BOTANIC GARDENS, PEOPLE AND PLANTS FOR A SUSTAINABLE WORLD

BOTANIC GARDENS, PEOPLE AND PLANTS FOR A SUSTAINABLE WORLD

FOLLOWING THE 8TH EUROGARD CONGRESS
HELD IN LISBOA, MAY 7TH-11TH 2018

Edited by
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Revised by
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8TH EUROGARD CONGRESS SECRETARIAT

TABLE OF CONTENTS

FOREWORD

On behalf of the European Botanic Gardens Consortium (EBGC), the University of Lisbon and Jardim Botânico da Ajuda (Botanic Garden of Ajuda) on the occasion of its 250th anniversary organized the 8th European Congress of Botanic Gardens – EuroGard VIII, that was held in Lisbon, 7th-11th may 2018. Under the theme "Botanic Gardens, People and Plants for a Sustainable World", it was intended to address many of the issues to which Botanic Gardens are contributing, in particular raising public awareness of environmental conservation challenges that our planet faces. EuroGard VIII bring together the participation of Botanic Gardens in Europe and other world regions. Moreover, the 15th Symposium of the Ibero-Macaronesian Association of Botanic Gardens took place at the same time, during which the aim was to assess the work carried out to meet the Aïchi Biodiversity Targets adopted by the Iberian-Macaronesian botanic gardens for 2020.

The Congress included a diverse range of subjects and topics on biodiversity conservation, especially related to plants and the complex and extensive roles of botanic gardens. It emphasized how Botanic Gardens have been actively involved in shaping national and international policies and practices in plant conservation. They continue to have an influential role at all levels through their engagement with governments (that are Parties to the Convention on Biological Diversity), and through their involvement in the Global Partnership for Plant Conservation (GPPC).

It is acknowledged that botanic gardens come from very different roots but since 2002, the Global Strategy for Plant Conservation (GSPC), and its update in 2010, has provided a focus and primary framework to guide Botanic Gardens' activities in strategic and practical contributions to plant conservation; The roles of Botanic Gardens in supporting the GSPC are manifold, from contributions of smaller gardens to single targets to potential contributions to all 16 targets by larger, better resourced, botanic gardens.

It was pointed out during the Congress that we are coming to a crucial time for plant conservation policies as the GSPC targets are due to be attained by 2020. It is therefore essential that botanic gardens should redouble their efforts for the GSPC targets and take a prominent role in the process of negotiating a renewed Global Strategy for Plant Conservation for the period after 2020. It is likely that this update will consider the importance of the Sustainable Development Goals and be even more closely aligned with the Aichi Targets than they have been previously. The 2030 Sustainable Development Goals provide an opportunity for botanic gardens to integrate more fully their work with more socio-economic concerns which impact on the conservation of biodiversity worldwide.

In addition to the GSPC, botanic gardens need to continue to engage with other key global policies, strategies and initiatives, such as the UNFCCC, the CBDs Nagoya Protocol, the World Heritage Convention, CITES, IPBES, the Florence Charter on the restoration of historic gardens, and many other national and international conventions, policies, initiatives and frameworks that are also relevant to their work in cultural, heritage, educational and social issue.

Support for botanic garden directions was also welcomed from the representative of the DG environment of the European commission, Humberto Delgado Rosa, who pointed out the range of existing European instruments relevant to botanic gardens, including the European Plant Conservation Strategy and the European Commission's Biodiversity Action Plan, as well as National Biodiversity Strategies and Action Plans. The special importance of ensuring that botanic gardens are in full compliance with the CBDs Nagoya Protocol on Access and Benefit Sharing was pointed out, as well as the EUs regulation on Access and benefit sharing too. The Congress was particularly successful in showcasing a wide range of projects, case studies, initiatives that clearly demonstrate outstanding progress in many areas of endeavour related to their collective mission.

While Europe is well supported with its own botanic gardens, many regions of the world that are rich in biodiversity still have too few and many are very under resources or supported. The European botanic garden can and should play important roles in supporting north south cooperation and partnering with such institutions and in capacity building. The development of new models for botanic gardens in other regions of the world can be explored too to ensure that they are most suited to local situations and needs. Such models may highlight too closer integration with other sectors, beyond the botanical community, to link with agriculture, forestry, and commercial horticulture too, as well as protected area networks and national environmental protection authorities. Linkages with communities at local levels were especially recommended, both in the urban and rural environment. Achieving sustainable communities is an essential part of attaining a sustainable environment.

Lisbon, May 11th, 2018

Dalila Espírito Santo
Head of Eurogard VIII Congress

Peter Wyse Jackson
Chairman of GPPC, Honourable President of ECBG

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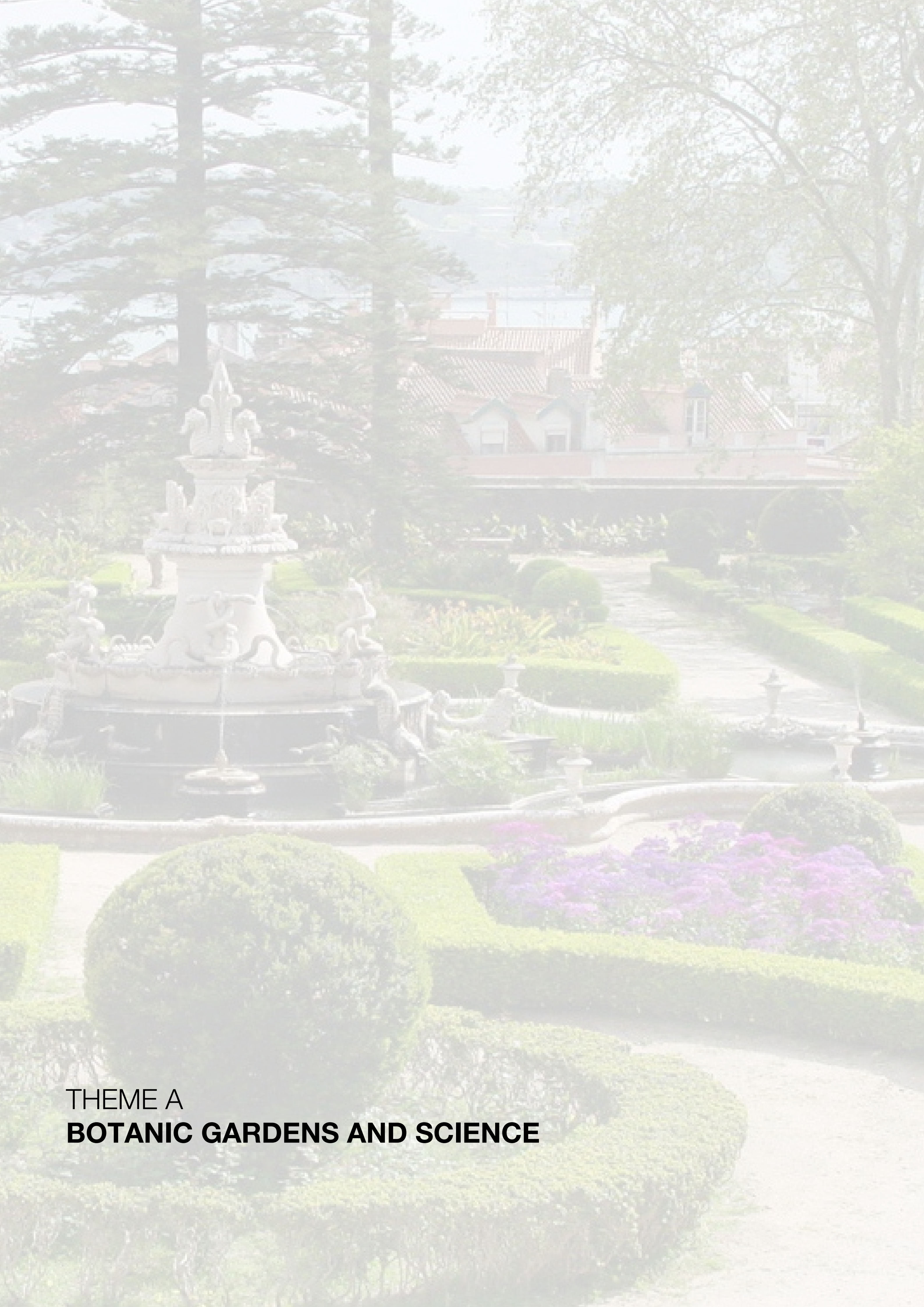

THEME A

BOTANIC GARDENS AND SCIENCE

UTILIZATION OF *LIMONIUM EX SITU* COLLECTIONS TO STUDY THE OCCURRENCE OF APOMIXIS

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ABSTRACT
Circa 2.2% of flowering plants genera are known to contain apomictic species, comprising 78 families, including the sea lavenders *Limonium* Mill genus from the Plumbaginaceae family. This genus is represented by taxonomically complex groups generally characterized by hybridization, polyploidy and sexual (outcrossing, selfing) and/or asexual modes of reproduction (apomixis), and/or male sterility. These reproductive modes appear to be associated to a pollen-stigma dimorphism linked to a sporophytic self-incompatibility system. We established an *ex situ Limonium* collection (circa 350 plants) with representative members of several species with the aim to characterize sexual and asexual accessions and hybrid biotypes, as well as to study the occurrence of apomixis. To achieve this, we combined a cytogenetic, ovule development, reproductive phenology, and transcriptomic approach using plants of these collections. Mother plants of *Limonium binervosum, Limonium dodartii, Limonium nydeggeri* and *Limonium ovalifolium* were characterized cytogenetically through genome size estimations and chromosome counts to assess their ploidy levels. Then, pollen–stigma dimorphisms were examined and ovules in distinct stages of development were analyzed. In this way, for each individual sexual and/or apomictic development was determined. These plants were further used to produce F1 offspring plants using either plant as a male donor or female receiver through crosses among diploid sexuals, and between tetraploid facultative apomicts and diploid sexuals. Interploid crosses mostly originated diploid plants whereas interploid crosses only produced between tetraploid and diploid plants. In the present study our goal was to characterize the reproductive phenology of offspring plants resulting from such crosses. In homoploid crosses both parental plants and the diploid offspring produced a lot of homogenously sized pollen with a high pollen grain viability. While in interploid crosses, both tetraploid parental plants and offspring plants mostly formed heterogeneous sized and non-viable pollen.
Cytogenetic and transcriptomic studies using these F1 plants are ongoing to investigate chromosome transmission and epigenetic alterations in the ovule tissue, and to find genetic-molecular factors associated to the occurrence of apomixis.

KEYWORDS
Genetic Crossing, Plant Reproduction, Pollen Viability, Polyploidy

INTRODUCTION
The halophytic *Limonium* genus (*Plumbaginaceae*), typically found in coastal areas and saline steppes distributed all over the world (Erben, 1993; Kubitzki, 1993), is an interesting biological system for studying the reproductive biology of groups with complex taxonomy, which harbour significant biodiversity (Ennos et al., 2005). These complexes are generally characterized by uniparental reproduction [e.g., self-fertilization, agamospermy (i.e., apomixis, clonal reproduction through seeds), gynogenesis], hybridization at some degree among its members, and polyploidy (Róis et al., 2012; Cortinhas et al., 2015; Róis et al., 2016; Caperta et al., 2017).
A huge cytological diversity has been reported in this genus, ranging from euploid and aneuploid diploid to octoploid cytotypes (Erben, 1978, 1993; Brullo & Pavone 1981; Arrigoni & Diana 1993; Artelari & Georgiou, 1999; Georgakopoulou et al. 2006; Castro & Rosseló 2007; Róis et al., 2012; Cortinhas et al., 2015; Caperta et al., 2017). Diploid species (e.g., *L. ovalifolium,* 2n =2x = 16) reproduce sexually (Erben, 1978; Róis et al., 2012; Róis et al., 2016) through the formation of meioticaly reduced

tetrasporic embryo sacs of *Gagea ova* type (Romanov, 1957; Róis et al., 2016), and tetrasporous gametophytes of *Adoxa* and *Drusa* types (Dahlgren, 1916; D'Amato, 1949; Róis et al., 2016). Tetraploid facultative apomicts (e.g., *L. transwallianum*, 2n = 4x = 35, 36) and tetraploid autonomous apomicts (e.g., *L. multiflorum*, 2n = 4x = 35, 36) (Róis et al., 2016) form meiotically unreduced diplosporous embryo sacs (Ingrouille & Stace, 1986; Hjelmqvist & Grazi). Triploid facultative apomicts (e.g., L. virgatum, 2n = 3x = 27) originate meiotic embryo sacs in parallel with apomictic embryo sacs (D' Amato, 1949). Diploid species (e.g., *L. ovalifolium*) display regular male meiosis but polyploid apomicts (e.g., *L. multiflorum*) frequently show disturbed male meiosis leading to low pollen quality and quantity or even complete male sterility (Róis et al., 2012). Diploid *L. ovalifolium* show regular male meiosis resulting in normal tetrads, which develop into the characteristic unicellular, bicellular, or tricellular pollen grains (Róis et al., 2012). These grains exhibit the typical micro- or macro-reticulate exine ornamentation patterns. Most of these grains are viable and produce pollen tubes in vitro (Róis et al., 2012). Tetraploid *L. multiflorum* show chromosome pairing and segregation irregularities during male meiosis leading to the formation of abnormal meiotic products and pollen grains with a collapsed morphology, which are unable to germinate in vitro (Róis et al., 2012). Hence, pollen stainability in *Limonium* appears to be high in sexual diploids, while in polyploids, low to high fertility has been reported (Erben, 1978, 1979). In the triploid *L. viciosoi* (2n = 3x = 27), pollen was either not produced or with very low stainability (2–13 %) (Erben, 1978). Contrastingly, in hexaploid *L. humile* (2n = 6x = 54), a high percentage of fertile pollen grains is observed (95 %) (Dawson & Ingrouille, 1995).

Previous embryological, reproductive biology experiments in Limonium (Róis et al., 2012; Róis et al., 2016) and but also on differences between diploids and tetraploids in their extent of morphological and genetic variation (Róis et al., 2013; Róis et al., 2016; Caperta et al., 2017), led us to hypothesize that differences in pollen production occur between the plants originated from homoploid and interploid crosses.

MATERIAL AND METHODS

Plant materials and growth conditions

A total of 13 self-incompatible plants representative of diploid species, *L. ovalifolium* and *L. nydeggeri* (2n = 2x = 16) (Erben, 1993, 1999; Róis et al., 2012), and tetraploid species, *L. binervosum* and *L. dodartii*, (2n = 4x = 35, 36) (Erben, 1993) were used in controlled crosses (Table 1). Five homoploid (diploid vs diploid) and four interploid (tetraploid vs diploid) crosses were made following the methodology in (Róis et al., 2016; Conceição et al., 2018 in revision). Parental plants and their offspring are maintained in the greenhouses at Instituto Superior de Agronomia.

Pollen viability analyses

Pollen viability was scored using Alexander's stain test (Alexander, 1969) in parental plants and in the resulting progeny. The total number of pollen grains was determined and pollen viability estimates were performed by one person using three flowers (five anthers) per plant; the number of pollen grains was counted under an optical light microscope (LeitzHM-LUX 3) at x20 magnification. The percentage of viable pollen grains per flower was estimated.

RESULTS AND DISCUSSION

In this study we observed that tetraploid plants started blooming earlier than diploid plants as well as differences on pollen viability were observed in diploid and tetraploid plants (Table 2). In general, diploid mother plants presented a higher number of pollen grains per flower than tetraploid plants. In diploid parental plants these pollen grains were homogenously sized, whereas in tetraploid plants heterogeneous sized pollen is detected. Differences in pollen quality (Fig. 1) were also found between diploid a tetraploid plants. Diploid parental plants showed a high percentage of viable pollen grains, over 90%, while in tetraploid parental plants differences in pollen viability were found among individuals from distinct species, respectively *L. binervosum* and *L. dodartii*. Even in tetraploid individuals of the same species, i.e. *L. binervosum*, there were remarkable differences in pollen grain viability (please see Table 2), from high (87.7%) to residual male fertility (8.3).

The offspring plants from diploid x diploid crosses showed a high (over 76%) but lower pollen viability percentage than their progenitors. Conversely, in general individuals originated from tetraploid x diploid crosses exhibited a very low pollen viability in comparison with both diploid and tetraploid parental plants. Offspring plants from tetraploid x diploid crosses showed much lower viable pollen production than offspring plants originated from diploid x diploid crosses.

In fact, diploid species (e.g., *L. ovalifolium*) show regular male meiosis (Róis et al., 2012) but polyploid apomicts (e.g., *L. multiflorum*) frequently present disturbed male meiosis leading to low pollen quality and quantity or even complete male sterility (Róis et al., 2012). In the putative triploid apomict *L. algarvense* (2n = 3x =25, 26, Caperta et al., 2017), heterogenous sized pollen with low fertility is also observed (Conceição et al., in revision). Remarkably, in the tetraploid *L. binervosum* complex (2n = 4x = 35), male sterile and male fertile colonies have been found in the British Isles (Ingrouille & Stace, 1985).

CONCLUSION

This study highlights contrasting responses in pollen production in diploid and polyploid plants with distinct reproductive strategies, sexual and/or apomixis, and diminishes the importance of apomicts as pollen donors.

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REFERENCES

Alexander M.P. (1969) *'Differential staining of aborted and nonaborted pollen'*. Stain Technology 44:117–122.

Arrigoni P.V. and Diana S. (1993) *'Contribution to the knowledge of the genus Limonium in Corsica.'* Candollea 48: 631–677.

Artelari R. and Georgiou O. (1999) *'Two new species of Limonium (Plumbaginaceae) from the island of Kithira (Greece)'.* Botanical Journal of the Linnean Society 131:399-415.

Brullo S., Pavone P. (1981) *´Chromosome numbers in the Sicilian species of Limonium Miller (Plumbaginaceae)'.* Anales Jardín Botânico de Madrid 37:535–555 .

Caperta A.D., Castro S., Loureiro J., Róis A. S., Conceição S., Costa J., Rhazi L., Espírito Santo D., and Arsénio P. (2017)*´ Biogeographical, ecological and ploidy variation in related asexual and sexual Limonium taxa (Plumbaginaceae)'.* Botanical Journal of the Linnean Society 183: 75–93.

Castro M. and Rosselló J.A. (2007) *'Karyology of Limonium (Plumbaginaceae) species from the Balearic Islands and the western Iberian Peninsula'.* Botanical Journal of the Linnean Society 155:257-272.

Conceição S.I.R., Róis A.S., Caperta A.D. (2018). *'Nonreduction via meiotic restitution and pollen heterogeneity may explain residual male fertility in triploid marine halophyte Limonium algarvense (Plumbaginaceae)'*. Caryologia, in Revision.

Cortinhas A., Erben M., Paula Paes A., Espirito Santo D., Guara-Requena M., and Caperta A.D. (2015) '*Taxonomic complexity in the halophyte Limonium vulgare and related taxa (Plumbaginaceae): insights from analysis of morphological, reproductive and karyological data'.* Annals of Botany 115: 369–383.

D'Amato F. (1949) *'Triploidia e apomissia in Statice oleaefolia Scop. var. confusa Godr.'* Caryologia 2: 71–84

Dahlgren K.V.O. (1916) *'Zytologische und embryologische Studien uber die Reihen Primulales und Plumbaginales'.* Kungliga Svenska Vetenskapsakademiens Handlingar 56: 1–80.

Dawson H. J. and Ingrouille M. J. (1995) *'A biometric survey of Limonium vulgare Miller and L. humile Miller in the British Isles'.* Watsonia 20: 239–254.

Ennos R.A, French G.C., Hollingsworth P.M. (2005) '*Conserving taxonomic complexity'.* Trends in Ecology and Evolution 20: 164–168

Erben M. (1978) *'Die Gattung Limonium im südwestmediterranen Raum.* Mitteilungen der Botanischen Staatssammlung München 14:361-631.

Erben M. (1979) *'Karyotype differentiation and its consequences in Mediterranean Limonium'.* Webbia 34: 409–417.

Erben M. (1993) *'Limonium Mill'.* In: Castroviejo S, Aedo C, Cirujano S, Laínz M, Montserrat P, Morales R, Garmendia FM, Navarro C, Paiva J, Soriano C, eds. Flora Iberica vol. 3. Madrid: Real Jardín Botânico, CSIC, 2–143.

Erben M. (1999) *'Limonium nydeggeri eine neue Art aus Sudwestportugal'.* Sendtnera 6: 103-107.

Georgakopoulou A., Manousou S., Artelari R., Georgiou O. (2006) *'Breeding systems and cytology in Greek populations of five Limonium species (Plumbaginaceae) '.* Willdenowia 36: 741-750.

Hjelmqvist, H. and Grazi, F. (1964). Studies on variation in embryo sac development. Botaniska notiser 117: 141–166.

Ingrouille M. J. and Stace C. A. (1986) *'The Limonium binervosum aggregate (Plumbaginaceae) in the British Isles'.* Botanical Journal of the Linnean Society 92: 177-217.
Kubitzki K. (1993) *'Plumbaginaceae.'* in: K. Kubitzki, J. Rohwer, & V. Bittrich (eds.), Flowering Plants · Dicotyledons SE- 62 , vol. 2. Springer Berlin Heidelberg, 523-530.
Róis A. S., Rodríguez López C. M., Cortinhas A., Erben M., Espírito-Santo D., Wilkinson M. J., and Caperta A. D. (2013) *'Epigenetic rather than genetic factors may explain phenotypic divergence between coastal populations of diploid and tetraploid Limonium spp. (Plumbaginaceae) in Portugal'.* BMC Plant Biology 13:205.
Róis A. S., Sádio F., Paulo O. S., Teixeira G., Paes A. P., Espírito-Santo D., Sharbel T. F. and Caperta A.D. (2016) *'Phylogeography and modes of reproduction in diploid and tetraploid halophytes of Limonium species (Plumbaginaceae): Evidence for a pattern of geographical parthenogenesis'.* Annals of Botany 117: 37–50.
Róis A. S., Teixeira G., Sharbel T. F., Fuchs J., Martins S., Espírito-Santo D., and Caperta A. D. (2012) *'Male fertility versus sterility, cytotype, and DNA quantitative variation in seed production in diploid and tetraploid sea lavenders (Limonium sp., Plumbaginaceae) reveal diversity in reproduction modes'.* Sexual Plant Reproduction 25: 305–18.
Romanov I.D. (1957) *'Embryo sac in the genus Tulipa'.* Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS 115: 1025–1027

TABLES AND FIGURES

Species	Accession number[a]	Origin[b]	DNA ploidy level[c]
L. binervosum	Lb2013I4P1SJ	Aveiro, São Jacinto	4x
L. binervosum	Lb2010I1CM	Figueira da Foz, Cabo Mondego	4x
L. binervosum	Lb2010I2CM	Figueira da Foz, Cabo Mondego	4x
L. dodartii	Ld2011I19CSa	Odemira, Cabo Sardão, Portugal	4x
L. nydeggeri	Ln2009I13B	Peniche, Baleal	2x
L. nydeggeri	Ln2009I3SR	Peniche, Sra. dos Remédios	2x
L. nydeggeri	Ln2009I4SR	Peniche, Sra. dos Remédios	2x
L. nydeggeri	Ln2009I6SR	Peniche, Sra. dos Remédios	2x
L. nydeggeri	Ln2009I1C	Aljezur, Carrapateira	2x
L. ovalifolium	Lo2009I2		2x
L. ovalifolium	Lo2009I2CR	Cascais, Cabo Raso	2x
L. ovalifolium	Lo2009I1L	Lagos, Praia da Luz	2x
L. ovalifolium	Lo2009I5CS	Vila do Bispo, Cabo de Sagres	2x

Table 1: Voucher specimens and provenance of plants used in the genetic crosses. All plants were originated from seeds collected in continental Portugal. Information on species is in alphabetical order, and information on ploidy is given.

Parental plant accession number	Percentage of viable pollen/ flower	No. of pollen grains/flower	Offspring average of pollen viability percentage	No. of offspring individuals
Diploid/Diploid			**Diploid x Diploid**	
Lo2009I1L	98.5	599	87.7 (2859)	9
Lo2009I2	98	844		
Ln2009I13B	99.2	784	82.7 (4302)	11
Lo2009I5CS	98.8	508		
Ln2009I14SR	100	715	82.4 (1163)	5
Lo2009I5CS	98.8	508		
Ln2009I6SR	99.6	464	82.8 (3036)	8
Lo2009I5CS	98.8	508		
Lo2009I2CR	99.9	661	76.1 (2322)	6
Lo2009I5CS	98.8	508		
Tetraploid/Diploid			**Tetraploid x Diploid**	
Lb2013I4P1SJ	8.3	456	3.1 (1766)	4
Ln2009I3SR	98.1	256		
Lb2010I1CM	87.7	397	0.5 (2385)	6
Ln2009I3SR	98.1	256		
Lb2010I2CM	82.4	450	2.1 (2706)	4
Ln2009I3SR	98.1	256		
Ld2011I19CSa	65.8	435	1.5 (1045)	2
Ln2009I1C	99.1	443		

Table 2: Pollen viability of mother plants and of offspring. The number of pollen grains analyzed in the offspring is given in parenthesis.

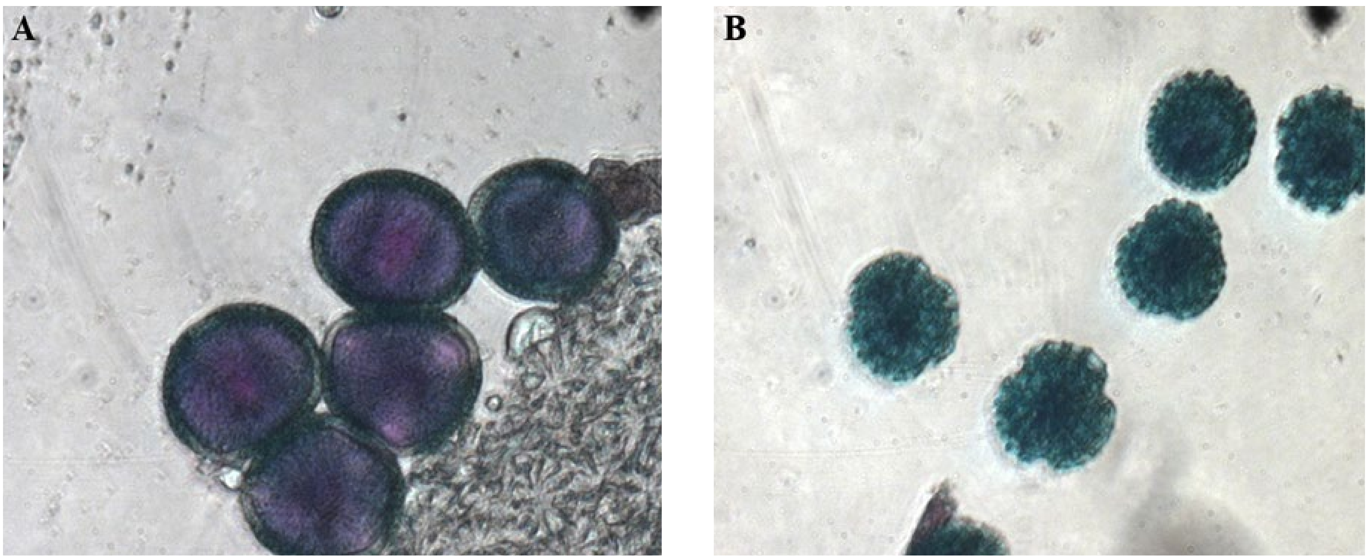

Figure 1: Pollen viability in *Limonium.* A. Viable pollen in *L. ovalifolium*; and B. Unviable pollen in *L. binervosum*.

THE INTERNATIONAL PLANT SENTINEL NETWORK

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ABSTRACT
Invasive alien plant pests and diseases already pose a considerable threat to plant health worldwide. With the increased globalisation of trade in plants and plant material, and the effects of a changing climate, this threat is predicted to continue to rise. In recent years, the world has seen a sharp rise in the number of these harmful invasive organisms which cause large scale environmental and economic damage. A significant issue in managing this threat is predicting which organisms will pose a threat in the future. Prevention is arguably the most effective way to manage these organisms; however regulation relies upon lists of known pests and diseases. Sentinel plants are individuals found outside their native ranges that can be surveyed for damage by organisms they would not otherwise encounter. Monitoring plant sentinels can also help to build knowledge and understanding of pest/host relationships to support the development of management plans and risk assessments.

KEYWORDS
Pests, Diseases, Sentinel Plants, Invasive, Monitoring, Capacity Building

INTRODUCTION
Introduced plant pests and diseases have had, and will continue to have, devastating impacts on plant species around the world. The threat from new pests and pathogens is only set to rise as the rate of international trade increases, involving greater numbers of countries and trade routes, creating new pathways for their introduction.

Most European countries utilise a process called Pest Risk Analysis (PRA) to regulate risk within trade, which focuses on known threats. As a result, damaging unknown organisms ('unknowns') are often left unregulated, increasing the chances of their introduction into new countries. A key issue that scientists face is trying to predict which of these organisms could/will cause problems for plants in the future, and where.

Botanic gardens and arboreta are in a unique position to aid in the identification of such unknowns; within their collections they play host to expatriate plants that can act as sentinels for these potentially invasive and damaging organisms.

The International Plant Sentinel Network (IPSN) was set up as an early-warning system for future pest and disease threats (Kramer and Hird 2011). There are over 3,000 botanical institutes around the world, which house 30-40% of known plants (Mounce *et al.* 2017). Introduced plants in these gardens are already established in non-native regions. The network uses enhanced monitoring of plants that are growing outside their natural regions for damage by all the organisms that exist in the new environment; i.e. 'sentinel plants'. As well as helping to identify 'unknowns' or 'future threats', research can also provide key information about pests and diseases that scientists already know but which are poorly characterised. The more scientists (and botanical institutes) know, the better the management plans that can be put in place to prevent the introduction of such pests and/or slow or stop their establishment and spread. For this reason, the aim of the IPSN is to bring together experts from different backgrounds who work in plant health, including those working in governments, academic institutions and NGO's combined with staff working in botanic gardens and arboreta.

BGCI manages two unique databases that contribute to IPSN activities. GardenSearch (2018), a global database of all known gardens listing key information such as significant collections, location (country, region, GPS coordinates) and contact details, all of which can be used to identify gardens in areas of interest. PlantSearch (2018), a global database cataloguing living plant, seed and tissue collections of gardens, allows the location of particular species in countries around the world to be identified. Both of these tools can be used to help identify, facilitate and drive research. For example, studying the susceptibility of *Fraxinus* to exotic pests and diseases. GardenSearch and PlantSearch can be used to identify gardens that have *Fraxinus* in their collections. These collections can be surveyed in regions where the species is not native in order to determine which exotic pests and diseases are likely to cause damage if introduced to their native region. Fig. 1 shows the common ash species Fraxinus excelsior in nearly 200 botanic garden collections around the world.

Advantages of botanic garden collections include established planting and also provide the opportunity to study older specimens, which can be important when assessing the risk a pest poses to a particular species. In addition botanic gardens and arboreta have trained and passionate staff that work on a day-to-day basis with the plants in their care. Garden staff's ability to recognise, and importantly understand, unusual changes in a plant's health will be central to the identification of damaging organisms

Although botanic gardens and arboreta offer excellent sites to carry out sentinel plant research they are currently often overlooked by researchers. The IPSN raises awareness and trains staff working in botanic gardens and arboreta so that they could look for pests and diseases within their gardens and share this information with appropriate experts.

The International Plant Sentinel Network.

The IPSN is funded through EUPHRESCO (an ERA-NET project) by the Department for the Environment, Food and Rural Affairs (Defra) and coordinated by BGCI. There are currently 17 Euphresco partners in 15 countries (fig. 2) carrying out research, capacity building and outreach related to botanic garden sentinel work. The partners are from Europe, USA, New Zealand and Australia.

Figure 1: Ash *(Fraxinus excelsior)* growing in botanic garden collections around the world.

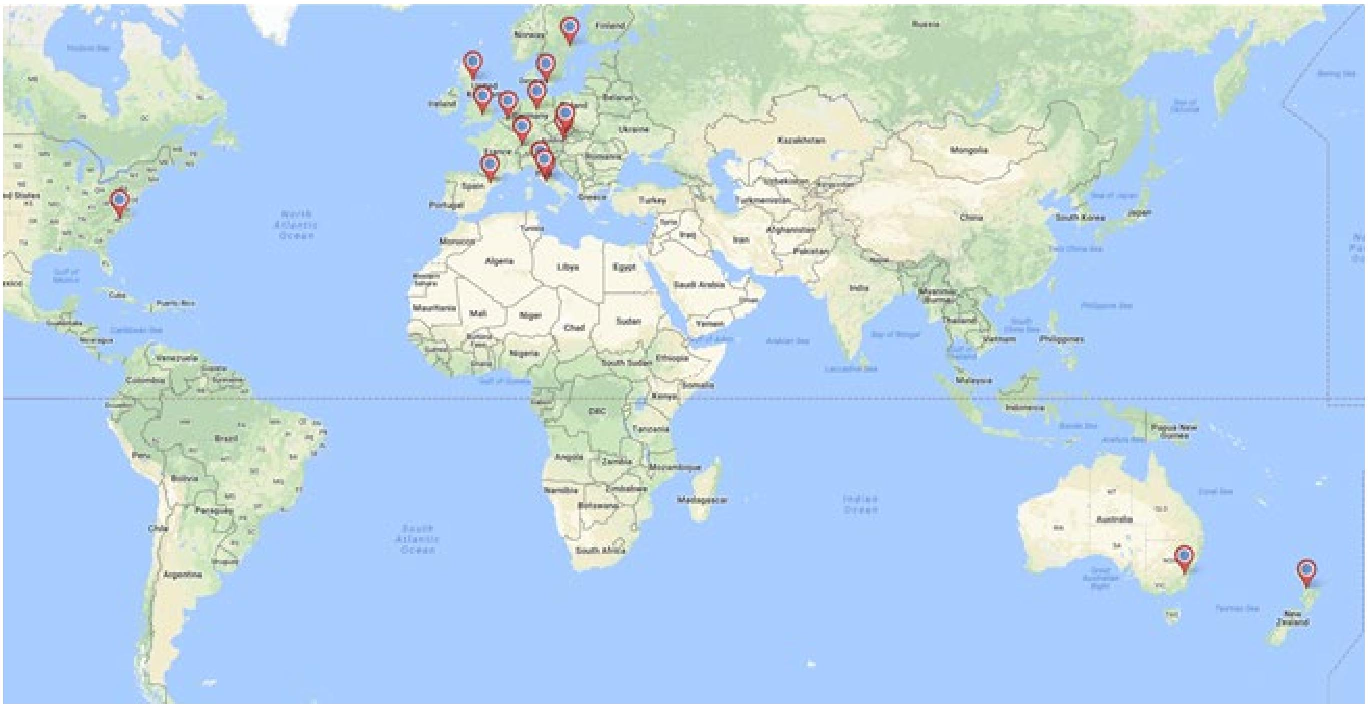

Figure 2: Euphresco partners involved in the IPSN network.

An example of activities of a Eurphresco partner includes the Botanic Gardens Meise (Agentschap Plantenuin) in Belgium, which has set up a National Sentinel Network working with 11 botanic gardens in the country to increase capacity for survey and identification of emerging pests and diseases.

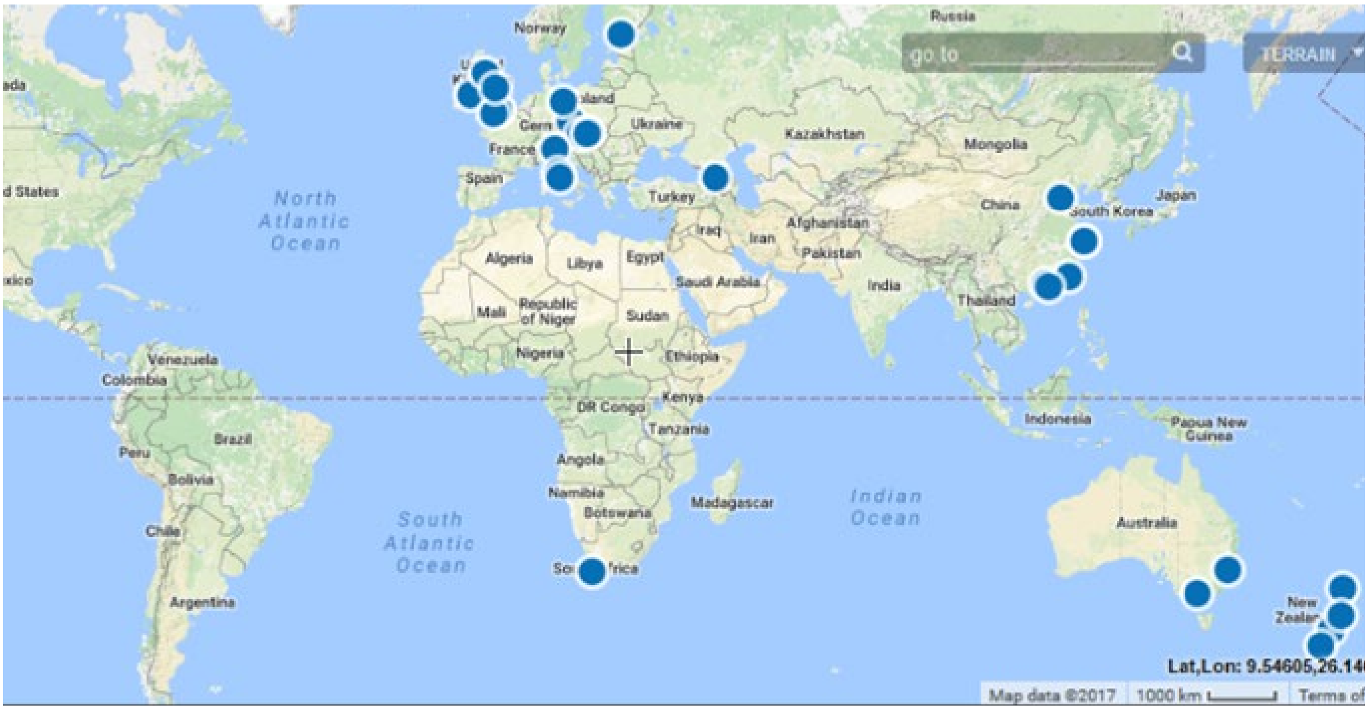

Figure 3: Location of IPSN member gardens.

There are 42 gardens that are members of the IPSN network (fig.3). All gardens in BGCI's network are encouraged to become part of the IPSN network. The network is truly international with participants from around Europe and further afield including Australia, New Zealand, China, Russia, South Africa and the US.

One of the main aims of the IPSN is to create links at the national level between botanic gardens and arboreta and national and regional plant protection organisations (RPPO's and NPPO's). Some examples of this include Plant Health Australia (PHA), which is working with 10 BG's in Australia and tasking them with surveillance, reporting and eradication of pests and diseases. In the UK, the IPSN holds an annual workshop that brings together UK gardens and Fera (the UK's NPPO). Activities include collaborations such as surveys on new and emerging pests and diseases.

International collaborations such as surveys for specific hosts/pests or regions are coordinated by BGCI. These surveys have been run to generate valuable research information on new and emerging pests and disease that can be used by NPPO's to evaluate risk on the national or regional PRA's. A few recent examples include Melaleuca, Tea tree species that are native to Australia. PHA was interested in which pests and diseases outside of Australia might affect this species. BGCI ran a survey, identifying those gardens that have these species in their collections and requesting information on pests and diseases that affect them. This information was then fed back to PHA. Facilitated by BGCI through the IPSN network; the European Plant Protection Organisation (EPPO) gathered information on *Massicus raddei*, a cerambycid beetle originating in Asia. This insect is reported as a pest of oak and chestnuts in its native range (*Quercus serrata, Q. acutissima; Castanea crenata, Castanea mollissima*). However, there is no data on its impact on European species of oak and chestnuts. EPPO was interested to know if botanic gardens & arboreta in China, Japan, Korea Vietnam or Far-East Russian have already recorded damage due to this insect on European species of Oak and Chestnut. Gardens with European oaks in the region were identified by BGCI and contacted to provide information to EPPO. This information was then incorporated into the PRA.

BUILDING CAPACITY

One of the aims of the IPSN is to build capacity within botanic gardens and arboreta to survey for new and emerging pests and diseases. Six workshops have been held in four countries in addition to a European conference held in collaboration with the EU Life+ project Observatree (a UK plant health citizen science project).

Several resources have been created and are available on the IPSN website www.plantsentinel.org. The website provides a 'centralised hub' for network participants to share general information about the IPSN, examples of best practise, current news and events. A key feature of the website is its 'Members Only' area which has been developed to share resources including training materials, standardised protocols, links and forums.

The IPSN Plant Health Checker is a major output of the IPSN. Early on, it was identified that the project required a tool to enable member gardens to assess and record changes in plant health in a consistent, systematic and rigorous way. This information could then be used by their peers or sent to diagnosticians to aid in diagnosis. This resource has been translated into several languages by IPSN member gardens.

CONCLUSIONS AND FUTURE WORK

The IPSN will continue to build the network and demonstrate the potential of the network to interested botanic gardens and arboreta and NPPO's/RPPO's. The network will be utilised to generate research finding to enable the reduction of the threat of new and emerging pests and diseases. BGCI will work to ensure that the IPSN has a long-term future, developing a framework for self-sustainability.

REFERENCES

GardenSearch https://www.bgci.org/garden_search.php Last accessed 31/07/2018

Kramer A. and Hird A. (2011) Building an International Sentinel Plant Network BG *Journal* 8 pp. 3-6

Mounce, R. Smith, P and Brockington, S. (2017) *Ex situ* conservation of plant diversity in the world's botanic gardens. *Nature Plants*.; 3: 795–802. doi: 10.1038/s41477-017-0019-3

PlantSearch https://www.bgci.org/plant_search.php Last accessed 31/07/2018

COPING WITH PESTS IN A SMALL BOTANIC GARDEN: 20 YEARS OF INTEGRATED PEST MANAGEMENT

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ABSTRACT

The Ghent University Botanical Garden is a small university garden of 2,75 ha with 4000m² of greenhouses. As the botanic garden houses more than 10 000 taxa, it creates a perfect environment for many organisms, both those beneficial and harmful.

Many years of chemical pest control in the public greenhouses resulted in sterile soil and outbreaks of different pest organisms such as aphids, mealy bugs and soft scale. Integrated pest control was introduced some 20 years ago in order to provide a healthier environment for both gardeners and visitors.

The aim is to minimize pest damage in the greenhouses by reducing the pest organisms to an acceptable level. The success of integrated pest management depends highly on a good knowledge of the life cycle of both pests and beneficial organisms that are present in the garden. Introducing the correct organisms at the right moment is essential to reach optimal results while reducing the costs.

