eISSN 2236-5257
10.46551/ruc.v26n2a9

Potential for using native species from rocky fields in gardens with ecological desing

Potencial de espécies nativas de campo rupestre para jardins com design ecológico

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ABSTRACT

Objective: Focusing on native species of the rocky fields of Serra de Itacambira, Minas Gerais state, Brazil, the objective of the work was to analyze the physiological and structural traits of leaves, flowers, stems and the plant as a whole, toward selecting out species with potential use for garden with ecological desing. **Methodology:** A total of 61 plant species belonging to 29 families were collected, analyzed, and the characteristics of their flowers, leaves, and stems were described. **Results:** These species were pointed out for uses in landscaping, as vertical gardens, roofing of buildings, borders, mass flower designs, and even isolated use in beds. Twenty three out of the 61 identified species were highlighted for supporting low water availability and having a high interaction with local fauna. **Conclusion:** Based on their structure and physiological traits, the 61 plant species collected in Serra da Itacambira have potential use in garden with ecological design, especially in drought-resistant gardens.

Keywords: Cerrado, Drought resistance, Flora; Ornamental potential, Native plants

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Recebido em	Aceito em	Publicado em
24-06-2024	14-08-2024	24-10-2024

RESUMO

Objetivo: Com foco nas espécies nativas dos campos rupestres da Serra de Itacambira, Minas Gerais, Brasil, o trabalho teve como objetivo analisar as características fisiológicas e estruturais de folhas, flores, caule e da planta como um todo, visando selecionar espécies com potencial uso para jardins com design ecológico. **Metodologia:** Foram coletadas e analisadas 61 espécies de plantas pertencentes a 29 famílias e descritas as características de suas flores, folhas e caules. **Resultados:** As espécies analisadas foram apontadas para uso em paisagismo, como jardins verticais, coberturas de edifícios, bordaduras, composição de maciços com flores e até uso isolado em canteiros. Vinte e três das 61 espécies identificadas foram destacadas por suportarem baixa disponibilidade hídrica e terem alta interação com a fauna local. **Conclusões:** Com base em sua estrutura e características fisiológicas, as 61 espécies de plantas coletadas na Serra da Itacambira têm potencial de utilização no paisagismo ecológico, especialmente em jardins resistentes à seca.

Palavras-chave: Cerrado, Flora, Plantas nativas, Potencial ornamental, Resistência à seca.

INTRODUCTION

Landscaping can be used as an instrument to combine plant ornamental value with other benefits plants can provide to the environment toward improving urban environmental quality[1]. One of the principles of contemporary landscaping focuses on ecology and integration with the environment as a whole, which is performed by the use of tools for planning and building spaces beyond providing scenic landscapes[2]. The creation of such spaces aims at criteria such as functionality and respect for the environment, with principles that value the environment and benefit all forms of life[2]. Recreating environments as refugia for fauna in urban environments, providing better absorption of rainwater, combating the effects of urban heat islands, and forming milder microclimates are also ecological services that can be offered through landscaping in addition to aesthetic services[3]. Thus, plant native species use in landscape projects can be adopted to integrate these services in gardens[1].

The use of plant native species has been increased in landscaping mainly due to the important ecological functions they play in the ecosystem and their adaptability to water requirements according to the climatic conditions of their region of origin[4]. Native plants are more resistant to the attack of pests and diseases, they attract specific insects as pollinators, promoting ecosystem balance, and their use in gardens facilitates restoration and regional

identity[5]. The cultivation of these species, especially those at risk of extinction, can serve as a means of conserving them outside their natural habitats, ensuring their protection in cases where their native environments are threatened by ongoing anthropogenic activities[6,7]. A range of species with ornamental features can be found in Brazilian biomes, and their domestication may allow greater diversity in gardens[1].

The Cerrado is the second-largest Brazilian biome, accounting for approximately 23% of the country's land area, and it is the most biologically diverse tropical savanna in the world[8]. The soils in Cerrado areas are mainly characterized by high acidity levels and nutrient deficiencies. This biome has different phytophysiognomies, and, according to its vegetation architecture and composition, can be subdivided into savanna (*cerrado stricto sensu* and *cerrado ralo*), forest (semideciduous seasonal forest, gallery forest, and *cerradão*), grassland (*campo sujo*, *campo limpo*) and rupestrian fields (*campos rupestres*)[9].

The rupestrian fields are characterized by shrubby herbaceous vegetation that develops on quartzitic, sandy, clear, and nutrient-poor soils at altitudes above 900 m[10]. Accordingly, the rupestrian fields are considered a hotspot of biodiversity and constitute a unique and diverse environment, where most of the species are endemic[11]. The vegetation in rupestrian fields is distributed in patches according to the type of microhabitat that is formed on various substrates, such as wet fields, sandy fields, rocky fields, and rocky outcrops[11]. With such diversity, it is natural that many species possess characteristics of interest for landscaping, but to date, they have not been used due to the lack of research from this perspective[12]. Among the important plant groups found in rupestrian fields, species of Orchidaceae and the group of 'everlasting' flowers are collected for the commercial use of their floral scapes and flower buds in handicrafts and dried floral bouquets[13]. These two specific categories were not inserted in this study because their use have been intensely studied in commercial ad ethnobotanical perspectives[14]. Currently, our objective is to identify and characterize the plant native species that occur in the rupestrian fields located in the Serra da Itacambira in the northern region of the Minas Gerais, Brazil, that have ornamental traits suitable for use in garden with ecological design. The species identified here compose a list of plants from rupestrian fields with potential use in projects of landscaping.

MATERIAL AND METHODS

Study Area

The collection area is at the Serra da Itacambira, 15 km away from the Itacambira city, northern Minas Gerais state, Brazil (Figure 1), with approximately 83 ha. The climate of the region is temperate and classified as Cwa of Köeppen[15]. It has an average temperature of approximately 19.9 °C, with drastic oscillations, intense heat during the day, and cold at night[16]. It has an average annual rainfall of 1,092 mm and an altitude of 1,113 m[16] with predominance of herbs and shrubs typical of rocky fields.

Figure 1. Map of the study area (marked in red) in rocky fields, where native species with ornamental potential were collected. Itacambira, MG, Brazil, 2019. (Google Earth, 2019)

Field expeditions and species collection

Field expeditions to the Serra da Itacambira were conducted between September 2019 and April 2020 to collect native plant species. The predefined area (Figure 1) was covered by unsystematic walking, and all plants with flowers, fruits, leaves, and stems, or whose whole-plant morphological characteristics could be considered ornamental were collected[17]. Due to the environmental heterogeneity of the area, data related to flowering period, and the type of substrate where the plants were found (wet, dry, sandy, rocky, and rocky outcrop) were annotated. Plant parts such as branches, leaves, and flowers were preserved in exsiccates, and

the plants were photographed in their natural environment to help identifying the species. The collection periods included the Spring, Summer, and Autumn, and the rainy (December to April) and dry (September to November) seasons, to obtain the highest number of observations of the species and the environment.

Voucher species was deposited in the Herbário Norte Mineiro (MCCA) of the Institute of Agricultural Sciences of the Universidade Federal de Minas Gerais (ICA-UFMG), after the standard procedures of pressing, drying, and identification[18]. The Botanical identity confirmation at species level and information on their occurrence, endemism, and flowering were obtained by consulting botanists, the database of the MCCA, and the Flora of Brazil 2020[19].

