GREEN GARDENS AZORES PROJECT: A BRIEF CHARACTERIZATION OF THE VASCULAR FLORA IN THE AZORES' HISTORICAL GARDENS

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Abstract

The Green Gardens Azores Project is part of the action plan for tourism development in Portugal (2014-2020) aiming to integrate the Azorean Gardens in the circuit of international 'Garden Tourism'. With that purpose we built a checklist of the vascular plants cultivated in 8 Azorean Historical Gardens. The analysis of this checklist reveals a richness of 1884 specific and infra-specific *taxa*, hybrids and cultivars. This richness is represented by 168 families, 514 genera, 991 species, 288 hybrids and 958 cultivars. *Camellia* hybrids correspond to 60% of all the hybrids and *Camellia* cultivars represent 71% of all the cultivars. *Zamiaceae* is the family best represented with 73 species while the best represented genera are *Encephalartos* with 48 species and *Camellia* with 45 species. The presence of 5 species extinct in the wild and 96 threatened species in the Azorean Gardens stresses the role of the Gardens in the Conservation of World Flora.

Keywords: Azores, Garden flora, Garden tourism.

EL PROYECTO «JARDINES VERDES DE AZORES»: BREVE CARACTERIZACIÓN DE LA FLORA VASCULAR DE LOS JARDINES HISTÓRICOS DE AZORES

Resumen

El proyecto «jardines verdes de Azores» es parte de un plan de acción para el desarrollo turístico de Portugal (2014-2020) pretendiendo integrar estos jardines en el circuito internacional de jardines turísticos. Con este propósito hicimos la redacción de un listado de plantas vasculares cultivadas en ocho jardines históricos de Azores. El análisis del listado señaló una riqueza de 1884 categorías específicas, infraespecíficas, híbridos y cultivares. Esta riqueza está representada por 168 familias, 514 géneros, 991 especies, 288 híbridos y 958 cultivares. El género *Camellia* contribuye con un 60% de todos los híbridos y un 71% de todos los cultivares. *Zamiaceae* es la familia mejor representada con 73 especies, mientras que los géneros mejor representados son *Encephalartos* con 48 y *Camellia* con 45 especies. La presencia de cinco especies extintas en la naturaleza y 96 especies amenazadas en los jardines de Azores subrayan el papel que estos juegan en la conservación de la flora mundial.

Palabras clave: Azores, flora de jardín, turismo de jardines.

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1. INTRODUCTION

For their historical, botanical, and landscape value, the gardens of the Azores are an important heritage that can answer to the global demand of 'Garden Tourism' (Benfield 2013; Čakovská 2018). If we want to understand the economic impact of garden tourism, we can take as an example the fact that in 2014, 20 million paid entries were registered in the National Trust's British Gardens (National Trust 2014). Until now tourism at the Azores has been grounded on 'Nature Tourism' and 'Adventure Tourism' (Fraga 2014; Governo dos Açores 2016; Guerreiro 2017; Ponte et al. 2018). Nevertheless, there are evident advantages in developing the segment of garden tourism at the Azores, not only because garden tourism is suitable for a greater number of people than adventure or nature tourism, but also because these segments of tourism represent complementary niche markets that are not associated with mass tourism. In the Azores the growing world demand regarding the uses of gardens, has corresponded: to an increasing number of visits and visitors (SDEA 2018; SREA 2019); to the acknowledgment of Terra Nostra Garden international distinctions (Cox et al. 2014; ICS 2019); and to the organization of thematic guided tours (Haslemere Travel 2013), International Meetings of Ancient Camellias at Furnas in São Miguel Island (ICS 2007), and several scientific, educational and cultural events in the gardens.