As sustainable management of botanic gardens is imperative, we try to maintain healthy collections by means of implementing an efficient monitoring system supporting integrated pest control.

Actions include improving the greenhouse climate conditions, mechanical control (by means of pruning or hosing) and introduction of beneficial insects (parasites and predators). Interventions with chemical pesticides are kept to an absolute minimum.

Although the initial cost was quite high, we managed to get good results on the management of many of the original pest organisms. Unfortunately, not using chemicals has led to other pests emerging such as armored scale. Amongst the problems we encountered were the lack of identification tools of the different species and the availability of beneficial organisms that is not always ensured.

KEYWORDS

Sustainability, Biological Management, Natural Enemies, Greenhouse

INTRODUCTION

The Ghent University Botanic Garden is a small garden of 2,75 ha with 4000 m² of greenhouses. The three main public greenhouses (Victoria, tropical and Mediterranean greenhouse) house some 2000 taxa on 1913 m².

Integrated pest management (IPM) tries to solve pest problems through a combination of multiple tactics (habitat manipulation, cultural practices, biological control) in an ecologically and economically sound manner (1,2). It was introduced in horticulture after World War II. Due to the extensive use of chemical insecticides problems such as pest resistance, secondary pest outbreaks and environmental contamination emerged (1). Nevertheless, it was only from the beginning of the 21st century that integrated pest management found its way into the Ghent University Botanical Garden.

The use of chemical insecticides in the greenhouses did not always have the aimed result. As some of the plants grow up to 13 m high and the canopy is very dense, it proved to be difficult to reach all plants with a chemical treatment. In order to create a healthy environment, both for garden staff and visitors, and to reduce the use of harmful chemicals, an integrated approach of pest control was introduced. The aim was to prevent or contain the occurring pests to an acceptable level.

As arthropods (insects and mites) are the main problem in the greenhouses of the botanical garden, this article focuses on the control of insects and mites emerging in the botanical collections.

Creating optimal growing conditions for the plants is of major importance. Healthy and good growing plants are less likely to be attacked by insects. Therefore, all environmental parameters such as temperature

and humidity need to be monitored and controlled. A good knowledge of the optimal growing conditions is necessary, yet in botanical collections with many different taxa providing the optimal conditions for all plants often proves to be difficult.
Biological pest control, which does not make use of chemicals, aims at creating a balance between harmful and beneficial organisms. Regular monitoring is essential in order to follow the evolution of both pest organisms and their natural enemies. A monitoring system was introduced, which controls all public greenhouses in a standard way.
The aim is to maximize the use of biological antagonists (predators and parasites) and at the same time to reduce the use of chemical pest control to an absolute minimum. Other suppressive tactics such as pruning or hosing are also used.

MATERIAL AND METHODS

Environment

The project focuses on the main public greenhouses: the Victoria greenhouse, the Tropical and the Mediterranean greenhouse. The greenhouses are between 9 m and 13 m high and have a total surface of 1913 m². Most plants are planted directly in the soil. As the plants are on display for the public, they stay in the same spot for many years and often form a dense canopy. Each year the trees and woody plants are pruned where necessary.
Temperature in the greenhouses is automatically controlled. The heating system consists of ventilators (hot air blowers), which have a drying effect on the air moisture level. During the last two decades there was no sprinkler system in place. Humidity was maintained by hosing the paths. The plants are watered manually with rainwater.
The Victoria greenhouse has a big central pond, which enhances the humidity in this greenhouse. The dense canopy creates a rather dark atmosphere down below in the Tropical greenhouse. The temperature in the Mediterranean greenhouse is slightly cooler than in the other greenhouses, which delays the start of the biological control in spring.
Throughout the growing season the plants are weekly fertilized by means of liquid fertilizer, in order to create healthy growth. Trees and big shrubs are also given start fertilization at the beginning of each growing season.

Monitoring

Proper pest identification is essential for good biological control. Monitoring of the crop provides information on both pests and biological control agents (2,3).
At the start of the project a monitoring protocol was set up, which has been used systematically for the past 17 years.
In the greenhouse individual plants are checked for the presence of pest organisms. The degree of damage is assessed as follows:

0- *no pest present*

1- *low infestation* : few infested leaves (< 25 % of the leaves and < 25 % of the lamina and petiole)

2 - *moderate infestation* : damage occurs to leaves without visibly suffering of the plant (> 25 % of the leaves and/or > 25 % of the lamina and petiole)

3 - *heavy infestation* : the plant is almost completely affected (> 90 % of the leaves); aboveground parts die off or are heavily contaminated.

The damage per greenhouse is evaluated as follows:

0- *no damage* : the organism is not found

1 - *low infestation* : throughout in the greenhouse, several plants are slightly affected [1]; up to 1 plant is moderately affected [2]

2- *moderate infestation* : throughout the greenhouse two or more plants are moderately affected [2]; maximum 1 plant is strongly affected [3]

3- *heavy infestation* : two or more plants are strongly affected [3].

Monitoring of the occurring damage takes place based on the estimated numbers of attackers. As many plants as possible are inspected. Nevertheless, it is not possible to monitor each and every plant in the greenhouse. Plants that are further from the path or above eye level escape thorough control. The percentage of affected leaves is estimated.
In order to perform a good control one needs to know and recognize the occurring pests and beneficial organisms as well as the damage picture.

Use of suppressive tactics

Mechanical control (pruning - hosing)

Heavy infested plants are thoroughly pruned in order to reduce the amount of pest organisms in the greenhouse. This happened especially during the first years of integrated pest control. Furthermore, every autumn most of the excessive growth is pruned. The use of a platform provides the opportunity to inspect the canopy above the eye level.
Heavy infestations of mealy bug are reduced by hosing the plants with water or by brushing the leaves. This method is especially used for plants close to the central

pond. The mealy bugs fall in the water of the pond and are subsequently eaten by fish.

Use of predators or parasites

Organisms that kill or otherwise reduce the numbers of another organism are called natural enemies (3). Currently many efficient species of natural enemies are commercially available (4). In this project the natural enemies reduce the populations of pest organisms primarily through parasitism or predation.

A predator kills and feeds on its prey. Most predators feed on a variety of similar organisms. Predators that control insect pests can belong to different taxa such as beetles (Coleoptera), bugs (Hemiptera), flies (Diptera), lacewings (Neuroptera) and wasps (Hymenoptera). Mites (family Phytoseiidae) are very important in the control of pest mites and certain insects. Parasites are organisms that live and feed in or on a larger host. They are usually specialized and parasitize only one host in their lifetimes. Parasitoids are insects that parasitize and kill other invertebrates. Most parasitoids are in the insect orders Hymenoptera (wasps) and Diptera (flies) (3).

RESULTS

At the start of the project the following pests were identified in the greenhouses: aphids, mealy bugs (citrus mealy bug, long tailed mealy bug), mites (*Tetranychus spp.*), scales (black scale, brown soft scale, hemispherical scale, oleander scale) and white flies.

Mealy bugs (*Planococcus citri and Pseudococcus longispinus*) were present in all greenhouses. During the first years parasitic wasps (*Leptomastix dactylopi, Leptomastidea abnormis* and *Anagyrus fusciventris*) and predatory lady beetles (*Cryptolaemus montrouzieri*) were used to cope with these parasites. As the levels of infestation dropped, from 2007 onwards only *Cryptolaemus* larvae were introduced. The larvae were introduced during spring and summer months and were able to manage the mealy bug populations to an acceptable level. In 2017 in all greenhouses the infestation with mealy bugs was low (Table 1).

Scale insects proved to be a major pest at the beginning of the project. In the Victoria greenhouse and more importantly in the Mediterranean greenhouse hemispherical scale (*Saissetia coffeae*) and oleander scale (*Saissetia oleae*) were abundantly present, whereas in the tropical greenhouse brown soft scale (*Coccus hesperidum*) formed the biggest population. A big part of this population was already parasitized from the start with *Encyrtus infelix*, a parasitic wasp that was introduced a couple of years before. Initially the endoparasitic wasp *Metaphycus flavus* was introduced. Additionally the parasitic wasp *Microterys flavus* was introduced in 2004. At present, there is only a low level of brown soft scale left in the Victoria greenhouse.

To cope with both hemispherical and oleander scale (*Saissetia coffeae* and *Saissetia oleae*) we started off with the introduction of Metaphycus flavus. As the availability of this parasitic wasp was not always ensured, the parasitic wasps *Coccophagus lycimnia, Microterys flavus* and *Metaphycus stanleyi* were introduced over the following years. The population of oleander scale has sufficiently been reduced over the duration of the project; nevertheless there are still important hearths of hemispherical scale. The latter organism proved to be harder to manage, especially as the parasitic wasps (*Coccophagus lycimnia*) are not always commercially available when needed. In 2017 other parasitic wasps (*Encyrtus lecaniorum* and *Anagyrus fusciventris*) were introduced to cope with this pest.

Hard scales proved to be difficult to identify at the start of the project. Experts found both *Furchadaspis zamiae* and *Diaspis boisduvalii*. Predatory lady beetles such as *Rhyzobius lophanta* and *Chilocorus nigritus* were introduced throughout the duration of the project. The introduction of these predators did not result in lower amounts of pest organisms. On the contrary, the amount of hard scales has grown over the years.

In the first year of the project there was a major attack of aphids in the Victoria greenhouse. Especially the plants in the pond (*Nymphaea* and *Victoria*) were attacked. In order to cope with this infestation predaceous midges and Asian lady beetle (*Harmonia axyridis*) were released. The result was not effective and the plants needed to be cut back, in order to contain the infestation. In 2004 syrphid flies or hover flies (*Episyrphus balteatus*) and predaceous midges (*Aphidoletes aphidimyza*) were used to manage the aphid population. In 2011 predatory lady beetles (*Adalia bipunctata*) and in 2013 parasitic wasps (*Aphidius colemani*) and predatory green lacewing (*Chrysoperla carnea*) were introduced. In the last year of the project the regular introduction of *Aphidoletes aphidimyza* reduced the aphid infestation to an acceptable level.

During the initial years spider mites (*Tetranychus sp.*)

were registered locally in the Mediterranean greenhouse during summer months. This is often an abundant pest of glasshouse and outdoor plants, which can develop quickly when conditions are hot and dry. Infested leaves become chlorotic and speckled with yellow (2).
The temperature in the Victoria and tropical greenhouses are optimal for spider mites, but the high relative humidity helps to contain the populations. In addition, the predatory mites *Amblyseius cucumeris* and *Phytoseiulus persimilis* are known to be extremely effective biological control agents (2,3). They were successfully released in order to maintain the population of spider mites in the greenhouses. In the spring of 2018 two-spotted spider mite was registered on Thalia in the Victoria greenhouse. In 2001 white fly was found in the subtropical greenhouse. A mixture of the parasitic wasps *Eretmocerus eremicus* and *Encarsia formosa* was used to cope with this pest. During the following years greenhouse white fly was only found on a few plants. The infestations were always easily dealt with by introducing sufficient amounts of parasitic wasps.
Table 2 provides an overview of the detected pests and their natural enemies that were used in the botanical garden during the project.

DISCUSSION

Although biological control alone can be effective against certain pests, often several methods must be combined for optimal pest control (3). Especially during the first years after the introduction of integrated pest control, it was necessary to combine pruning, introduction of beneficial organisms and chemical control. The latter was used locally if a high infestation on a certain plant had occurred.
The outcome of integrated pest management is highly dependent on the moment of introduction of natural enemies. Enough pests need to be present to support the introduced natural enemies but pest populations have to remain below the level that would require a pesticide treatment (3). Due to the lower temperatures in the subtropical greenhouse, useful organisms were only introduced from April onwards. As this practice often resulted in high infestations of several pest organisms, last year it was decided to introduce the beneficial organisms during March, even though the optimal temperature was not yet reached. In the tropical and Victoria greenhouse the temperature was never a limiting factor.
The most successful beneficial organism is undoubtedly *Cryptolaemus montrouzieri*. This mealybug destroyer is an important predator of exposed mealybug species. Both adult and larval lady beetles feed on all mealybug stages (3, 5). If temperature (>20°C) and humidity (60 - 80 %) are sufficiently high, this beetle can have four generations a year (3). The conditions in the tropical and Victoria greenhouses are perfect for the reproduction of this beetle, as are the summer conditions in the Mediterranean greenhouse.
As *Cryptolaemus* survives poorly over the winter, new larvae were introduced every spring. Afifi et al. (2010) found that three months after the release of *Cryptolaemus montrouzieri* the reduction rate of citrus mealybugs (Planococcus citri) was 100% (5). This result is consistent with our finding that after a release in April the pest usually is controlled during August and September. At that point, as mealy bugs grow scarce, beetles are often seen to feed on hemispherical scale.
Coccophagus lycimnia is known to be a primary parasitoid of brown soft scale (*Coccus hesperidum*). In laboratory circumstances the female parasitoids live longer at temperatures of 22 °C or 17°C as compared to 27°C (6). The temperatures in the tropical and in the subtropical greenhouses seem to be sufficient for the survival of the parasitic wasp. *Coccophagus lycimnia* and *Microterys flavus* are both parasites of brown soft scale, with the latter being more effective. *Coccophagus* has its greatest effect at high host density while *Microterys flavus* is also effective against low host densities (7). The latter parasitic wasp is also successfully introduced in commercial greenhouses (8). Following the introduction of both Coccophagus lycimnia and *Microterys flavus* heavy infestations of brown soft scale did not occur in the greenhouses.
Metaphycus spp. are the most important natural enemies of many scale insects e.g. black scale (*Saissetia oleae*), brown soft scale (*Coccus hesperidum*) and hemispherical scale (*Saissetia coffeae*) (2, 3).
In the botanic garden Metaphycus flavus and *Metaphycus stanleyi* were used to cope with soft scale (*Saissetia oleae* and *Saissetia coffeae*) during the first seasons. During the following years we introduced many of the abovementioned parasitic wasps (*Microterys flavus, Coccophagus lycimnia, Encyrtus lecaniorum* and *Anagyrus fusciventris*) without being able to successfully reduce the infestations. Possible reasons are the low rate of beneficial insects (due to low availability) and the possibility of scale insects to encapsulate the eggs of parasitic wasps.
Armored scales (family Diaspididae) have a flattened

platelike cover. They do not produce honeydew. The leaves of infested plants turn yellow and heavily infested plants may die (2). Rhyzobius lophanthae is an important predator of scale insects and mealy bugs. Adults and larvae feed on most scale stages (3, 9). Although during the project scale feeding lady beetles were introduced to cope with armored scale insects, it proved to be difficult to reach an acceptable level of infestation. This result is consistent with the findings of Pijnakker (2006) concerning the use of *Rhyzobius lophanthae* and *Chilocorus nigritus* against armored scale in orchids (8). The extended amount of hard scale could be due to a poor identification of the species present, which makes it more difficult to introduce the correct beneficial organism.

The parasitic wasp *Aphytis melinus* is the most important parasite attacking California red scale. Females attack and oviposit in immature female scales. The tiny yellow wasp can be released when temperatures are above 16°C. *Aphytis* can have two or three parasite generations for each scale generation (2, 3). Unfortunately this wasp is not always commercially available when needed.

During the project many organisms were introduced in order to cope with infestations of aphids. Especially in the subtropical greenhouse the aphids reach a heavy infestation level early in the season, when the temperature is still rather low (+/- 15 °C). Aphids develop in large colonies at the lower surface of the leaves. They turn the leaves yellow and stunt shoots. Aphids also produce honeydew, which then attracts sooty mould that turns the leaves black (2). In order to reduce the amount of aphids in the greenhouse, in 2018 predaceous midges (*Aphidoletes aphidimyza*) were introduced during March. They are known to feed on mites, aphids and other small, soft-bodied insects. The small larvae (2,5 mm) are yellow to red and feed within aphid colonies. They thrive under high humidity. Adult midges are mostly active at night, between half May and the end of summer (3).

Infestations with whiteflies almost exclusively occurred in the Mediterranean greenhouse. This pest organism has many host plants both inside greenhouses and outdoors. *Encarsia formosa* is the most important parasite of greenhouse whitefly. Females oviposit in whitefly nymphs. The larvae feed inside the host causing the nymphs to turn brown or black. The development of *Encarsia* is optimal at higher temperatures (19- 30 °C) and relative humidity (50- 80%) (3). Thanks to the availability of *Encarsia formosa* during the project greenhouse, whitefly was easily coped with.

Ants interfere with biological pest control. Many ant species protect and transport pest organisms, especially the ones that produce honeydew, such as aphids or mealybugs (10). They attack and feed on scale parasites and predators (2). Therefore, it is necessary to control ants in the greenhouse.

CONCLUSION

The overall number of pests occurring in the public greenhouses of the Ghent University Botanic Garden has dropped during the project. There is a very good control of mealy bugs (both *Planococcus citri* and *Pseudococcus longispinus*) thanks to the introduction of the predaceous lady beetle *Cryptolaemus montrouzieri*. The use of parasitic wasps has reduced the presence of soft brown scale (*Coccus hesperidum*) and black scale (*Saissetia oleae*). Moreover, there is a reasonable control of aphids with gall midges (*Aphidoletes aphidimyza*) and of greenhouse whitefly (T*rialeurodes vaporariorum*) with parasitic wasps. During the project there were not many spider mites (*Tetranychus species*) present in the glasshouses due to the unfavourable environmental conditions. When they occurred, they were coped with by means of predacious mites.

After nearly two decades of integrated pest control, only heavy infestations of armored scales, and to a lesser extent hemispherical scale (*Saissetia coffeae*), remain a recurring problem. The most important obstacles were the lack of availability of parasitic wasps in sufficient quantities and the identification of the different species of armored scale. The release of the lady beetle *Rhyzobius* and of the parasitic wasp *Aphytis melinus* have so far not pushed back the infestations of armored scale to an acceptable level.

REFERENCES

Ehler L.E. (2006) *'Perspectives Integrated Pest Management (IPM): definition, historical development and implementation, and the other IPM'.* Pest Management Science 62:787–789

University of California Agriculture and Natural Resources, Statewide Integrated Pest Management Program (2018) Online: http://ipm.ucanr.edu/index.html (accessed June, 2018)

Flint M.L., Dreistadt S.H. (1998) *'Natural enemies handbook. The illustrated guide to biological pest control'*. University of California Press, Berkeley

Van Lenteren J.C. (2012) *'The state of commercial augmentative biological control: plenty of natural enemies, but a frustrating lack of uptake'.* BioControl 57:1-20

Afifi A.I., et al. (2010) *'Biological control of citrus mealybug, Planococcus citri (Risso) using Coccinellid predator, Cryptolaemus montrouzieri Muls.'* Pakistan Journal of Biological Sciences 13(5): 216-222

Muegge M.A., Lambdin P.L. (1989) *'Longevity and fecundity of Coccophagus lycimnia (Walker) (Hymenoptera: Aphelinidae), a primary parasitoid of Coccus hesperidum (Homoptera: Coccidae)'.* Journal of Agricultural Entomology 6(3): 169-174

Tena A., Soto A., Garci-Marí F. (2008) *'Parasitoid complex of black scale Saissetia oleae on citrus and olives: parasitoid species composition and seasonal trend'*. BioControl 53: 473-487

Pijnakker J. (2006) *'Inventarisering bestrijdingsmethoden'.* Praktijkonderzoek Plant & Omgeving B.V. Business Unit Glastuinbouw, PPO nr. 3242002200

9. Stathas G.J. (2000) *'The effect of temperature on the development of the predator Rhyzobius lophanthae and its phenology in Greece'.* BioControl 45: 439-451

Delabie J.H.C. (2001) *'Trophobiosis between Formicidae and Hemiptera (Sternorrhyncha and Auchenorrhyncha): an overview.'* Neotropical Entomology 30(4):501-516

TABLES AND FIGURES

	Year	Soft brown scale	Brown coffea scale	Black scale	Citrus mealy bug	Long tail mealy bug	Spider mites	Aphids	Hard scale	White fly
Victoria greenhouse	2001	1	2	1	2	2	1	2	2	0
	2017	1	2	0	1	1	0	0	3	1
Subtropical greenhouse	2001	2	3	3	2	2	2	0	2	2
	2017	0	2	1	1	1	1	2	2	1
Tropical greenhouse	2001	3	2	0	1	1	1	0	0	0
	2017	0	2	0	1	1	0	1	2	1

Table 1: Measured infestations in the glasshouses during the project

Pest	**Natural enemy**	**Organism**
mealy bugs	*Leptomastix dactylopii*	endoparasitic wasp
(*Planococcus citri*)	*Leptomastidea abnormis*	endoparasitic wasp
	Cryptolaemus montrouzieri	predatory lady beetle
mealy bugs	*Anagyrus fusciventris*	parasitic wasp
(*Pseudococcus longispinus*)	*Cryptolaemus montrouzieri*	predatory lady beetle
aphids	*Episyrphus balteatus*	predatory syrphid larvae (hoverfly)
	Aphidoletes aphidimyza	predatory gall midge
	Aphidius colemani	parasitic wasp
	Chrysoperla carnea	predatory green lacewing
	Harmonia axyridis	predatory lady beetle
	Adalia bipunctata	predatory lady beetle
soft scale	*Metaphycus stanleyi*	endoparasitic wasp
(*Saissetia coffeae, Saissetia oleae*)	*Metaphycus flavus*	endoparasitic wasp
	Coccophagus lycimnia	endoparasitic wasp
	Microterys flavus	endoparasitic wasp
	Encyrtus lecaniorum	endoparasitic wasp
soft brown scale	*Anagyrus fusciventris*	parasitic wasp
(*Coccus hesperidum*)	*Microterys flavus*	endoparasitic wasp
hard scale	*Rhyzobius lophantae*	predatory lady beetle
(*Furchadaspis zamiae, Diaspis boisduvalii*)	*Chilocorus nigritus*	predatory lady beetle
	Aphytis melinus	ectoparasitic wasp
spider mites	*Amblyseius cucumeris*	predatory mite
(*Tetranychus species*)	*(Neoseiulus cucumeris)*	
	Phytoseiulus persimilis	predatory mite
white fly	*Eretmocerus eremicus*	ecto- and endoparasitic wasp
(*Trialeurodes vaporariorum*)	*Encarsia formosa*	endoparasitic wasp
mites	*Amblyseius cucumeris*	predatory mite
	Amblyseius swirskii	predatory mite

Table 2: Detected pests and their natural enemies

DEVELOPMENT OF EVALUATION SYSTEM FOR HERBACEOUS PLANT ADAPTATION – A TOOL FOR INVASION RISK ASSESSMENT

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ABSTRACT

The evaluation of adaptation ability of plants is important not only during the plant collection establishment, but also to follow the introduction of new taxa for landscape use, to control weeds and escaped garden plants spread etc. and finally for invasiveness risk assessment. In this study, the herbaceous perennials adaptation was evaluated to set out the correlation between life form, taxa origin and accession longevity in *ex situ*. The adaptation was analyzed based on the phenological observations of 536 taxa from collections of the Botanical Garden of the University of Latvia. Seven species attributes were studied: wintering, disease and pest persistence, the overall condition of the plant in the plantings compared to the wild, vegetative reproduction, self-sowing and seeding. Taxa in the adaptation groups were arranged according to the sum of the evaluation points. These data were evaluated considering species origin, life-form and longevity in present location. The statistical analysis with chi-square test showed there was no association between plant life form and adaptation degree, as well as between taxa origin and adaptation degree. There was a positive weak association between accession's longevity and adaptation degree (Spearman's correlation $r=0.235$ $n=520$ $p<0.001$).

KEYWORDS

Plant Adaptation Degree, Life Form, Plant Origin, Winter Hardiness, Longevity

INTRODUCTION

The majority of plants in the collections of botanical gardens are species with native origin and in greatest part – alien taxa. Successful introduction of plants depends on the adaptation ability of accessions to the garden conditions. The evaluation of adaptation ability of the plants is important not only during the plant collection establishment, but also to follow the introduction of new taxa for landscape use, to control weeds and escaped garden plants spread, and finally for invasiveness risk valuation. New spontaneous genotypes create possibilities between different plant diaspores from different geographic origins – this may be the main reason for considering botanical gardens as a source of new escapees from cultivation (Vinogradova, 2015). Hulme (2011) even estimated that the most aggressive invasive plants in the world have escaped from botanical gardens. In Eastern Europe, widely naturalized annual weeds are examples of such escapees: *Conyza canadensis, Echynocystus lobata, Bidens frondosa, Chamomilla suaveolens, Galinsoga parviflora* and other (Vinogradova, 2015). Development of horticulture, agriculture and trade on the background of climate change can be considered as one of the causes for invasiveness risk that can endanger the biological diversity (Pergl et al., 2016; Van Kleunen et al., 2018). Therefore the elaboration of method to evaluate the adaptation of alien plants is an important tool for invasion risk assessment and this study is a step to develop such a method. Since the highest degree of adaptation to new conditions is naturalization, studying the plant collections in the Botanical Garden of the University of Latvia (BGUL) it was decided to research how assessment of adaptation correlates with qualitative characteristics of plants such as life form and origin that are often used in assessing the possibility of naturalization (Andreu and Vilá, 2009; Castro et al., 2005; Goodwin et al., 1999).

The aim of our study was to forward the evaluation system for herbaceous perennial plant adaptation by setting out the relationship between life-form, taxa origin and accession longevity in the present location.

MATERIAL AND METHODS

The adaptation was analyzed based on the phenological observations of 536 taxa that are present in the collection of BGUL. Phenology data were collected from year 1991 to 2016. Seven species attributes were studied: overwintering, disease and pest resistance, the overall condition of the plant comparing to wild conditions, vegetative reproduction, vegetative expansion, seeding and self-sowing (Nāburga-Jermakova and Strazdiņa, in print). Taxa in the adaptation groups were arranged according to the sum of the evaluation points: 7-10 points – adaptation is bad: the plant does not go through the full cycle of development (plants can die, they have no seeds), suffers from poor overwintering, weak vegetative growth and reduced longevity.

11-15 points – adaptation is medium: habitus and the phenological rhythm differs from that within the natural range. Longevity periodically suffers during hibernation (part of the specimens die, or are partly damaged, during some winters the protection against frost is necessary). Flowers and/or seeds appear occasionally. There may be a slight vegetative spreading and no vegetative self-reproduction.

16-19 points – adaptation is good: plants have a regular complete life cycle. Habitus, phenological rhythm, longevity are slightly different or may be the same as in natural growth locations. Good overwintering successfully compensates winter damages during the growth season. Plants bloom, seeds ripen, may have a slight germination and a slight vegetative spread.

20-23 points – adaptation is very good: plants regularly complete the life cycle. Habitus, phenological rhythm, longevity correspond to natural growth areas. Wintering does not leave a negative impact. There is a good quantity of ripen seeds, self-seedlings or vegetative expansion with new metamorphs also in spontaneous plant communities.

Data were evaluated considering species origin, life form after Raunkiaer (1937) and duration of the cultivation in the present location at the Botanical Garden. Tested plants possessed three life forms: *chamaephytes* – includes plants with their bulbs or shoot-spices perennating on the surface of the ground or just above it (not exceeding 25 cm). They will be protected by snow or plant remains. *Geophytes* – herbal plants that survive an unfavourable period by means of underground food-storage organs (rhizomes, tubers, bulbs). Buds arise from these to produce new aerial shoots. *Hemicryptophytes* – have their perennating buds in the upper ground level just below it. The buds are protected with plant remains. The plant life forms are according to literature (Olsen, 2007; Demidov, 2009; Shantser, 1989) and LEDA Trait database (Kleyer et al., 2008).

To obtain the supplementing adaptation data together with geographic information the following sources were used: Candera (Zander) and Cherepanov's guides (Erhardt et al., 2002, Cherepanov, 1995). Statistical processing highlighted some of the areals and included a great variety of sites that are represented in plant samples of BGUL perennial collection. The data aggregate size allowed to highlight up to nine geographic regions from 58 (Erhardt et al., 2002) hosting both endemic and cosmopolitan species (Table 1).

Geographic region	Description	Tested taxa number
Central Europe	The Alps, the Carpathian Mountains, the Balkan Peninsula, the European part of Turkey, as well as the Crimea	77
Southern Europe	French and Benelux, Pyrenees, Apennine and Iberian Peninsula, Mediterranean coast of North Africa, Macronesian archipelago in the Atlantic	56
Other parts of Europe	Mostly Northern Europe from the British Isles to the Urals	36
Europe and Middle East	For large areas, which include both European and Asian continents, their continental part	28
Middle East	Eastern Caucasus, the East of Afghanistan and the Arabian Peninsula	41
Far East	Russian Far East with floristic regions such as Primorsky, West Amur, Eastern Amur, South Amur, Piedmont's mainland, Kamchatka, Komandor, Sakhalin and Kuril Islands (Voroshilov, 1982) and also from Japan and Korea	68

Northern and Eastern Asia	Eastern and Western Siberia, all China, Central Asia	71
North America	Greenland, Canada and USA territories	94
Other origins	The Himalayas, Latin America, New Zealand and Australia, cosmopolites and circumpolar species	67

Table 1: Geographic regions definition (description) and tested taxa number distribution.

Duration of the taxa cultivation in the present location was controlled in the archive and database of BGUL.
To test whether there is an association between the two variables measured at the nominal and ordinal levels we used the chi-square test of independence. For example, association between taxa origin and adaptation degree as well as the association between plant life forms and adaptation degree. To estimate the strength of the association between these variables Cramer's V index (measure of effect size) was calculated (Cohen, 1988). The Spearman's correlation was used to determine the strength and direction of the association between two ordinal variables such as accession's longevity and adaptation degree.

RESULTS

According to the studied parameters, observed taxa were grouped in four adaptation degrees: very good (9%), good (46%), medium (41%) and bad (4%) adapted species.

Plant origin and adaptation degree

The tested taxa had origin in 9 regions (Table 1). The lowest degree of adaptation was for plants from Southern Europe (7%) and from the group Other regions (Table 1) whilst the taxa with good adaptation were from Other parts of Europe – 61% and from North America – 60%. In both of these regions, there were 0% and 1% of bad adapted taxa and 19% and 31% medium adapted taxa respectively. The greatest part of very good adapted taxa had origin in Other parts of Europe – 20% and in Middle Asia – 17%. A chi-square test of independence showed no association between taxa origin and adaptation degree ($p>0.05$).

Accession's longevity and adaptation degree

Mainly, the longevity of accessions in the present location was 13-25 years – 58%, but 19% were above 25 years hosting the greatest part of good and very good adapted taxa. The taxa with the shortest longevity (up to 5 and 6-12 years) had the prevalence in bad (17%) and medium (8%) adaptation degree (Table 3). Good adaptation increased along with longevity: accessions that are cultivated for 6-12 years had 32% of good adapted taxa, for 13-25 years – 49% and above 25 years – 59% of good adapted taxa. The longevity for medium adapted taxa was highest for accession that are cultivated for 6-12 years (55%) and up to 5 years (46%). There was a positive weak association between accession's longevity and adaptation degree (Spearman's correlation $r=0.235$ $n=520$ $p<0.001$).

Taxa origin	Adaptation degree (%)			
	Bad	Medium	Good	Very good
Central Europe	3	45	47	5
Southern Europe	7	41	39	13
Other parts of Europe	0	19	61	20
Europe and Middle East	4	46	39	11
Middle East	5	37	41	17
Far East	1	46	46	7
Northern and Eastern Asia	4	45	47	4
North America	1	31	60	8
Other origins	7	45	40	8

Table 2: Adaptation of the taxa depending on the geographic origin.

Accession's longevity	Adaptation degree (%)			
	Bad	Medium	Good	Very good
Up to 5 years	17	46	31	6
From 6 to 12 years	8	55	32	5
From 13 to 25 years	2	38	49	11
Above 25 years	0	34	59	7

Table 3: Adaptation of taxa depending on accession's longevity in the present location in BGUL.

Plant life forms and adaptation degree

The proportion according to life forms (Raunkiaer, 1937) of the tested taxa was as follows – 74 % hemicryptophytes and 13% both chamaephytes and geophytes. Proportional distribution for the adaptation degree did not show great differences proving that adaptation did not depend on the life form (Table 4) as it was confirmed by a chi-square test of independence ($p>0.05$).

Plant life form	Adaptation degree (%)			
	Bad	Medium	Good	Very good
Geophytes	8	41	38	13
Chamaephyties	4	52	38	6
Hemicryptophytes	3	38	50	9

Table 4: Adaptation of taxa depending on plant life forms.

DISCUSSION

The tested taxa distribution by origin indicated several tendencies: firstly, the preferences of plant collection creators, and secondly, the historical garden-fashion trends (Van Kleunen, 2018). They are accumulated in plant collections of botanical gardens. BGUL cultivates 33 of the tested taxa for more than 50 years since 1962. In general, the origin distribution of tested taxa was similar to the results of inventory in Czech Republic: the mean origin for alien ornamentals were from Asia, America and Mediterranean (Pergl et al., 2016).

On the basis of the obtained data it appears that there was no association between taxa origin and adaptation degree. However, very good adapted taxa were mainly from the group Other parts of Europe – 20% and Middle Asia – 17%. Both groups included taxa that have a potential for naturalization. The attributes (vegetative and generative regeneration, self-sowing, seeding ability, hardiness, resistance to pests and diseases) had the highest score for these taxa. Statistical data about the alien plants in Europe showed that major donors of the taxa were different from other regions of Europe and temperate Asia (van Kleunen et al., 2015). The results of various studies searching for relationship between the plant attributes and successful naturalization were controversial: some confirmed the association between origin and probability of naturalization (Kolar and Lodge, 2001; Scott and Panetta, 1993), others did not find it (Hanspach et al., 2008).

The obtained results showed positive weak association between accession's longevity and adaptation degree. Most of the accessions with low adaptation died already during the first years of cultivation (Trulevich, 1991; Smolinskaya, 2002). By Trulevich (1991) mean part of new introduced taxa in the gardens died in the first five years (73,2%), in 6-10 years –16,9%, in 11-20 years – 8,9%, after 20 years – only 1% of taxa. There were taxa with good adaptation that are having short life cycle, for instance: *Jasione montana L., Knautia macedonica* Griseb. Probably, if the phenological and other data for statistical analysis were selected only from the accessions that died in certain periods it could make a closer link between longevity and adaptation degree.

Some authors have demonstrated that introduction contributes to determining the abundance of exotic species (Pyšek et al., 2003, Weber, 1998). It is closely related to dissemination, has an influx of new propagules through time (Kolar et al., 2001) and in final bring plant diaspores over the cenotic barrier (Vinogradova, 2015). According to theoretical and empirical studies the minimum residence time for naturalization have magnitudes of years to decades (Castro et al., 2005).

In the papers, describing the invasion success depending on plant attributes, the life forms do not influence the invasion success in warmer climates like Australia (Lake et al., 2004) or Mediterranean region (Loret et al., 2005). Whereas for temperate climate, winter hardiness of taxa generally increased the probability of their naturalization but growth forms affected herbs less than shrubs or trees (Hanspach et al., 2008). Earlier it was assumed that the adaptation to Latvia's climate could be more successful for geophytes – the plants having renewal bulbs deeper in the soil than rhizomes ensuring better protection during winter. Nevertheless, the obtained results lead to the conclusions that the life-form does not implicate the adaptation of the taxa. On the one hand the formation of adventitious buds on rhizomes and roots ensures regeneration from their fragments and survival after a severe disturbance (Hamdoun, 1972). But on the other – the origin of tested bulbs mostly was from Middle Asia or Southern Europe – the regions with completely different climates from Latvia where there is a sharp change of weather during the frost and thaw frequently interchanges (Nikodemus et al., 2018). It injured the tested bulbs and often led to their extinction after wintering. Especially sensitive are *Amaryllidacea* and *Iridaceae* taxa with Southern Europe origin. On the contrary, the geophytes from the Middle East have benefited from better winter hardiness and adaptation:

four from seven very good adapted taxa were from the *Liliaceae* family, other 40% of Middle East geophytes belonged to a good adaptation group. So, the life forms of herbaceous perennials have no important role in adaptation success and this quality can not be used for invasion risk assessment.

CONCLUSIONS

1. The statistical analysis with chi-square test showed that there was no association between plant life form and adaptation degree, as well as between taxa origin and adaptation degree.
2. The life form and origin as taxa characters are not the parameters to be used for the prediction of invasiveness possibility.
3. The longevity of the plants in the present location correlated with adaptation: longevity could be used as one parameter for the development of the evaluation system for the herbaceous alien plant adaptation.

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REFERENCES

Andreu J. and Vilà M. (2009) *'Risk analysis of potential invasive plants in Spain'*. Journal of Nature Conservation, doi: 10.1016/j.jnc.2009.02.002

Castro S.A., Figueroa J.A., Muñoz-Schick M., Jaksic F.M. (2005) *'Minimum residence time, biogeographical origin, and life cycle as determinants of the geografical extent of naturalized plants in continental Chile'.* Diversity and Distribution, 11: 183-191

Cherepanov S.K. (1995) Vascular plants of Russia and neighboring countries (within the former USSR). Sankt-Peterburg: Mir i Sem'ya, 990 s.

Cohen J. (1988). Statistical power analysis for the behavioral
sciences (2nd ed.). New York, NY: Psychology Press.

Demidov A. (ed.) (2009) Ornamental herbaceous perennials of the Main botanical Garden named after N.V. Tsitsin of the Russian academy of Sciences. Moscow: Nauka, 396 p.

Erhardt W., Götz E., Bödeker N., Seybold S. Dictionary of plant names. 17. Auflage.- Stuttgart: Ulmer, 2002, 990 p.

Goodwin B.J, McAllister A.J., Fahrig L. (1999) *'Predicting Invasiveness of Plant species based on Biological Information'.* Conservation Biology 13(2), 422-426

Hamdoun A.M. (1972) *'Regenerative capacity of root fragments of Cirsium arvense (L.) Scop.'* Weed research 12 (2):128-136

Hanspach J., Kühn I., Boos E., Klotz S. (2008) *'Correlates of naturalization and occupancy of introduced ornamentals in Germany'*. Perspectives in Plant Ecology, evolution and Systematics, 10:241-250

Hulme P.E. (2011) *'Addressing the threat to biodiversity from botanic gardens.'* Trends in Ecology & Evolution, 26: 168-174

Kleyer M., Bekker R.M., Knevel I.C., Bakker J.P., Thompson K., Sonnenschein M., Poschlod P., van Groenendael J.M., Klimeš L., Klimešová J., Klotz S., Rusch G.M, Hermy M., Adriaens D., Boedeltje G., Bossuyt B., Dannemann A., Endels P., Götzenberger L., Hodgson J.G., Jackel A-K., Kühn I., Kunzmann D., Ozinga W.A., Römermann C., Stadler M., Schlegelmilch J., Steendam H.J., Tackenberg O., Wilmann B., Cornelissen J.H.C., Eriksson O., Garnier E. and Peco B. (2008) *'The LEDA Traitbase: a database of life-history traits of the Northwest European flora'.* Journal of Ecology, 96: 1266-1274

Van Kleunen M., Dawson W., Essl F., Pergl J., Winter M., Kreft H., Weigelt P., Kartesz J., Nishino M., Antonova L.A. et al. (2015) *'Global exchange and accumulation of non-native plants'* Letter, 525: 100-103

Van Kleunen M., Essl F., Pergl J., Brundu G., Garboni M., Dullinger S., Early R., González-Moreno P., Groom Q.J., Hulme P.E. et al. (2018) *'The changing role of ornamental horticulture in alien plant invasions.'* Biological Reviews (2018): 000-000, doi: 10.1111/brv.12402

Kolar C.S, Lodge D.M. (2001) *'Progress in invasion biology: predicting invaders'.* TRENDS in Ecology & Evolution vol.16 (4), 199-204

Lake J.C., Leishman M.R. (2004) Biological conservation 117:215-226

Lloret F., Médail F., Brundu G., Camarda I., Moragues E., Rita J., Lambdon P., Hulme E. (2005) *'Species attributes and invasion success by alien plants on Mediterranean islands'*. Journal of Ecology 93:512-520

Nāburga-Jermakova I., Strazdiņa L. (in print) *'The adaptation of alien ornamental herbaceous perennials – benefits and risks'* Art. Hort.

Nikodemus O., Kļaviņš M., Krišjāne Z., Zelčs V. (scient. ed.) (2018) Latvija. Zeme. Daba. Tauta. Valsts. Rīga: Latvijas Universitātes akadēmiskais apgāds, 752 lpp.

Olsen S. Encyclopedia of Garden Ferns. Timber Press, 2007, 444 p.

Pergl J., Sádlo J., Petřík P., Danihelka J., Chrtek Jr.J., Hejda M., MoravcovaL., PerglováI., ŠtajerováK., Pyšek P. (2016) *'Dark side of the fence: ornamental plants as source of wild-growing flora in the Czech Republic'*. Preslia, 88: 163-184

Pyšek P., Sádlo J., Mandák B., Jarosik V. (2003) *'Chech alien flor and the historical pattern of its formation: what came first to central Europe.'* Oecologia, 135: 122-130

Raunkiaer C. (1937) Plant Life Forms. Clarendon Press, Oxford.

Scott J.K. and Panetta F.D. (1993) *'Predicting the Australian weed status of southern African plants.'*Journal of Biogeography, 20: 87-93

Shantser I. A. (1989) *'O zhiznennykh formakh u Filipendula.'* Byulleten' Glavnogo botanicheskogo sada, 151: 83-86

Smolinskaya M.A. (2002) *'Otsenka uspeshnosti introduktsii travyanistykh rasteniy.'* Nauk. visn. Chernivets un-tu. CHNU 145: 164.- 168.

Trulevich N. V. (1991) Ekologo – fitotsenoticheskiye osnovy introduktsii rasteniy. 1991, M.: Nauka, 213 s.

Vinogradova Yu.K. (2015) *'Effect of Alien Plant Species on Flora in the Main Botanical Garden of the Russian Academy of Sciences'.* Russian Journal of Biological Invasios, 7 (1): 22-41

Voroshilov V.N. (1982) Opredelitel' rasteniy Sovetskogo Dal'nego Vostoka. Vol. 1, 672 s.

Weber E. (1998) *'The dynamics of plant invasions: a case study of three exotic goldenrod species (Solidago L.) in Europe'.* Journal of Biogeography, 25: 147-154

MIXED MATING STRATEGY GUARANTEES REPRODUCTION UNDER LIMITED POLLINATION RESOURCES IN THE ENDEMIC VERBASCUM LITIGIOSUM SAMP.