Determination of ornamental characteristics

The characteristics considered essential for identifying potentially ornamental species were adapted from literature[17,20]. Information on the aesthetic important variables for characterizing the species as ornamental was the colour, growth habit, texture, symmetry, and aroma[20] (Table 1). The species were also classified according to their potential for use in landscaping as plants of gardens (indicated for hedgerows, formation of massifs and linings, borders, vertical gardens, or isolated use), plants for pots (indicated for cultivation in containers of different volumes), and plants for cut flowers and leaves (indicated for cultivation so that their flowers and leaves can be cut for floral arrangements)[20]. The analysis of ornamental potential was also based on hardiness attributes (species that occur in areas with different light intensities, moisture levels, and substrates)[17].

RESULTS AND DISCUSSION

Floristic survey and ornamental morphological characteristics

A total of 61 plant species that belong to 29 botanical families, including Asteraceae with nine genera (9 spp.), Melastomataceae with eight genera (8 spp.), Fabaceae with four genera (5 spp.), Apocynaceae with three genera (4 spp.), Eriocaulaceae with three genera (3 spp.), and Velloziaceae with two genera (4 spp.), were identified and characterized (Table 1). All species had leaf, flower, and stem characteristics indicative of ornamental use. Most species

flowered between September and February, coinciding with data on literature about the rocky field species[21]. The large number of species identified in this study reinforces the premise that the richness of plants with ornamental potential follows the richness of families in rocky field areas[22].

The 61 species include shrubs, herbs, and vine plants have ornamental characteristics, and have grown in diverse types of substrate (Table 2). Regarding the growth habit, 38 are shrub species (62%), 21 are herbaceous species (35%), and two are vine species (3%). Regarding hardiness, 22 species, especially *Thaumatophyllum uliginosum*, *T. undulatum*, and *Mandevilla tenuifolia*, had hardiness characteristics related to their natural adaptation in environments with different light intensities, moisture levels, and substrates. Among the 61 species analyzed, 51 are endemic (Table 2); that is, they do not occur in other environments, and 22 species were only recorded in Minas Gerais[23].

Table 1. Shrub, herbaceous, and vine species collected in the rocky field of Serra da Itacambira in Itacambira (Minas Gerais, Brazil) with description of the characteristics evaluated for identifying plants for ornamental use. Data collected between September 2019 and April 2020.

Family	Species/ Habits	Ornamental structure	Color structure	Leaf texture	Symmetry	Scent	Rust	Potential of use
	Shrub							
Rubiaceae	*Augusta longifolia*	Flower	Red	Sm/Gl	S	A		Garden/Pots
Apocynaceae	*Allamanda puberula*	Flower	Yellow	Sm/Gl	As	P/Ple	x	Garden/Pots
Fabaceae	*Andira humilis*	Inflo	Purple	Sm/Gl	As	A		Garden
Asteraceae	*Aspilia foliosa*	Flower	Yellow	Sm/Gl	S	A	x	Garden/Pots
Asteraceae	*Baccharis platypoda*	Inflo	Light green	Sm/Gl	As	A		Cut
Asteraceae	*Baccharis tridentata*	Leaf	Green	Sm/Gl	S	A		Cut
Malpighiaceae	*Byrsonima sericea*	Inflo	Yellow	Sm/Gl	As	P/Ple		Garden
Fabaceae	*Calliandra dysantha*	Inflo	Red	Sm/Gl	As	A	x	Garden/Pots
Fabaceae	*Calliandra asplenioide*	Flower	Whi/Pink	Sm/Gl	As	A	x	Garden/Pots
Melastomataceae	*Cambessedesia hilariana*	Flower	Red/Yel	Sm/Gl	As	A	x	Garden/Pots
Cactaceae	*Cipocereus minensis*	Fruit	Blue	Sm/Gl	S	A		Garden/Pots
Fabaceae	*Chamaecrista ramos*	Flower	Yellow	Sm/Gl	S	A		Garden
Clusiaceae	*Clusia obdeltifolia*	Wh. Plant	Green	Sm/Gl	S	A		Garden
Lytraceae	*Diplusodon hirsutus*	Flower	Pink	Sm/Gl	As	A		Garden/Pots
Asteraceae	*Disynaphia praeficta*	Inflo	Pink	Sm/Gl	S	P/Ple		Garden/Pots

Callophylaceae	*Kielmeyera regalis*	Flower	Pink	Sm/Gl	As	P/Ple	x	Garden
Melastomataceae	*Lavoisiera mellobarretoi*	Flower	Pink	Sm/Ha	As	A		Garden/Pots
Melastomataceae	*Lavoisiera imbricata*	Flower	Pink	Sm/Ha	As	A		Garden/Pots
Ochnaceae	*Luxemburgia mogolensis*	Leaf/Inflo	Red/Yel	Sm/Ha	As	A	x	Garden/Pots
Verbenaceae	*Lippia hederifolia*	Flower	Pink	Ro/Gl	As	A	x	Garden/Pots
Melastomataceae	*Marcetia taxifolia*	Inflo	White	Sm/Ha	As	A		Garden/Pots
Melastomataceae	*Microlicia tetrasticha*	Flower	Pink	Sm/Gl	S	A		Garden/Pots
Asteraceae	*Moquinia racemosa*	Inflo	Pink	Sm/Gl	As	P/Ple		Garden/Pots
Fabaceae	*Mimosa regina*	Flower	Pink	Sm/Ha	As	A		Garden
Malvaceae	*Pavonia viscosa*	Flower	Red/Oran	Sm/Ha	As	A		Garden
Cactaceae	*Pilosocereus fulvilanatus*	Fruit/Stem	Pink	Sm/Gl	S	A		Garden/Pots
Phyllanthaceae	*Phyllanthus klotzschianus*	Leaf	Light green	Sm/Gl	As	A		Garden/Pots
Ochnaceae	*Sauvagesia elegantissima*	Inflo	Yellow	Sm/Gl	S	A		Garden/Pots
Asteraceae	*Pseudobrickellia angustissima*	Stem/Inflo	Green/Whi	Sm/Gl	As	A	x	Garden/Pots
Araliaceae	*Schefflera gardneri*	Leaf	Green	Sm/Gl	S	A		Garden/Pots
Verbenaceae	*Stachytarpheta glabra*	Flower	Blue	Sm/Gl	S	A	x	Garden/Pots
Acanthaceae	*Stenandrium hatschbachii*	Flower	Purple	Sm/Gl	As	A		Garden/Pots
Marcgraviaceae	*Schwartzia adamantium*	Inflo/Leaf	Green/Red	Sm/Gl	As	A	x	Garden
Melastomataceae	*Tibouchina candolleana*	Flow/Leaf	Pur/Green	Ro/Ha	As	A		Garden
Melastomataceae	*Tibouchina heteromalla*	Inflo	Purple	Ro/Ha	S	A		Garden
Melastomataceae	*Tococa guianensis*	Inflo/Infr	Dark green	Ro/Ha	As	A		Garden
Velloziaceae	*Vellozia maxillarioides*	Wh.Pl/Flow	Purple	Sm/Ha	S	A		Garden/Pots
Asteraceae	*Wunderlichia mirabilis*	Wh. Plants	Silver	Ro/Ha	As	A	x	Garden/Pots
	Herbaceous							
Eriocaulaceae	*Actinocephalus bongardii*	Inflo	White	Sm/Ha	S	A		Pots/Cut
Alstroemeriaceae	*Alstroemeria cunha*	Flower	Red/Yel	Sm/Gl	S	A		Cut/Pots
Velloziaceae	*Barbacenia umbrosa*	Flower	Red	Sm/Gl	As	A		Garden/Pots
Begoniaceae	*Begonia grisea*	Inflo	Pink	Sm/Ha	As	A	x	Garden/Pots
Droseraceae	*Drosera graomogolensis*	Wh.Pl/Leaf	Red	Sm/Ha	S	A		Pots
Bromeliaceae	*Encholirium biflorum*	Wh. Plant	Green	Sm/Gl	S	A		Garden/Pots
Euphorbiaceae	*Euphorbia sarcodes*	Flow/Leaf	Yel/Green	Sm/Gl	As	A	x	Garden/Pots
Convolvulaceae	*Evolvulus glomeratus*	Flower	Blue	Sm/Ha	As	A	x	Garden/Pots
Amaryllidaceae	*Hippeastrum morelianum*	Flower	Red	Sm/Gl	S	A		Cut/Garden
Asteraceae	*Lychnophora itacambirensis*	Flower	Purple	Sm/Gl	As	A		Garden/Pots
Apocynaceae	*Mandevilla tenuifolia*	Flower	Purple	Sm/Gl	As	A	x	Garden/Pots