The present study resulted from the Azores Green Gardens Project implementation (Green Gardens Azores 2019). This project is part of the Action Plan for Tourism Development in Portugal and aims to integrate the Azorean Gardens in the Circuit of International Garden Tourism. The project, co-financed by the European Regional Development Fund through the Operational Program 'Azores2020', is promoted by the Azores Tourism Observatory, with the Azores University and Gaspar Frutuoso Institution as co-promotors, and involves several other Azorean private and public institutions. Broadly this project is developed in two steps: a) gardens selection and characterization and b) design of communication and dissemination strategies and their implementation and evaluation. To this project several sites were selected, including Faial Botanic Garden, Pinhal da Paz Park, and two vineyards at Pico and Terceira Islands; but this study aimed the characterization of the vascular flora present only on the nineteen century historical gardens: one from Terceira Island (Duque da Terceira Garden) and 7 from São Miguel Island (António Borges Garden, Sant'Ana Garden, José do Canto Garden, Azores University Garden, José do Canto Woodland Garden, Beatriz do Canto Park and Terra Nostra Garden) (figure 1).

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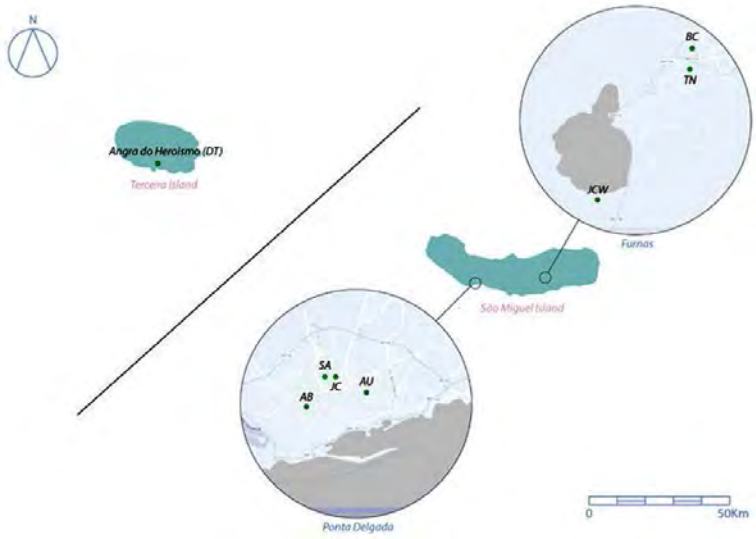

Figure 1. Locations of the gardens at Terceira and São Miguel islands: DT- Duque da Terceira Garden; AB - António Borges garden; SA - Sant'Ana garden; JC - José do Canto garden; AU Azores University Garden; JCW - José do Canto Woodland Garden; BC - Beatriz do Canto park; TN - Terra Nostra (courtesy of Ricardo Cruz architect).

2. MATERIAL AND METHODS

2.1. Study sites

The criteria to select the Azorean gardens and parks were the following: to be visitable, and accessible, possess maintenance services and facilities, and have historical, botanical, and landscape interest. Regarding the selected gardens, the first one to be established as a romantic garden, was the summer house called "Yankee Hall" in Furnas which became the genesis of the present Terra Nostra Garden (Carvalho 2017). All the other gardens are formed practically in the second half of the nineteen century (Albergaria 2005). José do Canto Woodland Garden is the one situated at the higher altitude, between 283 and 330 m, while the António Borges Garden is the garden located at the lowest altitude (20 m). José do Canto Woodland Garden has also the largest area with 120 ha, while the Azores University Garden has the smallest area only with 1.5 ha (table 1).

Regarding the gardens typology, the Terra Nostra Garden in its origin it's a romantic garden, but with time several elements were transformed or added (Albergaria 2000). The original cold water lake with canoes was replaced with a natural thermal water pool. Other elements were added as the memorial lane, and later, the *Victoria cruziana* A.D. Orb. tank, some animals covered with creeping plants and