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ABSTRACT

Verbascum litigiosum Samp. (Scrophulariaceae) is an endemic plant species from Portugal, growing in dune systems from the Centre (Serra da Boa Viagem, Figueira da Foz) to the South regions (Algarve), with an estimated area of occupancy of 200 km². This species has been classified by IUCN as Vulnerable B2; however, the recent detection of novel populations has decreased the category to Near Threatened (NT). Still, its habitat is severely endangered by anthropogenic activities and biological invasions, which, together with the current high levels of population fragmentation and small population sizes, increase the vulnerability to stochastic processes involved in steep population declines. Since no information was available about the reproductive biology of V. litigiosum, it was essential to understand the reproductive factors affecting population dynamics of this species. Our main objective was to study the reproductive biology of *V. litigiosum.* For that purpose, we studied floral development by monitoring flowers across time, and reproductive biology by performing controlled pollination experiments and examining pollen tube development. Results revealed a mixed mating strategy, i.e., flowers have a short lifespan, remaining available for pollinators for one day only; before corolla opening, the anthers open on top of the stigma, spontaneously depositing several pollen grains on the stigmatic papillae. As the plant is self-compatible, this pollen deposited prior to flower opening fertilizes one-third of the ovules, guaranteeing some level of fertilization (prior self-pollination strategy). Afterwards, pollinator visitation and outcrossing are enabled. This mixed mating strategy partially secures pollination in the absence of mating partners and/or pollinators; however, pollinator visits have the potential to significantly increase reproductive fitness. This strategy might be crucial to sustain populations under limited pollination resources such as the ones created by small and fragmented populations.

KEYWORDS

Controlled Pollinations, Plant Conservation, Pollen Germination, Pollen Tube Development, Pollinators, Reproductive Strategies

INTRODUCTION

Among the life-history traits of flowering plants, reproduction is of major importance for population maintenance. Estimates indicate that nearly 90% of the Angiosperms are pollinated by animals, with insects representing the main group of pollinators (Ollerton et al., 2011). Pollination is a mutualistic relationship between plants and animals; however, this relationship is based on advantages on both sides, i.e., plants evolved to achieve gamete dispersal, while pollinators search for food, shelter or heat (Bronstein et al., 2006). Consequently, the dependence on pollinators to move the male gametes to female structures led to the evolution of a diverse set of flower morphologies and floral rewards, as a mean to increase attractiveness and pollinator fidelity (e.g., Barrett, 2003; Bronstein et al., 2006; Donnelly et al., 1998; Lloyd, 1980). However, pollinator presence might be variable in time and space, especially in fragmented habitats, leading to insufficient pollination resources and compromising reproductive success of plant species (Willcock & Neiland, 2002; Kalisz & Vogler, 2003; Hadley and Betts, 2012). Thus, unpredictable pollination resources might lead to the evolution of mechanisms to overcome pollination deficits and to become less dependent on pollinators (Barrett, 2003; Goodwillie & Weber, 2018; Lloyd, 1992).

Pollen limitation due to pollinator scarcity might be overcome through different reproductive mechanisms. These mechanisms usually include autonomous self-reproduction assuring offspring production (Lloyd, 1992; Fausto et al., 2001). Plants may shift to a mixed mating system that combines cross-pollination with self-pollination as a reproductive assurance, in case of pollinators or mate limitation (e.g., Kalisz et al., 2004; Morgan & Wilson, 2005). Still, the reproductive assurance provided by self-pollination, if outcrossing is not possible, will constitute a trade-off, as selfing is related with subsequent fitness losses (inbreeding depression; Charlesworth & Charlesworth, 1987). Prior, competing and delaying selfing are the three types of autonomous selfing found in flowering plants, depending on the pollen from a given flower being deposited over its own stigma, before, during or after the opportunity for cross-pollination, respectively (Lloyd, 1992). Delayed selfing is the most common self-reproduction mechanism (e.g., Morgan & Wilson, 2005; Morgan et al., 2005), occurring only if cross-pollination fails, thereby reducing pollen and seed discounting (Lloyd, 1992; Goodwillie & Weber, 2018). By contrast, prior selfing occurs before any option for cross-pollination, and seems to be favored *in situ*ations of strong pollination limitation (Lloyd, 1992).

The occurrence of different mating mechanisms is of major importance as it structures the population genetic diversity and population dynamics of a species (Oostermeijer, 2000; Barrett, 2003). Reproduction is of an increased importance in endemic species characterized by a limited number of populations and/or small population sizes, where reproductive success may severely decrease with the number of individuals in the population (Schemske et al., 1994; Oostermeijer, 2000, 2003; Wilcock & Neiland, 2002). Because of these impacts of reproduction modes for plant populations, it is essential to understand the corresponding reproductive biology and main reproductive mechanisms in order to develop a management strategy to protect a particular plant species successfully (Schemske et al., 1994; Wilcock & Neiland, 2002).

Verbascum litigiosum Samp. (Scrophulariaceae) is an endemic species from the west coast of Portugal. A biannual species, it grows up to 2 m height (Benedí, 2009) and flowers from April to June, with a flowering peak in late May (D. Alves, field observations). It grows in dune systems from the Centre (Serra da Boa Viagem, Figueira da Foz) to the South regions of Portugal (Algarve), over an estimated area of occupancy of 200 km² (Lista Vermelha da Flora Vascular, 2019). The dune system where the species grows suffers from marked habitat degradation and quality loss due to anthropogenic activities, such as expansion of urban and touristic areas, agricultural activities and extraction of inert materials, as well as from biological invasions. Consequently, the populations of *V. litigiosum* are severely fragmented and frequently of small sizes, being highly vulnerable to stochastic events that may further threaten the species. *Verbascum litigiosum* has been classified by IUCN as Vulnerable B2 and it is legally protected in Portugal, being listed in the Annex II of the Habitats Directive; however, the recent detection of novel localities decreased the category to Near Threatened – NT. Nevertheless, the pressure on its habitat is menacing the populations (Lista Vermelha da Flora Vascular, 2019). Information on the biology of this species was non-existent, with IUCN recommending, as an important conservation measure, to increase the knowledge of the biology of *V. litigiosum.*

Thus, the objective of this work was to study the reproductive biology of V. litigiosum. In particular, we studied flower development, reproductive mechanisms, and degree of pollinator dependence and of reproductive assurance. For this, we followed flower development closely to determine flower lifespan, monitoring female and male organ maturations to depict mechanisms that may allow prior or delayed selfing. Controlled pollination experiments were also performed using pollen tube development as reproductive success variable of the different pollination treatments.

MATERIAL AND METHODS

Flower development

To assess flower development and flower lifespan of V. litigiosum, flowering stems with flower buds from 16 individuals were collected in natural populations and kept in the laboratory under optimal conditions (i.e., kept in vessels with a nutritional solution for cut flowers and with natural light conditions), and further excluded from pollinators. Flower buds were tagged in the inflorescences, and floral development was monitored daily until senescence. The following parameters were recorded: day of opening and closure, and presence/absence of pollen grains in the stigma after corolla opening. Flower buds were also collected from all the inflorescences to inspect the occurrence of anther dehiscence before the opening of the corolla.

Pollination experiments

To determine the reproductive system of *V. litigiosum*, we performed controlled pollinations in an environment excluding pollinators. For that, four flowers per inflorescence were tagged and assigned to one of the following four treatments: (a) emasculation immediately after corolla opening with no other manipulation – to assess autonomous self-fertilization before flower opening (i.e., prior self-pollination); (b) unmanipulated flowers – to assess prior and delayed selfing; (c) emasculation immediately after corolla opening and hand-pollination using outcross pollen – to assess prior self-pollination and outcrossing success; (d) no emasculation and hand-pollination using outcross pollen – to assess optimal pollination allowing all the strategies. After flower senescence, the pistils were collected and harvested in ethanol 70% for subsequent examination of pollen tube development. For this, the pistils were softened in 8 M sodium hydroxide for 2h, rinsed in distilled water and stained with aniline blue 0.1 M for 18h at dark conditions (Dafni et al., 2005). Pistils were then placed on a microscope slide with a drop of glycerin 50%, squashed beneath a cover slip and sealed. Pollen tubes were counted using an epifluorescence microscope with a UV-2A filter cube.

Statistical analysis

Differences in the number of pollen tubes between pollination treatments were analyzed using a one-way ANOVA, followed by a Tukey test for pairwise multiple comparisons.

RESULTS

Flower development

The lifespan of flowers of V. litigiosum is one day (Figure 1), meaning that in nature the flowers remain open and available for pollinators for one day only. Interestingly, we observed that the dehiscence of the anthers occurs before corolla opening, i.e., in the day before corolla anthesis, with self-pollen being deposited in the stigmatic papillae (Figure 2A-B). This opens the possibility for the prior self-fertilization mechanism. In the end of the day, the corolla starts to close (Figure 1C), and the anthers bend towards the stigma, enabling the deposition of more pollen on the stigma and the possibility for delayed self-pollination. However, the pollen grains also start to acquire a whitish color, possibly linked with lower viability. In the morning of the following day, the corolla is completely wilted (Figure 1D), easily falling from the inflorescence.

Pollination experiments

The controlled pollination experiments allowed the study of reproductive mechanisms in *V. litigiosum*. Significant differences are observed between treatments ($F_{3,52}$ = 14.87, $P < 0.001$; Figure 2D). First, the development of pollen tubes in the style after self-pollination (Figure 2C-D) suggest that the species is self-compatible, although we have not examined seed production. Treatments involving only self-pollination strategies (treatments a and b; Figure 2D) presented a similar number of pollen tubes ($P > 0.05$; Mean ± SE: a - 74.3 ± 13.4, b - 101.3 ± 16.3); however, the number of pollen tubes observed in these treatments was significantly lower than those observed in treatments involving outcross pollinations (treatments c and d; Figure 2D) ($P < 0.05$), the latter also not differing between themselves ($P > 0.05$; c - 199.8 ± 13.9, d - 186.9 ± 19.7; Figure 2C). Without pollen vectors (treatments a and b) the flowers of *V. litigiosum* self-pollinate with successful pollen tube development being observed (Figure 2C), although outcross pollinations significantly increased the number of pollen tubes in the styles (Figure 2D).

DISCUSSION

Verbascum litigiosum presents a mixed mating strategy that secures pollination in the absence of mating partners and/or pollinators through prior self-pollination; however, pollinator visits have the potential to significantly increase reproductive fitness afterwards. This reproductive strategy most probably evolved in response to strong pollinator limitation (Lloyd, 1992) and, at present, it might be an important strategy to sustain the highly fragmented and small size populations of this species; still, further studies are required to assess its impacts in plant fitness and genetic structure.

Floral development

The study of flower development revealed that flowers of *V. litigiosum* have a very short lifespan, remaining open and available for pollinators and for outcrossing for one day only. Anthers are dehiscent before corolla opening, releasing and depositing several pollen grains on the flower's own stigma. This developmental process promotes self-pollination before flower opening, i.e., prior self-pollination mechanism. At the end of day one, the corolla starts to wilt, closing over the sexual organs and promoting further self-pollination, i.e., delayed self-pollination mechanism.

Mating strategies

Pollination experiments revealed that *V. litigiosum* is a self-compatible species, although outcross-pollination significantly increases offspring production. Verbascum litigiosum produces offspring in a mixed mating mechanism because it can self-pollinate by prior self-pollination, which guarantees a priori approximately one-third of the offspring, followed by the opportunity for the occurrence of outcross-pollination (Lloyd, 1992). Additionally, our results also showed that delayed selfing might occur (treatment b had a slightly higher number of pollen tubes than treatment a; Figure 2D), although it did not significantly increase the reproductive success in comparison with prior self-pollination. Delayed selfing has been observed on the closely related V. thapsus L., with emasculated flowers experiencing a 50% reduction in pollen deposition by the time of flower closure (Donnelly et al., 1998). However, in *V. litigiosum*, the dominant selfing mechanism seems to be prior self-pollination. The lack of increase in the number of pollen tubes after delayed self-pollination might be related with loss of viability of pollen grains, as they start to acquire a whitish color at the end of the flower lifespan; still, further studies are necessary to test this hypothesis.

Delayed self-pollination is the most common mechanism of autonomous selfing (e.g., Morgan & Wilson, 2005; Morgan et al., 2005; Googwillie & Weber, 2018), since it does not compromise the occurrence of outcrossing, thus promoting genetic diversity while assuring the production of offspring when outcrossing fails (Lloyd, 1992). Thus, it was interesting to uncover that V. litigiosum exhibits prior self-pollination. This mechanism has several advantages and disadvantages. The reduced number of ovules available for outcross pollen (Lloyd, 1992; Donnelly et al., 1998) and the reduced genetic diversity (inbreeding depression; Charlesworth & Charlesworth, 1987) are among the main drawbacks (Spencer, 2003). In contrast, reproductive assurance and conservation of well adapted genotypes are of great relevance, especially in endemic plant species (Lloyd, 1992; Spencer, 2003). Prior selfing may also be advantageous due to its effects in flowering periods; the accomplishment of the flower function usually triggers flower senescence, resulting in small flower lifespan and short flowering periods, therefore, reducing the cost of flower maintenance (Kalisz & Vogler, 2003; Ashman & Schoen, 1994). This might be particularly advantageous in habitats with low resource availability such as dune systems. In the field, the reproductive strategy of *V. litigiosum* seems to be successful. Our field observations detected that all the flowers produced fruits, although with variable numbers of produced seeds, consistent with the results obtained in this study.

Future studies

The results of this study provide significant insights about the reproductive biology of V. litigiosum, although several hypotheses remain to be tested. First, additional studies are needed to quantify the contribution and importance of seeds resulting from selfing for the maintenance of natural populations. Second, analyses of the balance between the contribution of selfing and outcrossing for population dynamics and genetic structure are fundamental, not only because they are context dependent, depending on factors such as pollinator density and co-flowering communities (Kalisz et al., 2004), but also because they might affect plant fitness and increase inbreeding levels. Finally, exploring flower development such as pollen viability across the flower lifespan might help to understand the role of the different reproductive mechanisms in this species, such as delayed selfing.

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REFERENCES
Ashman T.L., Schoen D.J. (1994) *'How long should flowers live?'*. Nature 371:788–791
Benedí C. 2009. Verbascum L. In Flora ibérica: Plantaginaceae-Scrophulariaceae, Vol. 13, Castroviejo, S. et al. (eds.). Editorial CSIC-CSIC Press
Barrett S.C.H. (2003) *'Mating strategies in flowering plants: the outcrossing–selfing paradigm and beyond'.* Philosophical Transactions of the Royal Society of London B: Biological Sciences 358:991-1004.
Bronstein J.L., Alarcón R., Geber M. (2006) *'The evolution of plant–insect mutualisms'.* New Phytologist 172:412-428.
Charlesworth D., Charlesworth B. (1987) *'Inbreeding depression and its evolutionary consequences'* Annual Review of Ecology and Systematics 18:237-268
Dafni A., Kevan P., Husband B.C. (2005) *'Practical pollination biology'.* Cambridge, Enviroquest
Donnelly S.E.D., Lortie C.J.L., Aarssen L.W.A. (1998) *'Pollination in Verbascum thapsus (Scrophulariaceae): The advantage of being tall'.* American Journal of Botany 85:1618–1625
Fausto J.A., Eckhart V.M., Geber M.A. (2001) *'Reproductive assurance and the evolutionary ecology of self-pollination in Clarkia xantiana (Onagraceae)'.* American Journal of Botany 88:1794–1800
Goodwillie C., Weber J.J. (2018) *'The best of both worlds? A review of delayed selfing in flowering plants'*. American Journal of Botany 105:641–655
Hadley A.S., Betts M.G. (2012). *'The effects of landscape fragmentation on pollination dynamics: absence of evidence not evidence of absence'.* Biological Reviews 87:526-544
Kalisz S., Vogler D.W. (2003) *'Benefits of autonomous selfing under unpredictable pollinator environments'.* Ecology 84:2928–2942
Kalisz S., Vogler D.W., Hanley K.M. (2004) *'Context-dependent autonomous selfing yields reproductive assurance and adaptative mixed mating'.* Nature 430:884–887
Lista Vermelha da Flora Vascular (2019) Online: http://listavermelha-flora.pt/flora-single/?slug=Verbascum-litigiosum (accessed January 26, 2019)
Lloyd D. (1992) *'Self- and cross-fertilization in plants. II. The selection of self-fertilization'.* International Journal of Plant Sciences 153:370–380
Morgan M.T., Wilson W.G. (2005) *'Self-fertilization and the escape from pollen limitation in variable pollination environments'.* Evolution 59:1143-1148
Morgan M.T., Wilson W.G., Knight T.M. (2005) *'Plant population dynamics, pollinator foraging, and the selection of self-fertilization'.* The American Naturalist 166:169-183
Ollerton J., Winfree R., Tarrant S. (2011) *'How many flowering plants are pollinated by animals?'* Oikos 120:321–326
Oostermeijer J.G.B. (2000) *'Population viability analysis of the rare Gentiana pneumonanthe: the importance of genetics, demography and reproductive biology'.* In: Young A., Clarke G. (eds) Genetics, demography and viability of fragmented populations. Cambridge University Press, Cambridge, pp 313–334
Oostermeijer J.G.B. (2003) *'Threats to rare plant persistence'.* In: Brigham C., Schwartz M. (eds) Population viability in plants: conservation, management, and modeling of rare plants. Springer-Verlag, Heidelberg, pp 17–58
Schemske D.W., Husband B.C., Ruckelshaus M.H., Goodwillie C., Parker I.M., Bishop J.G. (1994) *'Evaluating approaches to the conservation of rare and endangered plants'.* Ecological Society of America 75:584–606
Wilcock C., & Neiland R. (2002) *'Pollination failure in plants: why it happens and when it matters'.* Trends in Plant Science 7:270-277

TABLES AND FIGURES

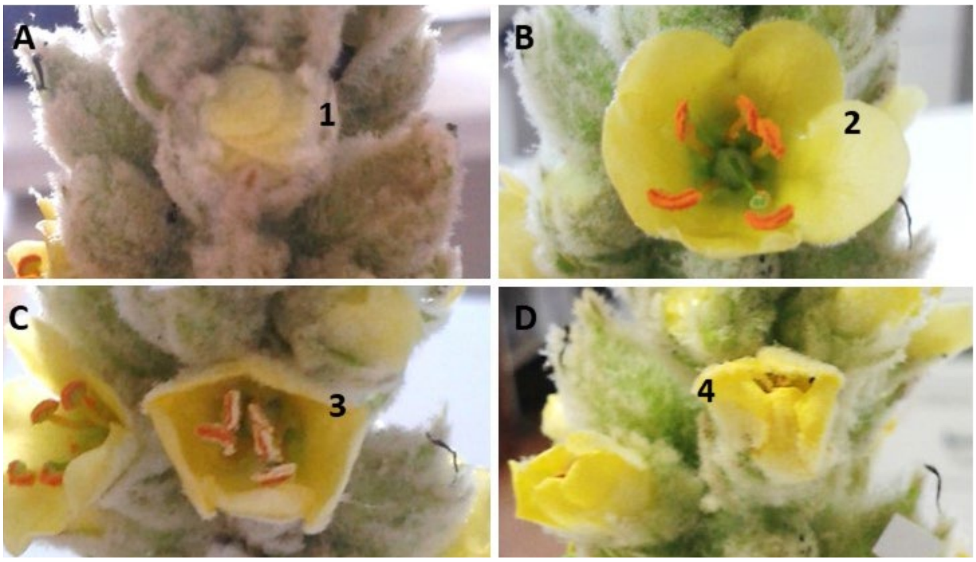

Figure 1: Development of the flowers of *Verbascum litigiosum*: (A) Day before corolla opening; (B) Day of corolla opening, morning; (C) Day of corolla opening, afternoon; (D) Day two after corolla opening. Flower development: (1) flower bud already with dehiscent anthers in the day before corolla opening; (2) flower with fully opened corolla on the morning of day one; (3) flower with the corolla starting to close in the afternoon of day one; (4) flower with wilted corolla on day two.

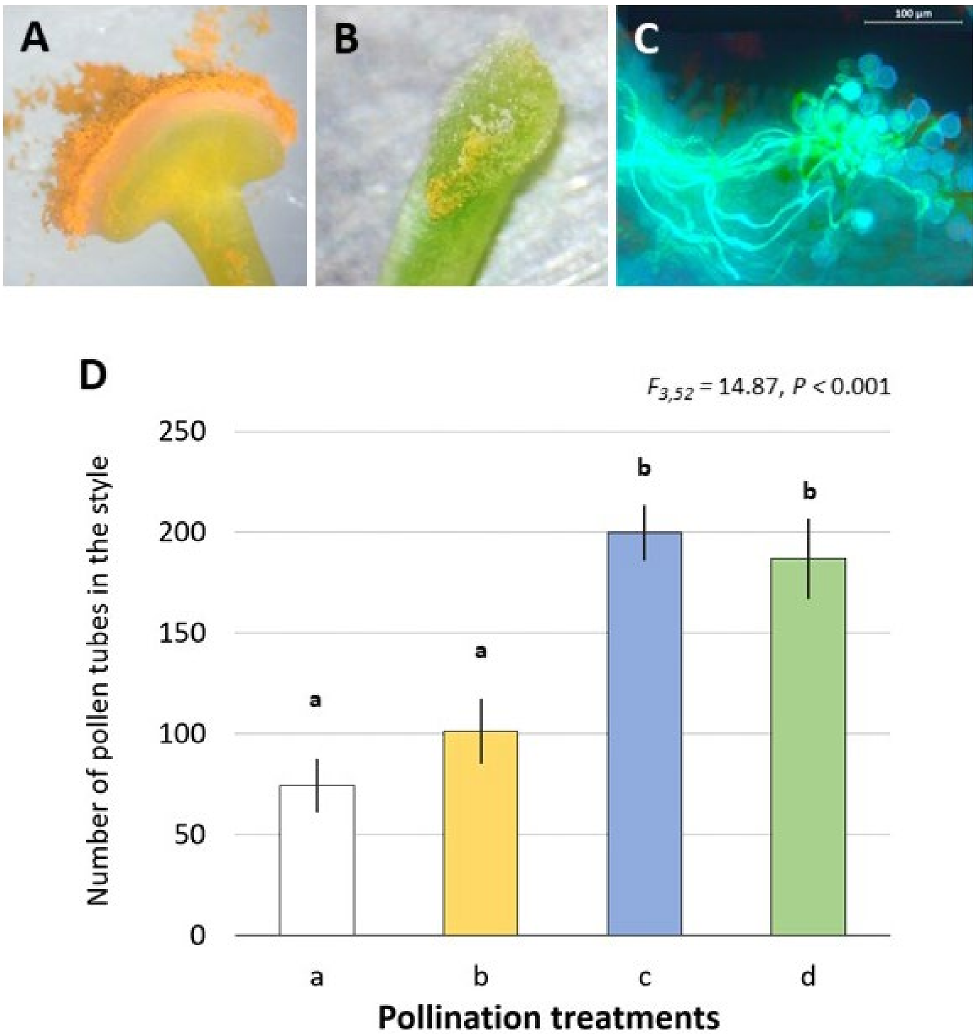

Figure 2: Pollen tube development in *Verbascum litigiosum*: (A) Anther on the day ofcorolla opening; (B) Stigma on the day of corolla opening, already with pollen from the anthers deposited in the stigmatic papillae; (C) Pollen tube development on the day of corolla opening; (D) Mean number of pollen tubes (± SE) in the style after controlled pollinations. Pollination treatments: (a) emasculated after corolla opening- detection of self-pollination before corolla opening; (b) unmanipulated - detection of selfing (prior and delayed selfing); (c) emasculated and self-pollinated; and (d) emasculated and cross pollinated. Significative differences between treatments at P < 0.05 are represented with different lette(C) Day of anthesis, afternoon; (D) Day two after anthesis. Flower development: (1) flower bud already with dehiscent anthers in the day before anthesis; (2) flower with fully opened corolla on the morning of day one; (3) flower with the corolla starting to close in the afternoon of day one; (4) flower with wilted corolla on day two.

WHAT GROWS WHERE? TOWARDS AN INFRASTRUCTURE TO CONNECT COLLECTIONS OF BOTANIC GARDENS FOR RESEARCH AND CONSERVATION

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ABSTRACT
Collections of botanic gardens are unique living resources for research, conservation and education. Their scientific value depends heavily on comprehensive documentation, identification and accessibility. Many botanic gardens manage their collections through databases, albeit using multiple different software and representing varying degrees of data quality. This heterogeneity of databases still hampers a thorough overview of living plant collections. In order to efficiently coordinate collection priorities amongst different gardens, an up-to-date plant inventory is crucial.
To address this problem, partners from the universities of Berlin (FU), Frankfurt and Heidelberg initiated a project on "Plant Collections in Botanic Gardens as Living Resources for Integrated Evolutionary Research" (Evo-BoGa). It combines evolutionary research with the harmonisation and interconnection of databases from eight German botanic gardens, focusing on their special collections of bromeliads and epiphytic cacti. Both plant groups are well-represented in botanic gardens, attractive to the general public and ideal models for studying the evolution of biodiversity. As part of the research packages, accessions are checked for their identity, linked to herbarium vouchers and DNA samples, and, thus, made accessible for research in a sustainable way. As an additional approach to improve usability, a barcoding based identification tool is implemented.
The project further aims at developing an online portal that combines all relevant information from the databases of the botanic gardens involved. The portal is based on the BioCASe Provider Software services, which allow for harvesting individual collection databases of different types following a standardised data access protocol and enabling a "live" connection to the original data providers. The portal will be accessible to different user groups such as network members, external researchers or interested garden visitors with specified data views in different detail. Possible benefits of the portal for the collection holders include feedback on data quality and the reconciliation of scientific names, notifications on new determinations of the same accession in other collections, statistical evaluations and the comparison with other collections. Thus, the portal will help individual botanic gardens to evaluate their own collections in comparison with others, to improve their collections and the associated data, and, ultimately, to develop a collection strategy in coordination with other botanic gardens. Altogether, the portal and the exemplified research may promote the use of living collections for research within the project network and beyond, and strengthen the importance of botanic gardens in maintaining these collections in the public eye.

KEYWORDS
B-Hit Harvester Software, Biocase Provider Software, Collection Database, Living Collection Network, Plant Accessions, Data Portal, Dna Barcodes

INTRODUCTION

The role of living collections of botanic gardens.
The global plant biodiversity is declining due to habitat destruction, climate change, and land-use transformation. The world's biomes are under immense pressure from the Human population and undisturbed habitats are becoming increasingly scarce leading to an on-going biodiversity loss (Murphy & Romanuk 2014). *Ex-situ* collections sustain a world-wide important

resource to conserve and study global biodiversity and to provide access to species from vanished ecosystems or remote and inaccessible areas. Botanic gardens are such places, which cultivate more than 100,000 different plant species - representing up to 30% of the global plant diversity (Mounce et al. 2017). Alone in the living collections of German botanic gardens we find more than 50,000 different species presenting a unique living resource for research, conservation and education (Figure 1). In order to fulfil their full potential, especially for scientific purposes, botanic gardens need to enhance accessibility to their collections and provide a comprehensive documentation.

Heterogeneous documentation of living collections.
The catalogues of living collections are nowadays mostly stored in electronic databases. However, multiple different data management systems and varying degrees of data completeness and quality lead to a very heterogeneous documentation landscape. Based on data from 53 botanic gardens, a survey carried out among members of the Association of Botanic Gardens in German-speaking countries depicted this large variety of used software solutions clearly (Figure 2).
Most of these solutions intended to account for the very specific nature of information linked to living accessions. Depending on the individual botanic garden's documentation practices, the digital record of an accession might hold information on provenance and gathering details, cultivation and propagation history, determinations or other curatorial comments and observations as well as associated scientific data (obtained from plants of this accession such as sequence or morphological data).
This structural heterogeneity hampers obtaining an instant overview of both the diversity and representation of plant species in living collections and the respective data quality. At the same time, botanic gardens are facing limited financial resources and, thus, are urged by the public sector to reduce duplications. There is a need to set collection priorities between different gardens based on reliable data and guided by an efficient and independent coordination. Furthermore, the high value and the largely still untapped potential of living collections for research might be promoted best by an easier accessibility to scientists.

Unlocking the vaults of living collections: Network solutions.
Researchers in need of plant material for their studies were commonly required to make an informed guess which living collection could supply relevant specimens or just directly sent out material requests to the largest and most well-known botanic garden collections.
However, in recent years online databases became available that increased the accessibility. The University of Ulm (Germany) developed the (online) data management system "SysTax" for Biodiversity Data (www.systax.org). In Systax, accession-based information is browseable for those 14 gardens using this management tool, which allows an immediate identification of the most promising collection holder. A much wider data source of over 1000 institutions has been gathered in the "PlantSearch" database by Botanic Gardens Conservation International (www.bgci.org). Taxon based material requests can be sent out to a number of anonymised collection holders instantaneously. However, this database depends on active updates by every single botanic garden, hence, might represent an outdated inventory list. For occurrence data, the Global Biodiversity Information Facility (www.gbif.org) has achieved a permanently updated online database, which holds more than 1 billion observation and specimen records from a large number of natural history collections and citizen science platforms, independent of their data management system.

Aim of this project.
An online, complete, and permanently updated plant inventory of living collections in botanic gardens is due. Here, we will outline the combination of various tools, developed at the Botanic Garden and Botanical Museum Berlin, which we used to set up into a data portal presenting accession-based information from living collections as a pilot project.

MATERIAL AND METHODS

An initiative of German botanic gardens.
Partners from the Botanic Garden and Botanical Museum Berlin (Freie Universität Berlin), the Senckenberg Nature Museum Frankfurt and the Botanic Garden and Herbarium of Heidelberg University initiated the project "Collections of Botanic Gardens: Living Resources for an integrative evolutionary Research" (Evo-BoGa). The main goal is enabling the interconnection of botanic garden's databases to promote the collections as resource for research.

During the pilot phase, we aim at connecting the databases for *Bromeliaceae* and *Cactaceae* from eight German botanic gardens into an online data portal. These plant families are well-represented in living collections, highly attractive to the general public and ideal models for studying the origin of biodiversity on evolutionary time scale.

Two research projects will exemplify the use of collections and improve usability by defining new molecular markers that will aid species identification of, for instance, sterile plants, and provide in-depth resolution for examination of hybridisation and uncertain species boundaries. An online tool for identification based on selected markers (barcoding) will be developed. Thereby, accessions will be validated for their identification and linked to obtained herbarium vouchers and DNA sequence repositories. The complete envisioned online documentation from the accession as source material and long-term referenced herbarium vouchers to scientific results will facilitate sustainable and reproducible research and will promote open access science.

The infrastructure for primary biodiversity data access.
All relevant information from local databases will be combined through the BioCASe (Biological Collections Access Service, Holetschek et al. 2009) Provider Software and the indexing tool B-HIT (Berlin Harvesting and Indexing Toolkit, Kelbert et al. 2015), which map the content of individual databases into the Biodiversity Information Standards (TDWG) data standard ABCD (Access to Biological Collection Data, Holetschek et al. 2012). The harvester queries BioCASe to store the standardized data in an index database (Figure 3). Through this infrastructure, the index database can be updated on demand without input from the providers. However, providers retain complete data ownership over the amount of shared data through their local installation of BioCASe.

The taxonomic backbone for *Cactaceae* will be assembled from the accepted classification and species list of the EDIT platform for Cybertaxonomy (caryophyllales.org), using the EDIT web services (Güntsch et al. 2017). For *Bromeliaceae* the taxon list has been provided by Butcher and Gouda (http://bromeliad.nl/taxonList/) and will also be imported to the EDIT platform. The up-to-date taxonomic backbone allows the verification of species names used in local databases and to provide feedback on outdated taxonomy or orthographic errors.

An online data portal of living collections.
The data portal as well as the B-HIT harvester is based on open-source software developed for the Global Genome Biodiversity Network (GGBN, Droege et al. 2014, Kelbert et al. 2015) and other projects at the Botanic Garden and Botanical Museum Berlin. It can be customised according to requirements of living collections and attached metadata (such as pictures, herbarium vouchers, tissue samples, etc.). The interface is mostly intended for users in botanic gardens and external researchers. Most curators will use the data portal for the purposes of determining collection strategies, for data curation, and, for example, the exchange of plant material or the reduction of redundancy. Therefore, a most complete insight into the collection, curation and cultivation data of accessions from different gardens is relevant. External researchers, on the other side, might be on the look-out for *'What grows where?'* with increased interest in accessions with well-documented origin and material from wild sources.

To meet these different needs and to deal with potentially sensitive information, the access to the data portal will be managed through a login and registration system with different user groups:

A. The complete information is freely shared among the data providers within the network of botanic gardens.

B. External users, such as researchers, will see most of the relevant collection data, origin of accessions, and associated metadata after login.

C. The general public such as stakeholders or interested garden visitors etc. will be presented the taxon list of species and the number of botanic gardens where these species are cultivated (without required login).

RESULTS & DISCUSSION

Development of standard entries for the data portal.
The heterogeneous data landscape leads to very individual data entries, whereby the output should appear standardised and allow quick comparisons. Hence, the representation of the data and the definition of which information should be presented to which user group requires the participation of each botanic garden joining the network.

The final output of the data portal (e.g. Figure 4) is a network effort that requires regular opinion exchange and transparent decision making.

The data portal is accessible from fall 2019.

CONCLUSION

Benefits for collection holders.

The efforts for a botanic garden to be hooked up to the data portal are low profile and the interconnection of living collections will provide several immediate benefits to the collection holder:

*After harvesting a local database, a data cleaning step is applied that will feedback erroneous data records to the data provider.

*The match with the taxonomic backbone will allow a quick overview of hierarchical taxon representation in a collection and notifications of orthographic or taxonomic problems with species names.

*Tools such as AnnoSys enable commentaries on f.i. new determinations or comments by external researchers.

*A comparison of accessions maintained in multiple botanic gardens will allow for a more efficient update and completion of data items. Furthermore, this will be achieved through statistical evaluations.

*The accession data will be connected to herbarium vouchers, DNA samples and specimen photographs.

*Simplified and easy-to-use "phylogenetic identification tools" via DNA barcodes will be implemented.

Benefits for the community access.

For the sustainability of this data portal, the challenge will be to raise interest in joining the data portal for additional botanic gardens and to open up their living collections to a wider public and new user groups such as researchers.

The botanic garden community will profit from a joint data portal through:

*The collections of even small and intermediate-sized gardens will receive enhanced visibility and increase their importance for research.

*Evaluation of collections in regards to species diversity, redundancy, contrasting priorities, etc., will become possible.

*Collection strategies can be improved by setting priorities for important or rare collections and maintaining duplicates elsewhere.

*The exchange of plant material (e.g. via the International Plant Exchange Network, IPEN) can be reinforced in its workflows through, for instance, correcting duplicated IPEN numbers.

*Lastly, the advent of obtaining a complete plant inventory of living collections in botanic gardens can be used for coordinated collection strategies.

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REFERENCES

Butcher D. & Gouda E.J. (cont. updated) The New Bromeliad Taxon List. [http://bromeliad.nl/taxonList/]. University Botanic Gardens, Utrecht (accessed: 13-06-2018).

Droege G., Barker K., Astrin J.J., Bartels P., Butler C., Cantrill D., Coddington J., Forest F., Gemeinholzer B., Hobern D., Mackenzie-Dodds J. (2014) *'The Global Genome Biodiversity Network (GGBN) Data Portal.'* Nucleic Acids Research. 42 (D1): D607-D612.

Güntsch A., Kohlbecker A., Müller A., Berendsohn W.G., Luther K., Plitzner P. (2017) *'EDIT Platform Web Services in the Biodiversity Infrastructure Landscape.'* Biodiversity Information Science and Standards. 1: e20363.

Holetschek J., Kelbert P., Müller A., Ciardelli P., Güntsch A., Berendsohn W.G. (2009) *'International networking of large amounts of primary biodiversity data.'* Proceedings Informatik 2009- Im Focus das Leben. Lecture Notes in Informatics, 26, 552-564.

Holetschek J., Droege G., Güntsch A., Berendsohn W. G. (2012) *'The ABCD of Primary Biodiversity Data Access.'* Plant Biosystems- An International Journal Dealing with All Aspects of Plant Biology 146 (4): 771–79.

Kelbert P., Droege G., Barker K., Braak K., Cawsey E.M., Coddington J., Robertson T., Whitacre J., Güntsch A. (2015) *'B-HIT-a tool for harvesting and indexing biodiversity data.'* PloS one, 10(11), e0142240.

Mounce R., Smith P., Brockington S. (2017) *'Ex situ conservation of plant diversity in the world's botanic gardens.'* Nature Plants 3: 795–802.

Murphy G.E.P., Romanuk T.N. (2014) *'A meta-analysis of declines in local species richness from human disturbances.'* Ecology and Evolution 4(1): 91–103.

TABLES AND FIGURES

Figure 1: Parts of the cactus collection at the Botanic Garden Berlin (© N. Köster).

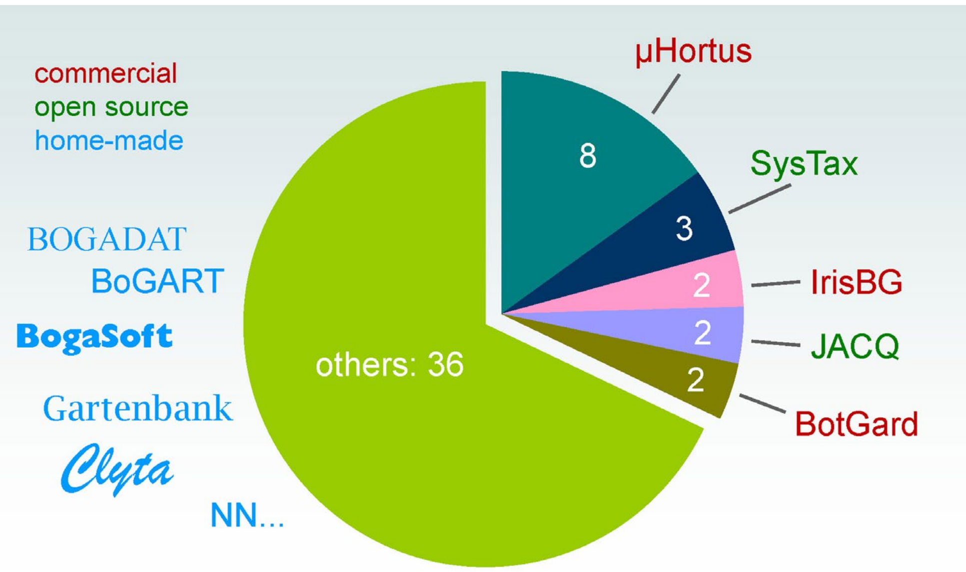


Figure 2: Results of a survey on database software used by 53 botanic gardens in German-speaking countries (N. Köster 2016, unpublished data).

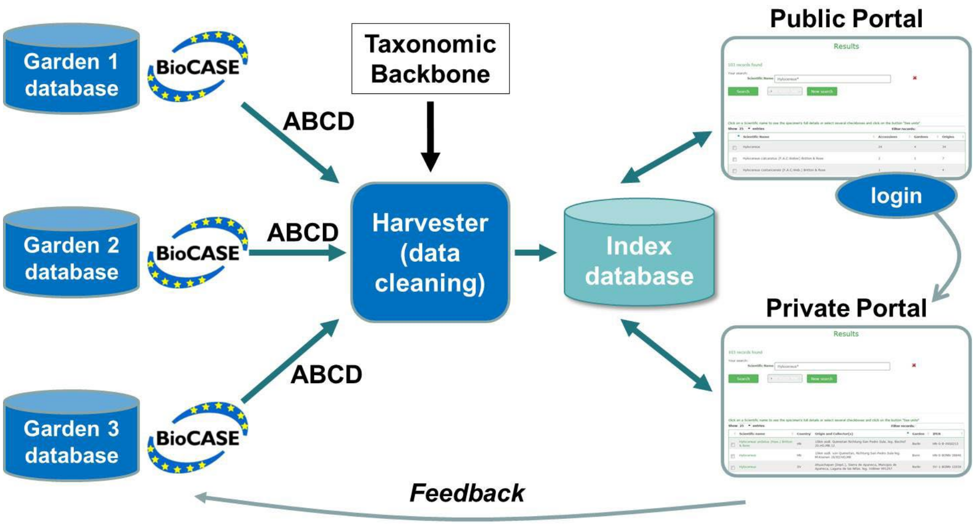


Figure 3: Overview of the harvester & data cleaning infrastructure leading to the data portal of living collections.