Euriocaulaceae	*Paepalanthus eriophaeus*	Inflo/Leaf	Whi/Green	Sm/Ha	S	A		Garden/Pots /Cut
Turneraceae	*Piriqueta duarteana*	Flower	Purple	Ro/Ha	As	A		Garden/Pots
Portulacaceae	*Portulaca mucronata*	Flower	Yellow	Sm/Gl	As	A		Garden/Pots
Portulacaceae	*Portulaca hirsutissima*	Flower	Yellow	Sm/Ha	As	A		Garden/Pots
Araceae	*Thaumatophyllum uliginosum*	Leaf	Light green	Sm/Gl	S	A	x	Garden/Pots /Cut
Araceae	*Thaumatophyllum undulatum*	Leaf	Dark green	Sm/Gl	S	A	x	Garden/Pots /Cut
Asteraceae	*Proteopsis argentea*	Flower	Purple	Sm/Ha	S	A	x	Garden
Euriocaulaceae	*Syngonanthus verticillatus*	Flor/Wh.Pl	Whi/Green	Sm/Ha	S	A		Garden/Pots /Cut
Velloziaceae	*Vellozia aloifolia*	Flower	Pink	Sm/Gl	S	A	x	Garden
Velloziaceae	*Vellozia subscabra*	Flower	Pink	Sm/Gl	S	A		Garden
	Vine			Sm/Gl				
Apocynaceae	*Mandevilla semirii*	Flower	Pink	Sm/Gl	As	A	x	Garden/Pots
Apocynaceae	*Stipecoma peltigera*	Flower	Pink	Sm/Gl	As	A	x	Garden/Pots

Legend: Rust = Rusticity Inflo = inflorescence; Wh. Plant = whole plant; Yel= yellow; Whi = white; Oran = orange; Pur = purple; Ro = rough; SM = smooth; Ha = hair; Gl = glabrous; ; S = symmetric; As = asymmetric; P = present; A = absent; Ple = pleasant.

Among the species identified, *Stenandrium hatschbachii*, *Disynaphia praeficta*, *Drosera graomogolensis*, *Mimosa regina*, and *Pilosocereus fulvilanatus* are considered endangered (EN) species, *Cipocereus minensis*, *Proteopsis argentea*, and *Hippeastrum morelianum* are considered vulnerable (VU) and *Encholirium biflorum* is considered a critically endangered (CR) species by the official list of threatened species of Brazilian flora[23] (Table 2).

Table 2. Types of substrates and occurrence of endemism of species collected in Serra da Itacambira, Itacambira, (Minas Gerais, Brazil). Data collected between September 2019 and April 2020.

Family	Habits/Species	Substrate	Endemism	Occurs only in MG
	Shrub			
Rubiaceae	***Augusta longifolia* (Spreng.) Rehder**	**Rock. Outcr.**	**Yes, Brazil**	
Apocynaceae	***Allamanda puberula* A.DC**	**Sandy**	**Yes**	
Fabaceae	***Andira humilis* Mart. ex Benth.**	**Sandy**	**Yes, Brazil**	
Asteraceae	***Aspilia foliosa* (Gardner) Baker**	**Sandy**	**Yes, Brazil**	
Asteraceae	***Baccharis platypoda* DC.**	**Sandy**	**No**	
Asteraceae	***Baccharis tridentata* Baker**	**Sandy**	**No**	

Malpighiaceae	***Byrsonima sericea* DC.**	**Sandy**	**No**	
Fabaceae	***Calliandra dysantha* Benth.**	**Sandy**	**No**	
Fabaceae	***Calliandra asplenioides* (Nees) Renvoize**	**Rock. Outcr.**	**Yes, Brazil**	
Melastomataceae	***Cambessedesia hilariana* (Kunth) DC**	**Rock. Outcr.**	**Yes, Brazil**	
Cactaceae	***Cipocereus minensis* (Werderm.) Ritter**	**Rock. Outcr.**	**Yes, Brazil (VU)**	**X**
Fabaceae	***Chamaecrista ramosa* (Vogel) H.S.Irwin & Barneby**	**Sandy**	**Yes**	
Clusiaceae	***Clusia obdeltifolia* Bittrich**	**Rock. Outcr.**	**Yes, Brazil**	
Lytraceae	***Diplusodon hirsutus* (Cham. & Schltdl.) A.DC**	**Sandy**	**Yes, Brazil**	**X**
Asteraceae	***Disynaphia praeficta* (B.L.Rob.) R.M.King & H.Rob.**	**Sandy**	**Yes, Brazil (EN)**	**X**
Callophylaceae	***Kielmeyera regalis* Saddi**	**Rock.Out/San**	**Yes, Brazil**	**X**
Melastomataceae	***Lavoisiera mellobarretoi* Markgr.**	**Rock. Outcr.**	**Yes, Brazil**	**X**
Melastomataceae	***Lavoisiera imbricata* (Thunb.) DC.**	**Sandy**	**Yes, Brazil**	
Ochnaceae	***Luxemburgia mogolensis* Feres**	**Rock. Outcr.**	**Yes, Brazil**	**X**
Verbenaceae	***Lippia hederifolia* Mart. & Schauer**	**Sandy**	**Yes**	
Melastomataceae	***Marcetia taxifolia* (A.St.-Hil.) DC.**	**Stony/Sandy**	**Yes, Brazil**	
Melastomataceae	***Microlicia tetrasticha* Cogn.**	**Rock. Outcr.**	**Yes, Brazil**	**X**
Asteraceae	***Moquinia racemosa* (Spreng.) DC**	**Sandy**	**Yes, Brazil**	
Fabaceae	***Mimosa regina* Barneby**	**Sandy**	**Yes, Brazil (EN)**	
Malvaceae	***Pavonia viscosa* A.St.-Hil**	**Rock. Outcr.**	**Yes, Brazil**	**X**
Cactaceae	***Pilosocereus fulvilanatus* (Buining & Brederoo) Ritter**	**Rock. Outcr.**	**Yes, Brazil (EN)**	**X**
Phyllanthaceae	***Phyllanthus klotzschianus* Müll.Arg.**	**Rock.Out/San**	**Yes, Brazil**	
Asteraceae	***Pseudobrickellia angustissima* (Spreng. ex Baker) R.M.King & H.Rob.**	**Sandy**	**Yes, Brazil**	**X**
Ochnaceae	***Sauvagesia elegantissima* A.St.-Hil**	**Rock.Out/San**	**Yes, Brazil**	
Araliaceae	***Schefflera gardneri* (Seem.) Frodin & Fiaschi**	**Sandy**	**Yes, Brazil**	**X**
Verbenaceae	***Stachytarpheta glabra* Cham**	**Sandy**	**Yes, Brazil**	
Acanthaceae	***Stenandrium hatschbachii* Wassh.**	**Sandy**	**Yes, Brazil (EN)**	**X**
Marcgraviaceae	***Schwartzia adamantium* (Cambess.) Bedell ex Gir.-Cañas**	**Sandy**	**Yes, Brazil**	
Melastomataceae	***Tibouchina candolleana* (Mart. ex DC.) Cogn.**	**Sandy**	**Yes**	
Melastomataceae	***Tibouchina heteromalla* (D.Don) Cogn**	**Rock. Outcr.**	**Yes, Brazil**	
Melastomataceae	***Tococa guianensis* Aubl.**	**Rock. Outcr.**	**No**	
Velloziaceae	***Vellozia maxillarioides* L.B.Sm**	**Sandy**	**Yes, Brazil**	**X**
Asteraceae	***Wunderlichia mirabilis* Riedel ex Baker**	**Rock. Outcr.**	**Yes**	