new formal flower beds (Albergaria 2000; Carvalho 2017). The Garden of Sant'Ana brings together the romantic elements such as the lake with the anchorage point and formal elements like the 'parterre' in front of the palace, assuming itself as a botanical park with a collection of exotic species (Albergaria 2000). José do Canto Garden is also a botanical park in the sense that it maintains and increases their plant collection, but we can also find the original romantic and formal elements as the small pond and the rose garden, respectively (Albergaria 2000). José do Canto Woodland Garden corresponds to a vast area of spontaneous native and exotic naturalized or invasive species, coexisting with the exotic species initially planted by José do Canto (Albergaria 2000). Beatriz do Canto Park, António Borges Garden, and Azores University Garden are in their essence romantic gardens with more or less sophisticated water elements from the water stream with small cascades and a water wheel at Beatriz do Canto Park to small artificial lake at Azores University Garden (Albergaria 2000). The artificial volcanic rock grottoes are also romantic features present *symbolically* at *Azores* University Garden *but much more* elaborated at António Borges Garden (Albergaria 2000). Finally, the typology of Duque da Terceira Garden, is that one of a public garden with an access to the higher part of the town and to the monument 'Alto da Memória' (Albergaria 2005).

TABLE 1. LOCATION AND APPROXIMATE DATES OF FORMATION, AREAS AND ALTITUDES OF THE SELECTED HISTORICAL AZOREAN PARKS AND GARDENS (ALBERGARIA, 2005)

Name	Location	Year	Approximate areas (ha)	Approximate altitudes (m)
Terra Nostra Garden	Furnas	1785	12,5	200
José do Canto Garden	Ponta Delgada	1845	5,8	40 - 70
Sant'Ana Garden	Ponta Delgada	1850	7,5	40 - 80
José do Canto Woodland Garden	Furnas	1852	120	280 -330
António Borges Garden	Ponta Delgada	1858	3	20
Beatriz do Canto Park	Furnas	1860	3,7	200
Duque da Terceira Garden	Angra do Heroísmo	1882	1,7	20 - 80
Azores University Garden	Ponta Delgada	1897	1,5	30 - 40

2.2. Plant list database and plant identifications

An excel worksheet was used to create the plant list database for the Azorean historical gardens. Plant names were gathered from published and non-published plant lists of the selected gardens and parks (table 2). Plant names were checked for synonyms using 'The Plant List' (2013) data base; we adopted the scientific names with the status 'Accepted' (e.g. *Araucaria heterophylla* (Salisb.) Franco). For the 141 *taxa* names with 'Unresolved name' status (e.g. *Viburnum treleasei* Gand.), we analyse the respective recent published scientific taxonomic works (e.g. Moura et al. 2015). Also, from 2016 to 2018 several visits were made to the listed gardens

and parks; during the visits digital images of selected specimens were taken and when needed parts of the plants were collected for posterior identification using regional floras, field guides, scientific papers and electronic databases. Table 3 lists the information gathered in the plant list data base for the Azorean historical gardens.

TABLE 2. DATA SOURCES FOR PLANT NAMES (HD - HISTORICAL DOCUMENT; ITD - INTERNAL TECHNICAL DOCUMENT; B - BOOK)

Name	Available lists	Type of document
Terra Nostra Garden	Costa 2018 - ITD	ITD
José do Canto Garden	Canto 1856	HD
	Quintal and Braga 2018	B
Sant'Ana Garden	Canto 1856	HD
	Pacheco 2016	ITD
José do Canto Woodland Garden	Quintal 2015, 2018	ITD
António Borges Garden	Topiaris 2008	ITD
Beatriz do Canto Park	Quintal 2018	ITD
Duque da Terceira Garden	CMAH 2017	ITD
Azores University Garden	Pereira et al. 2010	B

TABLE 3. INFORMATION AT AZORES' HISTORICAL GARDENS PLANT DATABASE

Floristic composition	Species name
Name status	Accepted / Unresolved
Species Conservation Status	IUCN categories
Species status to the Azores	Exotic / Native
Group	*Pteridophyta* / *Pinophyta* / Dicotyledon / Monocotyledon
Taxon categories	Family / Genus / Species / Subspecies / Variety / Form / Hybrid
Cultivars	Species cultivars / Species variety cultivars/ Hybrid cultivars
Origin	Horticultural / Natural [Native of (geographic region)]
Habit growth form	Herbs / Shrubs / Trees / Palms / Climbers / Ferns