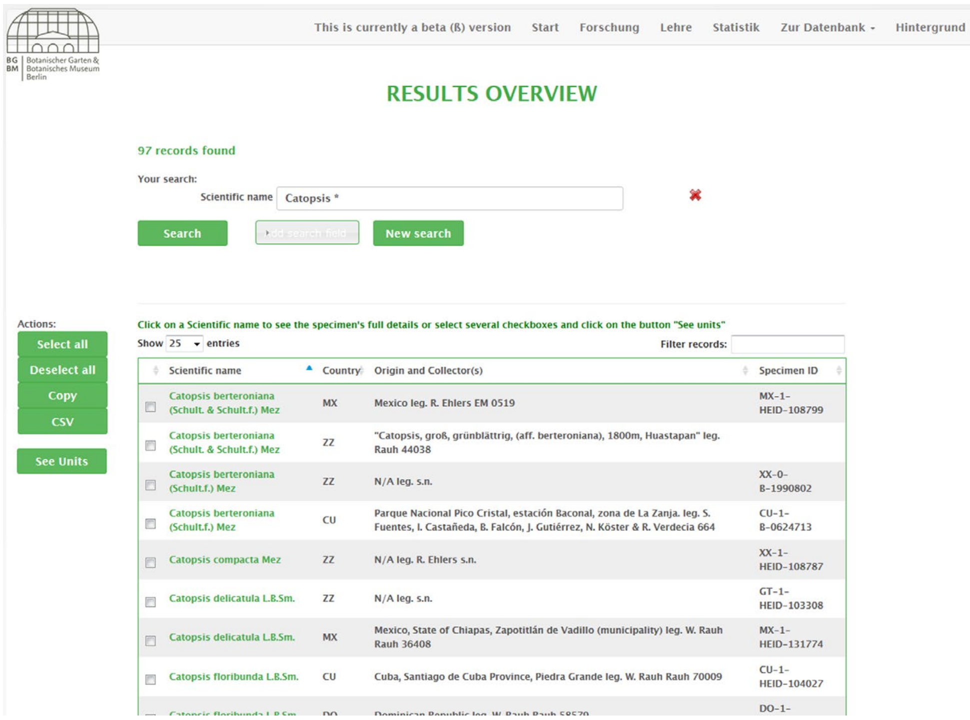
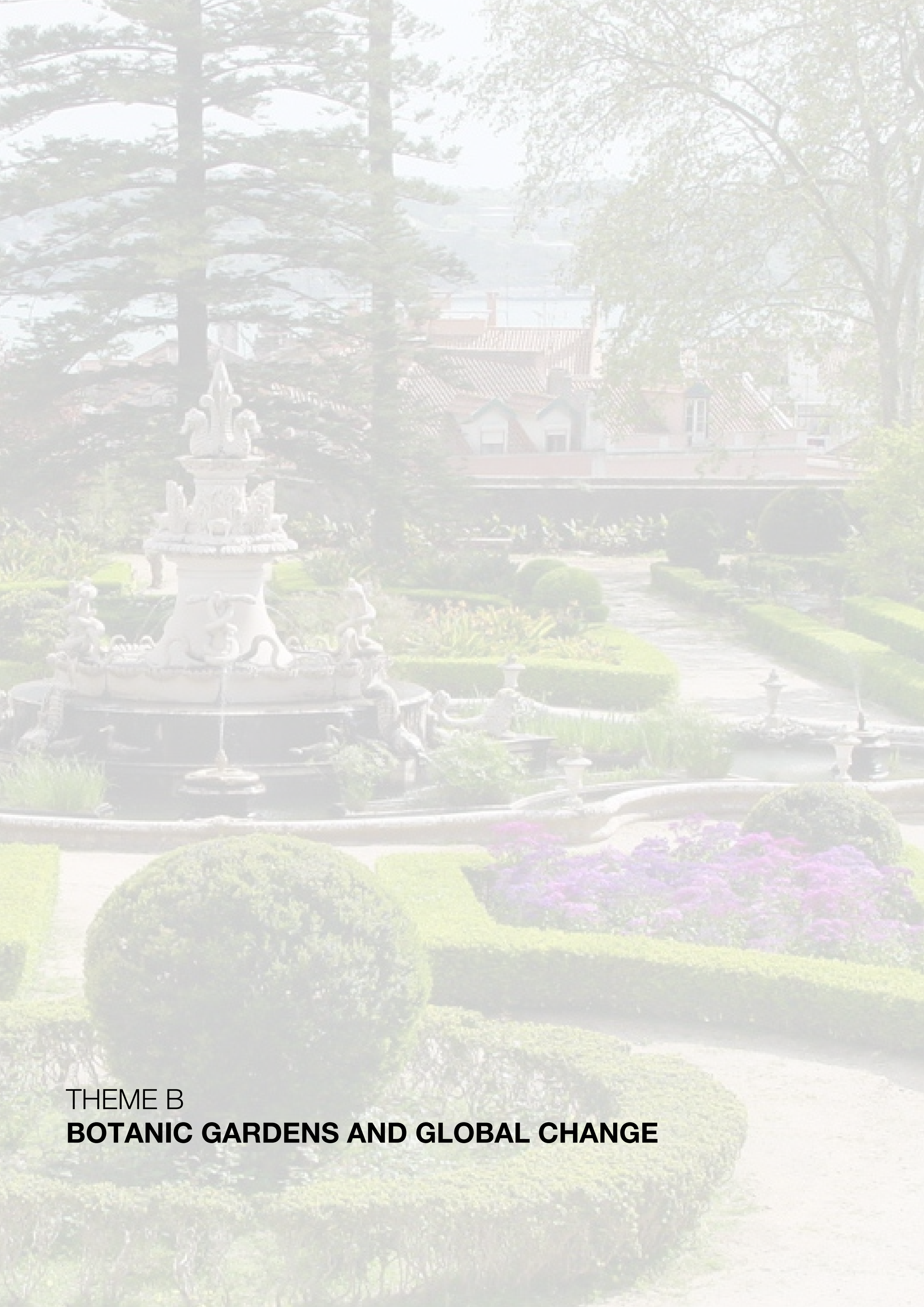


Figure 4: First glance at the accession-based data portal.



THEME B

BOTANIC GARDENS AND GLOBAL CHANGE

R-E-S-P-E-C-T: HOW ROYAL BOTANIC GARDENS VICTORIA IS RESPONDING TO CLIMATE CHANGE

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SOCIETAL IMPACT STATEMENT

Botanic gardens have a responsibility to lead, encourage, and contribute to research into climate change, particularly relating to plants and their habitats. We must educate, in the broadest sense of that word, and safeguard plants through seedbanking and other *ex situ* collections, and contribute to restoration. Good planning is essential to prepare for the succession of our living landscapes. We can engage on many levels, but most importantly with policy, politicians, and public opinion. Partnerships are essential and we should collaborate within regional networks. Finally, we must show tenacity. In short, R-E-S-P-E-C-T, respect.

SUMMARY

Climate change is our "biggest challenge," "most pressing issue" or simply, and starkly, "a crisis." As expressed in The Xishuangbanna Declaration on Botanical Gardens and Climate Change, there is much we can do as botanic gardens to help the world mitigate and adapt to global warming. We have a responsibility to lead, encourage, and contribute to research into the causes, consequences, and controls of climate change, particularly relating to plants and their habitats. Our core function, I think, is to educate, in the broadest sense of that word. We must safeguard plants through seed banking and other *ex situ* collections, and contribute to restoration. Good planning is essential and we need to prepare for the succession of our living landscapes. We can engage on many levels, but most importantly perhaps with policy, politicians and public opinion. Partnerships are essential and I would encourage botanic gardens to participate actively in peak bodies such as the International Association of Botanic Gardens and Botanic Gardens Conservation International, and to collaborate within regional networks. Finally, show tenacity—hold firm and true to our purpose, to safeguard plants and to care for people and our planet. In short, R-E-S-P-E-C-T, respect.

KEYWORDS

Adaptation, Botanic Gardens, Climate Change, International Association Of Botanic Gardens (Iabc), Partnerships, Planning, Seedbanking, Weeds

INTRODUC TION

All I'm askin' is for a little respect
O. Redding, adapted A. Franklin (1967)

Climate change is a threat to life on Earth. Or more accurately, to some life on Earth today. Human accelerated changes to the world's climate will lead to the extinction of some species, perhaps *Homo sapiens,* and the flourishing of others (Figure 1). This has been the impact of climatic change since the planet first sustained life more than 3.5 billion years ago. For human civilization, increasingly crowded into cities and with a total population considered unsustainable on this planet, the impacts are likely to be dramatic. Some people will lose their homes through rising sea levels, some will lose their food through inability to adapt to new agricultures, some will lose their lives or be dispossessed through increased severe weather events and social disruption. And so on. We may, in time, be able to innovate our way through the transition, assuming that is we can mitigate carbon and other climate-change pollutants to reach some sort of plateau. If we fail to mitigate the innovation and adaptation will be all the harder.

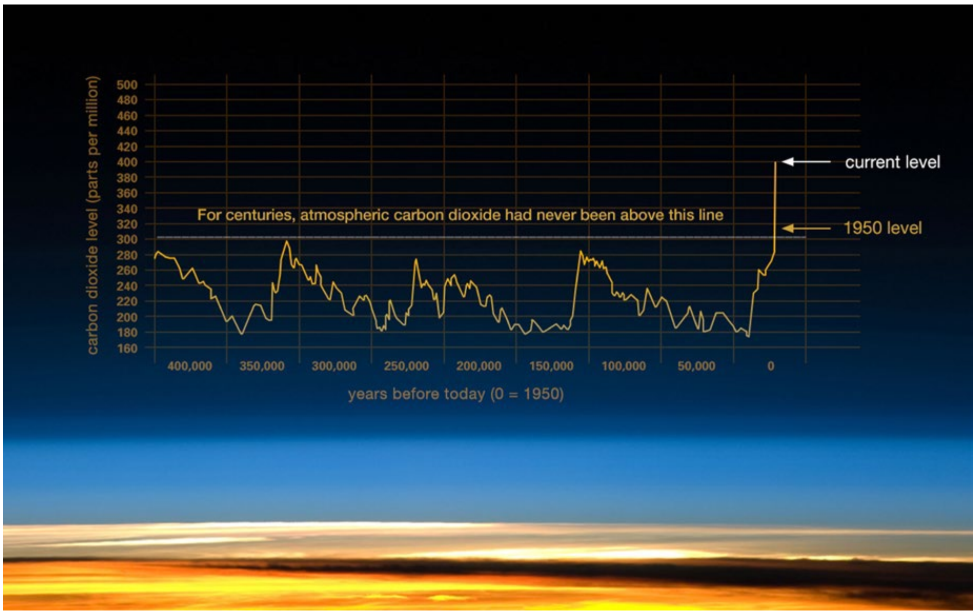

Figure 1: PComparison of atmospheric samples contained in ice cores and more recent direct measurements, providing evidence that atmospheric CO2 has increased since the Industrial Revolution. (image courtesy of NASA/JPL-Caltech, https://climate.nasa.gov/evidence/)

So this is a bleak scenario. Climate change has been described as our "biggest challenge," "most pressing issue" or simply, and starkly, "a crisis" (Pink, 2018). As expressed in T*he Xishuangbanna Declaration on Botanical Gardens and Climate Change* (Xishuangbanna International Symposium participants, 2014), there is much we can do as botanic gardens to help the world mitigate and adapt to global warming. I am not suggesting botanic gardens can save the world on their own but they are definitely part of the solution.

Indeed by default botanic gardens contribute to many things that either reduce the severity of climate change or help people adapt to its consequences. Every large tree we plant stores a tonne or so of carbon (Ecometrica, 2011), and there is almost as much again in the soil and microorganisms surrounding its roots in a botanic garden such as Melbourne Gardens, Royal Botanic Gardens Victoria (Cremins, 2016). By selecting particular species to plant, we adjust the dial on that carbon sink (Cremins, 2016). A lawn or a garden in any location reduces the temperature compared to an expanse of concrete: on a summer's day with maximum temperatures of 30 degrees Celsius, lawns in the Royal Botanic Gardens Victoria are about 24 degrees at their surface and nearby paths 40 degrees. Different parts of our landscape are cooler than others (Fern Gully in Melbourne Gardens is up to six degrees Celsius cooler than the nearby Central Business District of Melbourne) and we can plant to lower temperatures locally. While fine-tuning our plantings and landscape design to help mitigate climate change locally is admirable, there is much more botanic gardens can and should do.

In this adaptation of my plenary lecture at EuroGard VIII (the Eighth European Botanic Gardens Congress, Lisboa, May 2018) for the session "Botanic Gardens and Global Change," I propose seven themes, coerced into the mnemonic sung with such vigour by Franklin (1967): R-E-S-P-E-C-T, respect.

RESEARCH

Nearly a decade ago now, Primack and Miller-Rushing (2009), provided an excellent summary of the ways a botanic garden could contribute to climate change research. The capacity of a major botanic garden includes controlled growing conditions, living collections with broad taxonomic representation, meticulous record-keeping, networks spanning wide geographic areas, and knowledgeable staff. These resources are brought to bear on discovering the biological responses to climate change such as timing of flowering and leaf-out; understanding of the relationships among climate, physiology, and anatomy; use of herbarium specimens and historical photographs to understand past plant behaviour; biology and distribution of invasive species; and comparative studies of responses to climatic variation providing insights on important ecological, evolutionary, and management questions. Botanic gardens are also increasingly important meeting and study places for citizen scientists, and there are many climate monitoring programs worldwide: in Australia, ClimateWatch (www.

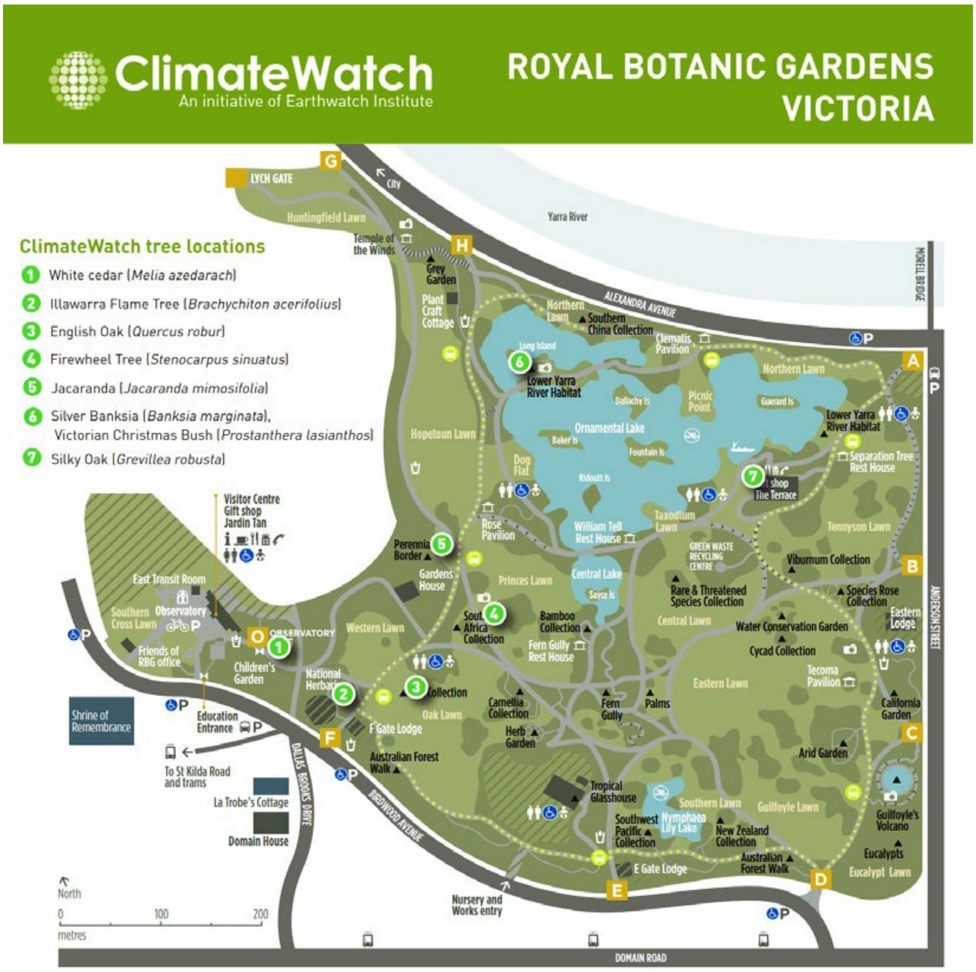

Figure 2: ClimateWatch trail at Melbourne Gardens, Royal Botanic Gardens Victoria (from http://www.climatewatch.org.au/uploads/trail/field_recording_sheet/4f6c0f8ceebda963fb000002/Revised_CWRBG VicTrail MapRecording Sheet.pdf)

climatewatch.org.au; Figure 2), run by EarthWatch and supported by many Australian botanic gardens. Botanic Gardens have a responsibility to lead, encourage, and contribute to research into the causes, consequences, and controls of climate change, particularly relating to plants and their habitats.

EDUCATION

A core botanic garden function, and perhaps where they should have their greatest impact, is education, in the broadest sense. In 2013, at a conference *Encountering the Anthropocene* (Sydney Environment Institute, 2013), I gave a talk on "Curing Plant Blindness and Illiteracy" which is still available online (Entwisle, 2013; Figure 3). In that talk, I argued that humans display symptoms of two potentially life-threatening diseases: plant blindness and plant illiteracy. We either take plants for granted, viewing them as a kind of green wall-paper, or we fail to appreciate just how important they are to life on Earth. Botanic gardens have always celebrated plant life, displaying its variety and beauty. I said then (and now), they must do more. Without losing their whimsy and charm, botanic gardens have a job to do. I then ran through the capacity of the organization to which I had just been appointed Director and Chief Executive, the Royal Botanic Gardens Victoria.

Figure 3: Title slide from "Curing Plant Blindness and Illiteracy" presentation in 2013

It includes two truly iconic botanic gardens; a State Botanical Collection of 1.5 million specimens, historically and scientifically the richest collection of preserved plants, algae and fungi in Australia; the Victorian Conservation Seedbank as an insurance policy and investment bank for our State's flora (and part of the Australian Seedbank Partnership, a collaboration with Royal Botanic Gardens Kew's Millennium Seed Bank in London); and over two hundred staff, volunteers, and associates who are experts in horticulture, systematics, ecology, conservation, and education. These are the kind of assets you find in most large botanic gardens, to varying degrees of size and impact, and all are positioned perfectly to contribute to a cure for plant blindness and illiteracy. Further, we must surely be obliged to do so. I used the talk to demonstrate how botanic gardens worldwide will help us survive the Anthropocene and one of its defining characteristics, human-induced climate change, and why plants, algae and fungi are really in control of this planet. This was education pure and simple, and the kind of case every botanic garden should make, as often as possible.

Of course every plant in a botanic garden should have a story (the key words in any useful definition of a botanic garden are that each plant, collection, or landscape should have a "purpose"; Entwisle, 2018) so every plant is an opportunity to educate. Indeed, every interaction with a visitor—real or virtual—is a chance to inform, encourage, and inspire. Some displays will be directly related to climate change, such as the Water Saving Garden at Cranbourne Gardens, Royal Botanic Gardens Victoria, where plants requiring less water are gathered together and interpreted. While drought and water shortages have always been part of gardening in Australia, the changes to Victoria's climate due to global warming are predicted to accentuate this limitation. Similarly with invasive species: weeds are a major threat to the environment and economy of Australia, and a changing climate will allow new incursions and extensions to existing ranges (as well of course as contractions and losses of other species, we hope). So when as a botanic garden, we assess new acquisitions for their weed potential (Virtue, Spencer, Weiss, & Reichard, 2008), as we should and must, it is useful to explain that to the visiting public (particularly if we decide to grow a species with strict horticultural protocols in place such as a "de-heading" to avoid any seed set).

This is not the place to discuss the philosophy and pedagogy of learning programs, but whether they are aimed at informing or inspiring, a core message for botanic gardens in the 21st century must be the need to mitigate and adapt to climate change, and the role plants play in this response.

SAFEGUARDING

Most botanic gardens contribute in some way to the physical protection of the world's flora. They do this through living collections of rare and threatened species, through seed and germplasm banks, or through direct management of natural or restored vegetation. There are many examples of integrated conservation programs involving botanic gardens, but the shining example is that of the extremely rare and only recently discovered conifer, Wollemi Pine (Wollemia nobilis), from New South Wales in Australia (Woodford, 2000). Climate change is yet another threat, adding to and sometime compounding land clearing, grazing, invasive species, inappropriate fire regimes, and so on. In the case of the Wollemi Pine with less than 100 individual trees growing in a small area north of Sydney, the existence of a widely distributed *ex situ* collection (in botanic, as well as home and other public, gardens) is essential for the continuation of this species should there be any impediment to the survival of the natural populations.

Another good, integrated example, is the Orchid Conservation Program at Royal Botanic Gardens Victoria, which relies on human, and other, partnerships. Australia has around 1,300 species of native orchid, with three-quarters of these terrestrial (ground dwelling). The south-eastern corner of the continent is particularly rich in terrestrial orchids, with many species under threat of extinction. To conserve these species and reduce their risk of extinction, many recovery plants include a reintroduction component. However, until recent years it has been extremely difficult to propagate and successfully translocate most terrestrial orchid species. Each terrestrial orchid species has its own complex relationship with the environment, including particular requirements for mycorrhizal fungi, pollinators, and microhabitat. To restore populations under threat, a thorough understanding of a plant's ecology and biology are required, as well as the support of relevant land managers and community groups. The Royal Botanic Gardens Victoria is leading an innovative conservation partnership to collect, store, propagate, and reintroduce threatened terrestrial orchids into their native habitat. It has many partners, including Catchment Management Authorities, national parks, conservation NGOs such as Trust for Nature, universities and various government

Figure 4: Crowd sourcing poster for Royal Botanic Gardens Victoria's Orchid Conservation Program

While seedbanks and genetically diverse living collections are the best ways to safeguard a species outside its natural habitat, even one or two specimens of the "living dead," as they are sometimes called are better than nothing. The Toromiro (Sophora toromiro) is extinct on Easter Island, the only place on Earth where it grew naturally, but is now grown in many botanic gardens worldwide. While we have some genetic variation in our collection at Royal Botanic Gardens Victoria, mostly the plants grown do not represent much of the natural variation that would have existed once on Easter Island. Still, better to keep a representative of a particular lineage, in this case a species, than to lose it. Much as the books lost in the burning of the library at Alexandria in 391 AD are irreplaceable, so is a particular evolutionary outcome, a species. Of course given limited space and resources, a botanic garden must triage the value of each specimen or sample if we are to safeguard the diversity of plant life on Earth.

PLANNING

When we plant a tree it is not for the life of a corporate plan or a government. It will be with us for 10–100 years, and quite possibly more. So the tree we plant today must be the tree that will survive and thrive in, say, 2090. This is at the heart of Royal Botanic Gardens Victoria's *Landscape Succession Strategy* (RBGV, 2016; Figure 5). As outlined in a recent paper (Entwisle, Cole, & Symes, 2017), the strategy recognizes that with 1.6 million visitors each year, responsibility for a heritage-listed landscape and the need to care for a collection of over 8,000 plant species of conservation and scientific importance, planting and planning must take into account anticipated changes to rainfall and temperature. Specifically, the Strategy sets out the steps needed over the next 20 years to transition the botanic garden to one resilient to the climate modelled for 2090. The document includes a range of practical measures and achievable (and at times somewhat aspirational) targets. Climate analogues are being used to identify places in Australia and elsewhere with conditions today similar to those predicted for Melbourne in 2090, to help select new species for the collection. Modelling of the natural and cultivated distribution of species will be used to help select suitable growth forms to replace existing species of high value or interest. Improved understanding of temperature gradients within the botanic garden, water holding capacity of soils, and plant water use behaviour is already resulting in better targeted planting and irrigation. The goal is to retain a similar diversity of species but transition the collection so that by 2036 at least 75% of the species are suitable for the climate in 2090. At all times there will be a strong focus on assisting the broader community in their response to climate change. An international Climate Change Summit was held late in 2018 with representatives for 10 allied botanic gardens from around the world, mostly in climates similar to those of Melbourne in 2018 or 2090. It is anticipated an alliance will be established to further encourage the sharing of knowledge and skills.

While the *Landscape Succession Strategy* is thought to be a world-first in terms of its focus on the botanical living collection and landscape, botanic gardens in Australia and elsewhere have been planning for climate change for at least the last 10 years: for example, Role of Australia's Botanic Gardens in Adapting to Climate Change (CHABG, 2008), Australian National Botanic Gardens Climate Change Strategy (ANBG, 2010), and Botanic Gardens in the Caribbean and Central American region are already experiencing an increase in the frequency and severity of hurricanes, and there and elsewhere rising sea levels are displacing land and horticultural options.

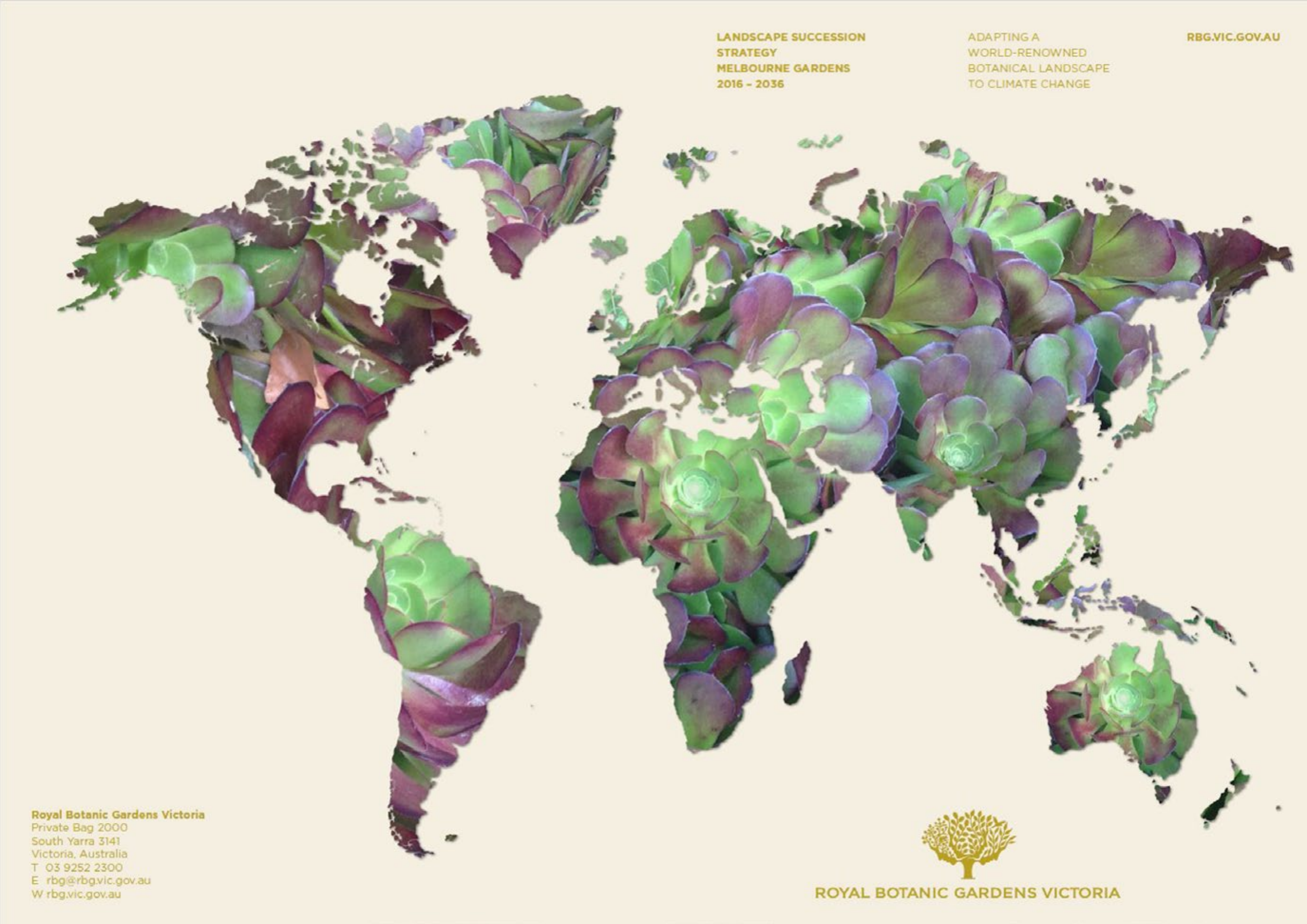

Figure 5: Responding to climate change in the management and planning of a botanical living collection and landscape: the Landscape Succession Strategy for Melbourne Gardens, Royal Botanic Gardens Victoria

ENGAGEMENT

Botanic gardens engage on many levels, starting with our visitors of course. Here, I want to focus on government policy and community projects. Each botanic gardens must respond to the needs and requirements of its owners, whether private or public. For those with a broader public remit, and funded primarily through taxes of some kind, there will be obligations to assist in the implementation of "election promises" and various high level strategies and commitments. I would encourage botanic gardens to extend this further and reach over the garden fence, to work on projects that help the government(s) respond to climate change. In my State of Victoria, Australia, we have Protecting Victoria's Environment— Biodiversity 2037 (Victoria DELWP, 2017) and Victoria's Climate Change Adaptation Plan (Victoria DEWLP, 2016) as two key drivers for our Government.

Botanic Gardens can also provide leadership and expertise for "community greening" projects, which while not always responding directly to climate change will strengthen a city's ability to maintain a liveable climate and make a contribution to carbon storage. In my own case, I was invited in 2016 by the Victorian Minister for Public Transport to chair what was called a Community Open Space Expert Panel (COSEP, 2017; Figure 6).

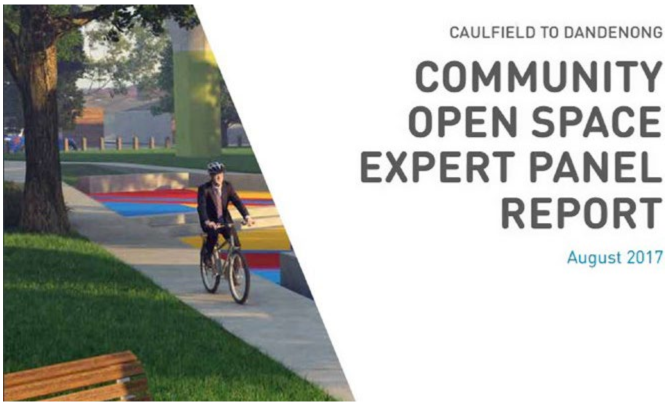

Figure 6: Report from the Community Open Space Expert Panel, chaired by the author

The Panel was established to advise the minister on the best use of 22.5 hectares of open space created by elevating the rail network in outer Melbourne. It included representatives of the local community (selected through an expression of interest), combined with expertise from Victoria Police, Bicycle Network, local council, and the Office of the Victorian Government Architect. The Panel met monthly over 12 months, reviewing, and advising on plans for this open space which include parks, gardens, play and sports equipment, walking and cycling pathways, car parking, and community art. Planting in this park had to be suitable for Melbourne's emerging climate as well as safety, amenity, and community cohesion.

COLLABORATION

Collaboration will be essential for everything I have mentioned so far, whether with colleagues inside or outside a botanic garden. Research, education, safeguarding plants, and planning all depend on partnerships of some kind, and engagement is always a collaboration when done well. As current President of the International Association of Botanic Gardens (iabg.scbg.cas.cn), I would encourage membership of this peak international body, as well as Botanic Gardens Conservation International (www.bgci.org), plus regional networks (e.g., Botanic Gardens Australia and New Zealand; www. bganz.org.au) (Figure 7). Little more need be said about collaboration other than to encourage more of it.

Figure 7: Visual identities for two international botanic garden networks (International Association of Botanic Gardens and Botanic Gardens Conservation International) and one regional network (Botanic Gardens Australia and New Zealand)

TENACITY

Finally, we should be tenacious: taking a firm grip on things, being determined, persisting (en. oxforddictionaries.com). "Like a limpet" (example of tenacity; en.oxforddictionaries.com) we must stick to our commitment to a life sustained and enriched by plants. Perhaps more aptly for our audience, we could model ourselves on the South American Ombú (*Phytolacca dioica*), a favourite specimen tree in many botanic gardens (Figure 8). It has a firm and unshaking grip on the Earth, with limbs reaching out as far as it can in all directions. It is also a tough plant, able to withstand drought and fire. Tough but tender: the Ombú, or Bella Sombra ("beautiful shade" in Spanish), provides comfort and shelter for those travelling through the extensive grasslands of Argentina and Uruguay. Not a bad role model for botanic gardens as they navigate their way through the climate change crisis.

Figure 8: Ombú (*Phytolacca dioica*) in Jardín Botánico de Ajuda, Lisbon, Portugal. Photograph: Tim Entwisle

R-E-S-P-E- C-T

These seven themes—*research, education, safeguarding, planning, engagement, collaboration,* and *tenacity*—sum up neatly how botanic gardens should respond to climate change. Conveniently, the first letters of these themes combine to spell "respect". If we show respect to each other, and to other life forms on this planet, we will be well on the way to dealing responsibly to crises such as climate change. Without that respect, our botanic gardens can become mere curious historical artefacts and our work philatelic rather than philanthropic. Not that there is anything wrong with the collecting and studying of stamps! It's just that we have a higher calling, to save the planet as well as celebrate the life on it.

At the broadest level, respect applies to the diversity of life and to the value of each species as a unique outcome of evolution (or if you like, something more spiritual). It applies to the way we view nature in the whole, but also a tree in the singular. It also applies to how we respond to dissenting or disinterested views. Rather than respond in anger or frustration, or give up on a particular cohort, we must remember the Ombú and persist. Through research we can provide the evidence to make sound decisions, through education we build an informed and committed community, by safeguarding we project our precious plant life, with adequate planning we leave a lasting legacy, by engaging with governments and community leaders we expand our influence, by collaborating we multiply our impact, and, through tenacity will prevail. As the young folk say, "respect!"

REFERENCES

ANBG. (2010). *Australian national botanic gardens climate change strategy.* Canberra: Australian National Botanic Gardens. Retrieved from www.environment.gov.au/system/files/resources/a43bcbb5-d4f4- 4db2-ae6c-59f292c683b4/files/anbgclimatechangestrategy.pdf.

CHABG. (2008). *National strategy and action plan for the Role of Australia's botanic gardens in adapting to climate change.* Canberra: Council of Heads of Australian Botanic Gardens. Retrieved from https://www.anbg.gov.au/chabg/climate-change/botclimate.pdf.

COSEP. (2017). *Community open space expert panel report.* Melbourne: Level Crossing Removal Authority/ Department of Public Transport. Retrieved from your.levelcrossings.vic.gov.au/22107/documents/61331.

Cremins, N. (2016). Accounting collides with botany. *Exchange Business & Economics, Autumn*, 12–16. Retrieved from fbe.unimelb.edu.au/exchange/edition2/accounting-collides-with-botany.

Ecometrica. (2011). A one tonne carbon tree. Retrieved from ecometrica.com/assets/one_tonne_carbon_tree_discussion_paper_3.pdf.

Entwisle, T. J. (2013). Curing Plant Blindness and Illiteracy. Presentation at Encountering the Anthropocene: the role of Environmental Humanities and Social Sciences. University of Sydney, December 2013. www.youtube.com/watch?v=4_BNUUV2sFw.

Entwisle, T. J. (2018). The top 10 'first' botanic gardens (Plant Portrait XVIII*). Talking Plants blog (http://talkingplants.blogspot.com.au/2018/03/the-top-10-first-botanic-gardens-plant.html)

Entwisle, T. J., Cole, C., & Symes, P. (2017). Adapting the botanical landscape of Melbourne Gardens (Royal Botanic Gardens Victoria) in response to climate. Plant Diversity, 39, 338–347. https://doi.org/10.1016/j.pld.2017.11.001

Frankiyn, A. (1967). Respect, song adapted from O. Redding, 1965. Released Atlantic Records Studio, New York City, 14 February 1967.

Pink, R. M. (2018). *The climate change crisis.* Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-319-71033-4_1.

Primack, R. B., & Miller-Rushing, A. J. (2009). The role of botanical gardens in climate change research. [Tansley Review]. *New Phytologist*, 182, 303–313. https://doi.org/10.1111/j.1469-8137.2009.02800.x

RBGV. (2016). *Landscape succession strategy,* Melbourne Gardens 2016-2036: *Adapting a world-renowned botanical landscape to climate change*. South Yarra: Royal Botanic Gardens Victoria. Retrieved from www.rbg.vic.gov.au/documents/Landscape_Succession_Strategy_lo_res1.pdf.

Sydney Environment Institute. (2013). Encountering the Anthropocene: The role of Environmental Humanities and Social Sciences. Conference held at University of Sydney, December 2013. sydney.edu.au/environment-institute/wp-content/uploads/2013/12/PROGRAMME_250022014.pdf.

Victoria DELWP. (2016). *Victoria's climate change adaptation plan*. East Melbourne, Australia: Department of Environment, Lanwd, Water and Planning. Retrieved from www.climatechange.vic.gov.au/__data/assets/pdf_file/0024/60729/Victorias-Climate-Change-Adaptation-Plan-2017-2020.pdf.

Victoria DELWP. (2017). *Protecting Victoria's environment—Biodiversity* 2037. East Melbourne, Australia: Department of Environment, Land, Water and Planning. Retrieved from https://www.environment.vic.gov.au/__data/assets/pdf_file/0022/51259/Protecting-Victorias-Environment-Biodiversity-2037.pdf.

Virtue, J. G., Spencer, R. D., Weiss, J. E., & Reichard, S. E. (2008). Australia's Botanic Gardens weed risk assessment procedure. *Plant Protection Quarterly*, 23, 166–178.

Woodford, J. (2000). *The Wollemi Pine: The incredible discovery of a living fossil from the age of the dinosaurs.* Melbourne, Australia: Text Publishing.

Xishuangbanna International Symposium participants. (2014). The Xishuangbanna declaration on botanical gardens and climate change. Statement issued at The Third Xishuangbanna International Symposium, Botanical Gardens and Climate Change, held at the Xishuangbanna

CITY TREES AND ROLE OF BOTANIC GARDENS

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ABSTRACT
Trees are an indispensable part of urban environment. They provide shade and help to reduce the city temperature, what nowadays is especially important due to global warming. One of the usual problems for city trees is the space available for the tree under the ground and above it. Because of specific environmental factors in cities, where it is needed shade during the summer and light during the winter , the choice of right tree species, that will give the greatest feeling of comfort to the citizens, is essential. The University Botanic Gardens of Ljubljana have a long-lasting cooperation with the Ljubljana Municipality. This has been intensified since 2007, when the Botanic Gardens have been actively participating in the urban green policy where city trees play an important role. Hence, we participated by preparing a study about management of city trees. The Botanic Gardens were also co-author and publisher of the book "City Trees", where management instructions and list of appropriate city trees species are indicated. This was followed by many revisions of planting plans for city trees in the Slovenian capital. Later on, also the evaluation of tree situation and the selection of new tree species were prepared. Some common tree species used for centuries (like *Aesculus hippocastanum* L.) have nowadays become less useful or even useless because of diseases and pests. For this reason, we started to introduce autochthonous species into the planting plans. Species diversity is very important for the city biodiversity. As a result of our suggestions we became the main reference for selection of city trees and for their management. One of the biggest projects whith the participation of the University Botanic Gardens of Ljubljana, was the renovation of the main avenue in Ljubljana. We suggested that the autochthonous tree species *Fraxinus ornus* L. should be planted there. On this avenue 67 specimens of the aforementioned plant species are now growing. In a smaller newly arranged park, 32 trees of *Sorbus aria* (L.) Crantz were planted based on our suggestion. For upcoming projects of street renovation in the next year, species like *Prunus mahaleb* L., *Ostrya carpinifolia* Scop. and *Carpinus betulus* L. were suggested. Also, other Slovenian city municipalities are asking the University Botanic Gardens of Ljubljana for advice and assistance on this issue. With help of our knowledge, workshops and lectures are being prepared for different interest groups. With such activities, we want to achieve a better recognition of the public services in respect to city trees.

KEYWORDS
Trees, Urban Environment, Autochthonous Species

INTRODUCTION

Trees have existed in cities since the time people started living in societies. They represent a part of nature, greenery, or the most beautiful nature in cities that we are not even aware of. With the warming of the atmosphere and especially of the urban centres the trees are becoming more and more important buffers of extreme temperatures (Burden 2006; Ennos 2010). They also absorb 30% of the water and then release it again into the atmosphere. Trees absorb CO2 and emit O2, what improves the conditions in urban centres (Burden 2006, Hewitt et al). Properly selected trees prevent heating of buildings in summer and mitigate low temperatures in winter (Wolf 1998 a, b, c). Trees in cities cause less water loss and increase air humidity, what additionally mitigate the effects of high temperatures. They influence the retention of precipitation water, which in the urban environment is also important (McPherson et al 1997; Xiao & McPherson 2016). Of course, these properties are related to specific tree species (Escobedo et al 2015 a; Scharenbroch et al. 2016). They are the real drainage system of the city (Denman et al. 2012). Trees with appropriate planting can alleviate noise, reduce dust particles emissions by filtering and absorb certain pollutants from the air: ozone, carbon monoxide, sulfur dioxide (Burden 2006; Harris & Bassuk 1993; Hiemstra et al. 2008; Anon 2010; Livesley et al 2016), reduce

UVB radiation (Heisler et al. 2002) and at the same time contribute to a more beautiful environment (Dixon & Aldous 2014). In cities they have a structural function (Burden 2006; Escobedo et al. 2011, 2015 a; Mullaney et al 2015). With the aging of the population of Europe and other developed parts of the world, their environmental function of extreme temperature mitigation is of particular importance. No less important are trees along the roads both in cities and on local roads. Trees are also important in car parks where the appropriate trees can significantly reduce the temperature of the parked cars if the treetops above are dense.

Trees in cities also have socio-economic and sociological functions. They influence on the well-being of the inhabitants and they increase the chance of staying in open areas all day, what is even more important in the summer. Trees in cities also have a significant effect on well-being and health of people (Hiemstra et al. 2008; Anon 2010). Therefore, their sociological function is often more important, although it may be less measurable than their ecological function (Kane 2009). Trees have a symbolic meaning, they are a place for sociability, they give a feeling of a roof over people's heads and more. Trees in the cities are the building blocks of the space. Pleasant green environment increases the value of real estates. To some of the trees is given as many as 20 properties which help and contribute to a better life in cities (Burden 2006). Despite all the positive effects of the trees, they also cause conflicts. The space in cities is valuable and expensive so it is very important for city urban planning. It is necessary to select the proper space for an individual tree because for the same tree species in the urban environment its behaviour is different from that in the forest (Anderson & West 2006; Peper et al 2014). Good ventilation of the soil enables the respiration of the roots and the growth of soil organisms. In cities, however, all this is missing, causing a lack of water and nutrients (Kozlowski 1999). This is why the growth of trees in cities is less successful. Trees in cities can also be dangerous if they are not regularly inspected and properly maintained. In addition to the above-mentioned, trees in cities are also natural micro-habitats where the birds and other animals are kept, what increases the biodiversity of the urban environment. Nowadays, it is desirable to keep points of green passages through the city as corridors which lead us back to intact nature. Green oases in the middle of cities are becoming increasingly important (Kuo 2003).

Some cities have a special strategy for city trees (Peurasuo et al. 2014; Dahlhausen et al 2016). The city of Ljubljana also uses its special strategy, which we are co-shaping with our decisions in the University Botanic Gardens of Ljubljana. Nowadays, a good strategy is particularly important since the contractors for the management of urban trees are selected through a call for tenders and are often changed for this reason. In case there are no permanent instructions and strategies, there may be a problem with maintaining the city trees. After changing various services and concessionaires Ljubljana finally acquired a proper urban company that takes care of the city trees. For advice representatives of the company turn to the University Botanic Gardens of Ljubljana, where we are always ready to help.

Botanic gardens are old institutions in which tree species were important from the very beginnings (Monem 2007; Oldfield 2010). The Botanic Garden in Ljubljana celebrated its opening in 1810 by planting one or even eight trees (Strgar 1973; Bavcon 2000, 2010). Knowledge of trees and their ecology is also an integral part of our fieldwork, which is carried out throughout Slovenia. Due to the knowledge of ecology and the desire to try to plant as many indigenous trees within the city, as possible, we have been cooperating with the City of Ljubljana for many years. In the city, we have taken in hand the role of determiners for the selection of new tree planting in the city, and they are asking us for help also from other parts of Slovenia. The task is not easy, but it is interesting because we are constantly looking for new solutions which could be permanent and not short-term.