	Herbaceous			
Eriocaulaceae	***Actinocephalus bongardii* (A.St.-Hil.) Sano**	**Sandy**	**Yes, Brazil**	
Alstroemeriaceae	***Alstroemeria cunha* Vell.**	**Sandy**	**Yes, Brazil**	
Velloziaceae	***Barbacenia umbrosa* L.B.Sm. & Ayensu**	**Rock. Outcr.**	**Yes, Brazil (EN)**	**X**
Begoniaceae	***Begonia grisea* A.DC**	**Rock.Out/San**	**Yes, Brazil**	
Droseraceae	***Drosera graomogolensis* T.Silva**	**Rock. Outcr.**	**Yes, Brazil (EN)**	**X**
Bromeliaceae	***Encholirium biflorum* (Mez) Forzza**	**Sandy**	**Yes**	**X**
Euphorbiaceae	***Euphorbia sarcodes* Boiss.**	**Sandy**	**Yes, Brazil**	
Convolvulaceae	***Evolvulus glomeratus* Nees & Mart.**	**Sandy**	**No**	
Amaryllidaceae	***Hippeastrum morelianum* Lem.**	**Sandy**	**Yes, Brazil (VU)**	
Asteraceae	***Lychnophora itacambirensis***	**Rock. Outcr.**	**Yes, MG**	**X**
Apocynaceae	***Mandevilla tenuifolia* (J.C.Mikan) Woodson**	**Rock. Outcr.**	**No**	
Euriocaulaceae	***Paepalanthus eriophaeus* Ruhland**	**Sandy**	**Yes, Brazil**	**X**
Turneraceae	***Piriqueta duarteana* (Cambess.) Urb.**	**Sandy**	**Yes, Brazil**	
Portulacaceae	***Portulaca mucronata* Link.**	**Sandy**	**No**	
Portulacaceae	***Portulaca hirsutissima* Cambess.**	**Rock. Outcr.**	**Yes, Brazil**	**X**
Araceae	***Thaumatophyllum uliginosum* Mayo.**	**Wet/Sandy**	**Yes**	
Araceae	***Thaumatophyllum undulatum* Engl.**	**Wet/Sandy**	**No**	
Asteraceae	***Proteopsis argentea* Mart. & Zucc. ex Sch.Bip.**	**Sandy**	**Yes, Brazil (VU)**	
Euriocaulaceae	***Syngonanthus verticillatus* (Bong.) Ruhland.**	**Sandy**	**Yes, Brazil**	**X**
Velloziaceae	***Vellozia aloifolia* Mart.**	**Clayish/San**	**Yes, Brazil**	**X**
Velloziaceae	***Vellozia subscabra* J.C.Mikan.**	**Sandy**	**Yes, Brazil**	**X**
	Vine			
Apocynaceae	***Mandevilla semirii* M.F.Sales et al**	**Rock.Out/San**	**Yes, Brazil (EN)**	**X**
Apocynaceae	***Stipecoma peltigera* (Stadelm.) Müll.Arg**	**Stony/Sandy**	**No**	

The use of native plants in gardens can prevent their extinction, as popularized by Burle Marx, who used many previously unknown species in his projects[24]. Many projects may face the challenge of preserving the environment, establishing ecophysiological relationships in gardens, and enhancing the regional landscape. Species of Bromeliaceae from the Atlantic Forest, for example, became popular due to their frequent insertion in gardens designed by Burle Marx, the great landscaper of Brazil[25]. In addition, to using them in his projects, Burle

Marx also collected many species of the rupestrian fields biome and, as a result, contributed to an increase in the collection of native plants with ornamental potential, and possibly, because of his efforts, several of these species are conserved[26].

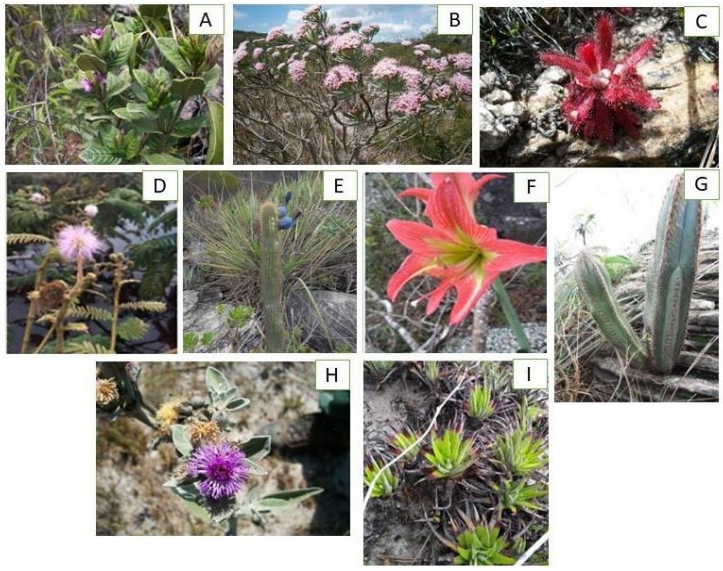

Figure 2. Species classified as Endangered: A. *Stenandrium hatschbachii*, B. *Disynaphia praeficta*, C. *Drosera graomogolensis*, D. *Mimosa regina*; Vulnerable: E. *Cipocereus minensis*, F. *Hippeastrum morelianum*, G. *Pilosocereus fulvilanatus*, H. *Proteopsis argentea*; and Critically Endangered: I. *Encholirium biflorum*.

Considering that the 61 plants identified in the rupestrian fields of the Serra de Itacambira have ornamental potential, their dissemination contributes to the better recognition of their potential for landscaping projects. Thus, the introduction of these plants in commercial cultivation systems can be an effective tool for their conservation[27]. In addition, their propagation in regulated nurseries reduces the risk of their illegal collection in nature[25].

Categories of species use

All the 61 species are heliophytes collected in open rupestrian fields under intense insolation; and therefore, can be indicated for use in open areas with full sunlight. Most of the collected plants have a shrub growth habit (39 species) with the potential for cultivation in pots or gardens.

The large number of different sized plants (trees, shrubs, and herbs) is of great relevance in landscaping because a variation in height promotes different shapes and volumes, resulting in gardens better resembling natural spaces. The promotion of the diversity of plants with variable sizes breaks the monotony of gardens and can provide a better experience of using these spaces[25].