Data analysis. To the 8 historical gardens the plant list resulted in a database with 1884 plant entries. Some species are represented only by a particular subspecies; variety or cultivar. From this database 'richness' (the number of different plants present in the studied sites) was calculated independently for the *Pteridophyta, Pinophyta*, dicotyledons and monocotyledons, and for the families, genera, species, subspecies, varieties, forms, cultivars and hybrids. Families representativeness at the Azores' historical gardens, regarding the total of extant families on the world plant list data base (The Plant List 2013) was calculated. We also calculated the proportions: of different hybrids and cultivars, of different origins, and of different habit growth forms.

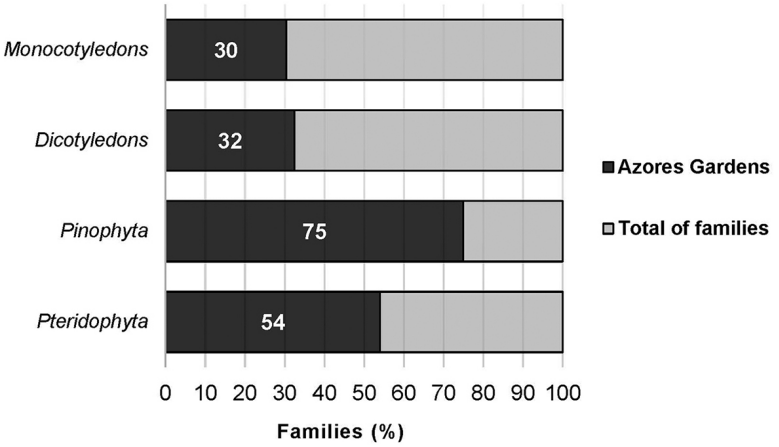

Figure 2. Representativeness of *Pteridophyta*, *Pinophyta*, dicotyledons, and monocotyledons families in the Azores' historical gardens (total number of families estimated by The Plant List, 2013).

3. RESULTS

The data base analysis reveals 1884 different plant entries that correspond to 168 families, 514 genera, 991 species, 958 cultivars, and 288 hybrids (table 4). Although Pinophyta are the group with the fewest families, in fact they are the best represented group since Azorean gardens own 75% of the *total Pinophyta* families registered in The Plant List (2013) database (figure 2). *Arecaceae* is the family represented by the large number of genera with 19 genera; while *Zamiaceae* is the family represented by the large number of species with 73 species; also the best represented genera are *Encephalartos* (with 48 species) and *Camellia* (with 45 species) (table 5). *Camellia* hybrids correspond to 60% of all the hybrids and *Camellia* cultivars represent 71% of all the cultivars (table 6).

TABLE 4. RICHNESS VALUES CALCULATED INDEPENDENTLY FOR EACH PLANT GROUP FOR 8 HISTORICAL GARDENS AT AZORES ISLANDS (DUQUE DA TERCEIRA, ANTÓNIO BORGES, SANT'ANA, JOSÉ DO CANTO, AZORES UNIVERSITY, JOSÉ DO CANTO WOODLAND GARDEN, BEATRIZ DO CANTO PARK, AND TERRA NOSTRA GARDEN)

Group	Totals	*Pteridophyta*	*Pinophyta*	Dicotyledons	Monocotyledons
Frequency	**1884**	205	138	1261	280
Families	168	27	9	108	24
Genera	514	61	34	300	119
Species	**991**	166	127	492	206
Subspecies	6	1	0	4	1
Varieties	31	5	2	15	9