METHODOLOGY

There are many important factors in choosing city trees that influence the choice. Trees in the city usually have problems with the underground area. Usually, this space is too small. Trees can damage the underground community infrastructures in the city with root interweaves. When planting trees it is, therefore, necessary to ensure the tightness of the underground community installations so that there is no air or water permeability in them because of the roots growing to the water and the air spaces. The installations must be sufficient away from the roots so that the roots do not overgrow and thus damage them. Particularly important is the distance from hot water lines and pipelines, which can result in fatal consequences if they reach the roots. The tree should be provided with an adequate space above and below the ground. It has to be chosen a right

tree for the right place. Trees are chosen according to the underground and above ground space. A large tree does not belong to the narrow and small streets, because it causes problems. Trees in the city should be pruned as little as possible, so it is necessary to get trees of the appropriate size with appropriate crown corresponding to the given space.
In Ljubljana, we set a strategy for planting drought-tolerant species, and preferably, trees that feed honeybees and are indigenous because they are most adapted to our environment. They should also not cause allergies and should not be breakable.
Planting holes must be properly prepared with a substrate suitable for a particular species (Din 18920, 2002; Bühler et al. 2007; ZTV-Vegtra-Mu 2008) and if possible we form planting channels that are left perforated (Figure 1). This way roots have conditions for growth and air. Also in places where the soil at the top is treated in any way we leave the ventilation shafts and additional ventilation tubes, which in the great drought at least in the first year of rooting can serve for additional watering. The outer part of the planting hole is designed so that the grid protection can be removed and the space for the trunk is increased. It should only be slightly paved so that it is permeable for air and water. The upper part can be secured only with a grid and the roots are below. Depending on the spatial possibilities we are always looking for optimal solutions for the root system.

RESULTS

The University Botanic Gardens of Ljubljana always participated in the works aiming at the planting oftrees. It had its little tree nursery, which is evident through history (Strgar 1973; Bavcon 2010). We also cultivated species to replace the existing trees in the garden. In 1999 we received three hundred saplings of Japanese cherries, which were a protocol's gift from Japan to Slovenia. These young trees need to be quarantined for one year, and that is why we set up a special new field where we planted the above-mentioned species. Already in the second year of growth, we started to cultivate young trees as trees for promenade. We pruned the lower part of the branches and gradually lifted the crowns according to the rules for shaping trees for promenade. Trees were prepared for plantations in front of the entrance to the new site of the Botanic Garden. We later planted them right there (Bavcon 2001). In 2006, the City of Ljubljana was invited to participate in the rehabilitation of an illegal kitchen garden settlement near the Žale cemetery, which is the work of the Slovene famous architect Jože Plečnik who also worked in Vienna and Prague (Hrausky et al 2007). Given that there was no money for planting in the initial phase, we proposed a very simple solution. The solution was the removal of all ballast and preserve the existing trees, which gardeners have planted over the years. Of course, not all trees were suitable, so we made the appropriate selection. A very simple park was made only by laying out and sowing the lawn. Later we planted there more trees and formed park elements. Even today the original trees, including fruit trees, represent a very diverse park, which people have gladly accepted their own (Simoneti 2010).
Later we participated in the selection of some tree and shrub species for the banks of the Ljubljanica River (Bavcon & Ravnjak 2017 a, b). Requests for proposals for planting different tree species continued to flow from different parts. In particular, we were consulted by architects who included trees in various plantings not only in Ljubljana but in different parts of Slovenia. The yield of these various pieces of advice and consultations was the creation of a budget for a public enterprise that takes care of greenery in Ljubljana (Maljevac et al. 2010), and that a little later also allowed the publication by the University Botanic Gardens of Ljubljana of the book "Mestno drevje" (the City trees), in which we are also co-authors (Šiftar et al. 2011). The book opened new chapters in the planning and selection of trees, and in particular, mean a further enforcement of the Botanic Garden in terms of advice on the trees in the city. With this, we were faced with new challenges.
A major urban project was the renovation of the central city street - "Slovenska cesta" in Ljubljana (Figure 2). On this street, which was the main road and the city traffic route, there were no trees. From the beginning, we have worked with architects at workshops and advised them on how to tackle the selection of the tree species and what conditions should be prepared for the trees. On this main road, planned for, in the future, forbid the individual traffic and allow only the public transport and pedestrians was intended to plant as many as 67 new trees. The selection took place for a long time and in the end, we succeeded with our proposal for planting a small tree species according to the availability of space underground and in view of the desire that the trees should extend too high. The strategy that we decided on was to use species that are indigenous, drought-tolerant and trees that feed honeybees. Already the architect Jože Plečnik used the Mediterranean elements

in Ljubljana during the two wars and our choice was only an upgrade of his. So we included in the shortlist sustainable tree species from the Sub-Mediterranean environment which can stand the Ljubljana winter and the urban environment of summer, especially the water shortages. For the central line of the street, we selected the manna ash (*Fraxinus ornus* L.), which proved to be a good choice, because the plant blooms very beautifully, is little demanding and at the same time very beautifully coloured in autumn. The latter brings an additional element of diversity into this central space (Bavcon & Ravnjak 2014; Bavcon & Ravnjak 2017 a, b). This larger avenue is then connected to the crossroad and the road which goes across the avenue is an approach road to the centre from the north side. Here, as a supplement, we added another drought-tolerant species from the same phytogeographical region of Slovenia - European hop-hornbeam (*Ostrya carpinifolia* Scop.) (Figure 3). In the next street, we added a whitebeam (*Sorbus aria* (L.) Crantz). Both of the added species are also very attractive for bees, which implied the placement of this central part of the city into the bee path, which also begins at the University Botanic Gardens of Ljubljana and then spreads through different parts of the city. For this triangle, we then proposed a mahaleb cherry (*Prunus mahaleb* L.) (Bavcon & Ravnjak 2017 a, b). Whitebeam (*S. aria* (L.) Crantz) was proposed for planting in the park, which was given to the city by the Belinka company. We proposed this species to the company since the whitebeam was once milled as an addition to the flour and because it has white leaves below. This name is most consistent with the name of the company (Belinka is derived from white), which again belongs to the concept of our strategy (Bavcon & Ravnjak 2017 a, b).

For a smaller cutting down park with lower trees we proposed a European bladdernut (*Staphylea pinnata* L.). For a smaller market, where we needed enough shade and there was room for planting we proposed a European nettle tree (*Celtis australis* L.). It is most suitable because it satisfies given conditions and is again a species that is very drought-tolerant and persistent. When designing a small park by railway we preserved already existing trees growing on a neglected surface. We removed invasive species and trees that were in poor condition. Only park elements were added to the park. We proposed various solutions for other new emerging banks along the Sava River, which passes by the city. There we combined natural riparian vegetation, removing only damaged trees and some non-native species. Thus we established the original vegetation along the river. In one of the coastal towns, we proposed the planting of the evergreen oak (*Quercus ilex* L.) in the sunniest and windy parts of the city. Soon it turned out to be a very appropriate species. In the city of "Novo mesto" on the margin of the Sub-Pannonian part of Slovenia, we had to estimate the condition of already existing, quite damaged promenade and find a potentially more suitable type for replacement. We have chosen our domestic species (Bavcon & Ravnjak 2016). In addition to the concrete proposals, we also organized a workshop for workers who manage green surfaces where we especially highlighted the work with city trees. Moreover, we participated in various other consultations or workshops on this topic (Bavcon & Ravnjak 2015, Zanoški et al 2017).

DISCUSSION

In the past, very few tree species were planted in the cities, city parks were perhaps an exception. Only two to five species were used in tree lines and other public plantations. In the Habsburg Monarchy, which included today's Slovenia, horse-chestnut was very common. The horse-chestnut tree (*Aesculus hippocastanum* L.) is a Balkan species that came to Europe as a horticultural species in the 16th century thanks to Mathioli (Lack 2000). The species was first very popular in Istanbul and later it was planted massively in the Habsburg Monarchy, mainly due to its fine inflorescence, large and interesting leaves, and, last but not least, the fruit. Horse-chestnut tree-lines are still very common in Slovenia today. In the mid-nineties, horse-chestnut was attacked by a horse-chestnut leaf miner (*Cameraria ohridella* Deschka & Dimić), which severely aggravated the state of the trees. They began to lose most of the green leaves too fast. At the same time horse-chestnut was attacked by the fungus that causes leaf blotch disease (*Guignardia aesculi* (Peck) V. B. Stewart). Leaf miner and the fungus thus shorten the vegetation period for horse-chestnut, which is bad for young and old trees. (*https://www.forestry.gov.uk/pdf/horsechestnut.pdf/$FILE/horsechestnut.pdf*). We do not recommend the horse-chestnut tree today in new plantings for the above-mentioned reasons. Similarly, the genus of a plane tree (*Platanus* L.) is known from the old age as a tree for tree-lines, which was later planted in Europe a lot. In Ljubljana, we have two such very old plane trees, which are the remnants of the two-line avenue from 1744 (Šmid Hribar & Šubić 2010). Plane trees are no longer the most suitable trees for planting today, as they are also attacked by various diseases and insects (Pilotti 2002). Plane trees in Ljubljana are potentially planted only in places that are well-supplied with water and have enough space underground, which is rare in the city.

In the University Botanic Gardens of Ljubljana we follow diversity when choosing tree species, what allows us to create different microhabitats for different animals in the urban environment, as suggested by various authors across Europe and the world (Santomor 2002; Nowak 2002; Burden 2006; Eder 2006) and we have also specially treated this in the book by Šiftar et al. 2011. In our urban environment, we are planting our autochthonous species that are more suited to drought, what is also being pursued in other European cities (Eder 2006).

In the light of the population ageing in Europe and also in Slovenia it is extremely important that the urban environment becomes as friendly as possible for people. In the warm part of the year, however, the residence in the city must be endurable, and the trees surely offer this with their shade (Nowak 2002; Burden 2006; Šiftar et al. 2011; Bavcon & Ravnjak 2016). But in the winter there must be enough light. Therefore in our strategy in the vicinity of buildings and streets, we do not recommend planting evergreen conifers but planting deciduous tree species, which are also adapted to the dry conditions. When looking for suitable species, we relied on the ecological conditions that species have in nature and the space constraints in the city. We have selected the species of our karst - Sub-Mediterranean phytogeographical area - which are adapted to water shortages, high temperatures and at the same time exposure to cold and strong north wind. They are therefore also resistant to breaking branches in the wind what is just as important in cities. Ljubljana has a great advantage over many cities throughout Europe because nature is still preserved in the middle of the city. Today, the City of Ljubljana has 46% of forests and 75% of surfaces are green, of which 20% are protected. As much as 16.5% of the Ljubljana area is located in the Natura 2000 area (Čušin 2004, Ljubljana European Green Capital, 2016, *http://www.greenljubljana.com/, http://ec.europa.eu/environment/europeangreencapital/winning-cities/2016-ljubljana/*). Nevertheless, in the centre itself and in the most urbanised parts of the city there is always a lack of green spaces. Planting new trees on previously asphalt surfaces is a great contribution to the city. In doing so we create new islands of greenery in the city and these islands play an important role in the green network of the city that connects the city with nature. This is also noted by experts in different cities in Europe (Sukopp 2011; Ferakova & Jarolimek 2011; Crawley 2007, 2011; Godefroid 2011, *https://www.forestry.gov.uk/*). Trees positively affect various factors of the environment (Wolf 1998 d; Escobeado et al 2015 b) and even reduce crime (Kuo and Sulivan 2001 a, b). In such environments people are socializing more and staying in the public space.

Urban trees represent the main green infrastructure. Due to the lack of space in the cities, the growth of trees is lower in comparison with the species in the natural environment (Quigley 2004). For this reason on the most exposed parts of Ljubljana , where the lack of underground space is the most acute, we select the species from our Karst, what proved to be a good decision. In places where there were no trees before we created with planting a more friendly environment and the number of people who sit there leisurely or take a walk, has greatly increased. In addition to the new planting in the cities of Slovenia and Ljubljana, it is also important to take care of the old tree-lines. Today many tree-lines that were planted after the war or even later are in such a state that they need to be replaced. Many authors state that on average urban trees have the age of up to 60 years under the best conditions (Skiera and Moll 1992), otherwise the age is considerably shorter, from 19 to 28 years (Roman and Scatena 2011). Therefore, the inspection of the city trees and the proper planning of the restoration planting is necessary. Many formerly useful species no longer come into consideration. These are some invasive species such as elf maple (Acer negundo L.), which was planted in a large extent in some places. It is similar with a tree of heaven (Ailanthus altissima (Mill.) Swingle) and some other species like princesstree (*Paulownia tomentosa* (Thunb) Steud.) and cigartree (*Catalpa bignonioides* Walt.), which in cities are already becoming invasive. Therefore, it is better to switch to other species. At the same time, the reduced diversity of urban trees increases the chance of various diseases attack and lessens the possibility of adapting to climate changes (Johnston & Hirons 2014). Although in Central Europe more than 250 different species can be used in the green city infrastructure (Roloff et al. 2009), in many cities there is less than 5 species present and they represent 50 to 70% of all urban trees (Pauleit et al. 2002; Sæbø et al. 2005; Bühler et al. 2007; Jim 1987) or even just a few of these species represent over 80% of city trees (Breuste 2012). In North America, only two dominant genus are present in some cities (Raupp et al 2006). A few more species are present only in South Europe (Sæbø et al. 2005). All of the above mentioned points to the very high sensitivity of this green infrastructure since every new disease or pest that occurs on any one of these species can damage a significant part of the trees. The occurrence of disease on trees is not new. In the last few decades, the diseases attacked elms (*Ulmus* L.), then the horse-chestnuts (*A. hippocastanum* L.) and plane trees (*Platanus* L.). Despite illnesses, these species survived very well. New diseases are coming that attack common ash (Fraxinus excelsior L.) (Keßler 2012). Of course, any of the plant species is always a potential target for new diseases.

For this reason, the diversity of species in urban plantations is even more important. Greater plant diversity means the creation of different habitats, which represent a living space for different animals and this consequently means greater animal diversity. Trees in cities need to be selected according to the ecological conditions and according to the economic and social benefits for the citizens (Šftar 2001, Šiftar et al 2011). The choice of only naturally grown species implies that these species are less adapted to climate changes (Knox et al. 2008). Therefore, in Ljubljana and in the interior of Slovenia we strive to select drought-tolerant and heat-tolerant species for planting in the cities, which are still indigenous in Slovenia. These are species from the Karst (Sub-Mediterranean part of Slovenia), which are winter-hardy and at the same time highly adapted to drought.

REFERENCES

Anderson S.T., West S.E. (2006) Oen space, residential property values, and spatial context. Reg. Sci. Urban Econ. 2006, 36, 773–789.

Anon (2010) Benefits of green infrastructure. Report by forest research. Forest Research, Farnham

Bavcon J. & Ravnjak B. (2014) *Zasaditev dreves na Slovenski cesti: recenzija projekta*. Ljubljana: Botanični vrt Univerze v Ljubljani, Oddelek za biologijo, Biotehniška fakulteta, 12 pp.

Bavcon J. & Ravnjak B. (2015) *Urejanje mestnih zelenih površin : končno poročilo posveta*. Ljubljana

Bavcon J. & Ravnjak B. (2016) *Arboristično mnenje o stanju Kettejevega drevoreda v Novem mestu : končno poročilo.* Ljubljana: Botanični vrt Univerze v Ljubljani, Oddelek za biologijo, 2016. 31

Bavcon J. & Ravnjak B. (2017 a) Botanic gardens integration into city green policy. V: Ravnjak B. (ur.), Bavcon J. (ur.), Sharrock S. (ur.). *Autochthonous plants in the urban environment,* Slovenian second meeting of European Botanic Gardens Consortium with symposium, Ljubljana from 25. 5. to 29. 5. 2016. Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta. 2017, str. 15-28, ilustr.

Bavcon J. & Ravnjak B. (2017 b) *Botanični vrt v letu zelene prestolnice Evrope = Botanic gardens in the year of European green capital.* Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2017. 126 str.

Bavcon J. (2000) Botanični vrt v Ljubljani: "Vrt domovinske flore" = Botanical garden in Ljubljana: "Native Flora Garden". Ljubljana: Kmečki glas, 2000. 111 str., ilustr. ISBN 961-203-200-9.

Bavcon J. (2001) Zasaditev japonskih češenj. Vestnik, ISSN 0354-1517. [Tiskana izd.], 2001, letn. 32, št. 1-2, str. 18.

Bavcon J. (2010) *Botanični vrt Univerze v Ljubljani = University Botanic Gardens Ljubljana.* Ljubljana: Kmečki glas, 2010. 231 str.

Breuste JH (2012) Investigations of the urban street tree forest of Mendoza, Argentina. Urban Ecosyst 15:1–18

Bühler O., Kristoffersen, P., Larsen S. U. (2007) Growth of Street Trees in Copenhagen With Emphasis on the Effect of Different Establishment Concepts. Arboriculture & Urban Forestry, 33/5: 330-337.

Burden D. (2006) Urban Street Trees 22 Benefits Specific Applications. Glatting Jackson Wakable Communities INC 22pp. Located on-line at: http://www.walkable.org/download/22_benefits.pdf

Crawley M. (2011) London. Plants and Habitats of European Cities. Ed. Kelcey J. G. & Muller N. Springer.pp. 207- 236.

Crawley M. J. (2007) London In: Plants and Habitats of European Cities, Ed.: Kelcey J.G. & Muller N. Springer, pp. 131-170.

Čušin B. ed. (2004) Natura 2000 v Sloveniji. Rastline 168 pp.

Dahlhausen J., Biber P., Rötzer T., Uhl E. and Pretzsch H. (2016) Tree Species and Their Space Requirements in Six Urban Environments Worldwide Forests

Denman E., May P., Moore G. (2012) The use of trees in urban stormwater management. In: Johnston M, Percival G (eds) Trees, people and the built environment. Forestry commission research report. Forestry Commission, Edinburgh

DIN 18920. (2002) Vegetationstechnik im Landschaftsbau - Schutz von Bäumen, Pflanzenbeständen und Vegetationsflächen bei Baumaßnahmen: 6 str.

Eder E. (2006) An attempt to promote autochthonous plants in the City of Vienna, or How to combine science with local politics. Conference Paper · 4th European

Conference on Biological Invasions, Volume: BFN-Skripten 184, 107. Bonn, Germany: Bundesamt für Naturschutz

Ennos R. (2010) Urban cool. Physics World. August issue, 2–5

Escobedo F.J., Adams, D.C., Timilsina N. (2015 a) Urban forest structure effects on property value. Ecosystem Services, In Press, http://dx.doi.org/10.1016/j.ecoser.2014.05.002.

Escobedo F.J., Clerici N., Staudhammer C.L., Corzo G.T. (2015 b) Scio-ecological dynamics and inequality in Bogotá, Colombia's public urban forests and their ecosystem services. Urban For. Urban Green. 2015, 14, 1040–1053.

Escobedo F.J., Kroeger T., Wagner J.E. (2011) Uban forests and pollution mitigation: Analyzing ecosystem services and disservices. Environ. Pollut. 2011, 159, 2078–2087.

Ferakova V. & Jarolimek I. (2011) Bratislava In: Plants and Habitats of European Cities, Ed.: Kelcey J.G. & Muller N. Springer, pp. 131-170.

G. R. Dixon & D. E. Aldous (eds.) (2014) *Horticulture: Plants for People and Places*, Volume 2, 2014

Godefroid, S. (2011) Brussels. In: Plants and Habitats of European Cities, Ed.: Kelcey J.G. & Muller N. Springer, pp. 131-170.

Harris R. W., and Bassuk, N. (1993) Tree planting fundamentals. Journal of Arboriculture 19

Heisler G. M., Grant R. H. & Gao W. (2002) Urban tree influences on ultraviolet irradiance. In: Slusser, James R.; Herman, Jay R.; Gao, Wei, eds. Proceedings of SPIE: Ultraviolet ground- and space-based measurements, models, and effects: Volume 4482; 2001 July 30- August 1; San Diego, CA: 277-290.

Hewitt N., Stewart H., Donovan R. and MacKenzie R., undated. Trees and Sustainable Urban Air Quality, Research summary from Lancaster University at http://www.es.lancs.ac.uk/people/cnh/docs/UrbanTrees.htm

Hiemstra J., Schoenmaker E., Tonneijck A. (2008) Trees: relief for the city. Plant Publicity, Holland

Hrausky A., Koželj J., Prelovšek D. (2007) Jože Plečnik: Dunaj, Praga, Ljubljana. 1. ponatis. Ljubljana: Cankarjeva založba, 231 pp.

http://arnoldia.arboretum.harvard.edu/pdf/articles/1993-53-3-sustainable-trees-for-sustainable-cities.pdf

https://www.forestry.gov.uk/pdf/eng-casefortrees.pdf/$FILE/eng-casefortrees.pdf

https://www.forestry.gov.uk/pdf/horsechestnut.pdf/$FILE/horsechestnut.pdf

Jim CY. (1987) The status and prospects of urban trees in Hong Kong. Landscape and Urban Planning 14:1–20

Johnston M. and Hirons A. (2014) Urban Trees. Horticulture: Plants for People and Places, Volume 2.

Kane B. (2009) Value, Benefits, and Costs of Urban Trees. Virginia Cooperative Extension, Virginia state University 1-4.

Keßler M. (2012) Dieback of ash (Fraxinus excelsior and Fraxinus angustifolia) in Eastern Austria: Disease development on monitoring plots from 2007 to 2010. Journal of Agricultural Extension and Rural Development Vol. 4(9), pp. 223-226 Marion Keßler, Thomas L. Cech, Martin Brandstetter and Thomas Kirisits

Knox J., Weatherhead K., Kay M. (2008) Climate change impacts on water for horticulture. Environment Agency and Cranfield University, Cranfield

Kozlowski TT (1999) Soil compaction and growth of woody plants. Scand J For Res 14:596–619

Kuo FE. (2003) *The role of Arboriculture in a Healthy Social Ecology* [in] Journal of Arboriculture 29(3), pp 148 - 155

Kuo FE. and Sullivan WC. (2001 a) *Environment and Crime in the Inner City. Does Vegetation Reduce Crime* [in] Environment and Behaviour 33(3), pp 343- 367

Kuo FE. and Sullivan WC. (2001 b) *Aggression and Violence in the Inner City - Effects of Environment via Mental Fatigue,* [in] Environment and Behaviour 33(4), pp 543 – 571

Lack W. (2000) Lilac and Horse-Chesnut Discovery and Rediscovery. Curtis Botanical Magazine, 17(2): 109-137.

Livesley S.J., McPherson G.M., Calfapietra C. (2016) The Urban Forest and Ecosystem Services: Impacts on Urban Water, Heat, and Pollution Cycles at the Tree, Street, and City Scale. J. Environ. Qual. 2016, 45, 119–124.

Maljevac T., Simoneti M., Šiftar A., Bavcon J. (2010) *Pravila za ravnanje z mestnim drevjem v Mestni občini Ljubljana : zaključno poročilo o raziskovalni nalogi. I. del, Načrtovanje in izvedba. II. del, Smernice in standardi za kvalitetno vzdrževanje.* Ljubljana: [s.n.], 2010. zv. (114, 52 str.), graf. pril., ilustr.

McPherson E.G., Nowak D., Heisler G., Grimmond S., Souch C., Grant R., Rowntree R. (1997) Quantifying urban forest structure, function, and value: The Chicago Urban Forest Climate Project. Urban Ecosyst. 1997, 1, 49–61.

Monem N. K. (2007) Botanic Gardens a living history, London: Black dog publishing.

Mullaney J., Lucke T., Trueman S.J. (2015) A review of benefits and challenges in growing street trees in paved urban environments. Landsc. Urban Plan. 2015, 134, 157–166.

Nowak DJ. (2002) *The Effects of Urban Trees on Air*

Quality, USDA Forest Service, Syracuse, NY
Oldfield S. (2010) Botanic Gardens: Modern-Day Arks.
Pauleit S., Jones N., Garcia-Martin G., Garcia-Valdecantos J., LRivière LM., Vidal-Beaudet L., Bodson M., Randrup TB. (2002) Tree establishment practice in towns and cities-Results from a European survey. Urban For Urban Gree 1:83–96
Peper P.J., Alzate C.P., McNeil J.W., Hashemi J. (2014) Allometric equations for urban ash trees (Fraxinus spp.) in Oakville, Southern Ontario, Canada. Urban For. Urban Green. 2014, 13, 175–183.
Peurasuo P., Saarikko J., Tegel S., Terho M., Ylikotila T. (2002) Urban Tree Policy 2014 Helsinki
Pilotti, M. (2002) Main diseases of plane tree [Platanus spp.] (Istituto Sperimentale per la Patologia Vegetale, Rome (Italy))
Quigley MF. (2004) Street trees and rural conspecifics: will long-lived trees reach full size in urban conditions? Urban Ecosyst 7:29–39
Raupp MJ., Buckelew Cumming A., Raupp EC. (2006) Street tree diversity in Eastern North America and its potential for tree loss to exotic borers. Arboric Urban For 32(6):297–304
Roloff A., Korn S., Gillner S. (2009) The climate-species-matrix to select tree species for urban habitats considering climate change. Urban For Urban Gree 8:295–308
Roman LA., Scatena FN. (2011) Street tree survival rates: meta-analysis of previous studies and application to a field survey in Philadelphia, PA, USA. Urban For Urban Gree 10:269–274
Sæbø A., Borzan Z., Ducatillion C., Hatzistathis A., Lagerström T., Supuka J., García-Valdecantos JL., Rego F., Van Slycken J. (2005) The selection of plant materials for street trees, park trees and urban woodland. In: Konijnendijk CC., Nilssoon K., Randrup TB., Schipperijn J. (eds) Urban forests and trees. Springer, Heidelberg
Santomour, F. S. (2002) TREES FOR URBAN PLANTING: DIVERSITY UNIFORMITY, AND COMMON National Arboretum Agricultural Research Service U.S. Department of Agriculture Washington, D.C..
Scharenbroch B.C., Morgenroth J., Maule B. (2016) Tree species suitability to bioswales and impact on the urban water budget. J. Environ. Qual. 2016, 45, 199–206.
Šiftar A. (2001) Izbor in uporaba drevnine za javne nasade. ZTI- Zavod za tehnično izobraževanje, Ljubljana. 193 pp.
Šiftar A., Maljevac T., Simoneti M., Bavcon J. (2011) Mestno drevje. Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2011. 207 str.
Simoneti M. (2010) *Šmartinski park : zgodba o tem kako v mestu nastaja čisto nov park : Botanični vrt Ljubljana.* 17. nov.
Skiera B. & Moll G. (1992) The sad state of city trees. Am For (March/April):61–64
Šmid Hribar M., Šubic J. (2010) Platana 1 na Streliški ulici v Ljubljani. DEDI - digitalna enciklopedija naravne in kulturne dediščine na Slovenskem, http://www.dedi.si/dediscina/141-platana-1-na-streliski-ulici-v-ljubljani. Zato imajo pomembno vlogo Botanični Vrtovi s svojim znanjem in izobraževanjem
Strgar V. (1973) Botanični vrt univerze v Ljubljani. Kulturni in naravni spomeniki Slovenije 41. Založba Obzorje, Maribor.
Sukopp H. (2011) Berlin In: Plants and Habitats of European Cities, Ed.: Kelcey J.G. & Muller N. Springer, pp. 53-79.
Wolf K. (1998 a) *Trees in Business Districts - Positive Effects on Consumer Behaviour*, University of Washington College of Forest Resources, Factsheet #30.
Wolf K. (1998 b) *Trees in Business Districts - Comparing Values of Consumers and Business*, University of Washington College of Forest Resources, Factsheet #31.
Wolf K. (1998 c) *Urban Forest Values: Economic Benefits of Trees in Cities*, University of Washington College of Forest Resources, Factsheet #29.
Wolf K. (1998 d) *Urban Nature Benefits: Psycho-Social Dimensions of People and Plants,* University of Washington College of Forest Resources, Factsheet #1.
Xiao Q., McPherson E.G. (2016) Surface water storage capacity of twenty tree species in Davis, California. J. Environ. Qual. 2016, 45, 188–198.
Zanoški N., Tekstor V., Bavcon J., Bernard G., Hudoklin A., Ravnjak B., Simič M., Zelič Ž., Žitnik D. (2017) *Dihaj z mano: mestno drevje v Novem mestu. Novo mesto: Est=etika, društvo za vzpodbujanje etike v prostoru,* 2017. 39 str.
ZTV-Vegtra-Mü. (2008) Zusätzliche Technische Vorschriften für die Herstellung und die Einbau verbesserter Vegetationstragschichten. Landeshauptstadt München, Baureferat-Gartenbau: 24 str. www.bodeninstitut.de/files/ZTV-Vegtra_2008_Anhang1.pdf (januar 2010)

TABLES AND FIGURES

Figure 1: Planting hole

Figure 2: New planted main street in Ljubljana

Figure 3: Last renovation of streets in Ljubljana in 2018

SCIENCE CAFÉS AND FOOD SECURITY

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ABSTRACT

The trust and expectations that citizens have placed in science compromise scientists to communicate their results in a comprehensible and effective way to reach the public. Science communication has had to evolve and adapt to new communication trends in recent years. Thus, it has shifted from a one-way knowledge transfer model to a two-way dialogue model, which promotes participation, engagement and impact. In this sense, science cafés have become one of the most popular tools worldwide, being one of the main ones used in the European Big Picnic (Horizon 2020) project on engaging the public on food security. In this study, four science cafés carried out within this project and covering different aspects of food security (alternative supply chains, consumer decisions, food sovereignty and sustainable food) are presented. Our results indicate that: (1) science cafés are an ideal tool both to communicate science and to gather peoples' views on food security considering the high level of participation in the debates (from 59% up to 100%); (2) that there is a growing concern on food issues in our society, with citizens demanding better information about food processes and how to access higher quality food, as well as having more power to influence present market trends by enhancing local and organic production, and (3) that the peoples' interests and worries recorded around food are reflected on the United Nation's Sustainable Development Goals, with goals 12, 4 and 9 being the most relevant to the public. In conclusion, science cafés are an effective tool not only for outreach and communication, but also for research.

KEYWORDS

Science Communication, Outreach, Co-Creation, Public Debate, Sustainable Development Goals

INTRODUCTION

Science communicators face many challenges every day, from making science comprehensible to anyone, to engaging diverse audiences or causing impact. In an effort to make science communication and outreach more effective, science communication has emerged as a discipline which has evolved from a one-way transmission of knowledge model to more participatory and experiential engagement model, which makes a higher impact on individuals' decisions and behaviours than does the transfer of mere facts (Varner, 2014). Therefore, new and direct person to person communication tools have emerged over the past few decades; with science cafés having become one very popular tool worldwide (Cafe Scientifique, 2007).

Science cafés are events that usually take place in casual settings such as pubs and coffeehouses, they are open to everyone, and imply a face to face conversation with scientists about a particular topic. They welcome people who may or may not be familiar with scientific discussions, and are not club meetings for scientists.

The informal atmosphere encourages participation, creating a dynamic, two-way interaction between a scientist and the public. In this way, the public can make the most of this learning experience, and the scientist speakers can give a valuable and practical perspective on their own work. Furthermore, themes, venues and dynamics can be very flexible making science cafés a motivating communication tool for organizers of the event. Science cafés are one of the main tools used in the Big Picnic project (Horizon 2020) both to engage the public and to collect relevant data in food security.

Food security, that is, ensuring the availability of and access to sufficient safe and nutritious food, has become a key priority that impacts all citizens. Thus, the EU Horizon 2020 program has identified it as a major challenge to be addressed. The Big Picnic project (www.bigpicnic.net) comprises 15 countries working together to engage the public on food security. Through a co-creation approach and public debate, it aims to enable the public to understand and articulate their views to contribute to Responsible Research and Innovation (RRI) in the field of food security, with plants being the perfect guideline and botanic gardens a great meeting point for this purpose.

The present study analyses the results of four science cafés carried out in Madrid between 2017 and 2018 by the Spanish partners of the Big Picnic project, that is, the Royal Botanic Gardens of Madrid and Alcalá de Henares. The specific aims of this study were: (1) to gather information on peoples' interests and worries around food security, and (2) to link these results to the United Nations' Sustainable Development Goals (SDG), in order to contribute to the Responsible Research and Innovation (RRI) objective of the Big Picnic project.

MATERIAL AND METHODS

Co-creation of science cafés

Different formats of science cafés were designed and developed using a co-creation approach. BigPicnic partners use co-creation to develop exhibitions and events in collaboration with their communities and stakeholders, combining expertise to produce relevant and engaging activities on food security. This participatory process aims to create a shared ownership of the project, raising awareness and sensitivity beyond the scope of the project.

At the beginning of the project a co-creation session was held with an advisory group of experts on a wide range of subjects around food security (agriculture, environment, policies, industry, etc.). From this first session a series of hot topics emerged and provided the starting point for the subsequent materials, events and science cafés that were designed. Each science café was then co-created with different people (experts and general public) and took place in a diversity of scenarios, from the botanic gardens to a community centre and a university campus. The details of the science cafés reviewed in this study are summarized in Table 1.

Data Analysis

Participants' questions and comments were recorded, categorized, linked to the United Nations' Sustainable Development Goals (SDGs) and descriptively analysed using SPSS v.24.0

Title	**Alternative food supply chains, are they possible?**	**A decision in every spoonful: consumer choices**	**Food sovereignty**	**Sustainable food on the university campus**
Venue	Royal Botanic Garden of Madrid	Arganzuela Community Centre	Royal Botanic Garden of Madrid	University of Alcalá Canteen
Participants	6 speakers 36 participants	4 speakers 27 participants	1 speaker 25 participants	4 speakers 19 participants
Theme	New ways of accessing food, through short-chain distribution models (from producers to consumer).	Consumers' options in their decisions, taking into consideration: (1) production methods (organic vs. conventional); (2) guarantees in organic certifications; (3) participatory guarantee systems, and (4) consumer power on market trends.	The ecological and social footprint of a given sample of everyday products in order to raise awareness of their impact worldwide and the possible solutions to reduce it.	Reflecting on how and why we make the food choices we make and decide how to better food offer in the university campus.
Speakers description	A scientist on agroecology and rural development. A representative from: A food facilitator company. A consumer group. A production and selling social cooperative. An agricultural park. An association that groups together different direct-to-consumer initiatives.	A scientist on agroecology and rural development. A scientist in agronomy. A specialist in organic certifications An ecological produce	An expert on food sovereignty	University lecturer, expert in health and eating habits. A university lecturer, expert on food labelling. A university lecturer, expert on food and health. An association for sustainable food production. A representative of a Project on sustainable university campuses in Madrid. A fair trade organization. A food supplier.
Dynamics	Each speaker made a short presentation of their theme. People then wrote questions and comments for each speaker on provided papers. Discussions with each speaker took place in turns of 15 minutes in small groups.	The discussion started with the presentation of a series of striking news about food markets, which was used as an ice breaker. Speakers were initially anonymously seated among the public in a big circle, and were presented afterwards. People were asked to write questions at the beginning of the café which were then launched to the speakers, with new questions that arose during the debate.	This café followed the format of a workshop in which participants were distributed in small groups and had to discuss and analyze the ecological impact of some everyday products. Results were then presented to the rest of the group and all comments and questions were recorded.	Each speaker made a short presentation of their topic and participants were asked to write questions and comments on a board to contribute to the debate following.

Table 1: Description and characteristics of the Big Picnic science cafés in Madrid.

RESULTS

Participants at the four science cafés held in Madrid contributed to the debate with 202 questions and comments. The participation rate varied between 59 – 100% depending on the café, with the cafés on alternative food supply chains (100% participation) and food sovereignty (96% participation) being the most successful.

Participants in the first science café about alternative supply chains were mainly interested in the functioning of these models (25%) and how they could get involved (12%) (Fig. 1. SC1). Attending to the number of questions posed, the distribution models that received higher attention were the food facilitator company and the agricultural co-op (20% of all questions were on their organizational issues); but when it came to enrolling in these initiatives it was the food facilitator company and the consumer group that seemed more attractive to the participants (9% of all questions were on enrolling on these projects). Moreover, half the questions and comments fell in the categories of market trends, economic and social impacts of these type of supply chains (Fig. 1. SC1), with questions like "are there enough local producers to attend the growing demand?" arising.

Results of the second science café on consumers' elections and power showed that participants concerns focus on market trends, together with the possibility of changing them (37%), followed by the urge to learn more about all aspects of organic production and its guarantees for consumers (23%) (Fig. 1. SC2). In this sense, some participants pointed out that all the controversy on conventional vs. organic production is relatively modern since as they said "the world has being feeding organically until very recently".

In relation to sustainable food in the university campus participants pointed out that the reasons for our decisions and their reflection on university menus are mainly due to personal habits, consumers' lack of information and more global market trends (Fig. 1.SC3). Comments like "more awareness on the social impact of our decisions and not only of the feeding function is needed" illustrate these results.

Finally, the food sovereignty science café yielded results on becoming more conscious of what we eat, how it is produced and reducing excess packaging as a must (67%) (Fig. 1. SC4). "We should go back to consuming more locally" and "consume bulk products" were some of the opinions launched by participants to tackle these problems, as we become more and more aware of the

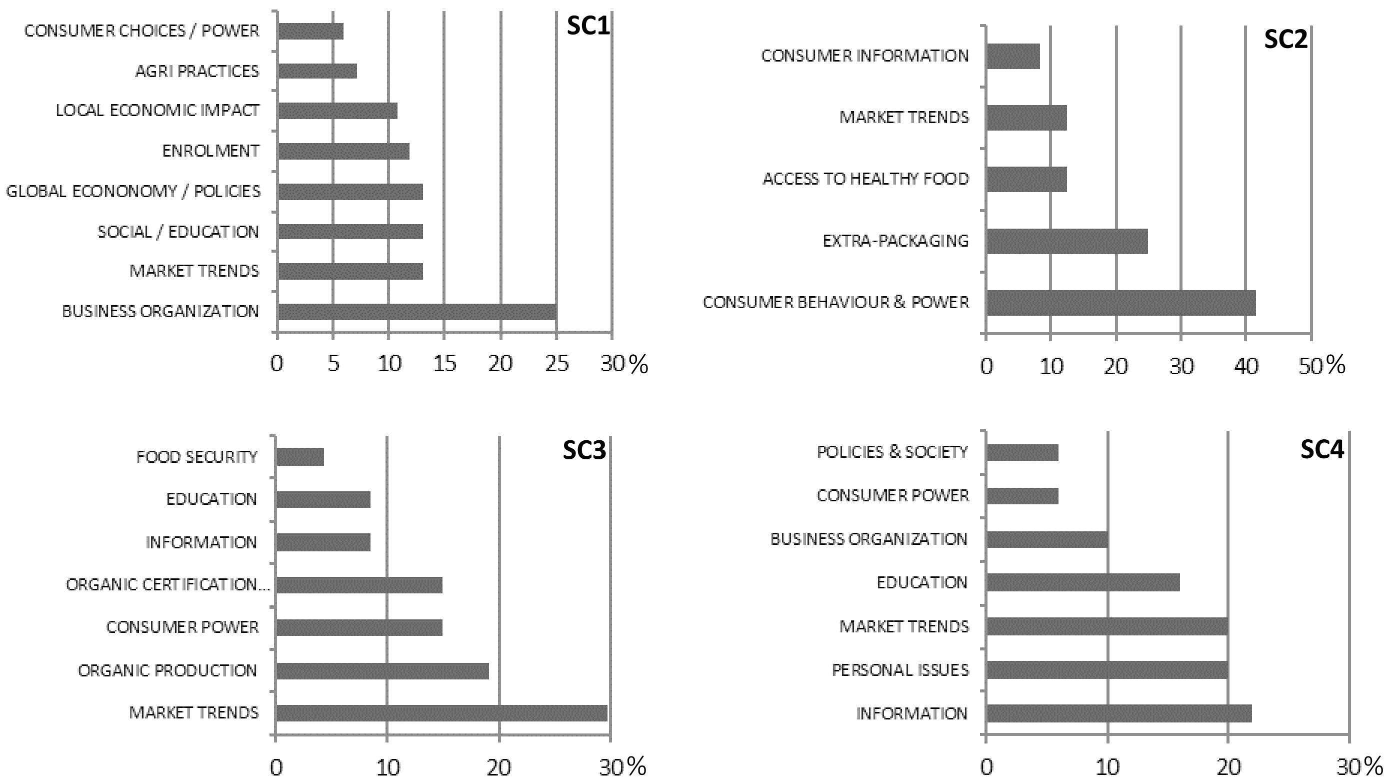

Figure 1: Percentage of categorized participants' questions and comments for the Big Picnic science cafés (SC1: alternative food supply chains; SC2: consumer decisions; SC3: food sovereignty; SC4: food in the university).

social and environmental effects of our decisions.

Overall, global results of all four science cafés suggest that citizens demand: (1) better information about food processes and how to access higher quality food, and (2) having more power to influence market trends. These results, which represent citizens' concerns on food security, align with the Sustainable Development Goals of the United Nations and specifically with the *Responsible Consumption and Production* goal (SDG 12) mainly, but also with the *Quality Education* (SDG 4) and the *Industry, Innovation and Infrastructure goals* (SDG 9).

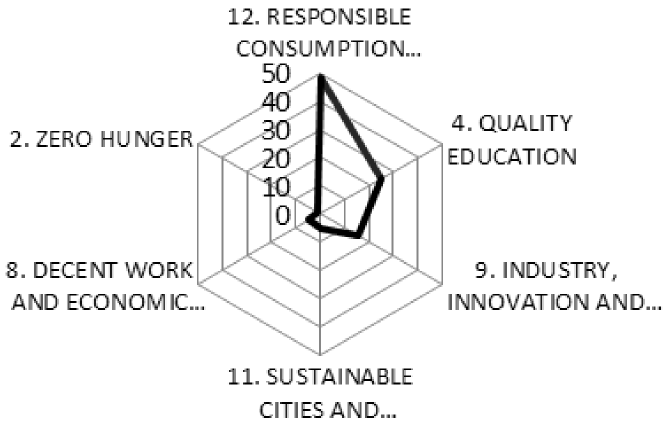

Figure 2: Percentage of partipants' questions and comments in relation to the Sustainable Development Goals.

DISCUSSION

Science cafés as a communication tool

The results from our four science cafés showed that this communication tool can be very effective to inform, engage and gather peoples' views, taking into account the high level of participation achieved (up to 100%). Science and technology are still valued positively in Europe and citizens expect a lot from scientific progress (Claessens, 2008). Therefore, communicating science has become a must to meet their expectations. Furthermore, communication has changed from being something optional to being planned and accounted for from the beginning of a project. In this sense, many research funding organizations, including the European Commission, now demand communication plans as part of funding applications (Riise, 2008). Under this scenario and taking into account the new options that have arisen with the Internet, new formats for science communication have had to be developed, with face-to-face events like science cafés having become very popular. Many institutions all over the world have implemented science cafés successfully in their communication scheme, and sometimes as part of larger events. Indeed, making the public take part in the interpretation of the message raises their interest (Lehr et al., 2007).