Some larger species, such as *Tibouchina heteromalla*, *T. candolleana*, *Clusia obdeltifolia*, *Moquinia racemosa*, *Pavonia viscosa*, *Andira humilis*, *Banisteriopsis* sp. and *Allamanda puberula* (Figure 3), can be used in public squares and open places individually or in groups, as they can reach 1.7 to 4 m in height[19], and have long-lasting and showy foliage and flowers, as observed in the field. *Allamanda puberula* can be used as a cover on pergolas, planted near walls or in pots, as its shape allows use in irregular soils, and when in small clusters, it provides amplitude to a garden, and *A. cathartica* is a commonly used species, already widespread in landscaping[20]. In addition to aesthetic values, species such as *M. racemosa*, *T. heteromalla*, *T. candolleana*, *A. humilis*, and *P. viscosa* provide shade for much of the year and attract pollinators through the pleasant scent of their inflorescences.

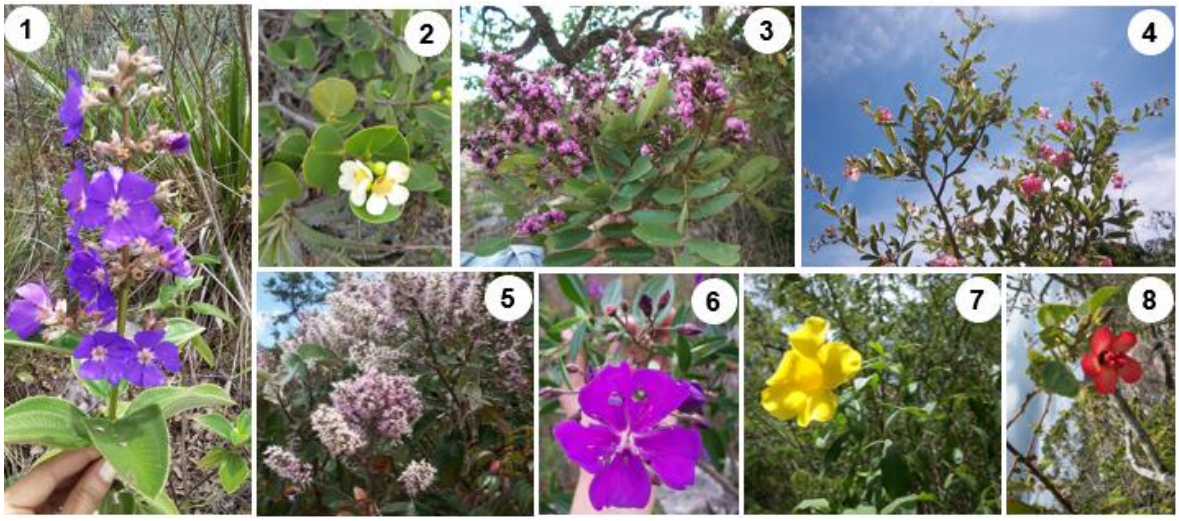

Figure 3. Shrub species with potential for cultivation in public squares: 1. *Tibouchina heteromalla*, 2. *Clusia obdeltifolia*, 3. *Andira humilis*, 4. *Banisteriopsis* sp., 5. *Moquinia racemosa*, 6. *T. candolleana*, 7. *Allamanda cathartica*, and 8. *Pavonia viscosa*.

Calliandra dysantha, *C. asplenioides*, and *M. regina* have an average size up to 3 m high, with many branches and floral structures that stand out for their colours and textures, providing

natural garden characteristics[28]. Species of the genus *Calliandra* and *Mimosa* are highlighted by their potential as bonsai due to the volume and shape of the canopy, which accept artistic pruning[26]. These species also have the potential to be cultivated in gardens as isolated plants or mass flowers[28]

The shrub species that stand out for their potential use as mass flowers, in pots in full sun, and individually or forming borders in gardens are *Disynaphia praeficta*, *Kielmeyera regalis*, *Diplusodon hirsutus*, *Luxemburgia mogolensis*, *Pseudobrickellia angustissima*, and *Microlicia tetrasticha* (Figure 4). These plants have valuable ornamental traits, such as large or abundant flowers, scent, attractiveness to fauna, and leaves with different characteristics, that together with the other colours of the garden cause high visual impact.

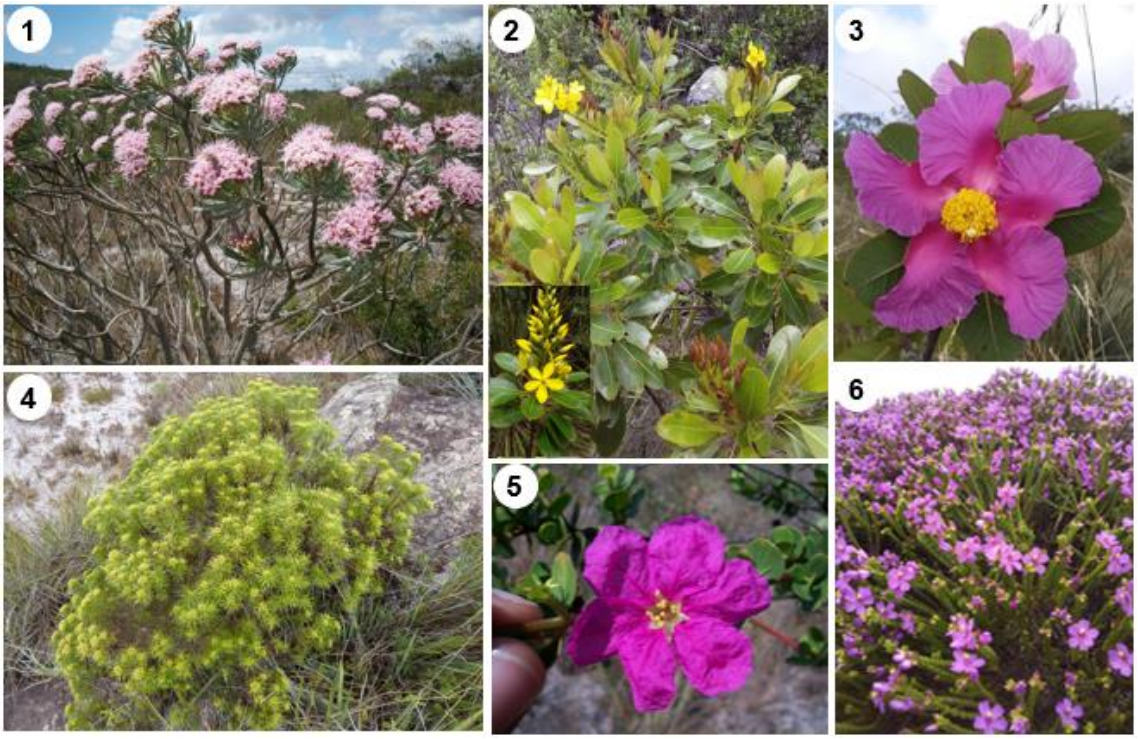

Figure 4. Shrub species with potential for use in gardens: 1. *Disynaphia praeficta*, 2. *Luxemburgia mogolensis*, 3. *Kielmeyera regalis*, 4. *Pseudobrickellia angustissima*, 5. *Diplusodon hirsutus*, and 6. *Microlicia tetrasticha*.

Stachytarpheta glabra (Figure 5) is suggested for cultivation as a hedge or mass flowers, or in containers under full sun. The architecture of this species does not require pruning since they already assume an ordered shape of the canopy. *Wunderlichia mirabilis* and *Sauvagesia elegantissima* (Figure 5) have an unusual and delicate appearance due to their architecture, the shape and color of their leaves; in addition, their inflorescences contrast with their foliage, which makes these species recommended for the formation of small clusters with the rocks or as isolated plants highlighted in a garden.