Forms	3	1	1	1	0
Cultivars	**958**	60	11	802	85
Hybrids	**288**	2	1	232	53

TABLE 5. BEST REPRESENTED FAMILIES AND GENERA AT THE AZOREAN HISTORICAL GARDENS

Family	Number of Genera	Family	Number of Species	Genus	Number of Species
Arecaceae	19	*Zamiaceae*	73	*Encephalartos*	48
Myrtaceae	18	*Theaceae*	48	*Camellia*	45
Asparagaceae	17	*Bromeliaceae*	46	*Tillandsia*	22
Asteraceae	17	*Myrtaceae*	43	*Quercus*	16
Fabaceae	17	*Poaceae*	32	*Blechnum*	15
Poaceae	17	*Pteridaceae*	32	*Dryopteris*	13
Bromeliaceae	13	*Asparagaceae*	31	*Pteris*	13
Amaryllidaceae	12	*Arecaceae*	28	*Cycas*	11
Rosaceae	11	*Dryopteridaceae*	26	*Polystichum*	11
Cupressaceae	10	*Blechnaceae*	24	*Acer*	10
Ericaceae	10	*Ericaceae*	21	*Ficus*	10
Malvaceae	9	*Fagaceae*	21	*Rhododendron*	10
Pteridaceae	8	*Fabaceae*	20	*Adiantum*	9
Solanaceae	8	*Asteraceae*	18	*Cyathea*	9
Zamiaceae	8	*Cupressaceae*	18	*Eucalyptus*	8
Araceae	7	*Proteaceae*	16	*Asplenium*	7
Iridaceae	7	*Sapindaceae*	15	*Vriesea*	7
Polypodiaceae	7	*Rosaceae*	14	*Aechmea*	6
Acanthaceae	6	*Moraceae*	14	*Araucaria*	6
Apocynaceae	6	*Malvaceae*	13	*Bambusa*	6
Lauraceae	6	*Solanaceae*	13	*Banksia*	6
Oleaceae	6	*Amaryllidaceae*	12	*Ceratozamia*	6
Pinaceae	6	*Polypodiaceae*	12	*Macrozamia*	6
Proteaceae	6	*Oleaceae*	12	*Magnolia*	6
Xanthorrhoeaceae	6	*Pinaceae*	11	*Salvia*	6
Bignoniaceae	5	*Lamiaceae*	11		
Blechnaceae	5	*Cycadaceae*	11		
Lamiaceae	5	*Acanthaceae*	10		
Moraceae	5	*Cyatheaceae*	10		
Sapindaceae	5				
Remaining families	≤ 4	Remaining families	≤ 9	Remaining genera	≤ 5

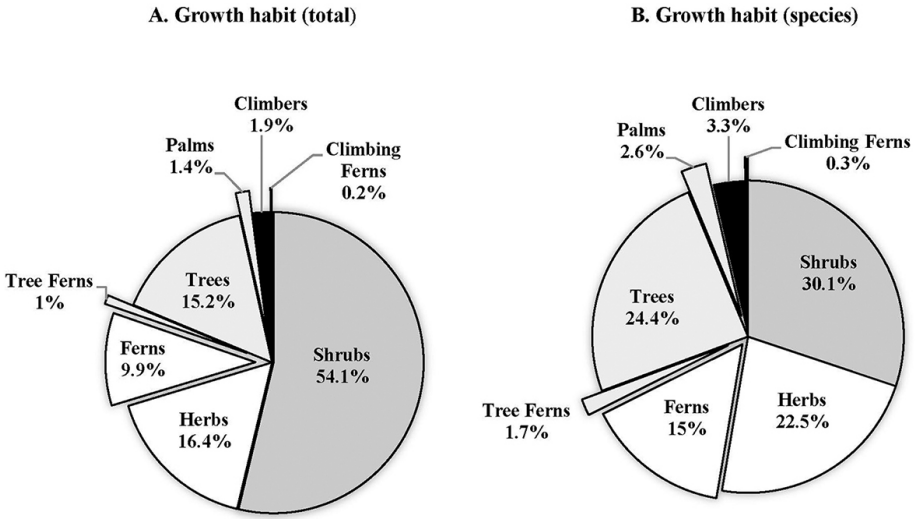

Figure 3. Growth habit distribution for the total of the plant database entries (A) and for the species (B).