Food Security: views from the public

Results from science cafés provided us with an understanding of how a small sample of Spanish citizens view different aspects of the food security challenge. Citizens demand better information about what they eat and reliable ways to access safe and nutritious food. More and more consumers question food production practices in the food supply chain, since distances from the production origin have grown larger and become increasingly questionable sometimes (La Trobe & Acott, 2000). In addition, a number of food scandals have come to make things worse and have brought consumers to demand greater transparency and information on food origin (Feldmann, 2015). Thus, many consumers have turned towards more local food (Holloway et al., 2007). In the USA and Europe this has led some supermarket chains to start selling organic and local foods to meet consumer demands, and an increasing number of alternative food networks have emerged (Jones et al., 2004). These alternative models include short supply chains, alternative food networks, local farming systems or direct sales (Kneafsey et al., 2013b). Our results are congruent with these trends, showing that consumers are eager to get access to more naturally produced food, but sometimes lack the adequate information. Furthermore, many Spanish citizens are still not aware of these new alternatives and very often their willingness to pay for organic and local food is low (Soler et al., 2002). For this reason, our first science café on alternative food supply chains aimed at introducing citizens to new alternatives to access local and organic products that would better fit their way of life; whereas our café on consumers' choices pretended to reconnect producers and consumers, by promoting proximity and reliability on agricultural practices and food production.

Food choices are an empowering tool for consumers. However, the more developed and urbanized a country is it becomes more disconnected to producers, less aware of the impact of our food choices and seem less interested in making a change (Oxfam, 2014). In this sense, participants in our science cafés were highly concerned about global market trends and the possibility of changing them, although some had the tragic perception that citizens only react when a scandal arises in the news. But it is not only corporations and governments that have power over the system. Consumers, with their everyday actions of buying, cooking and eating food are more powerful than we might think. When, together, we say we want this rather than that, we become a force that can trigger the system to meet our demands. Consumers play an important role in food security, by driving demand for high quality, low cost food (Kneafsey et al., 2013a). Furthermore, in the last decades the Internet has increased consumer power in comparison with that of previous times over traditional markets, because (a) it overcomes many information asymmetries that characterize traditional consumer markets and thus provides higher levels of market transparency, (b) allows individuals to associate against companies, and (c) to take on a more active role in the value chain by influencing products and prices based on individual preferences (Rezabakhsh et al., 2006)

Sustainable Development Goals

In 2015, world leaders gathered at the UN to adopt 17 Sustainable Development Goals to set the way to achieve several crucial world objectives by 2030: end poverty, promote prosperity and well-being for all, and protect the planet (United Nations, 2015). These goals aim to promote action from all sectors across the world (governments, businesses, foundations, academics, civil society groups, entrepreneurs, etc.). Furthermore, the proposed goals and targets can be seen as a network, in which links among goals exist through targets that refer to multiple goals (Griggs et al., 2013).

By creating measurable goals, we can keep track of where we are doing well and where we need to do better. For this reason, many people have highlighted the importance of improving data collection and use around the world. The data collected from the public via our science cafés showed that their interests and worries are reflected in the Sustainable Development goals. More specifically, peoples' views on food security fall in the *Responsible Consumption and Production* goal (SDG 12) mainly, but also with the *Quality Education* (SDG 4) and the *Industry, Innovation and Infrastructure* goals (SDG 9) (Fig. 2). Attempts at policy integration across areas will have to be based on further studies of the biophysical, social and economic systems at appropriate scales (Le Blanc, 2015).

CONCLUSION

In conclusion, science cafés have proved to be an ideal tool both to communicate science and to gather peoples' views on food security. There is a growing concern on food issues in our society, with citizens demanding better information about food processes and how to access higher quality food, as well as having more power to influence present market trends by enhancing local and organic production. Therefore, peoples' interests and worries around food are reflected on the United Nation's Sustainable Development Goals, with goals 12 (*Responsible Consumption and Production*), 4 (*Quality Education*) and 9 (*Industry, Innovation and Infrastructure*) being the most relevant to the public, in order of importance. In conclusion, science cafés can be an effective tool not only for outreach and communication, but also for research.

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REFERENCES

Cafe Scientifique. Organisers' Conference (2007): Online: http://www.cafescientifique.org/attachments/article/263/conference%20report.pdf (accessed July 2018)

Claessens M.(2008) *'European Trends in Science Communication'.* In: Cheng D., Claessens M., Gascoigne T., Metcalfe J., Schiele B., Shi S. (eds.). Communicating Science in Social Contexts. New models, new practices. Springer Science & Business Media, 320 pages

Feldmann C., Hamm U. (2015) 'Consumers' perceptions and preferences for local food: A review'. Food Quality and Preference 40:152–164

Griggs D., Stafford-Smith M., Gaffney O., Rockström J., Öhman M.C., Shyamsundar P., Steffen W., Glaser G., Kanie N., Noble I. (2013) *'Policy: Sustainable development goals for people and planet'.* Nature 495:305–307

Jones P., Comfort D., Hillier D. (2004) *'A case study of local food and its routes to market in the UK'.* British Food Journal 106(4): 328-335

Kneafsey M., Dowler E., Lambie-Mumford H., Inman A., Collier R. (2013)a *'Consumers and food security: Uncertain or empowered?'* Journal of Rural Studies 29:101-112

Kneafsey M., Venn L., Schmutz U., Balázs B., Trenchard L., Eyden-Wood T., Bos E., Sutton G., Blackett M. (2013)b *'Short Food Supply Chains and Local Food Systems in the EU. A State of Play of their Socio-Economic Characteristics'.* JRC Scientific and Policy Reports. Publications Office of the European Union.

La Trobe H.L., Acott T.G. (2000) *'Localising the global food system'.* International Journal of Sustainable Development & World Ecology 7(4): 309-320

Le Blanc D. (2015) *'Towards Integration at Last? The Sustainable Development Goals as a Network of Targets'.* Sustainable Development 23: 176-187

Lehr J.L., McCallie E., Davies S.R., Caron B.R., Gammon B., Duensing S. (2007) *"The value of "dialogue events" as sites of learning: An exploration of research and evaluation frameworks"*. International Journal of Science Education 29: 1467-1487

Rezabakhsh B., Bornemann D., Hansen U., Schrader U. (2006) *'Consumer Power: A Comparison of the Old Economy and the Internet Economy*' . Journal of Consumer Policy 29:3–36

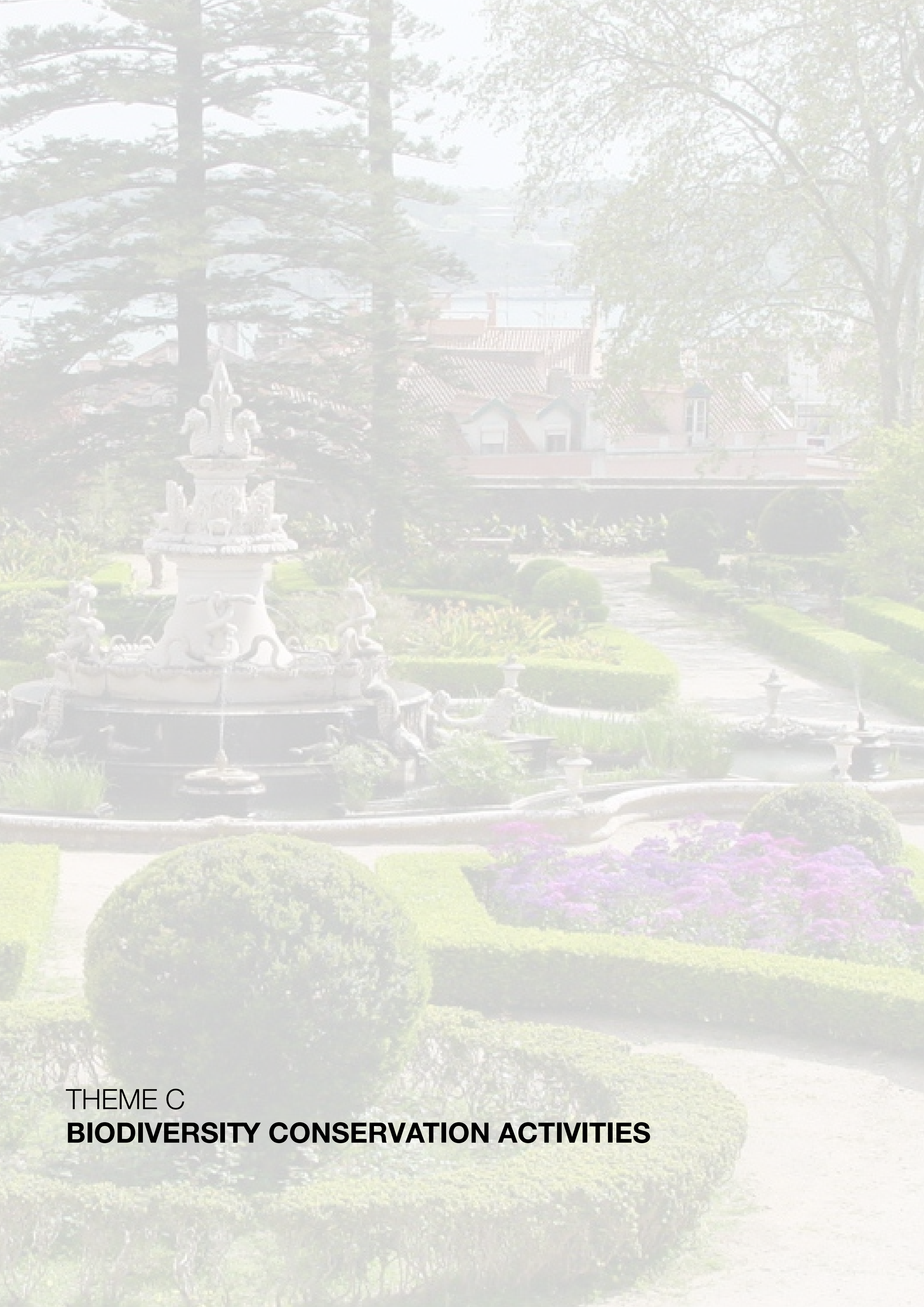
Riise J. (2008) *'Bringing Science to the Public'*. In: Cheng D., Claessens M., Gascoigne T., Metcalfe J., Schiele B., Shi S. (eds.). Communicating Science in Social Contexts. New models, new practices. Springer Science & Business Media, 320 pages

Soler F., Gil J.M., Sánchez M. (2002) *'Consumers' acceptability of organic food in Spain: Results from an experimental auction market'*. British Food Journal 104(8): 670-687

United Nations. Sustainable Development Goals (2015) Online: https://www.un.org/sustainabledevelopment/sustainable-development-goals/ (accessed July 2018)

Varner J. (2014) *'Scientific outreach: toward effective public engagement with biological science'.* Bioscience 64:333–340

VV.AA. (2014) *'The food transformation. Harnessing consumer power to create a fair food future'*. OXFAM International Report.



THEME C

BIODIVERSITY CONSERVATION ACTIVITIES

DEVELOPING AND IMPLEMENTING AN EFFECTIVE PLANT CONSERVATION PROGRAM FOR INDIVIDUAL BOTANIC GARDENS

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ABSTRACT
The Global Strategy for Plant Conservation (GSPC) of the U.N. Convention on Biological Diversity provides a valuable framework to guide the plant conservation priorities and actions of each botanic garden. While the GSPC was created to provide an international over-arching plan for plant conservation through governments, nevertheless it has become an important reference point for the individual actions of numerous institutions, including botanic gardens. Some specific targets of the GSPC may be more important for different botanic gardens than for others, it is important that each botanic garden should consider their own institutional priorities and responses to local, national and international plant conservation needs. This will help them to determine where their resources can be best used and help to ensure that the work of the botanic garden is coordinated effectively, rather than relying on any ad hoc approach where different staff and departments are responding or acting individually. Building a clear and coherent response to plant conservation needs into the botanic garden's strategic plan will also be a valuable approach.
This paper draws on examples of the plant conservation work of the Missouri Botanical Garden. The aim is to illustrate the approaches to plant conservation challenges being applied throughout the institution, through different departments, especially in horticulture, research, education and sustainability. The important and unique roles of botanic garden horticulture are highlighted, including the need for the development of exemplary data recording systems, documenting cultivation and propagation protocols for threatened species and implementing a planned approach to secure the most threatened priority plants in conservation programmes. New and innovative methodologies in conservation biology research can also help to guide the achievement of valuable conservation results, helping to understand why particular species are threatened and what factors need to be overcome if species are to be conserved effectively. Some opportunities and strategies for raising funds and attracting resources for plant conservation programmes in individual botanic gardens are also considered.

KEYWORDS
Plant Conservation, Botanic Gardens, Strategic Planning

INTRODUCTION

Over the last few decades, botanic gardens worldwide have increased their involvement in plant conservation very considerably so that today there are few regions anywhere in the world where botanic gardens are not yet contributing effectively to implementing plant conservation actions (Wyse Jackson and Sutherland, 2017; Wyse Jackson and Sutherland, 2000). They have been encouraged and supported in this by the development of major new international, national and other initiatives, including the Global Strategy for Plant Conservation (GSPC) of the U.N. Convention on Biological Diversity (CBD), national biodiversity strategies and action plans (that are in place for most Parties to the CBD), as well as through a wide variety of regional and local plant conservation efforts. These all provide a valuable global context for each individual botanic garden's commitment to plant conservation. The GSPC has also provided an important framework for the specific plant conservation activities of each individual botanic garden.

Today the botanic garden provides a remarkable and unrivaled global community and worldwide network of institutions supporting plant conservation. While it is fully recognized that there is a huge task to undertake if the world's plant species and their diversity are to be safeguarded, and that botanic gardens cannot achieve success all on their own, nevertheless we must be optimistic that the commitment, experience, resources and expertise of botanic gardens for plant conservation can help to ensure that many, if not most, of the world's tens of thousands of 'at risk' plant species can be conserved with botanic gardens' support and involvement.

While the work of any botanic garden in plant conservation will vary greatly, based on current conservation needs and priorities, and available resources, most botanic gardens incorporate conservation activities, including *ex situ* conservation of rare plant species or those at risk of extinction and plant conservation education and awareness raising activities. Other botanic gardens include aspects of *in situ* conservation as well, such as managing nature reserves, other plant habitats and wild plant populations, monitoring threatened species, species recovery activities and ecological restoration. Some botanic gardens too have active programs in research relevant to plant conservation, including conservation biology, taxonomy, phenology, conservation genetics, restoration ecology, invasive species control, and other areas. In this paper some elements for a successful plant conservation programme in an individual botanic garden are suggested, illustrated with examples and experiences from the Missouri Botanical Garden.

The Global Strategy for Plant Conservation

As pointed out already, the Global Strategy for Plant Conservation (GSPC) provides a valuable framework for any individual botanic garden to use to guide its responses to plant conservation needs. The GSPC was first adopted by the Parties to the Convention on Biological Diversity at its 6th Conference of the Parties (COP) held in The Hague, Netherlands on 19th April, 2002. It was subsequently updated for the period 2011–2020 on 29th October 2010 in Nagoya, Japan. The GSPC incorporates a concise framework of objectives and targets which aim to halt the loss of plant diversity worldwide by 2020. Its five objectives are as follows:

1. Plant diversity is well understood, documented and recognized; (3 targets)
2. Plant diversity is urgently and effectively conserved; (7 targets)
3. Plant diversity is used in a sustainable and equitable manner; (3 targets)
4. Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on Earth is promoted; (1 target)
5. The capacities and public engagement necessary to implement the Strategy have been developed. (2 targets)

The GSPC incorporated 16 targets, of which botanic gardens have been identified as primary stakeholders in the achievement of 50% of the targets, but botanic gardens can and do contribute to progress made in all 16 targets.

Objective	Target
Objective I: Plant diversity is well understood, documented and recognized	Target 1: An online flora of all known plants.
	Target 2: An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action.
	Target 3: Information, research and associated outputs, and methods necessary to implement the Strategy developed and shared.
Objective II: Plant diversity is urgently and effectively conserved	Target 4: At least 15 per cent of each ecological region or vegetation type secured through effective management and/or restoration.
	Target 5: At least 75 per cent of the most important areas for plant diversity of each ecological region protected with effective management in place for conserving plants and their genetic diversity.
	Target 6: At least 75 per cent of production lands in each sector managed sustainably, consistent with the conservation of plant diversity.
	Target 7: At least 75 per cent of known threatened plant species conserved *in situ*.

Objective II: Plant diversity is urgently and effectively conserved	Target 8: At least 75 per cent of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.
	Target 9: 70 per cent of the genetic diversity of crops including their wild relatives and other socio-economically valuable plant species conserved, while respecting, preserving and maintaining associated indigenous and local knowledge.
	Target 10: Effective management plans in place to prevent new biological invasions and to manage important areas for plant diversity that are invaded.
Objective III: Plant diversity is used in a sustainable and equitable manner	Target 11: No species of wild flora endangered by international trade.
	Target 12: All wild harvested plant-based products sourced sustainably.
	Target 13: Indigenous and local knowledge innovations and practices associated with plant resources maintained or increased, as appropriate, to support customary use, sustainable livelihoods, local food security and health care.
Objective IV: Education and awareness about plant diversity, its role in sustainable livelihoods and importance to all life on earth is promoted	Target 14: The importance of plant diversity and the need for its conservation incorporated into communication, education and public awareness programmes.
Objective V: The capacities and public engagement necessary to implement the Strategy have been developed	Target 15: The number of trained people working with appropriate facilities sufficient according to national needs, to achieve the targets of this Strategy.
	Target 16: Institutions, networks and partnerships for plant conservation established or strengthened at national, regional and international levels to achieve the targets of this Strategy.

Table 1: The GSPC Objectives and the 16 targets for the period 2011-2020.

The Sustainable Development Agenda

The 2030 Sustainable Development Agenda, and the Sustainable Development Goals that the Agenda incorporates, was adopted by the United Nations in 2015 also provides a valuable overarching framework to enable plant conservation to be included in a broader developmental framework. The Sustainable Development Goals (SDGs) have become the successors to the Millennium Development Goals (MDGs). They include 17 Goals and 169 targets and recognize the inter-relationships between human development and environmental, economic, social and political context. While plant conservation is relevant to the achievement of many of the SDGs, one in particular, SDG 15 'Life on Land' is particularly relevant to plant conservation (Sharrock and Wyse Jackson, 2017). This goal aims to address the sustainable management of forests, combat desertification, halt and reverse land degradation and halt the loss of biodiversity. The Sustainable Development Agenda and its SDGs are expected to shape government actions in the future and it is therefore crucial that botanic gardens should align their efforts in plant conservation with sustainable development concerns and this global agenda. Indeed, it is expected that the post-2020 global biodiversity framework that is currently being negotiated through the CBD will also be closely associated with the SDGs.

Background to the Missouri Botanical Garden and its role in plant conservation

The Missouri Botanical Garden was opened in 1859 by its founder, Henry Shaw, an English merchant who settled in St Louis, Missouri in 1819 and created the Garden after his retirement at the age of 40. The Garden is one of the oldest botanic gardens in the United States and, since its creation, it has developed and maintained important collections (living collections, herbarium and library). Currently the living collections include over 17,000 taxa and the herbarium has incorporated in excess of 7.5 million preserved specimens. Other collections include a seed bank with over 2,000 accessions, a DNA bank with 26,000 accessions and a biocultural collection with approximately 1,850 items included. The Garden is visited by over one million people each year, and has the following mission: *to discover and share knowledge about plants and their environment in order to preserve and enrich life*. The Garden has had extensive programmes in botanical research, notably in tropical botany, for many decades and has been and continues to be a leading institution especially involved in plant systematics and taxonomy. Recent projects have included major contributions to the Flora of China, Flora Mesoamericana, the Flora of North America, the Flora of Costa Rica, and many more projects particularly in Africa, Madagascar and Latin America.

The conservation programmes of the Garden have expanded in recent years, especially with the establishment and growth of a dedicated Center for Conservation and Sustainable Development (CCSD) within the Garden that includes research focus on species and population biology of threatened and rare plant species in the U.S. and internationally, ecological restoration, conservation genetics and climate change. Conservation has continued to be an important theme at the Missouri Botanical Garden and in recent years a significant expansion has been put in place to mainstream plant conservation into all of the Garden's activities. The Garden's Strategic Plan adopted in 2015 includes plant conservation and its first Strategic Objective, closely aligning itself with the GSPC and supporting a growing focus on practical conservation measures being implemented in the region, in the U.S. and worldwide.

Priority tasks at the Missouri Botanic Garden in conservation include:

- Securing the knowledge base – support for the development of the 'World Flora Online' to implement Target 1 of the GSPC. The Garden provides leadership and is active with a wide range of international partners, many of them botanic gardens, towards the achievement of the GSPC goal of having a comprehensive Flora of the World online by 2020 to provide a baseline of knowledge of the world's plants that can be used to guide plant conservation efforts and an understanding of global plant diversity. The World Flora Online (WFO) portal is available at www.worldfloraonline.org.
- Strengthening the conservation base of living plant collections – growing an increasingly important and diverse *ex situ* conservation collection – today (September 2019) the Garden manages a total of 1,350 species that are at risk of extinction in the wild. The Garden had previously set a target to achieve 700 threatened plants in the Garden's living collections by 2020 but had already gone way beyond that figure by 2018. This activity is designed to make major contributions to the achievement of GSPC target 8 on *ex situ* conservation.
- The establishment of a new Conservation Genetics Laboratory and program (Edwards and Wyse Jackson, 2019). Understanding the genetic diversity of threatened plant species and their surviving populations is often a key to conserving many species effectively and comprehensively.
- Creation of a new Seed Bank – the primary focus of the Seed Bank is on conserving the diversity of plant species in the State of Missouri and surrounding regions of the U.S. Midwest. However, seed accessions from other regions of the world in which the Garden has active collaborative research and conservation programmes are also included.
- Building a 'state of the art' Botanic Garden Plant Records and Management System – This system, a computer-based 'Living Collections Management System' (LCMS), has continued to expand since it was created in the years since 2011, includes a database that has the capacity to prepare comprehensive summaries and analyses of the living collections at any time, as required to track data on all accessions in the living collections. The LCMS is web-enabled and users can locate any individual accessions in the collection on its website and so use it to explore the collection themselves.
- Increasing a focus on species recovery and ecological restoration – for example, the Garden maintains a 2,400 acre / 970 Ha 'Shaw Nature Reserve', situated 30 miles (48 km) west of the main botanic garden campus. The purposes of this Reserve are to 1) support nature-based environmental education, 2)

promote native plant horticulture and 3) provide a living outdoor laboratory on ecological restoration. The Reserve includes a diverse landscape of native, restored and created tallgrass prairies, woodlands, glades (rocky grasslands) and wetlands. A native plant display garden, the Whitmire Wildflower Garden, includes c.600 species and aims to promote the use of native plants in home gardens, restoration projects and ornamental horticulture.

Elements of a successful institutional commitment to plant conservation

The achievement of an effective institutional commitment to plant conservation requires very careful planning, resourcing and implementation. Some of the key elements for developing an institutional response to current and future plant conservation challenges, commitments and responsibilities may be developed under the following categories.

1. Strategy – developing the commitment within the framework of a strategic plan for the institution/ organization and determining the strategic objectives.
2. Planning – ensuring that the institution's strategic objectives are elaborated within a carefully determined planning framework that highlights resource needs (including funding required and available), staff responsibilities, timelines, metrics and targets and reporting feedbacks.
3. Priorities – setting priorities, achieving across-institutional support for these priorities and allocating resources to the top priorities.
4. Resourcing – ensuring that funds, facilities and capacity are in place to achieve the strategic objectives.
5. Understanding – building a knowledge base to support the plant conservation needs, including information management tools and research on related conservation biology.
6. Implementation – carrying out the plant conservation projects identified and planned in an efficient and timely manner.
7. Collaboration – establishing the collaboration needed for the successful delivery of institutional projects within the institution, between research, horticulture and educational departments. It is always important to create or strengthen partnerships with other external bodies, such as land-managing agencies, funding sources, community groups, the media, etc. Also essential is putting in place any permits and securing permissions required, including for import, export of plant material and collecting, prior informed consents and material transfer/acquisition agreements.

Growing a living collection to meet conservation priorities

Most well established botanic gardens include legacy collections of living plants assembled in an often ad hoc manner from diverse sources. Sometimes these have been derived from, for example i) commercial sources; ii) received through exchanges with other botanic gardens; iii) accumulated as a result of research projects or special interests of the staff or others associated with the Garden; iv) collected to meet some particular educational purpose, or through a wide variety of other means. While these ad hoc collections have often resulted in remarkable and valuable assemblages of plants, nevertheless this approach is rarely effective in ensuring that all the plants are included that are needed for a comprehensive collection for conservation purposes. Planning and implementing a coherent living collections policy for many botanic garden is, somewhat surprisingly, a rather recent development. Nevertheless, for several decades most botanic gardens have realized the importance of maintaining a good record system to record the names, provenance (including wild origin where known) and locations in the Garden. This is the essence of what is a genuine 'botanic garden', separating it in form and function from a park or amenity display garden where such records are rarely maintained. Today we realize that exemplary record-keeping and the tracking of accessions is an essential part of managing a living collection for species conservation.

Since 2011 the Missouri Botanical Garden has developed its computer-based Living Collections Management System (LCMS) as a tool for such tracking and management of the Garden's living collections. This custom built system is maintained as a web-based SQL database, integrated with the Garden's Tropicos database (which provides the essential taxonomic backbone for all records) (www.tropicos.org) and using data mapped in ESRI's (Environmental Systems Research Institute) ArcGIS software to manage all geographic data (both in the Garden and to map the origins of the material in the wild or from other sources). Since the LCMS is web-based, data can be retrieved, mapped or managed with a variety of internet-connected devices, such as smartphones, tablets and desktop devices. This allows users, including the horticultural staff managing the collection, to have immediate and easy access to data. The LCMS system also incorporates labelling for all accessions, including embossed labels that include the accession number, the plant name and the collector's name and number. Identifications and verifications of all plants in the collection are undertaken by the horticultural and scientific staff of the Garden and herbarium voucher specimens are made to provide a long-term record of the identity of the plant material. The names of those people verifying each specimen is recorded. Interpretative labels are also used for many plants, the simplest of which include the scientific and vernacular names, the native distribution of the species/taxon and the family to which it belongs. These labels are made in the Garden from UV stable micro-surfaced impact acrylic (2-ply matte finish, 1/16 inch thick) and are engraved with a laser engraver. The labels are generated from data directly exported from the LCMS system. Other more extensive interpretative labels are also widely used in the Garden that illustrate specific information with several paragraphs of text about particular plants or Garden features and they generally include an image.

A key part of the Missouri Botanical Garden's collections policy is to have rigorous prioritization of all new species acquisitions, to meet specific priorities. Foremost amongst these are to focus on plants of conservation concern, especially those that are threatened, rare or endangered, where the institution can assist with conservation efforts. Plants of conservation concern that are widely cultivated or included in many other collections are therefore not regarded as a priority.

Some priorities for new species acquisitions at the Garden are:

- Specific targeted collections where the Garden has a particular interest or expertise;
- Materials that comes from wild sources, where detailed collection data are available;
- Threatened and endangered species, particular those that have not been included in other conservation collections;
- Where the material meets geographic and taxonomic interests, such as locally in the U.S. mid-west and from countries where the Garden has close partnerships, active research programmes and strong links;
- Material that is of value for the Garden's decorative and horticultural displays;
- Plant species that are hardy in the St Louis region;
- Plants that are not invasive, especially in the current or projected Missouri climate.

The Garden aims to use extensive research and data to drive priorities. For example, to identify taxa in need of conservation, data derived from IUCN and national Red Lists are used extensively, including valuable conservation status data from BGCI's ThreatSearch (https://tools.bgci.org/threat_search.php). To alert the Garden to potential invasiveness, a wide range of invasive species lists have been reviewed and incorporated into the LCMS system, to ensure that invasive species or their near relatives are not grown. Floras, other floristic accounts and inventories from many parts of the world form valuable sources for the development of targeted list of potential plants to include in new conservation programmes.

The following are some of the data sets and methods that are consulted or utilized by the Missouri Botanical Garden in identifying priorities for adding new plants to the living collections for conservation purposes:

- Floras
- Inventories
- Weather/climate data
- Distribution data
- Ethnobotanical data
- Cultural data
- Gardening data
- Endemic species lists
- Libraries
- Checklists
- Catalogues
- Legislation
- Plant trials
- Cultivar registrations
- Plant hardiness
- Pests and diseases
- Phenological data
- Atlases
- Herbaria
- Journals
- Surveys
- GAP Analysis

BGCI's PlantSearch (https://tools.bgci.org/plant_search.php) provides a valuable source of data for determining whether a species or taxon is one that should be considered for inclusion in the Garden's *ex situ* conservation programme. This database provides extensive information on the whereabouts of each particular taxon in other *ex situ* collections (living collections and seedbanks). In general, we aim to target species only that are currently known in less than five other *ex situ* collections. We hope that this will result in enhancing conservation for species and other taxa that have been neglected or overlooked to date and help to fill gaps. We also believe that collection planning should extend beyond reviews of one's own institution, to take account of the efforts and collections of other botanic gardens, to avoid duplication and to promote close collaboration in meeting shared or complementary objectives.

Another BGCI tool, the GlobalTreeSearch (https://tools.bgci.org/global_tree_search.php), is a unique source of information on tree distributions. It currently includes data on the distribution of over 60,000 trees. Using such data we can generate lists of target species automatically from our database.

It should be noted that investing in wild collected material of high value for conservation purposes requires much more time than securing plants from commercial sources. However, wild material is generally of much greater value for conservation than material that can be obtained from commercial sources, and indeed often better than material sourced through the international Index Seminum seed exchange scheme. Figure 1 shows the relative time involved in bringing new material into a Garden from these different source categories.

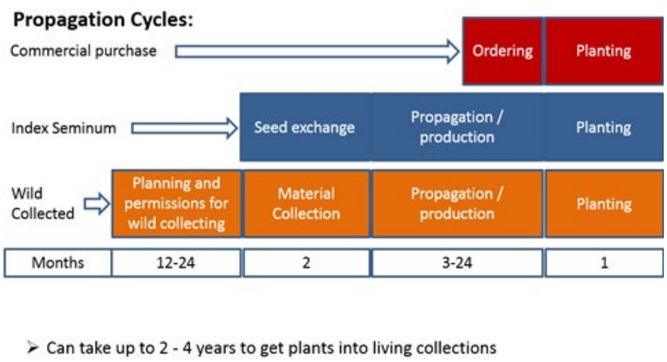

Figure 1: *Source: Andrew Wyatt, 2018, unpublished*

Collecting material from the wild is generally very complex, not only in locating and securing plants and propagation material but also in obtaining appropriate permissions to allow the collecting of plants from wild sources. It is essential that botanic gardens give due attention to building partnerships with the relevant authorities and other agencies who can give permission for collecting, especially when this includes the export and import of material across national boundaries. Botanic gardens should NEVER collect material from other countries without having first received written permissions and prior informed consent from the correct and appropriate authorities. Furthermore, the collection of conservation material should be undertaken wherever possible with close partner institutions in the country or region where the plant species occur. In this way it should be possible to establish multi-site and multi-purpose collections, notably including *ex situ* collections in the country of origin. This approach ensures also that botanic gardens fully comply with the provisions of the U.N. Convention on Biological Diversity and its Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization.

Plant Conservation and Sustainable Development

As noted above, the adoption of the 2030 Sustainable Development Agenda, and the Sustainable Development Goals provide new opportunities for botanic gardens to establish links between their plant conservation activities and sustainable development activities, particularly at local and community levels (Sharrock and Wyse Jackson, 2017). Habitat losses and pressures on wild plant populations are often derived from unsustainable socio-economic impacts and so conservation of wild plants and their habitats can rarely be achieved without seeking to address these indirect human influences.

The Missouri Botanical Garden has maintained an extensive research and conservation programme in Madagascar for several decades (Fathman, 2013). A key component of this work involves working at community levels with local people to establish and manage important conservation areas, which the Garden has helped to identify as crucial for safeguarding important plant habitats and plant diversity. The Garden is currently active in assisting local communities to manage 13 sites, amounting to 515,000 acres (208,413 ha). These sites contain an estimated 3,500 plant species (one quarter of the flora of Madagascar), including 52 plant species that are unknown outside of these sites. In addition to plant conservation importance, these sites are also valuable opportunities for the conservation of other biodiversity too. For example, a total of 32 lemur species have been recorded in these conservation sites. The community partnerships are only successful if local people are closely involved in all aspects of the management of these sites and gain substantial benefits from them. For example, in the Garden's Madagascar work, local people are hired to assist in the management of the sites, including establishing and maintaining fire-breaks, removal of invasive species, providing guides for tourists, operating nurseries and implementing ecological restoration projects. A wide variety of projects that seek to involve the lives of the local people involved in these sites are implemented too and have included assistance in building schools and health centers, crop irrigation projects, agroforestry training, ecotourism initiatives, duckling distributions, establishing school fruit and vegetable gardens, fruit tree distribution, a basket making association and fish farming initiatives.

Building aspects of sustainable development into plant conservation projects can provide great benefits, raising awareness and involvement of local communities in delivering real conservation outcomes.

Resources for plant conservation through a botanic garden

Adequately funding and resourcing a strong botanic garden plant conservation programme is generally a challenge. However, resources will rarely be sufficient if the plant conservation outcomes are not recognized as central to the strategy, objectives and priorities of the institution. At the Missouri Botanical Garden, plant conservation is included as the first of four strategic directives of the institution (the others are the cultural importance of the Garden in its own region; the need to invest in its people and infrastructure and the achievement of financial sustainability). The transformed and increasingly sophisticated botanic garden agenda related to biodiversity conservation at this Garden, and many others too, has been heavily influenced by the GSPC. The GSPC has demonstrated the importance of high level national and international policy frameworks to which we can link, which helps to justify our resource needs to governing bodies, donors and local and national authorities. Of course, conservation work shares the botanic garden with many other priorities and activities but successful strategies for integrating all aspects of a botanic garden's concerns can be found through careful strategic planning.

Fund-raising is an everyday task for most of us and can succeed best when effective means of communicating the mission and work of the institution are developed. One should not overlook the importance of incorporating resources for plant conservation into the core costs of the institution, rather than relying solely on special one-off funding for conservation projects. It is valuable to include a responsibility for achieving plant conservation in the mission of the botanic garden, as well as in the job profiles of all staff, whether they are working in horticulture, research, education or administration. Building the base of support in the community is essential too and volunteers and member groups can become a wonderful asset for implementing conservation projects, both through their volunteer labour and their donations. At the Missouri Botanical Garden, private individuals and local foundations have generously supported infrastructure developments and specific plant conservation projects recently, such as the construction of a new state-of-the-art hardy plant nursery where tens of thousands of new conservation plants can be raised. Private philanthropy also played an important part in supporting the development of the Garden's seedbank. The Garden's membership of 47,000 households and 2,000 volunteers provides a remarkable base of support for the Garden.

Plant conservation and climate change

We recognize today that the increasing impact and pace of climate change is impacting plant conservation very significantly. Plant conservation becomes significantly more difficult as a result of climate change and many more plants will be threatened than we had previously predicted. The Gran Canaria Declaration II, on climate change and plant conservation provides a useful summary on likely climate change impacts on plants (https://www.bgci.org/files/All/Key_Publications/gcdccenglish.pdf).

At the level of the individual botanic garden, there will be a growing need for each garden to assess the potential impact and consequences of climate change on their operations and the living collections they manage. For example, based on the best predictions on future climate change scenarios it is likely that many of the plants that are grown outdoors in most botanic gardens will change and that we will see substantial changes in the floras of many Gardens. This will include plants that are no longer suited to the changed climate of the Garden's own region. Plants which have not shown any tendencies to be invasive may also become so, and require to be removed. As we have also seen, there is an increasing occurrence of catastrophic weather events in many regions, including devastating floods, sea-level rises and storm surges, storms, hurricanes, tornadoes, as well as untypical periods of drought and climate-influenced wildfires. Our confidence has been shaken that the *ex situ* collections of many botanic gardens are as safe into the future as we might formerly have hoped and believed.

In addition, achieving the GSPC targets has become even more challenging than ever before due to climate change. We realize that many native plants are no longer secure in their natural habitats, even within protected areas. Often these will be threatened due to changed environmental conditions to which they are not suited, also due to loss of pollinators, the spread of new invasive pests and diseases, the loss of seed dispersal agents, and other climate-influenced factors. It is therefore important that botanic gardens factor in the impact of climate change into their own institutional planning, their living collections priorities and into the ways in which they communicate their needs and priorities to their visitors and stakeholders. Developing close partnerships with other botanic gardens are important where back up collections of conservation collections can be held.

A contemporary approach to plant conservation

The remarkable development of botanic gardens over the last few decades has helped to transform their approach to plant conservation. While *ex situ* conservation (in living collections, seedbanks and tissue collections) remains foundational to their approach, there has been a growing sophistication in methodologies applied. This has included much more focus on documenting and tracking the genetic diversity of the plants with which they are concerned, applying an approach that aims to conserve and understand plant diversity at all levels, including genetic diversity, individual plants, populations, species and their role or place in functioning ecosystems. Such an approach had required considerable new investment in research, particularly in conservation biology. Conservation genetics has become a fruitful research direction for some botanic gardens and is expected to grow in importance (Edwards and Wyse Jackson, 2019).

New awareness has grown of the importance of indigenous and local knowledge of plants, as well as innovations and practices associated with plant resources, with awareness of the value of such knowledge to support customary uses, sustainable livelihoods, local food security and health care. Research in ethnobotany is a valuable plant conservation-related area for scientific investigation. Many botanic gardens now include biocultural collections of artifacts which can be useful for educational displays and for research (Salick et al, 2013).

Other traditional and non-traditional research areas to support plant conservation through individual botanic gardens are: taxonomy (for example, many of the c.200 plant species newly discovered and described by the Missouri Botanical Garden's scientific staff each year are found to be threatened species); restoration ecology; phenology; horticultural research on propagation, cultivation, seed biology and storage and *in situ* conservation, restoration and recovery methods.

It is clear that to be truly effective in plant conservation an individual botanic garden needs to mobilize and apply its diverse teams and expertise in horticulture, science, education, restoration, advocacy, knowledge management, administration and community outreach. The key to success will be continued committed institutional and network responses to the plant conservation challenges we face, the implementation of strategic, planned and coordinated approaches and dedicated individuals and leadership. The world needs botanic gardens to be successful in this work today, even more than ever before.

REFERENCES

Edwards, Christine E. and Wyse Jackson, Peter. (2019). The development of plant conservation in botanic gardens and the current and future role of conservation genetics for enhancing those conservation efforts. Molecular Frontiers Journal, Volume 3 Number 1 2019: 44-65. https://www.worldscientific.com/doi/pdf/10.1142/S2529732519400078

Fathman, Liz. (2013). The Missouri Botanical Garden in Madagascar. Celebrating 25 years of exploration, discovery, and conservation on the "eighth continent". Missouri Botanical Garden, St Louis, Missouri.

Salick, Jan; Konchar, Katie and Nesbitt, Mark (Eds). (2014). Curating Biocultural Collections – A Handbook. Pp. 329-346. Royal Botanic Gardens Kew, U.K.

Sharrock, Suzanne and Wyse Jackson, Peter. (2017). Plant Conservation and the Sustainable Development Goals: a policy paper prepared for the Global Partnership for Plant Conservation. Annals of the Missouri Botanical Garden: 102: 290–302.

Wyse Jackson, P.S. and Sutherland, L. (2000). The International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International (BGCI), London, U.K.

Wyse Jackson, Peter and Sutherland, Lucy A. (2017). Role of Botanic Gardens. In: Reference Module in Life Sciences, Elsevier, 2017, ISBN: 978-0-12-809633-8, http://dx.doi.org/10.1016/B978-0-12-809633-8.02046-X

PRESERVING THE FLORA OF THE FRENCH OVERSEAS DEPARTMENTS, COUNTRIES AND TERRITORIES (ODCT). *IN SITU* AND *EX SITU* CHALLENGES

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ABSTRACT
Biodiversity in Metropolitan France cannot be compared to that of the tropics but through the variety of the terrestrial and marine biomes held in its Overseas Departments, Countries and Territories (ODCT), from the Northern Boreal (Saint-Pierre-et-Miquelon) to Southern Sub Antarctic (TAAF), through the tropical zones of three great oceans, it presents a remarkable biological diversity. This positions France as the most biodiverse country in Europe giving it a great responsibility.
The first part of the presentation describes how France is implementing targets 1, 2, 5, and 7 of the Global Strategy for Plant Conservation in its ODCT. It then focuses on two French Departments of the Indian Ocean: Reunion and Mayotte, where biodiversity has been well explored.
It presents the current in and *ex situ* conservation programs and action plans that are already in place in these two Departments. Looking more precisely at target 8, it analyzes, using the BGCI PlantSearch tool, the representativeness of the CR and EN threatened flora maintained in *ex situ* collections, botanical conservatories, botanical gardens and seed banks in these Departments or in other locations within or outside France.
According to the latest IUCN lists, the flora of Reunion Island includes 91 taxa that are rated CR and 80 EN, and for Mayotte 36 CR and 41 EN. This study showcases the percentage of critically endangered and endangered taxa that are maintained in *ex situ* collections, showing where they are held and by obtaining information on the accession data of the species of special concern helps to identify what percentage could be actually used for recovery and restoration programs.
When fully implemented, in Metropolitan France and in the French ODCT, the array of programs and action plans set up for the implementation of the Global Strategy for Plant Conservation, the Aichi targets 12 and 15 of the Sustainable Development goals should allow to ensure the preservation of the threatened species in their natural habitats.