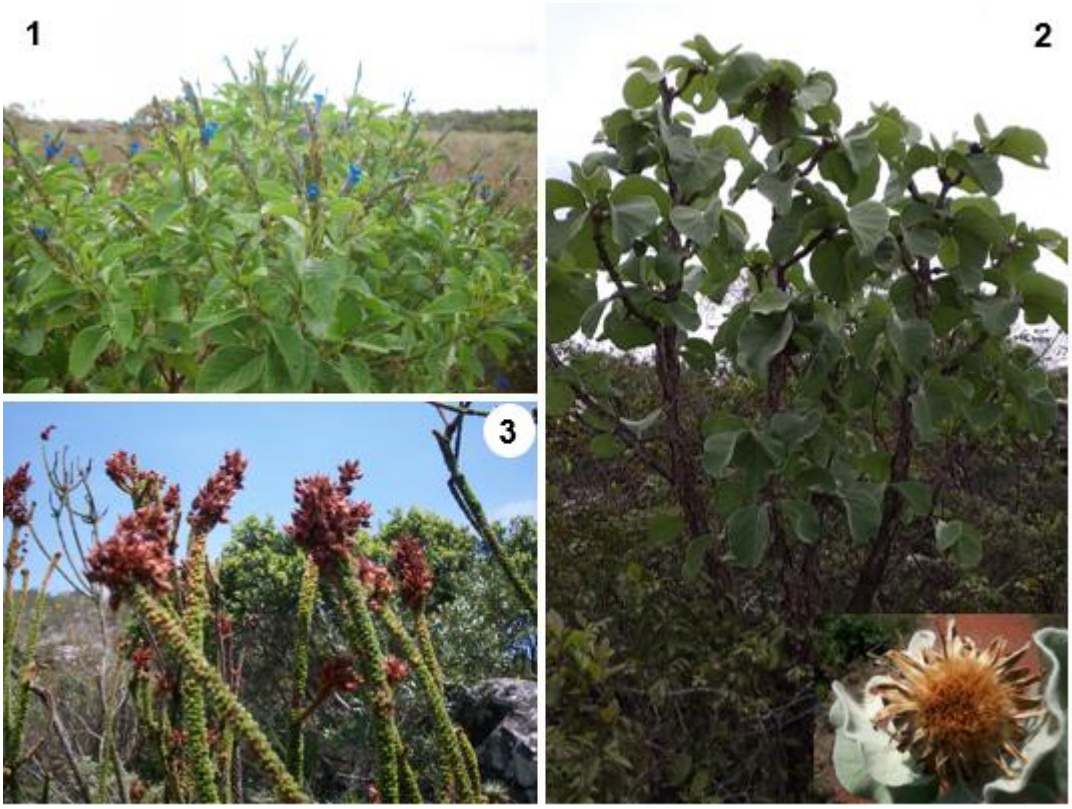

Figure 5. Shrub species with potential for use in gardens: 1. *Stachytarpheta glabra*, 2. *Wunderlichia mirabilis* and 3. *Sauvagesia elegantissima*

For forming borders in gardens and growing in pots, *Chamaecrista ramosa* (Figure 6) stands out due to its natural symmetry and crown with ornamental architecture. It can serve as a potential substitute for already widespread exotic species, such as *Buxus sempervirens*, due to the similarity between characteristics such as growth habit, architecture and size of its

leaves[29]. *Euphorbia sarcodes*, and *Proteopsis argentea*, which also have the potential to be used as mass flowers (Figure 6).

Figure 6. Shrub species with potential uses in borders and pots: 1. *Chamaecrista ramosa*, *2. Euphorbia sarcodes* and *3. Proteopsis argentea* and details of floral structures.

Among the studied shrubs, *Stenandrium hatschbachii, Cambessedesia hilariana, Marcetia taxifolia, Aspilia foliosa, Augusta longifolia, Lavoisiera imbricata, Vellozia maxillarioides* and *Lippia bradei* stands out (Figure 7). The ornamental potential of these species is supported by their unique small flowers with abundant colour combinations. Thus, they are recommended for planting in pots and planters, and in borders in full sunlight.

Figure 7. Shrub species with potential for cultivation in pots and borders in gardens: 1. *Stenandrium hatschbachii*, 2. *Cambessedesia hilariana*, 3. *Augusta longifolia*, 4. *Lavoisiera imbricata*, 5. *L. mellobarretoi*, 6. *Marcetia taxifolia*, 7. *Lippia bradei*, 8. *Vellozia maxillarioides*, and 9. *Aspilia foliosa*.

Species of Cactaceae, such as *Cipocereus minensis* and *Pilosocereus fulvilanatus* (Figure 8), can be planted directly in the soil in xerophytic gardens due to their appropriate ornamental and physiological characteristics[30]. These plants can be cultivated alone, but it is also suggested to plant them in homogeneous masses to build patches of diversity in large gardens.

Figure 8. Species of the family Cactaceae with potential for use in xerophytic gardens: 1) *Pilosocereus fulvilanatus* and 2) *Cipocereus minensis*.

Twenty-three of the collected species have herbaceous habits and can be cultivated as garden ground cover plants, including *Evolvulus glomeratus*, *Lychnophora itacambirensis*, *Piriqueta duarteana*, *Portulaca hirsutissima*, *P. mucronata*, *Vellozia aloifolia* and *Barbacenia umbrosa* (Figure 9).

Figure 9. Herbaceous species with potential for use as ground cover plants: 1. *Evolvulus glomeratus*, 2. *Portulaca mucronata*, 3. *Lychnophora itacambirensis*, 4. *Vellozia aloifolia*, 5. *P. hirsutissima*, 6. *Piriqueta duarteana*, and 7. *Barbacenia umbrosa*.

The species indicated for cultivation in pots were *Drosera graomogolensis, Encholirium biflorum, Begonia grisea,* and *Mandevilla tenuifolia* (Figure 10).

Figure 10. Herbaceous species indicated for cultivation in pots: 1. *Encholirium biflorum*, 2. *Begonia grisea,* 3. *Mandevilla tenuifolia*, and 4. *Drosera graomogolensis*.

Among the vine species (Figure 11), both *Mandevilla semirii* and *Stipecoma peltigera* have the potential for cultivation in pots, use as ground cover, and use in hedgerows and even vertical gardens.

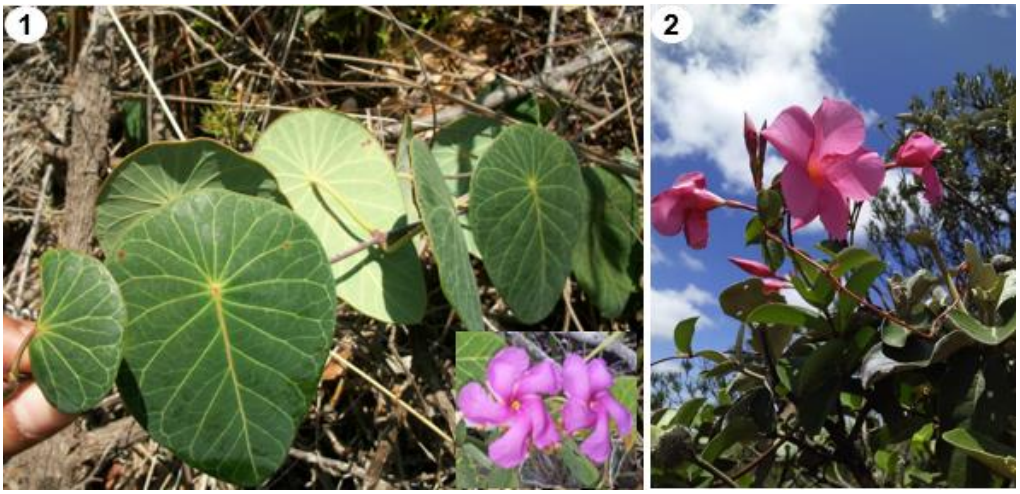

Figure 11. Vine species with potential for cultivation in pots and gardens: 1. *Stipecoma peltigera* and 2. *Mandevilla semirii.*

Mandevilla semirii has large pink flowers and leaves with white veins, and *Stipecoma peltigera* has peltate dark green leaves with reddish veins, and pink flowers that are appreciated in gardens, both with high ornamental potential.