TABLE 6. DISTRIBUTION OF HYBRIDS AND CULTIVARS AT THE AZOREAN HISTORICAL GARDENS BY GENERA. (OTHERS = LESS THAN 5 HYBRIDS OR CULTIVARS PER GENUS)

Genera	Hybrids (%)	Cultivars (%)
Camellia	60	71
Rhododendron	7	2
Gusmania	5	2
Acer		2
Vriesea	4	1
Canna	2	
Magnolia	2	
Others	20	22

Nearly half (49,2%) of the data base entries correspond to plants with horticultural origin. Also, nearly half (54%) of all the entries of the database represent shrubs (figure 3A) but at species level the shrubby growth habit decreases to 30.1% of the database entries (figure 3B).

Regarding the nativity of plant species Asia is the geographic region best represented in the gardens with 354 species (29%) of which 254 species are exclusively from Asia, followed by the plants native from the Americas (26%) (figure 4).

Also, 96 of the species found at Azorean Gardens are under a IUCN (2012) threatened species category. Five species are extinct in the wild (e.g. *Encephalartos*

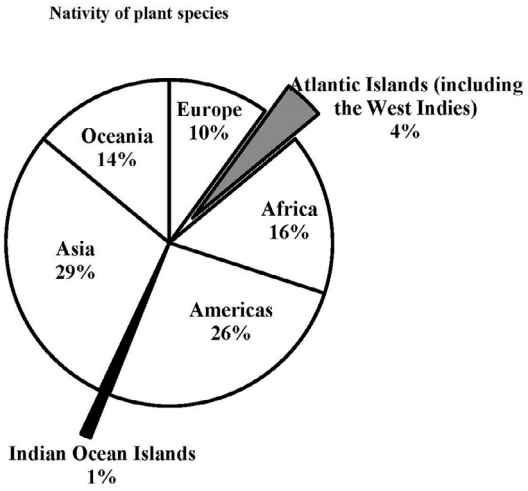

Figure 4. Nativity of plant species found at the Azorean Gardens.

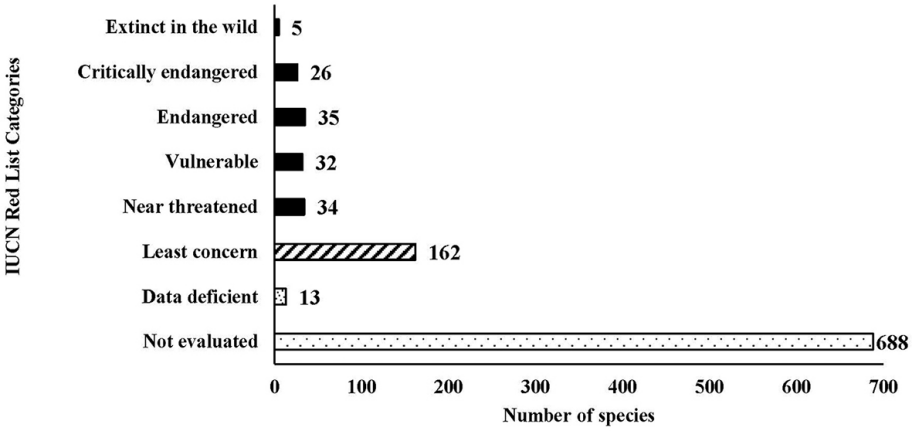

Figure 5. Conservation status: IUCN categories for the species found at the Azorean Gardens.

nubimontanus P.J.H. Hurter and *Encephalartos woodii* Sander) and 26 species are critically endangered (e.g. *Aechmea apocalyptica* Reitz, *Camellia impressinervis* H.T. Chang & S.Y. Liang, *Wollemia nobilis* W.G. Jones, K.D. Hill & J.M. Allen, and *Zamia vazquezii* D.W. Stev., Sabato & De Luca) (figure 5).

In a different analysis, 88 species found at Azorean Gardens are naturalized in the Azorean landscape including the worst invasive species at Azores as *Pittosporum undulatum* Vent. and *Hedychium gardnerianum* Sheppard ex Ker Gawl.