KEYWORDS
Aichi Targets, Biodiversity, *In situ* and *Ex situ* conservation, French Overseas Departments, Countries and Territories, GSPC, Protected areas, Red lists, Threatened species

INTRODUCTION

During the Earth Summit in 1992, the international community agreed upon a strategy to halt the loss of the biological diversity, aiming at ensuring its conservation, the sustainable use of its components and the fair and equitable sharing of benefits arising from the use of the genetic resources. The Convention on Biological Diversity (CBD) entered into force on 29 December 1993 and France ratified the Convention in September 1994.
The Convention is implemented through a Strategic Plan for biodiversity which was reconducted in 2010. The new Strategic Plan for Biodiversity 2011-2020 and its Aichi targets were adopted in Nagoya, Japan during Convention's 10th Conference of the Parties (COP10).
The European Union (EU), a party to the convention since March 1994, adopted in 2011 a strategy to protect biodiversity in Europe by 2020. It sets out six objectives aiming at reducing the major pressures on nature.
In line with the commitment made by all the other European Union member states of halting the loss of biodiversity by 2010, a French National Biodiversity Strategy (NBS) 2011-2020 was launched in 2011.
The NBS reflects the country's commitment to meeting Aichi's objectives. The twenty objectives were set to preserve, restore, strengthen, enhance biodiversity and ensure its sustainable and equitable use and concern all sectors of activity and all territorial scales, both in

Metropolitan and Overseas France.
In July 2007, major consultations brought together representatives of the State, local authorities, NGOs, companies and their employees to develop in France new actions in favor of ecology and the environment. Following these consultations, two laws known as "Grenelle I" and "Grenelle II" were adopted in 2009 and 2010. The Grenelle II law (of 12 July 2010) sets as national objectives, the development of regional and local biodiversity strategies in Metropolitan France and in the French Overseas Departments, Countries and Territories (ODCT). These strategies have been developed taking into account the competences of the territorial collectivities and in consultation with all stakeholders.
The more recent Law for the reconquest of biodiversity, nature and landscapes of August 9th, 2016, has provided France with an ambitious and all-encompassing legal framework at the service of the preservation of the environment and the quality of life. On 1st January 2017, the French Agency for Biodiversity (AFB) was created. It is today the State's central operator for terrestrial, aquatic and marine biodiversity in Metropolitan and Overseas France.
The Muséum National d´Histoire Naturelle (MNHN) is a public scientific and cultural institution nationally and internationally renowned for its expertise on biodiversity and its conservation. It falls under the joint authority of the Ministry in charge of Higher Education, Research and Innovation and of the Ministry of Ecological and Inclusive Transition.
The Institution fulfils its role through five missions: basic and applied research, conservation and expansion of its collections, education, expertise and the dissemination of knowledge. Its scientists operate in a very wide array of disciplines. The studies of the past enlighten the future, and natural sciences mingles with human sciences. Furthermore, the MNHN is a member of the Consortium of Scientific Partners to the Convention on Biological Diversity and collaborates with other scientific institutions worldwide with the aims to contributing to the implementation of the Strategic Plan on Biodiversity.
Created in January 2017, the natural heritage joint service unit PatriNat pursues a wide array of missions from expertise to knowledge management for its three branches, namely the French Agency for Biodiversity (AFB), the MNHN and the National Center for Scientific Research (CNRS). It is in charge of the scientific conduct of the National Inventory of Natural Heritage (INPN) and the development of the National Information System on Nature (SINP) gathering all available knowledge on biodiversity and geodiversity in Metropolitan France and in French ODCT.

AN EXCEPTIONAL BIODIVERSITY RICHNESS OVERSEAS

Geographically

With a land area of 551,500 km², Metropolitan France is the largest country in Western Europe. In addition, thanks to the diversity of locations of its Departments, Countries and Territories (ODCT) beyond the mainland, Overseas France cover 110,000 km² spanning three continents (Europe, the Americas and Oceania) and three oceans (Pacific, Indian and Atlantic) (Figure 1). It comprises the following islands: New Caledonia, 18,600 km², French Polynesia, 3,521 km², Wallis & Futuna, 140 km² and Clipperton, 2 km² (Pacific Ocean); Austral Islands, 7,800 km², Reunion, 2,512 km², Mayotte, 376 km² and Eparse Islands, 53 km² (Indian Ocean); Guadeloupe and its dependencies, 1,628 km², Martinique, 1,128 km², St-Pierre-et-Miquelon, 242 km² and St-Martin and St-Barthelemy, 78 km² (North Atlantic Ocean). The largest ODCT is French Guiana (84,000 km²) in South America, which is not an island.
The country boasts the world's second-largest maritime domain after the United States (10.3 million km²), ahead of Australia, Canada and Russia. Its ODCT account for 97 % of its Exclusive Economic Zone (EEZ). France shares 4,082 km of land borders with 11 countries – eight of which are in Europe – and has maritime borders with 30 countries (Protected areas in France, 2013).

Politically/Administratively

Amongst the European Union (EU) Member States, France, Portugal and Spain have part of their territory located beyond the boundaries of Europe, which are known as Europe's Outermost Regions (ORs). Namely, these are the Azores and Madeira for Portugal, and the Canary Islands for Spain. Five French ORs have the status of Departments: Guadeloupe, French Guiana, Reunion, Martinique, Mayotte, while Saint-Martin is a French Overseas Community.
In addition to this, in the EU, Denmark, France, the Netherlands and the United Kingdom count Overseas Countries and Territories (OCTs) which are associated to the EU but are not part of it. Overseas France has different status (Ministère des Outre-Mer, 2019). French Polynesia and New Caledonia are recognized as Overseas Countries (Pays d'Outre-Mer) within the Republic (POMs is a status affording the possibility of future total independence,

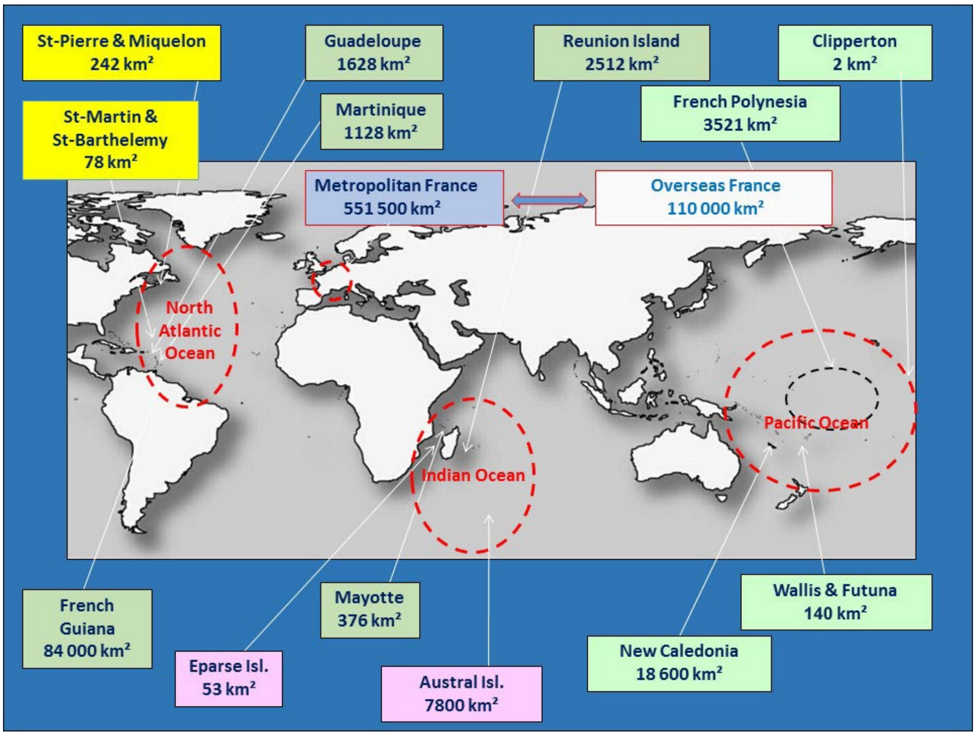


Figure 1: Metropolitan and Overseas France

if this is the wish of the inhabitants). Wallis and Futuna and Saint-Pierre-et-Miquelon are Overseas Collectivities (Collectivités d'Outre-Mer – COMs), the French Southern and Antarctic Territories remain a TOM (Territoire d'Outre-Mer). The DOM-TOMs are run in the same way as Departments and Regions in Metropolitan France, while the COMs have a degree of autonomy with their own elected assemblies and some legislative powers.

Environmentally

France holds a unique natural and cultural heritage, on account of the diversity of terrestrial and marine biogeographic regions and the variety of geographical distribution of its ODCT which span from the tropical and equatorial zones, to the Boreal and Southern Sub Antarctic.
Metropolitan France counts 4 biogeographical regions (Atlantic, Continental, Alpine, Mediterranean). 81 % of European ecosystems and 68 % of European threatened habitats are present in Metropolitan France (Observatoire National de la Biodiversité, 2018).
Overseas France is characterized by an outstanding diversity of terrestrial and marine habitats which have been far less modified by human activity than Metropolitan France. The plant and animal species numbers are also exceptionally high. It is commonly stated that at least 80 % of the national biodiversity is located overseas (four in five French species are found overseas).

Of the world's 36 designated biodiversity hotspots, five land hotspots (the Mediterranean basin, Antilles, Polynesia, New Caledonia and Indian Ocean) and two out of 10 marine hotspots (Reunion and New Caledonia) are in France. A biodiversity hotspot is a geographic area with at least 1,500 endemic plant species that has already lost at least 70 % of its original natural vegetation. Hotspots represent just 2.3 % of the Earth's land surface. Over 50 % of the world's endemic plant species and 42 % of terrestrial vertebrates live in these hotspots. The ODCT however count 14 out of the 17 French eco-regions (WWF defines an ecoregion as a large unit of land or water containing a geographically distinct assemblage of species, natural communities, and environmental conditions) (French policy on biodiversity, 2019).
All ODCT have in common a high terrestrial and marine biological diversity, historical and biogeographic originality, strong endemism, heritage species and the importance of traditional knowledge. If we exclude French Guiana, it is important to note the importance of coral ecosystems and the heritage value of the marine areas. These characteristics give France a considerable asset but impose on it an international responsibility to maintain and preserve such an exceptional biodiversity (Gargominy, 2003; Mueller & Meyer, 2012).
One common characteristic of the French ODCT is that they possess a high level of endemism in all groups. The ODCT are presenting a lot more endemic species than in

Metropolitan France (100 times more freshwater fishes, 60 times more birds, 26 times more plants, 3.5 times more molluscs). In the latest report on the state of biodiversity, the French Observatoire National de la Biodiversité (ONB) confirms the exceptional richness of France's natural heritage and the international responsibility that it implies, particularly for safeguarding the 19,424 endemic or sub-endemic species (4/5 overseas). 22 % of species are endemic in overseas islands compared to 3 % in Metropolitan France (Observatoire National de la Biodiversité, 2018; Chiffres clés de la biodiversité en France, 2018). While presenting a series of common traits, each French ODCT reveals and retains its natural and cultural identity and specificity.

In the Atlantic Ocean

The Overseas Collectivity of Saint-Pierre-et-Miquelon lies in the north-west Atlantic, 25 km off the coast of Newfoundland, Canada. It has two main islands, with a total area of 242 km². The soil is acid and thin with peat bogs, scrubs and remnants of Boreal forest in parts of the Island of Langlade.

In the Caribbean the archipelago of the Lesser Antilles belongs to a small volcanic arc with about 21 main islands and numerous islets, all belonging to the Caribbean Islands Biodiversity Hotspot. Martinique and Guadeloupe are the largest islands. Natural types of terrestrial vegetation include semi-deciduous dry forests, seasonal evergreen forest, ombrophilous forest, mangroves, beaches and littoral cliff vegetation and montane savanna.

Martinique Island has an area of 1,128 km². Volcanic in origin, it offers a varied landscape dominated by the volcano of Montagne Pelée (1,397 m above sea level).

Guadeloupe is the largest island in the French West Indies with an area of 1,438 km² (1,628 km² with its dependencies). It comprises Basse-Terre, dominated by the volcano of La Soufrière (1,484 m above sea level), and Grande-Terre, with the adjacent Islands of La Désirade, Iles des Saintes and Marie-Galante. Further to the North, St Barthélemy (25 km²) and the French part of St Martin (53 km²) are other ODCT among the Lesser Antilles.

French Guiana is continental, situated in the north-eastern part of South America between Surinam and Brazil and covers an area of 83,534 km². It encompasses a large block of tropical ombrophilous lowland forest and submontane forest, which covers nine tenths of the territory with a great diversity of fauna (insects, amphibians, turtles, birds ...) and flora. Moderate local variability is found, including marsh forest along rivers. Some other vegetation types are recognized including patches of savannas and some patches of herbaceous swamps along the coastal lowlands (Lindeman & Mori, 1989).

In the Indian Ocean

The Island of Reunion with an area of 2,512 km² is part of the Mascarene Archipelago. It presents an extreme diversity of environments. No fewer than 130 different types of habitats are recognized after the Corine biotopes European classification. They consist largely of forests, at lower altitude and at higher altitude (upper tamarind forests with the dominant species *Acacia heterophylla*; 'misty forests' or cloud forests…), but also cover a wide variety of other remarkable habitats: dry forests, semi-dry forests, meadows, wetlands, ravines, savannas, moors and heaths on the peaks, coral reefs... No mangrove forests are however observed on the island. Reunion belongs to the Madagascar and Indian Ocean Islands Biodiversity Hotspot.

The Overseas Departmental Collectivity of Mayotte (376 km²) is the most southerly of the four islands of the Comoro archipelago: It comprises two main islands and 30 or so islets. The main natural habitats of the territory are the natural forests, the riverine forests, the humid zones, the mangroves, the coastal habitats like mudflats, coastal forests and sand beaches (egg-laying places for marine turtles), the islets (dry forest and sea birds), the seagrass and the coral reefs. Like Reunion, Mayotte belongs to the Madagascar and Indian Ocean Islands Biodiversity Hotspot.

The French Southern and Antarctic Lands, the TAAF (*Terres Australes et Antarctiques Françaises*), consist of the Islands of St Paul (8 km²) and Amsterdam (58 km²), the Crozet Islands (340 km²), the Kerguelen Islands (7,215 km²) and the Terre Adélie (432,000 km² in the Antarctic continent, which is not taken into account in our survey because of its particular status). The climate and vegetation of the above-mentioned islands are Sub Antarctic. Since 2007, the TAAF also comprise the Scattered Islands (Eparse Islands) in the Indian Ocean, comprising the Islands of Bassas da India (less than 1 km²), Europa (30 km²), Glorieuses (7 km²), Juan de Nova (5 km²) and Tromelin (1 km²). These islands are subjected to tropical climatic conditions, from arid (South) to humid (North). Their flora and vegetation are described in Gigord et al., 2013. Amongst the important plant formations of these islands are mangroves and coastal vegetation which serve as important refuge areas for nesting birds.

In the Pacific Ocean

New Caledonia is part of the group of islands which make up Melanesia and covers 18,575 km². The archipelago comprises Grande Terre (main island) and the Islands of Loyalty, the Bélep Archipelago, the Isle of Pines and a few remote islets, forming one of the 36 biodiversity hotspots. New Caledonia is known for its distinctive maquis vegetation (shrubland) on ultramafic soils, rainforests, sclerophyllous forests (dry forests), savannas, wetlands, coastal ecosystems (mangrove, beaches…) and vegetation on limestone (Loyalty Islands).

French Polynesia with a land area of 3,521 km², consists of five archipelagos of 118 volcanic or coral islands, covering a total see area of 2.5 million km²: the Society, Marquesas, Austral and Tuamotu-Gambier Islands. It comprises many relatively preserved atolls and a large EEZ with significant halieutic potential, especially tuna resources in the Marquesas. The flora is not especially rich but shows an exceptional diversity for endemism among Angiosperms (75 %), depending on the islands (54 % of the vascular flora of the French Polynesian archipelagos is endemic, according to Meyer and Claridge, 2014). A great diversity of forest ecosystems is found, at different elevations (dry forests, coastal forest, mesophilous forests, montane rain forests, cloud forests…) along with other types of ecosystems (wetlands, shrublands, montane land ferns and savannas, atoll vegetation…).

The archipelago of Wallis and Futuna (140 km²) is part of Polynesian Oceania. It is comprised of the three volcanic Islands of Wallis (76 km²), lying to the Northeast, and Futuna (46 km²) and the islet of Alofi (18 km²) forming the Horn archipelago. The vegetation is divided into mangrove, littoral, dense evergreen forest (lower elevation and high montane forest), wetlands, *Dicranopteris* fernlands.

Wallis and Futuna and the French Polynesia Islands belong to the Polynesia-Micronesia Biodiversity Hotspot.

Located in the Northeastern Pacific Ocean, Clipperton is an inhabited and very small atoll (2 km²) of volcanic origin. Unlike the fauna which is rich (fishes, birds, corals, mollusks, shellfish…), the flora is poor, little diversified and mainly composed of introduced species.

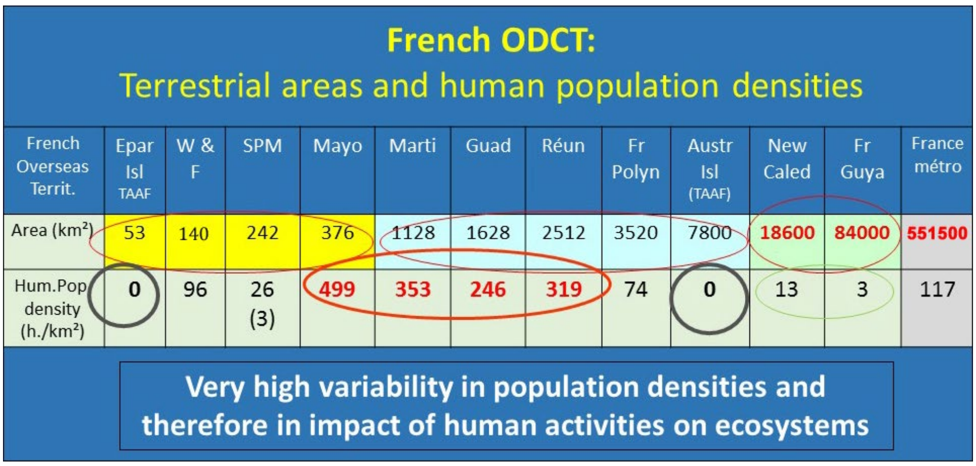
VULNERABILITY AND THREATS

Due to their geographical characteristics, the French ODCT encompass a wealth of natural contrasts, an array of different climatic conditions, landscapes, flora and fauna, from the tropical and equatorial zones- to the Saint-Pierre-et-Miquelon and Southern and Antarctic Lands. As mentioned earlier, all French ODCT are islands, with the exception of French Guiana and Terre Adélie. Some of them are very small, increasing their vulnerability, a lower resilience to natural hazards, which increase significantly their exposure to the consequences of climate change. The French Observatoire National de la Biodiversité (ONB) indicates that the global context for the evolution of biodiversity in all these territories is worrying.

France, which notably holds a great part of species diversity from its ODCT is unfortunately among the top ten countries in the world with the highest number of plant and animal threatened species: 1,147 species, among which 278 are in Metropolitan France (The IUCN Red List of Threatened species, 2017).

- The French ODCT show a very high variability in human population densities and therefore in impact of human activities on ecosystems (Figure 2).

These overseas lands have suffered from an important reduction of their natural areas after human colonization and are facing habitat destruction by an increasing development of agriculture, industry and urbanization.



French ODCT:
Terrestrial areas and human population densities

French Overseas Territ.	Epar Isl TAAF	W & F	SPM	Mayo	Marti	Guad	Réun	Fr Polyn	Austr Isl (TAAF)	New Caled	Fr Guya	France métro
Area (km²)	53	140	242	376	1128	1628	2512	3520	7800	18600	84000	551500
Hum.Pop density (h./km²)	0	96	26 (3)	499	353	246	319	74	0	13	3	117

Very high variability in population densities and therefore in impact of human activities on ecosystems

Figure 2: Terrestrial areas and human population densities in the French ODCT

A first outstanding example concerns the New Caledonian dry forests ecoregion, only found on the Western side of Grande Terre Island (Figure 3). It is home to more than 450 species, including a large number of endemics. This ecosystem had almost disappeared until the implementation of drastic measures for its preservation. It currently accounts for only ca. 1-2 % of the original cover and exists mainly in disjunct forest patches.

The case of Reunion Island is another striking example (Figure 3). In the last three centuries the human activities have caused an accelerating loss of biological diversity due to the destruction and fragmentation of native tropical forests and the introduction of alien organisms, which have considerably modified the process of primary succession in this ecosystem.

- Biological invasions / Invasive Alien Species (IAS) are now considered as the 1st or 2nd cause of erosion of the biodiversity in tropical Islands, also in French overseas islands (Figure 4).

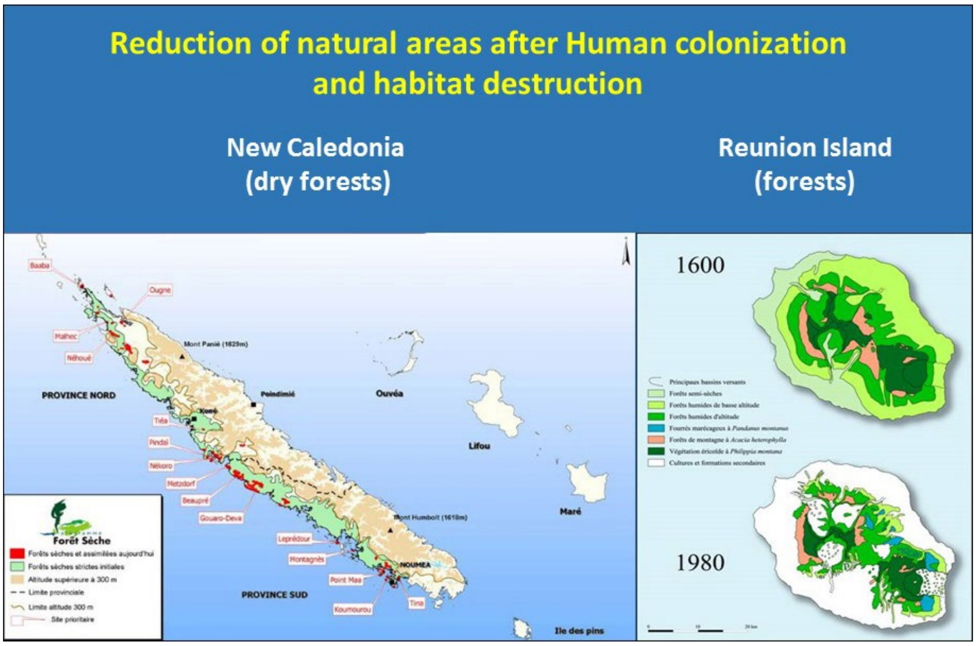


Figure 3: Important reduction of natural areas after Human colonization and habitat destruction in New Caledonia and Reunion Island. New Caledonia: the original (green) and current dry forests (red). Reunion: more than 3 centuries of evolution/degradation (maps of vegetation cover in 1600 and 1980)

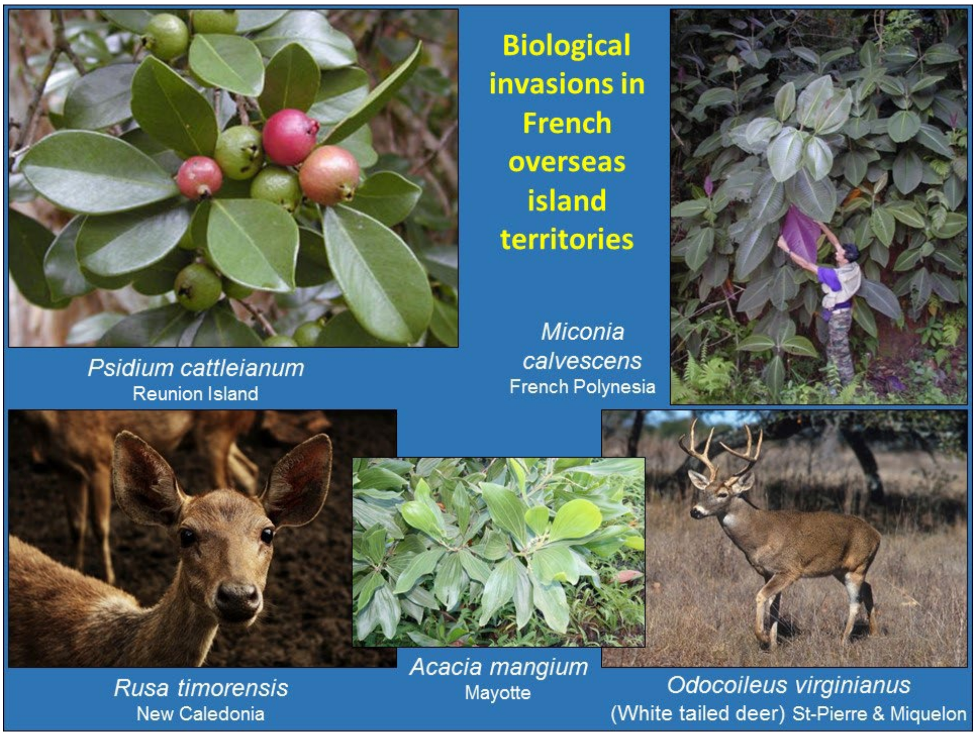


Figure 4: Invasive Alien Species as a major cause of erosion of biodiversity in tropical islands

Some examples for the French ODCT include: *Rusa timorensis*, the Rusa deer, in New Caledonia and *Odocoileus virginianus*, the White tailed deer, in St-Pierre-et-Miquelon (fauna), *Acacia mangium* in Mayotte, *Psidium cattleianum* in Reunion Island and *Miconia calvescens* in French Polynesia (flora).

- Overseas lands are also threatened by climate change. In French Guiana, researchers have shown a strong decrease of the floristic richness of the forest cover on an isolated rock hill (inselberg) in relation with an increase of temperature during the 50 last years (Fonty et al., 2009).

In the Austral Islands a significant temperature elevation has permitted the reproduction of introduced plants such as *Poa pratensis* or *Taraxacum sp*., which now produce viable seeds. Their anemochorous dissemination leads to their invasion. The Saint-Pierre-et-Miquelon Arcto-alpine tundra is also very sensitive to climate change. In 2008, S. Muller set up permanent plots in the aim to study these changes (Muller, 2011; Muller et al., 2012). In Tahiti (French Polynesia) cloud forests ecosystems and their biodiversity are affected by climate change (cloud reduction or elevation).

WHICH MEASURES ARE IN PLACE?

The Law for the reconquest of biodiversity, nature and lansdcapes

Since the promulgation of the Law for the reconquest of biodiversity, nature and landscapes on August 9th, 2016, the protection and valorization of the French Natural heritage is now enshrined in French law. The legal instruments for the conservation of threatened species are reinforced. The national action plans for the preservation and protection of endemic species (Aïchi target 12) will be reinforced and sanctions will be enforced to fight illegal trade.

- Law promulgated August 9, 2016
- A dynamic and renewed vision of biodiversity
- An ambition to protect and enhance the French natural heritage
- Aim for environmental excellence
- Implementation of the Aïchi targets

Amongst the Aïchi targets the most concerned in our study on the French ODCT are the following:

- Target 1: By 2020, at the latest, people are aware of the values of biodiversity and the steps they can take to conserve and use it sustainably.
- Target 2: By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems.
- Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.
- Target 7: By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.
- Target 8: By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity.
- Target 12: By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained.
- Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

The protected flora and areas in the French ODCT

Table 1 presents the richness of the vascular flora (indigenous and endemic species) and the protected vascular plant species in the French ODCT. One of the significant features is the number of more than 3000 endemic vascular plant species (evps) overseas, to compare to the 210 evps in the French Metropolitan territory. It is also interesting to note the disparities between territories regarding the protection of the flora and the percentage of protected areas.

To know and preserve biodiversity, in Metropolitan France and the ODCT the French Ministry of Ecology (now called the Ministry of Ecological and Inclusive Transition) has developed tools adapted to the contexts and issues (Ministère de la Transition Ecologique et Solidaire, 2019 a, b). The Strategy of Creation of Protected Areas (SCAP) is a national strategy aiming at enhancing the coherence, representativeness and efficiency of the network of terrestrial protected areas in France by contributing to maintaining biodiversity, the good functioning of ecosystems and improving ecological connectivity. Figure 5 presents a panorama of the biodiversity and the protected areas in Metropolitan France and Overseas.

French Overseas DCT	Epar Isl TAAF	W & F	SPM	Mayo	Marti	Guad	Réun	Fr Polyn	Austr Isl TAAF	New Caled	Fr Guya	French Métro
Area (km²)	53	140	242	376	1128	1628	2512	3520	7762	18600	84000	551500
Hum. Pop. Density (h/km²)	0	96	26	499	353	246	319	74	0	13	3	117
Nb **INDIGEN.** vascular plant sp.	123	351	385	681	1403	1600	848	881	70	3261	5750	4900
nb/km²	2.3	2.5	1.6	1.8	1.2	1.0	0.3	0.25	0.01	0.2	0.07	0.01
Nb **ENDEM.** vascular plant sp.	3	7	0	**56**	33	31	**237**	**514**	24	**2423**	~150	~210
(% end.)	3 %	5 %	0 %	**8 %**	2 %	2 %	**28 %**	**58 %**	**34 %**	**74 %**	3 %	4 %
French Overseas : more than 3000 evps <---> 210 evps : French Métropole												
Nb **PROTECT.** vascul. plant sp.	0	0 **in project**	0	111 **under revision**	41	49	238	167	0	172 (Sth Prov)	83	429 (2700)

Table 1: Richness of the vascular flora (indigenous and endemic species) and the protected vascular plant species in the French ODCT

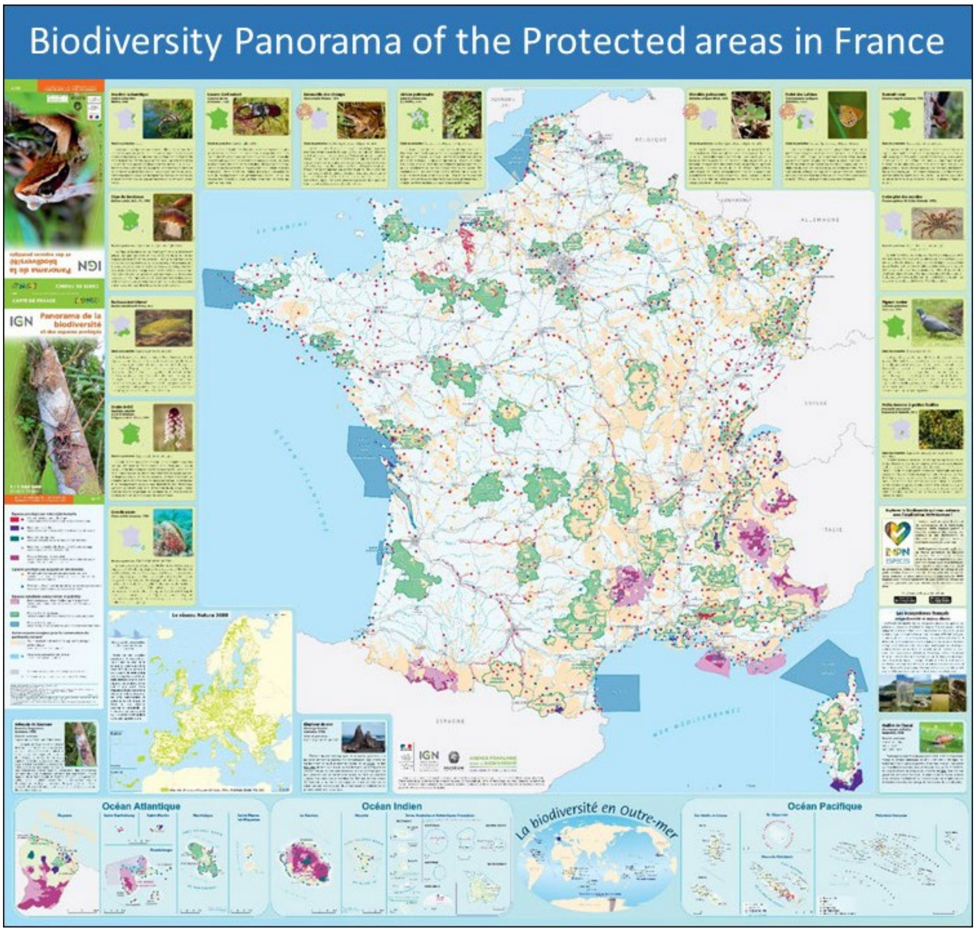


Figure 5: Biodiversity Panorama of the Protected areas in France (Metropolitan and Overseas). This map was produced in 2018 in partnership with the Institut Géographique National (IGN), the MNHN and the French Agency for Biodiversity/ Agence Française pour la Biodiversité (AFB)

Among the most numerous and largest protected areas in France are the national parks and the regional natural parks.
French national parks cover a variety of land and maritime domains with the aim to protect biodiversity, manage the cultural heritage and educate the public. As of August 2018, France counts ten national parks: seven in Metropolitan France (Cévennes, Ecrins, Mercantour, Port-Cros, Pyrenées, Vanoise and Calanques) and plans to reinforce this network by adding a new national park (Parc National des « Forêts de Plaine »), and 3 Overseas (Guadeloupe, French Guiana, Reunion). All ten together, they represent nearly 9 % of the French territory for a total of about 60 000 km². Proportionally to their size, the French ODCT have a greater proportion of protected areas than Metropolitan France.
The French regional natural parks, developed under the responsibility of the region, are spaces of natural, cultural or landscape importance at the national level. Their aim is to protect and manage this heritage as well as ensuring the economic and social development of the area. They also welcome and inform the public, participate in education and training programmes. The first regional natural park was created in 1968 (Scarpe-Escault). As of May 2018, there are 53 regional natural parks, among which two Overseas.
The main protected areas in the French ODCT:

- 3 national parks have been created in Reunion, French Guiana and in Guadeloupe, the latter being extended, including at sea; the regional natural parks of Martinique and French Guiana; creation of the adjoining marine natural parks of Mayotte and the Glorious Islands (Scattered Islands, TAAF). A total area of 100 000 km²;
- national nature reserves, such as the Guiana nature reserve network, the Saint-Martin and Saint-Barthélemy nature reserves, the Reunion marine nature reserve or even the sub-Antarctic TAAF Islands (22 000 km² of which 15 000 at sea, the largest French national reserve whose biodiversity bill allows for expansion into EEZs);
- establishment by New Caledonia of the largest French marine protected area 'Coral Sea' on all its territorial waters and in EEZ, more than 1.1 million km², part of an international project broader cooperation, particularly with Australia (Great Barrier Reef);
- project of large marine areas in French Polynesia, around the Marquesas and Tuamotu.

Other protected areas are internationally recognized through the UNESCO World Heritage inscriptions, in the ODCT (the Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems; Pitons, cirques and remparts of Reunion Island and Marquesas project) and the Man and Biosphere Program (the biosphere reserve of the Guadeloupe archipelago and the biosphere reserve of Fakarava in Polynesia).
Regarding the wetlands of international importance, France, in February 2018, has 48 sites registered under the Ramsar Convention, 37 of which are in Metropolitan France and 11 Overseas. These sites cover an area of about 36 000 km².

A ZOOM ON TWO ISLANDS OF THE INDIAN OCEAN

Reunion (2512 km²) and Mayotte (374 km²) are two French Departments and European Union's outermost regions located in the Indian Ocean (Figure 6). Both territory hosts a biodiversity of world importance, but the completion of Red listing and the significant knowledge accumulated has allowed to identify many threats thanks to the presence of a National Botanical Conservatory/ Conservatoire Botanique National (CBN) on the Island of Reunion. The two islands belong to the same biodiversity hotspot, together with other islands of the South West Indian Ocean and are designated by scientists as being of global priority for nature conservation. However, it must be emphasized that they show two contrasting situations, in terms of land surface, relief, habitat diversity and number of protected areas.

Flora, vegetation and threatened species

Reunion, an island situated in the Indian Ocean, about 700 kms East of Madagascar, profits from an exceptional biogeographical situation (insular, volcanic and tropical) and has a unique biological diversity. Its human colonization is quite recent (17th century). The global uniqueness of its flora and its organisation in numerous habitats is also unique (Boullet, 2007) and has led to their registration on the list of the UNESCO World Heritage sites in 2010.
The native or indigenous flora of Reunion Island comprises 1,764 species of vascular plants, of which there are 1,503 Spermatophytes (85,2 %) and 261 Pteridophytes (14,8 %) (CBN Mascarin, 2018; data from 2015). They are divided into:

- 867 native species which is about half (48 %) of the native flora,

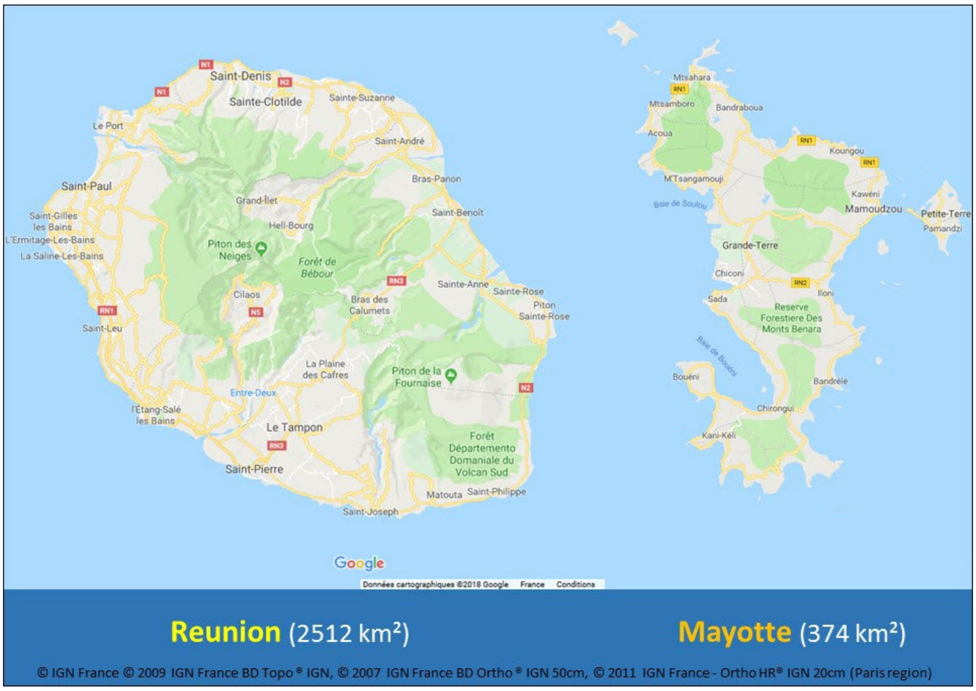


Figure 6: A zoom on two islands of the Indian Ocean: Reunion and Mayotte

- 843 exotic species, which is approximately the other half (48 %),
- 54 cryptogenic species, with possible but still uncertain indigenous status (3 %).

The native flora of the island may present a relatively reduced plant diversity but a high level of endemism (26.3 % for the strict endemism and 45.3 for the Mascarene endemism), awarding it with an important patrimonial value worldwide.

However only 30 % of the surface is occupied by indigenous vegetation and only 30 % of the vegetation types which occurred before human colonization in the 17th century, are still present (Strasberg et al., 2005) (Figure 7). More data on the flora and habitats of the Reunion Island can be found in Carié, 1927; Rivals, 1952; Cadet, 1974, 1977; Dupouey & Cadet, 1986; Blanchard, 2000; Strasberg et al., 2000; Boullet, 2006 a, b.

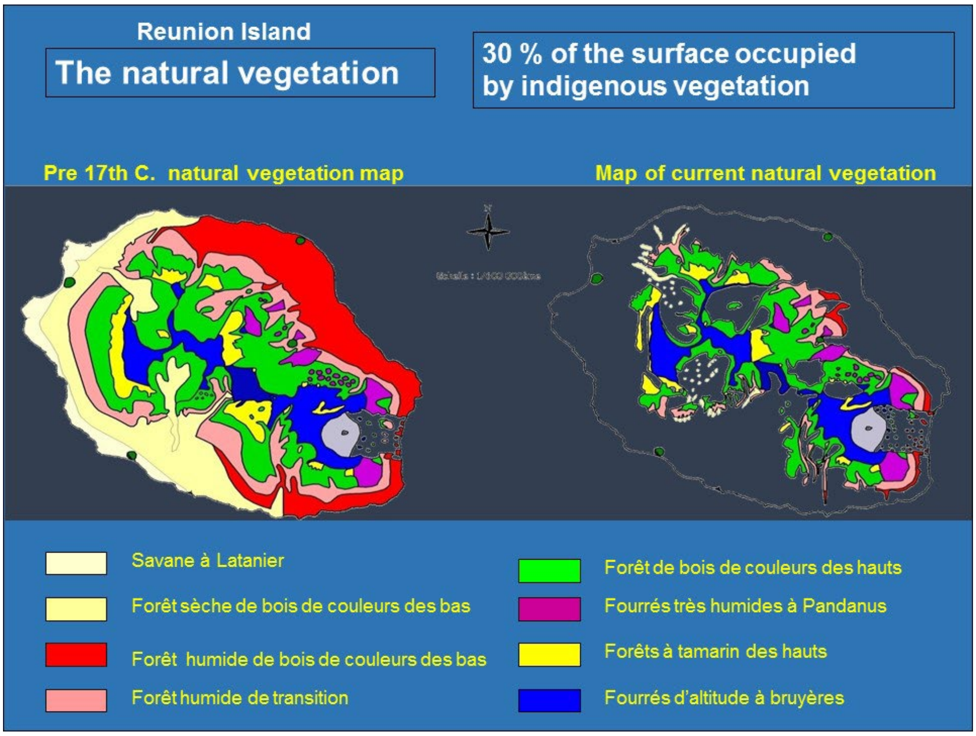


Figure 7: Evolution of the natural vegetation of Reunion Island (Pre 17th century and now)

Due to the strong regression of the surface of certain habitats, the island's flora is today extremely threatened and this is furthermore accentuated by the biological invasions that strongly contribute to biodiversity loss in the oceanic islands (Loope & Mueller-Dombois, 1989; MacDonald et al., 1991; Meyer & Florence, 1996; Lavergne et al., 1999; Kueffer & Lavergne, 2004; Meyer, 2004; Frenot et al., 2005; Baret et al., 2006; Beauvais et al., 2006; Donlan & Wilcox, 2008; Kueffer et al., 2010; Kiehn, 2011; Barbé et al., 2015).

Human settlement during the middle of the 17th century enriched the flora of the island with an exotic component that would gradually play a more and more important role in the development of society on Reunion Island. The wide range of usage (agricultural, forestry, economic, medicinal, ornamental...) and an ever-increasing flow of goods and services lead to the intentional or unintentional introduction of several thousands of species from tempered tropical zones all over the world. A certain proportion of these species now pose a real threat to the native flora.

Insularity and micro-endemicity make the native flora more fragile and vulnerable, enhancing the risk of extinction and the biodiversity crisis on these oceanic islands. The alteration and destruction of habitats has had a hugely detrimental impact on the biodiversity of the island. Although the process has slowed down considerably under the combined action of an association of vigilants and a proactive policy for the preservation of native habitats and the conservation of native biodiversity, native vegetation continues to shrink here and there.

A variety of human disturbances (fires, wild grazing and the planting of crops in high mountain areas, plantations under trees, wild camping, the opening of paths, overcrowding, ...) are contemporary examples that illustrate the more global problem of biological invasions by introduced species (CBN Mascarin, 2018).