Eight of the studied species have desirable characteristics for sensory landscaping, especially in terms of touch: *Wunderlichia mirabilis*, *P. argentea*, *P. uliginosum*, *P. undulatum*, *S. elegantissima*, *C. dysantha* and *C. asplenioides* (Table 2). Their leaves have various shapes, and the trichomes confer diverse textures. *Wunderlichia mirabilis* stands out for its thick and fissured stem and leaf trichomes, which allows a soft touch sensation. This velvety touch can also be observed in the flowers of the species of *Calliandra*, which have red stamens that draw much attention to the vegetation. In fact, leaves are the ideal organ for touch analysis because they present great morphological variety and are constant on the plants, since the flowers are restricted to the flowering phase[31].

Disynaphia praeficta, *M. racemosa*, *Byrsonima sericea*, *K. regalis*, and *A. puberula* (Table 2) have very pleasant and striking scent, and are consequently suggested for sensory gardens. The interaction of fauna with leaves, fruits and flowers produces several sounds, such as the singing of birds, the flight of bees, and due to the movement performed by the contact with the wind. Such sounds sharpen the sense of hearing, and the use of native species increases the chances of attracting this fauna[4]. Feeling the textures, scents, and sounds that nature offers can cause sensations, allowing the landscaping to have a biophilic design, which means a closer relationship with nature, constituting an attraction for people who seek a more pleasant space in the urban environment. A diverse garden has effective elements to awaken the capacity for contemplation by all the senses, not only the vision[32].

Species resistant to water deficit

Pseudobrickellia angustissima (Figure 4), *M. tetrasticha*, *V. maxillarioides*, *S. elegantissima*, *L. mogolensis* and *C. ramosa* (Figure 12) are species that have flowers and foliage appreciated because in addition to possessing remarkable flowering in the dry season, they maintain their ornamental characteristics even when they are in vegetative phase, due to the more open and symmetrical shape. In addition, the leaves of these plants are perennial and remain relatively lush green even in the dry season, which lasts approximately 6 months.

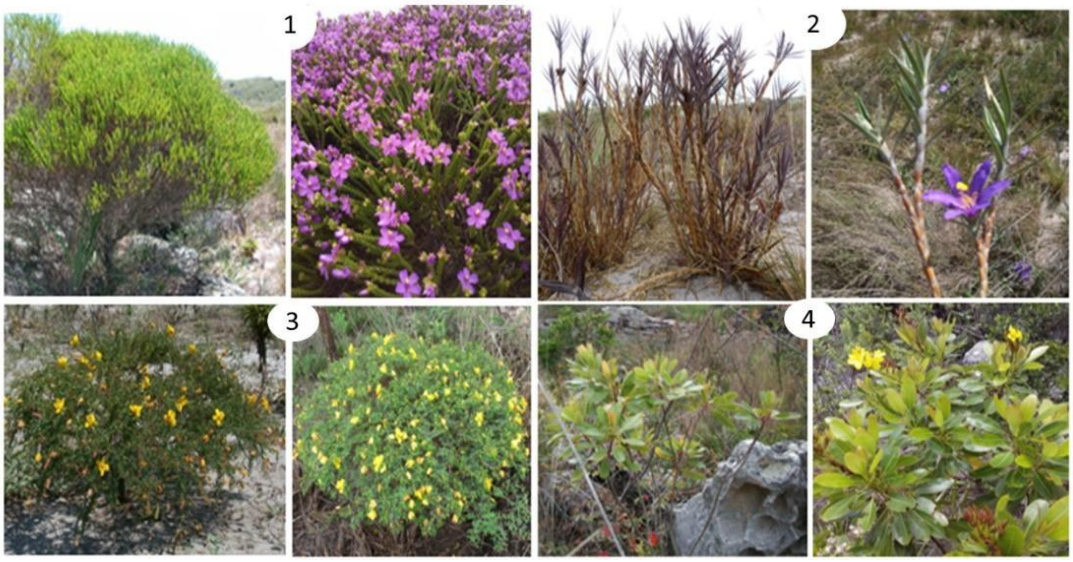

Figure 12. Species that present ornamental landscape attributes in the dry (left) and rainy (right) seasons: (1) *Microlicia tetrasticha*, (2) *Vellozia maxillarioides* (3) *Chamaecrista ramosa*, and (4) *Luxemburgia mogolensis.*

Even in periods where temperatures are higher (September to February) and there is no rainfall (between April and September)[16], these plants retain ornamental characteristics, which make them beneficial for use in landscaping.

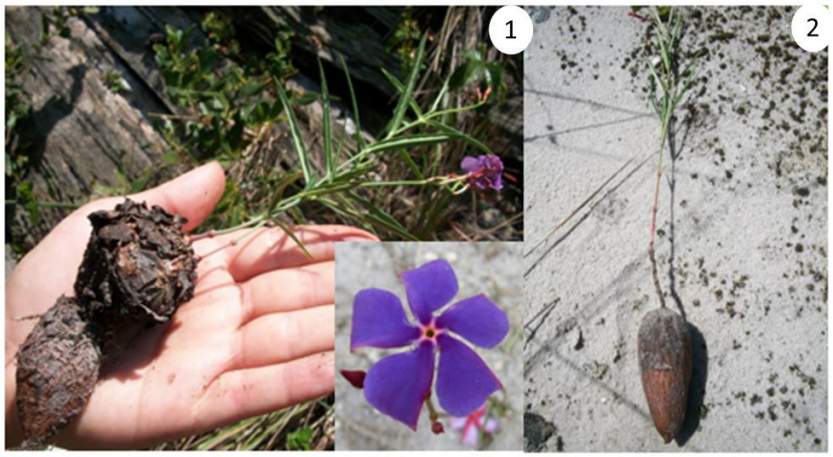

Figure 13. Subterranean structure of *Mandevilla tenuifolia* and detail of flower (1). Detail of the whole plant with the tuberous root (2).

They are able to survive in soil with low nutritional availability, as occurs in campo rupestre[33] and high temperature fluctuations throughout the day and year. Some of the structures that make these plants adaptable to survive under drought conditions through the storage of water and nutrients are their underground reserve organs, such as the bulbs present in *Alstroemeria cunha* and *Hippeastrum morelianum* and the tuberous roots in *Mandevilla tenuifolia*[34] (Figure 13).

These underground organs are important for the survival of plants that lose their shoots in unfavorable periods, such as times of greater water restriction[34]. For use in landscaping, it is recommended to use plant species with these subterranean structures together with other species that have a perennial shoot throughout the year. These perennial plants will fill the spaces of gardens when the other plants are dormant, forming the vegetation cover over the soil throughout the year. Thus, the flowering of these tuberous species that remained dormant will be a new element in the garden.

Figure 14. Species with leaf trichomes: (1) *Wunderlichia mirabilis*, (2) *Proteopsis argentea*, (3) *Portulaca hirsutissima*, and (4) *Begonia grisea*.