Finally, the number of listed species is very different between the surveyed gardens: Terra Nostra Garden possesses the highest number of species, genera and families (respectively 70%, 70% and 80% of the total database entries) (table 7). Also, Terra Nostra Garden possesses the largest collection of *Camellia* hybrids and cultivars (table 7).

TABLE 7. COMPARATIVE RICHNESS IN THE AZOREAN HISTORICAL GARDENS

Categories	Species	Genera	Families	Hybrids	Cultivars
Number of total listed categories	991	514	168	288	958
Terra Nostra Garden	691	360	135	266	859
José do Canto Garden	283	227	109	7	12
José do Canto Woodland Garden	195	144	78	7	16
Sant'Ana Garden	189	140	61	20	34
Duque da Terceira Garden	134	122	68	6	6
Azores University Garden	100	88	53	4	1
António Borges Garden	62	53	32	3	1
Beatriz do Canto Park	53	49	34	3	3

4. DISCUSSION

The analysis of the extensive list elaborated by José do Canto in 1856 reveals that a substantial part of the imported plants has been lost. Although this study verified the specimens' existence in the Azorean historical gardens according to the extant lists of plant names, several specimens found on the gardens still lack identification and many ornamental herbaceous plants are not listed. It is also necessary validate the specimens' identification with vouchers properly preserved at registered Herbariums. Therefore, it is expected that the total richness of Azorean gardens will increase with further studies and some specimens may have their identification rectified.

Nowadays the Azorean gardens under public administration tend to preserve the existent specimens while private gardens linked to hotels (Terra Nostra and José do Canto gardens) are increasing their plant collections due to the development of touristic activity.

In relation to the *Azores, the island* of Madeira has a greater number of historical farms and gardens sooner linked to *tourism*, which helps to explain, the maintenance of high specific diversity in these *gardens* (table 8). As in Portuguese mainland (Silva and Carvalho 2015), the preservation of old specimens and the high numbers of cultivated *taxa* and cultivars in the private insular historical gardens are linked to the resources obtained from the economic activity of tourism (e.g. Parque terra Nostra possesses 1532 plant entries considering all the *taxa* and cultivars).

Considering the Azorean historical gardens, Terra Nostra Garden possesses the highest number for species specific richness (691), and is comparable in area

and floristic richness to Quinta do Palheiro Ferreira at Madeira Island (table 8). Due to their mission the Portuguese Historical Botanical Gardens continuous to be the leaders in floristic richness: Madeira Botanical Garden with 3000 *taxa*, Botanical Garden of Lisbon University with 1086 *taxa,* and Botanical Garden of Ajuda with 1300 *taxa* (IFCN 2019; BGCI 2019).

TABLE 8. PLANT RICHNESS BETWEEN THE PORTUGUESE ARCHIPELAGOS OF AZORES AND MADEIRA. *DATA FROM QUINTAL (2007)

	Historical Gardens (17th-19th centuries)	Area (ha)	Families (n)	Genera (n)	Species (n)
Azores	Terra Nostra Garden	12,50	135	360	691
	José do Canto Garden	5,80	109	227	283
	José do Canto Woodland Garden	120,00	78	144	195
	Sant'Ana Garden	7,50	61	140	189
	Duque da Terceira Garden	1,70	68	122	134
	Azores University Garden	1,50	53	88	100
	António Borges Garden	3,00	32	53	62
	Beatriz do Canto Park	3,70	34	49	53
Madeira	Quinta do Palheiro Ferreiro	14,30	136	420	631
	Quinta Monte Palace	5,67	131	339	484
	Estalagem Jardins do Lago	1,37	113	336	433
	Quinta Palmeira	3,41	118	313	414
	Quinta Jardins do Imperador	3,85	96	223	284
	Quinta da Magnólia	2,47	95	221	263
	Quinta da Vigia	0,56	88	216	260
	Jardim do Hotel Quinta das Vistas	0,80	77	159	186
	Quinta da Bela Vista	1,06	87	171	185
	Pousada da Juventude Garden	0,21	73	132	156
	Hotel Pestana Casino Park Garden	2,32	74	142	155

Contrarily from the 179 worldwide botanic gardens analysed by Golding et al. (2010), we didn't find a correlation (Pearson correlation coefficient = 0,002) between the Portuguese insular historic gardens' areas and the number of plant species (table 8).

