Panicum racemosum*	Capim-das-dunas	Teixeira e Silva (2019)
Pavonia cancellata (L.) Cav.	*Payonia cancellata*	Malva-rasteira	Akinaga et al. (2010)
Pluchea sagittalis Less.	*Pluchea sagittalis*	Macela	Akinaga et al. (2010)
Rhynchospora corymbosa (L.) Britton	*Rhynchospora corymbosa*	Capim-Navalha	Akinaga et al. (2010)

Rhynchospora nervosa (Vahl) Boeckeler	*Rhynchospora nervosa*	Capim-estrela; Tiririca branca	Akinaga et al. (2010)
Senecio pinnatus Poir.	*Senesio pinnatus*		Akinaga et al. (2010)
Senna bicapsularis (L.) Roxb.	*Senna bicapsularis*	Canudo-de-pito	Teixeira e Silva (2019)
Tarenaya hassleriana (Chodat) Iltis	*Cleome hassleriana*	Mussambê de espinhos	Akinaga et al. (2010)
Tibouchina sellowiana Cogn.	*Tibouchina sellowiana*	Quaresmeira	Teixeira e Silva (2019)

Source: Prepared by the authors, 2021