Another mechanism of drought resistance is the reduced leaf size, as identified in *S. elegantissima* (Figure 15 H), which has very small and densely clustered leaves along its stem, which in addition to conferring ornamental value, protects the plant against excessive water loss[35,36]. This strategy also occurs in species of the genus *Lychnophora* and *Pseudobrickellia*. The presence of leaf trichomes also constitutes a morphological adaptation since these

structures act by decreasing water loss, in addition to protecting the plant against predator attacks. These structures are mainly present in *P. hirsutissima*, *W. mirabilis*, *B. grisea* and *P. argentea* (Figure 14).

Native species resilient to the dry season are valuable options for public gardens and squares that often have few resources for installing and maintaining irrigation systems, especially in regions where rainfall is low, such as the semiarid regions[37]. In gardens located in regions with high temperatures and low water availability, the use of exotic plants that demand large amounts of water causes loss of their full ornamental potential, when they are not irrigated according to their needs. In this case, the use of native species resistant to the edaphoclimatic conditions of the region decreases the costs with maintenance, which reduces the chances of compromising the ornamental value of these gardens during the dry season.

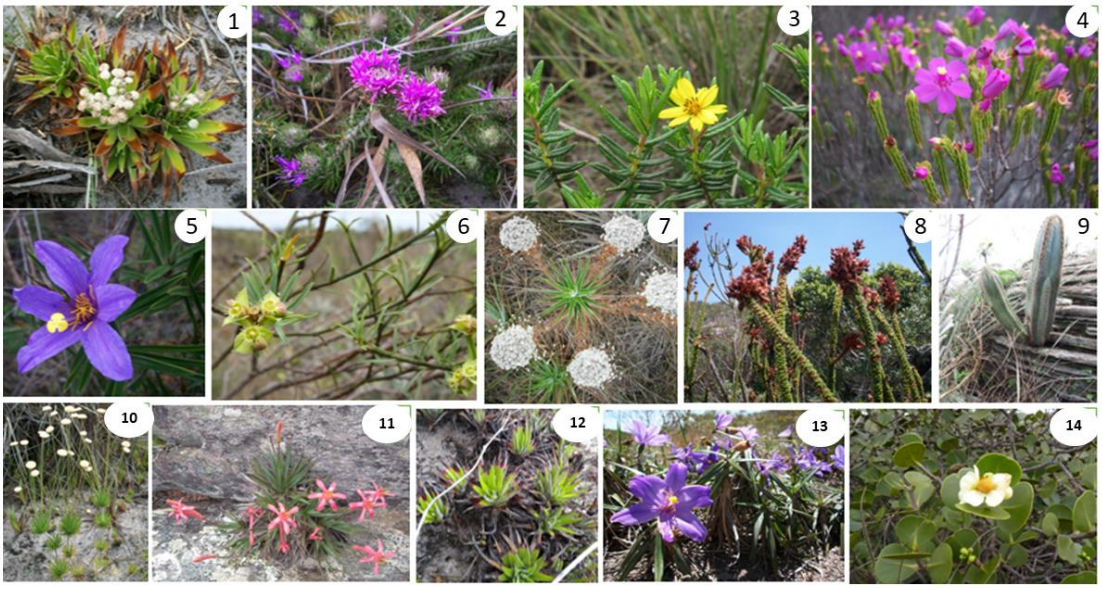

Figure 15. Species with ornamental potential and attributes for use in water-restricted gardens: (1) *Paepalanthus eriophaeus*, (2) *Lychnophora itacambirensis*, (3) *Aspilia foliosa*, (4) *Microlicia tetrasticha*, (5) *Vellozia aloifolia*, (6) *Euphorbia sarcodes*, (7) *Actinocephalus bongardii*, (8) *Sauvagesia elegantissima*, (9) *Pilosocereus fulvilanatus*, (10) *Syngonanthus verticillatus*, (11) *Barbacenia umbrosa*, (12) *Encholirium biflorum*, (13) *V. subscabra*, and (14) *Clusia obdeltifolia*.

Ornamental species that have adaptive traits toward drought resistance, for instance, can be used to start sustainable landscaping projects, such as ecological, or naturalist gardens, that aim to preserve natural resources and develop more biodiverse environments. The use of plants

naturally adapted to semiarid environments, may promote the conservation of water resources and favor an appreciation of the regional identity of gardens[38]. The other species of the rupestrian fields herein collected with such characteristics and potential use in gardens are *E. sarcodes*, *C. minensis*, *Pilosocereus fulvilanatus*, *E. biflorum*, *Actinocephalus bongardii*, *Syngonanthus verticillatus*, *L. itacambirensis*, *Paepalanthus eriophaeus*, *V. aloifolia*, *V. subscabra*, *V. maxillarioides*, *B. umbrosa*, *A. foliosa*, *C. obdeltifolia*, *M. tetrasticha*, and *S. elegantissima* (Figure 15).

The diversity of the species collected at Serra do Itacambira was related to the formation of microhabitats and the substrates where the plant groups grew. Each microenvironment provides specific characteristics, such as the accumulation of organic matter and water saturation, which influence plant traits characteristics[39]. Nevertheless, some species of the genera: *Begonia*, *Mandevilla*, *Thaumatophyllum*, *Proteopsis*, *Vellozia*, *Wunderlichia*, *Stachytarpheta*, *Sauvagesia*, *Luxemburgia*, *Calliandra*, and *Aspilia* did not show any preference regarding substrate conditions, occurring in both dry, humid rocky fields, and rock crevices, indicating possible hardiness characteristics.

Throughout the sampling period at the Serra de Itacambira, some species flowered even in the very dry period, which lasts approximately 6 months. The flowering phase, in addition to being a well-appreciated aesthetic feature in landscaping, is important for interactions with the local fauna, as pollinator attraction, for instance[40,41]. The use of these species in building green areas can ensure the restoration and maintenance of important ecological agents such as bees and birds, as these plants provide food and shelter, contributing to the increase in biodiversity[42] even in urban environment. Species, such as *M. tetrasticha*, whose flowers are the main ornamental structure, maintain its ornamental appearance even in the absence of flowers and in the dry season, due to their beautiful green leaves, a characteristic observed in all genera of the Melastomataceae collected in the area.

Native plants can be used in landscaping for the benefit they bring to the local fauna. Species that have fruits may offer food resources, and their seeds can be dispersed. As an example, the palatable fruits of *Tococa guianensis* attract birds that are the main dispersers of its seeds[43]. *Schwartzia adamantium* has extrafloral nectaries that are attractive to small predatory insects due to the availability of nectar[44]. These predatory insects are natural enemies of other pests, promoting a beneficial interaction[45] and biological control in gardens, an

important ecological service for the balance of the ecosystem. Regarding the commercial applicability, the characteristics presented by all studied species indicate their use in landscaping, however, researching efforts are needed on propagation and legalization of these species for commercial purposes, so that the seedlings are safely available on the market, without harming the ecosystem where they exist.

CONCLUSIONS

Rupestrian fields of the Serra de Itacambira has a great diversity of species with desirable ornamental and sensory attributes for use in landscape projects. The flowers, leaves, and stems of the described species have aesthetic characteristics with ornamental potential for several uses in landscaping. The species studied also present, in addition to characteristics that confer resistance to high temperatures and water deficit, interactions with the local fauna, which enables their use in garden with ecological design with biophilic characteristics.

Funding

This research was financed by the Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG, process number 13673 and Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPQ Scholarship for RMSI number 304535/2019-2.

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