At the Azorean historical gardens, the good representativeness of *Pteridophyta* and *Pinophyta* families is mainly explained by the fern and *Cycadales* collections at Terra Nostra Garden. A brief analysis of families and genera representativeness highlight the importance of the 19 genera of palms (*Arecaceae*) collection on all the Azorean historical gardens, and the important collections of *Zamiaceae* (73 species) and *Camellia* (45 species) at Terra Nostra Garden.

Hybrids and cultivars of camellias dominate the lists of hybrids and cultivars present at the Azorean gardens. Once again the collection of camellias at Terra Nostra Garden has 680 plant entries in the total database, placing this garden in the world list of 'Gardens of Excellence' (ICS 2019).

The shrub habit of growth dominates both total entries in the database and plant species. If we considered all the woody plants (shrubs and trees) they represent 69.3% of the total listed plant names. Nevertheless, the extant lists do not consider many ornamental herbaceous plants.

In spite of the ornamental value of many native Azorean species (Amazon 2019; Future Forests 2019), the local flora is almost neglected at the Azorean historical gardens. The specimens represent probably non planted specimens left in the gardens (as the *Picconia azorica* (Tutin) Knobl. tree), or result of spontaneous establishment (e.g. the fern *Polypodium macaronesicum* A.E.Bobrov subsp. *azoricum* (Vasc.) F.J. Rumsey, Carine & Robba). For many years only Terra Nostra Garden had a collection of woody Azorean native species. Today, the native Azorean flora is valued in the tourism market and consequently native specimens receive identification tags and plantations of several endemic Azorean species were made in the last years at José do Canto and Terra Nostra private gardens.

The European flora is poorly represented at the Azores historical gardens and embodies only 10% of the total plant database entries, reflecting one of the European naval expeditions purposes of collecting plants across the Atlantic, Indian and Pacific oceans (Taillemite 2004; Rice 2010). Species native to Asia and/or Oceania represent 43%, of all the species present at the Azorean gardens. At 19th century plants from Asia and Oceania were the novelty since they resulted from the last great expeditions around the world at the end of 18th century; the *Araucaria heterophylla* tree is a good example, since this coastal species was first seen by Captain Cook from the sea in 1774 on his second voyage around the world (Hooker 1843).

Although the botanical gardens were, in a historical context, responsible for the introduction of many exotic species that later became invasive (Galera and Sudnik-Wócikowska 2010; Hulme 2015; Guo et al. 2019) today many botanical gardens including the historical ones have programs for rare species conservation (Chenabc and Sunabc 2018). In the current Azorean gardens' database only 4,7% of plant entries correspond to escaped naturalized plants while 5,2% of plant entries correspond to extinct in wild or under some IUCN (2012) threatened species category. Nevertheless, the percentage of escaped and naturalized plants will increase if we included in the database all the current exotic non-cultivated flora present at the gardens. The recent pressure to recover and improve these historical gardens with new species and cultivars, stresses the importance to perform a risk assessment analysis for any species that is intended to introduce at the gardens (Daehler and Carrino 2000; Groves et al. 2001; Conser et al. 2015). At the same time due to the rarity of many endemic Azorean plants species, the Azorean gardens should play a more important role in their conservation.

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6. AUTHORS CONTRIBUTION

I. Albergaria conceived the present study; R. Raimundo, M.J. Pereira and C. Costa analysed the extant plant lists, locate the plants at the gardens and verify the existing identifications. M.J. Pereira treated the data and took the lead in writing the manuscript but all the authors provided critical feedback.

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