Red list of threatened species of the Vascular Flora of Reunion

Among the indigenous vascular plants, 905 species of ferns and flowering plants have been assessed using the Categories and Criteria of the IUCN Red List of Threatened Species. The study was carried out by the IUCN French National Committee, the MNHN, the Federation of National Botanical Conservatories/Fédération des Conservatoires Botaniques Nationaux and the Conservatoire Botanique National de Mascarin. This study highlights the current state of affairs on Reunion; it shows that 49 plant species (5.4 %) have already disappeared from the island and that another 275 species (30.4 %) are now classified as Threatened, in the following categories: CR (91 species), EN (80) and VU (104) (The Flora of Reunion Island at Risk, 2010) (Figure 8).

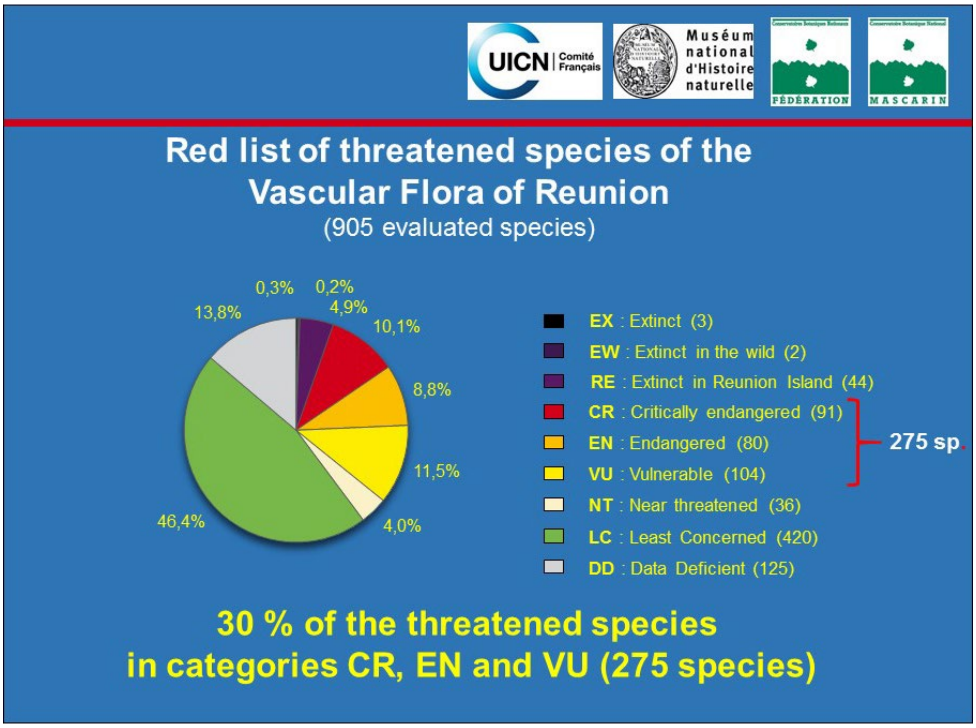


Figure 8: Red list of threatened species of the Vascular Flora of Reunion Island

Some examples (Figure 9) include:
-*Foetidia mauritiana* (Lecythidaceae) and *Hibiscus columnaris* (Malvaceae); CR
-*Aloe macra* (Asparagaceae) and *Asplenium nidus* (Aspleniaceae); EN
-*Disperis tripetaloides* (Orchidaceae); VU
-*Heterochaenia rivalsii* (Campanulaceae); NT

Figure 9: Examples of threatened species of the Vascular Flora of Reunion Island

Mayotte is composed of a group of volcanic islands more than 8 million years old, in the Comoros Archipelago, which is located in the Mozambique Channel and the Indian Ocean. Mayotte is made up of two main islands and several small islands. They are home to a biodiversity of worldwide importance.
Due to the subsidence of the island that gradually took place over the past 500,000 years, a large coral reef and lagoon surrounding the island emerged. These are exceptional for their size (1,000 km²) and for the rich biodiversity they host (more than 760 marine fishes of which 17 are threatened, according to the IUCN Red List of Threatened Species, 581 marine arthropod species, more than 450 cnidaria and 24 marine mammals) (IUCN Country Focus, Mayotte, 2019).
Mayotte's flora is not evenly distributed on the island – more than 50 % is found in only 10 % of the total territory. The existing flora is therefore not very representative of the actual natural heritage which the island could have and what remains is highly threatened with extinction.
The large wealth of Mayotte's flora is shown by the high number of native species versus its land surface (Mayotte: 171 native species/100 km², Maurice: 37/100 km²; Reunion: 34/100 km²). According to 2011 data, there are 1,317 plant species of which 767 are native and 550 are exotic. Among the species, 48 are strictly endemic to the island.
However, much of Mayotte's forests are degraded due to a very early human occupation of the island (from the end of the 8th century). More recently, the reduction in natural and secondary forest coverage between 1987 and 2002 concerned more than 12,000 hectares of land, according to estimates. This reduction still continues today at a pace ranging from 50 to 100 hectares per year, as urban and agricultural pressures increase and there is a lack of control measures in place.
Only 5 % of the original natural vegetation remains. This vegetation has been preserved thanks to the topographic features of the areas (forests on slopes, crests and summits) which have limited the expansion of agricultural and the exploitation of forest and thanks to local beliefs (Ziyaras: holy lands inhabited by the Djinns people). The natural land forests cover a surface of 1,123 hectares which represents 3 % of the total terrestrial lands in Mayotte (5% according to Pascal, 2002). In addition, there are 666 hectares of mangroves.
The forests host five types of vegetation: dry forests and underbrush, mainly on the small islets (such as the National Nature Reserve of Mbouzi), the summits and peak domes; the mesophile forests on the West and South of the island; the wet forests above 300 meters of altitude; the xero-submontane forests at the summit of Month Choungi and secondary forests mainly hosting exotic species. The majority of the territory is covered by a

tree formation which present little diversity or originality in its composition and is interspaced with cultivated areas and fallow land. These formations are the result of recurrent human activities such as fires, scrub clearings, crops and construction (Boullet et al., 2005; Barthelat & Viscardi, 2012; IUCN, Mayotte's flora and forests – a threatened heritage, 2013). Additional data on the Mayotte vegetation, flora and protected species and areas can be found in the following references: Pascal et al. (2001), Rolland & Rolland (2005), Barthelat et al. (2006), Barthelat (2007), Fadul (2010, 2011), Amann et al. (2011), Guiot (2011).

Red list of threatened species of the Vascular Flora of Mayotte

In Mayotte, out of the 610 evaluated indigenous vascular plant species, 43 % of the threatened species (264 species) fall in the following categories: CR (36 species), EN (41) and VU (187) (Figure 10).

Some examples (Figure 11) include:

-*Adansonia madagascariensis* (Malvaceae) and *Foetidia comorensis* (Lecythidaceae); CR

-*Huperzia phlegmaria* (Huperziaceae) and *Aloe mayottensis* (Asparagaceae); EN

-*Vanilla humblotii* (Orchidaceae); V

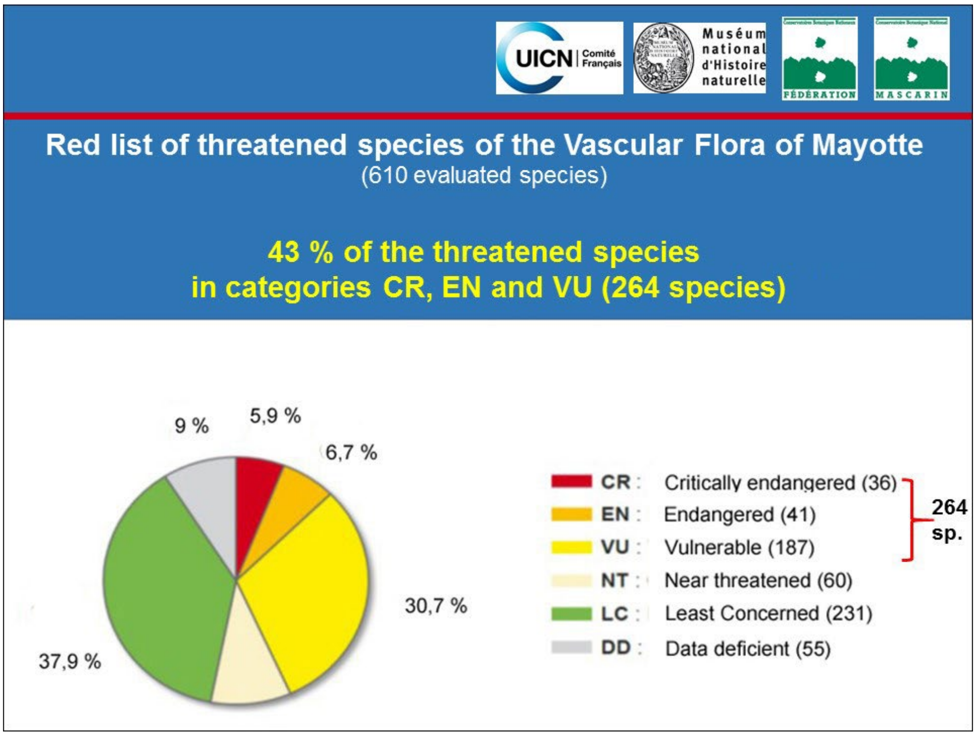


Figure 10: Red list of threatened species of the Vascular Flora of Mayotte

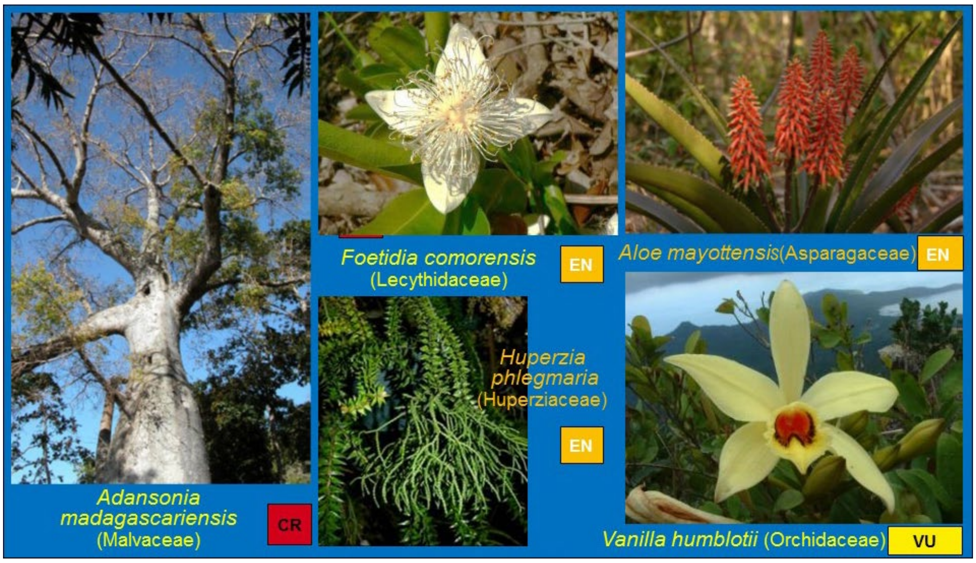


Figure 11: Examples of threatened species of the Vascular Flora of Mayotte

Conservation strategies

Today, in Reunion Island, the flora is extremely threatened (Conservatoire Botanique National de Mascarin, 2007; Baret et al., 2012). Facing this situation, it has been considered essential to devise a concerted island-wide strategy for the conservation of species and habitats. In this respect, Reunion Island constitutes an ideal ground for the study, experimentation and dissemination of methods and tools for the protection of biodiversity. The "Stratégie Réunionnaise pour la Biodiversité" (SRB) 2013-2020 is supported by a strong political governance body whose mission is to ensure a political support for programmed actions and to verify that the protection of biodiversity is well integrated at all levels (Stratégie réunionnaise pour la biodiversité, 2014; Stratégie de conservation de la flore et des habitats de la Réunion).

In Mayotte, most terrestrial natural habitats are fragmented and, compared to other overseas territories, only a few of them are under legal protection status.

The French IUCN Committee has been involved in Mayotte since 2012. Mayotte has been under French rule since 1841, and became a DOM in 2011. The Committee proposed its expertise to the local stakeholders to guide them towards the adoption of a territorial strategy for the protection of the biodiversity, an important local heritage. Mayotte has thus become the first overseas collectivity to develop its strategy for the conservation and valorisation of its biodiversity. Mayotte meets the objectives of the National Strategy for Biodiversity 2011-2020 and, at the international level, the Convention on Biological Diversity (Stratégie biodiversité pour le développement durable de Mayotte, 2014).

Protected areas

In Reunion all types of vegetation are present in the network of natural protected areas. The island is home of a National Park (core area: 1,054 km², which correspond to 42 % of the island surface; Figure 12), a National Nature Reserve (Etang de St-Paul, 4,5 km²), several Biological Reserves, such as Bébour or Mazerin, many sites belonging to the Conservatoire du Littoral/Coastal Protection Agency and a Marine Nature Reserve of 35 km². The Decrees for the Protection of Biotopes/Arrêtés de Protection de Biotope and Sensitive Natural Areas/ Espaces Naturels Sensibles (ENS) are other protection measures that have been undertaken in Reunion Island. The most important site however is the 'Pitons, Cirques and Remparts', which form 40 % of the territory. This protected land has been registered on the list of the UNESCO World Heritage sites in 2010.

Being fully aware of the wealth of the nature on the island and the multiple threats that it faces, the local players have implemented efficient tools for preserving and enhancing this unique environment, among them National Action Plans (NAPs) for the protection of endangered species, campaigns for combating and

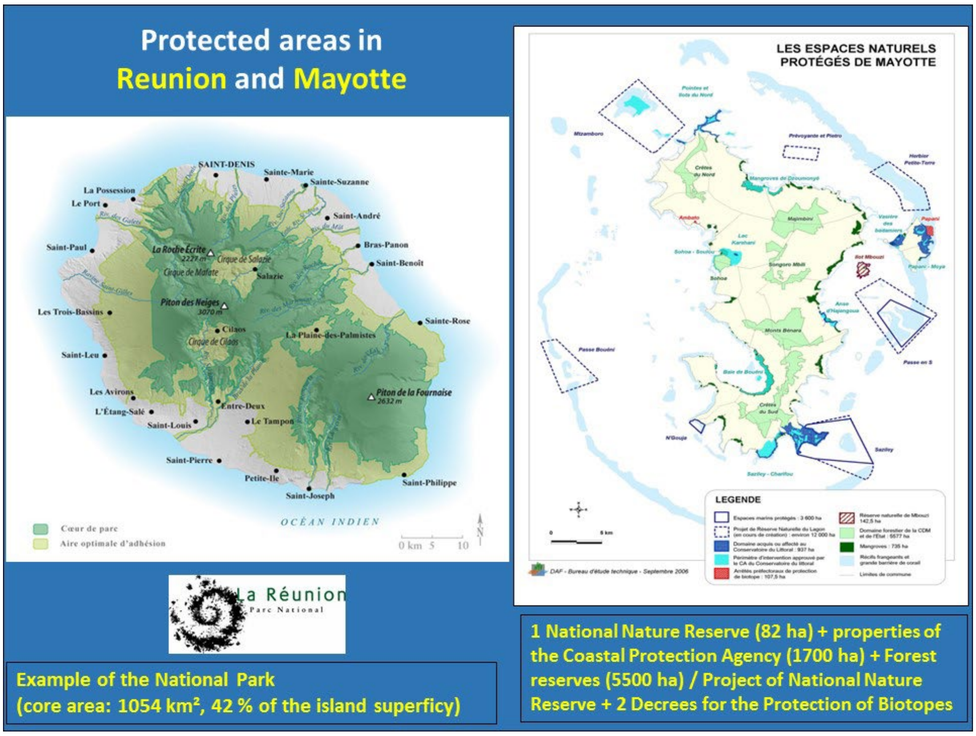


Figure 12: The protected areas in Reunion and Mayotte

control alien invasive species or for increasing the value of local perfume, aromatic and medicinal plants.

In Mayotte only 0.2 % of the territory are protected (National Nature Reserve of 82 ha created in 2007), on the small Island of M'Bouzi. If this total is combined with the properties acquired by the Conservatoire du Littoral (1,700 ha), the protected areas achieve almost 5 % of the territory. It should be added that there are six "forest reserves" (5,500 ha, 15 % of the territory) which are state-owned and departmental forests. These represent the last refuges where natural forest formations are found which are exceptional and unique in terms of biodiversity (ecosystems), as well as in their structure (forest stands) (Figure 12). A National Nature Reserve on 3,000 ha of forests (see below) and two Decrees for the Protection of Biotopes/Arrêtés de Protection de Biotope are also projected.

Case studies

A restoration program in Reunion Island

The site of "Grande Chaloupe' (250 ha) is one of the ultimate remnants of xerophilous forest of the island, with 23 protected plant species. The ecosystems have been damaged by fire and biological invasions. The program (LIFE+ COREXERUN) was cofinanced by the European Commission and led by the National Park of Reunion Island, with the help of the Coastal Protection Agency, the Directorate for Environment, Development and Housing (DEAL), the Regional Council and the General Council of La Reunion (Figure 13).

A high diversity of habitats characterize the Grande Chaloupe area (Figure 14). The program aimed at the restoration of 30 ha of forests on slopes and the reconstitution of 9 ha on plateau.

The restoration and reconstitution processes were as follows:

- collecting of about 300 000 seeds (2010/11) in the field,
- germination and cultivation in private nurseries for 6 months (2011),
- plantation of 100 000 plants of 50 indigenous and endemic species in 2012/13 for restoration of 30 ha and reconstitution of 9 ha, with management against invasive species.

The reconstitution on plateau happened during the 1st term of 2012 with introduction of 30 000 plants of 50 species in 500 plots of 20 m², with a density of 2 to 4 plants/m² and 10 to 15 different species by plot.

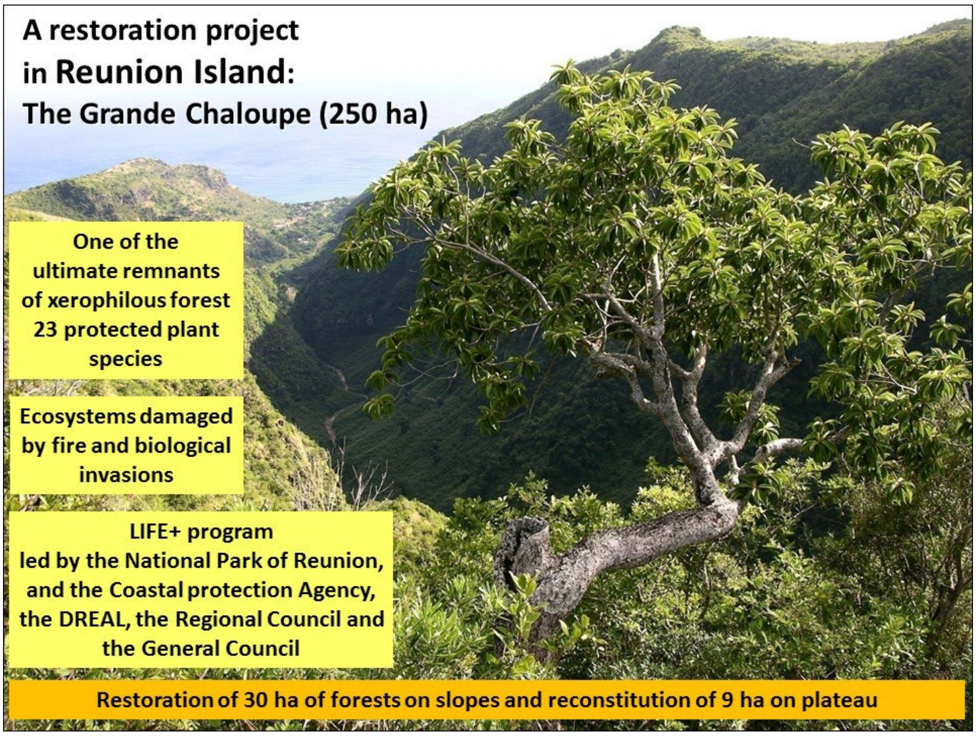


Figure 13: The restoration project of "Grande Chaloupe" in Reunion Island

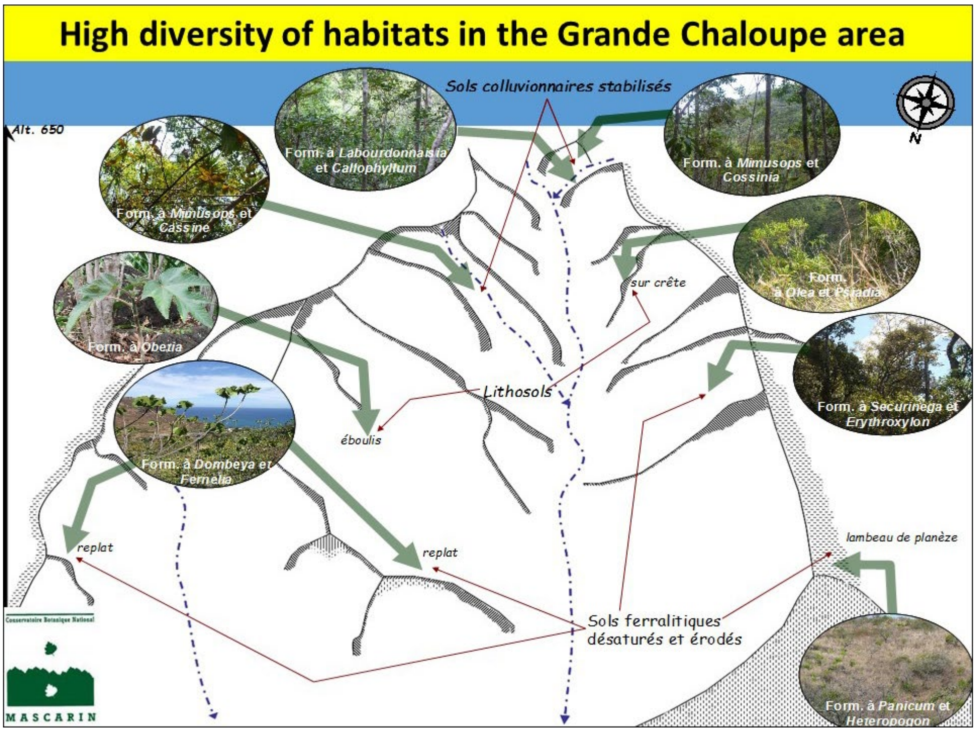


Figure 14: The high diversity of habitats in the "Grande Chaloupe" area

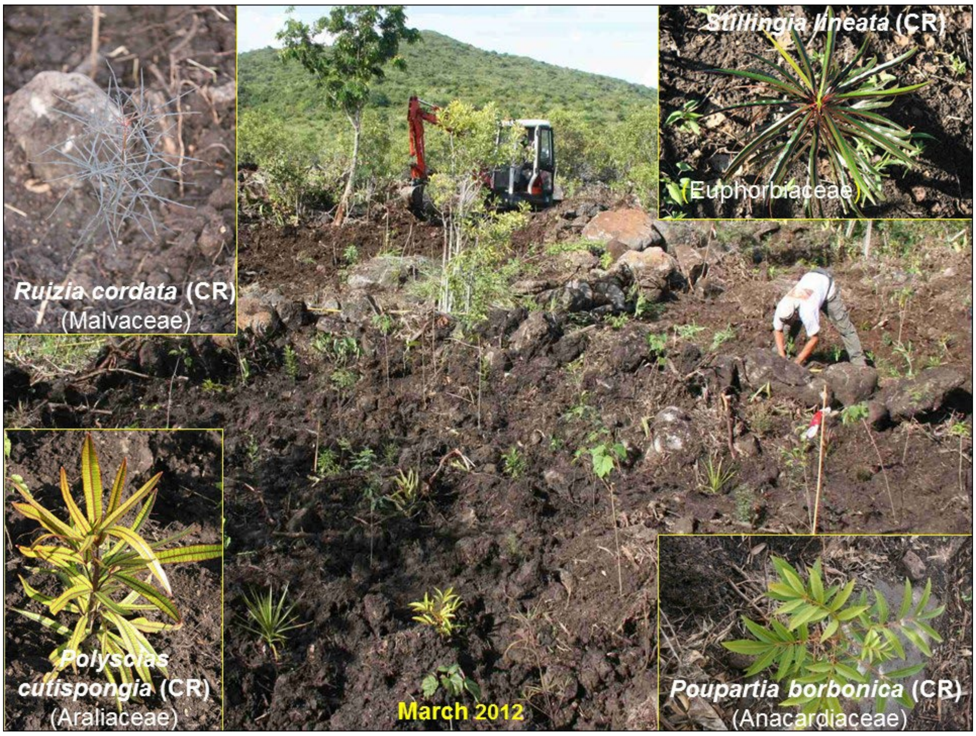


Figure 15: The planting of CR threatened species in March 2012 in "Grande Chaloupe"

Figure 15 shows the planting of CR threatened species in March 2012, with examples of *Ruizia cordata* (Malvaceae), *Polyscias cutispongia* (Araliaceae), *Stillingia lineata* (Euphorbiaceae) and *Poupartia borbonica* (Anacardiaceae).
The second step of plantations happened in 2013 (70 000 plants).

Figure 16 shows the favorable evolution of plants introduced in 2012 with examples of *Dombeya acutangula* and *Abutilon exstipulare* (Malvaceae), and other species.
The next phase, Life+ Forêt sèche, was initiated in 2014 with a plantation program of 80 000 additional trees by 2020 to allow the establishment and development of a young forest.

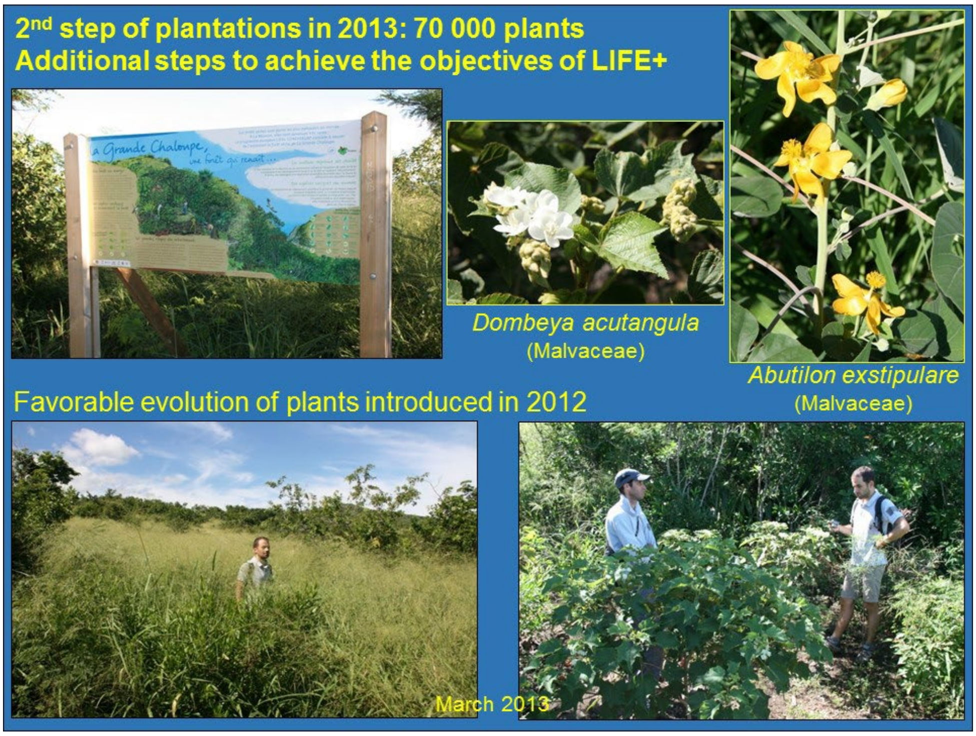


Figure 16: The favorable evolution of plants introduced in 2012 in "Grande Chaloupe"

Ultimately, and in return, the COREXERUN project will help disseminate a methodology and intervention procedures in other areas of the Mascarenes, allowing to increase knowledge around this under studied habitat and to raise awareness of the needs to preserve this fragile and iconic ecosystem.

A project of protected area in Mayotte

The project for the creation of a new National Nature Reserve in Mayotte aims at preserving 3,000 ha of forests (ca. 8 % of Mayotte surface) that are subject to growing anthropogenic pressures and impacts (Figure 17). The reserve will cover 6 areas of State and Departmental forests on the island. This reserve project, located on a hotspot of terrestrial biodiversity, is supported by the Ministry of Ecological and Inclusive Transition since 2017 and launched with the departmental council of Mayotte. It is also supported by the French committee of the International Union for the Conservation of Nature (IUCN) which had alerted, last May, on the state of mangroves "in critical danger". The new National Nature Reserve will be added to the management plan for sensitive natural areas and to the ecological coherence scheme of Mayotte. A classification of the lagoon as a UNESCO World Heritage is also planned (Actu-Environnement, 2017).

Key actors of the conservation

The implementation of the Global Strategy for Plant Conservation (GSPC) is ensured in France by work undertaken by multiple actors. Two networks are particularly active and committed: the network of National Botanical Conservatories (Conservatoires Botaniques Nationaux/CBN) and the network of Botanic Gardens.

The National Botanical Conservatories (Conservatoires Botaniques Nationaux/CBN)

Conservatoires Botaniques Nationaux
FÉDÉRATION

The National Botanical Conservatories benefit from legislative recognition since the law on the national commitment for the environment known as the Grenelle II law was enacted on July 12, 2010. They exercise missions of knowledge of the state and the evolution of the wild flora and natural and semi-natural habitats, identification and conservation of rare and endangered flora and habitats, scientific and technical competitions with public authorities (State, local authorities) and public awareness. They participate in the development and implementation of the National Inventory of Natural Heritage (INPN). As part of their public service mission, and based on their field inventory work, they prioritize the conservation of rare or endangered species in their territory of approval. In support of this strategy, they manage, where

necessary, seed banks and conservatory collections. They carry out their conservation actions in partnership with numerous institutional or associated structures.
The National Botanical Conservatories are today major tools for the implementation of State policy in the framework of international conventions, European directives, national legislation, for the knowledge and protection of wild flora and fauna and natural habitats.
The network of CBN employs over 300 people and includes eleven structures approved by the Ministry in charge of nature protection: ten in Metropolitan France and one for Reunion, Mayotte and the Scattered Islands. Two conservatories are currently preparing an application for approval in the West Indies and two further projects are under development, one in French Guiana and one for full geographical coverage in Northeastern France.

The Conservatoire Botanique National de Mascarin (Figure 17), created in 1986 in Reunion Island, conducts missions of knowledge, conservation and expertise on wild flora, vegetation and natural habitats. Until 1996, the main goal of CBNM was primarily focused on *ex situ* conservation; the cultivation and the propagation of rare and threatened plants endemic to Reunion and of the other Mascarene Islands (namely Mauritius and Rodrigues) and Madagascar. Now, The Conservatory is becoming more involved in the management and monitoring of species and populations in their natural habitats, including the study and control of invasive plants, which are recognized as one of the major threats to island native floras, and are also of growing importance for botanic gardens. *Ex situ* propagation is considered as the last lifebuoy of a species on the verge of extinction (as quoted by the late J.-P. Galland who founded the network of National Botanical Conservatories in France in 1988), and a tool for *in situ* conservation programs (reintroduction, population reinforcement in the wild, habitat restoration) (The Conservatoire Botanique National de Mascarin, 2001).
The Conservatoire Botanique National de Mascarin is currently the only conservatory in the French ODCT and has become a key player on the major issues of biodiversity conservation throughout the South West Indian Ocean. The National agreement has been delivered for Reunion Island in 1993 and for Mayotte & Eparse Islands in 2007.

The Conservatoire Botanique National de Brest is a public, scientific and technical establishment, created in 1975. Its first mission is to preserve the wild plant diversity of the West of France. It also supports plant conservation projects in other parts of the world. It is not only involved in the rescue of plant species that are endangered in the wild, but also in the preservation of plants in their natural environments. It is especially involved in the conservation of endangered plant species of the overseas islands (Reunion, Guadeloupe, Martinique and Polynesia). It has also carried out conservation actions for endangered and protected species of French Guiana. Furthermore, its international actions include the conservation of threatened plants of some oceanic islands (Mascarenes, Madagascar, Haïti and the Caribbean). As an accredited Conservatoire botanique, it also participates in the implementation of national biodiversity policies.

The network of French Botanic Gardens

Metropolitan France includes 90 botanic gardens, a mosaic of structures of different statutes: university botanic gardens, national or municipal gardens, conservatoires botaniques, associative or private gardens. The oldest French botanic garden was created in Montpellier in 1594. These botanic gardens have been organized in a national professional network since 1979 under the aegis of a legally recognized association. The association was then opened up in 1994 to membership by the botanic gardens in Francophone countries and is now called "Jardins botaniques de France et des pays francophones". Overseas, it includes the Jardin botanique de Mascarin, in Reunion Island. Its network now extends well beyond the national territory, in French-speaking European countries such as Switzerland, Luxembourg and Belgium, in the Caribbean and also in the Southern hemisphere in Madagascar, Senegal and Vietnam. It now includes over 200 members.
These structures participate, each in their own way, in programs for the conservation of plant diversity through research projects, integrated conservation, education,

as well as in raising public awareness of the need to preserve biodiversity and the sustainable management of resources of the planet. The association supports the creation or evolution of botanic gardens and organizes scientific and technical training sessions each year bringing together the different actors working in these institutions.
After almost 40 years of existence and 30 accredited gardens, the association pursues its primary mission: to promote the perpetuation and creation of plant collections. It ensures the link between its members, with varied statutes but animated by the same will, that of growing and supplying botanical knowledge for purposes of scientific research, conservation and education. The association is represented in major European and International bodies mobilizing botanic gardens for the conservation of biodiversity and education for sustainable development.

The Directions régionales de l'Environnement, de l'Aménagement et du Logement (DEAL) and the French National Action Plans (PNA/NAPs)

National Action Plans are guidance documents aimed at defining the actions necessary for the conservation and restoration of the most endangered animal and plant species in order to ensure their good state of conservation. The first plans were launched between 2012 and 2015. They are locally coordinated by the Directions régionales de l'Environnement, de l'Aménagement et du Logement (DEAL). On Reunion Island, the DEAL Reunion coordinates the following four action plans:

- PNA 'Bois de poivre'- *Zanthoxylum heterophyllum* (EN)
- PNA 'Bois de papaye'- *Polyscias aemiliguineae* (CR)
- PNA 'Bois blanc rouge'- *Poupartia borbonica* (CR)
- PNA 'Bois de senteur blanc'- *Ruizia cordata* (CR)

The Conservatoire du Littoral

The Conservatoire du Littoral (Coastal Protection Agency) is a unique administrative public institution created in 1975 and dedicated to the acquisition and protection of coastal areas. Its purpose is to conduct, in partnership with the local authorities, a land policy to safeguard the coastal areas and the respect for natural sites and their ecological balance.
The actions are conducted according to 3 areas of intervention:

- Maintain large natural landscape,
- Protect coastal ecosystems with strong ecological interest,
- Welcome the public to the sites to discover and raise awareness on the challenges of preserving the natural and cultural heritage.

The aim is to protect a third of the coastline of Metropolitan and Overseas France by 2050, including, in addition to the Conservatoire sites, the coastline protected by national parks, nature reserves, listed heritage sites, state-owned forests and sensitive natural areas (Protected areas in France, 2013).
Since 1975, the Conservatoire du Littoral has acquired vulnerable and threatened coastal and lakeshore areas to ensure their permanent protection. This land-purchasing policy aims at safeguarding natural areas of ecological and landscape value on the coastline and lakeshores, while ensuring public access. The land is acquired amicably, by pre-emption, and only in exceptional cases by expropriation. Once incorporated into the public domain, it becomes virtually inalienable.
Numerous planning operations aimed at receiving visitors and restoring natural habitats, as well as daily management interventions, are performed in order to restore often degraded ecosystems and to regulate public visits and use.
Inspired by the British National Trust, the Conservatoire du littoral sets up management partnerships, primarily with local communities, to promote a local sense of ownership of the sites. Today, nearly 13 % of the French coastline (1,450 km, 203,645 ha, 750 sites) are protected under this system (Conservatoire du littoral, 2019).
In Reunion Island, the Conservatoire du littoral currently manages 17 sites with a total area of approximately 1,713 ha, that are spread over the entire coastline. The Agency owns the sites, but the management is carried out by partners, primarily local authorities, or other structures (Associations, NFBs, Parks, ONCFS, etc.) (Conservatoire du littoral de la Réunion, 2016).
In Mayotte, the Conservatoire du littoral permanently protects 1,708 hectares of woody, sandy or rocky shores spread over fifteen sites. Many habitats of endangered species and remarkable ecosystems are thus preserved: beaches for sea turtles, lakes, mangroves, islets, dry forests.

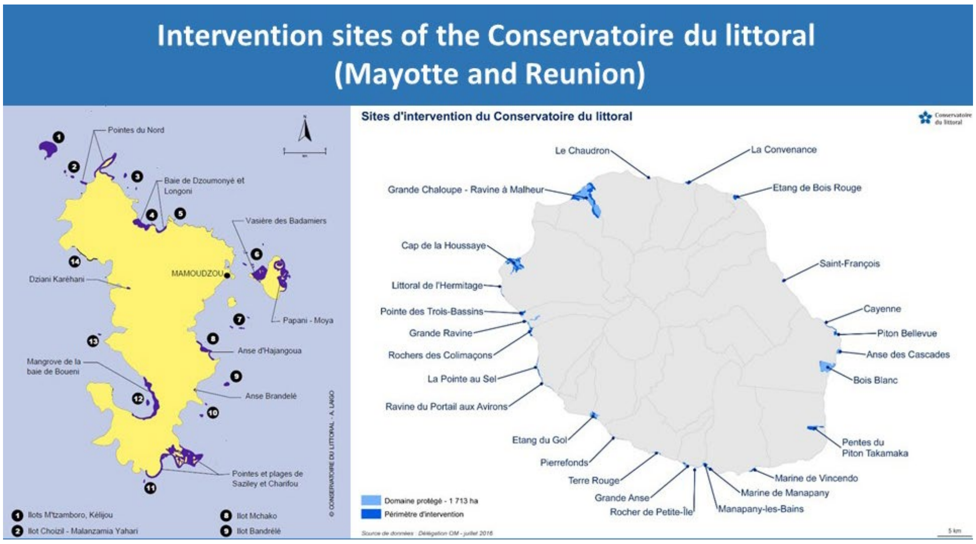


Figure 17: Intervention sites of the Conservatoire du Littoral/ Coastal Protection Agency (Mayotte and Reunion)

The Figure 17 presents the sites of the Coastal Protection Agency in Mayotte and Reunion Islands.

The Muséum National d´Histoire Naturelle (MNHN)

The Muséum national d'Histoire naturelle has a long tradition of overseas research in all areas of its statutory missions (collections, research, teaching, dissemination, expertise). The Muséum has representatives in French Guiana and Reunion Island but it is also involved in all overseas collectivities where it initiates and performs many studies, in particular in the field of biodiversity inventories. For example, Reunion and Mayotte are home of a vast array of studies undertaken by the Muséum's scientists and experts (plant inventories and taxonomy, islands hygrophilous habitats, phototrophic microorganisms and new cyanobacteria in volcanic areas, interactions between ecology and anthropology, etc.).

In the field of expeditions, "La Planète revisitée/Our Planet Reviewed" is a major exploration programme of the natural world aiming at acquiring new knowledge in the regions of the planet with the greatest biodiversity, but which have remained largely unexplored. French Guiana was visited in 2014-2015 and New Caledonia in 2016-2018.

Initiatives for raising awareness on the biodiversity of other French ODCT and on the threats they face include the establishment of the New Caledonian greenhouse in 2010 with its specific plant collections (Larpin et al., 2011). The five most threatened or important ecosystems of the archipelago (humid forest, dry forest, mine maquis, savanna and mangrove) have been reconstituted and enhanced by an original scenography. Another striking example is the Great Greenhouse of the renovated Parc zoologique de Paris (reopened in 2014) in which the atmosphere (plants and animals) of the Guianan-Amazonian and Malagasy tropical rainforests has been recreated (Zoological Park of Paris, 2014).

The threatened flora of Mayotte and Reunion Islands in *ex situ* collections, botanical gardens and seed banks

In order to be in line with GSPC target 8, France should aim at conserving at least 75 % of the threatened flora of Mayotte and Reunion Islands in *ex situ* collections, botanic gardens and seed banks, preferably in the country of origin and make sure that at least 20 % are available for recovery and restoration programs.

A first census of these threatened taxa with IUCN Status EN, CR, EX EW, RE conserved in national *ex situ* collections has been made using the BGCI PlantSearch Database (https://www.bgci.org/plant_search.php) and other sources of information. 20 taxa in these categories are found in Mayotte and 61 in Reunion. Table 2 shows the contribution of the French Botanic Gardens and National Conservatories, among them some that have not yet been mentioned in this article (Conservatoire botanique et jardins botaniques de Nancy, Jardin botanique de la ville de Lyon, Jardin botanique de la ville de Paris, Jardin botanique de la ville de Strasbourg).

The census has also been made for threatened taxa

with IUCN Status EN, CR, EX EW, RE from Mayotte and Reunion conserved in international *ex situ* collections (38 taxa for Mayotte and 94 for Reunion are included). The results are presented in Tables 3 and 4 respectively for Mayotte and Reunion, showing the largest contributions for some botanic gardens in Europe (Kew, Edinburgh, Meise), North America (Bishop Museum, Marie Selby, Atlanta), Asia (Singapore) and Australia (Sydney).
Lastly the threatened taxa (IUCN Status EN, CR, EX EW, RE) of these two French Overseas Departments not represented in *ex situ* collections are shown in Table 5 (29 for Mayotte and 104 for Reunion).

For Mayotte out of 71 threatened species evaluated with IUCN Status EN, CR, EX EW, RE, 42 (59 %) are conserved in *ex situ* collections (French and international) and 29 are not represented.
For Reunion out of 216 threatened species evaluated with IUCN Status EN, CR, EX EW, RE, 112 (52 %) are conserved in *ex situ* collections (French and international) and 104 are not.
The results of the census carried out for both French Overseas Departments are encouraging with more than half of the threatened evaluated species currently conserved *ex situ*. But these taxa have unequal

Mayotte and Reunion
Census of Taxa in French *ex situ* collections
IUCN Status EN, CR, EX EW, RE

INSTITUTION	Nb TAXA	MAYOTTE (20)	REUNION (61)
Conservatoire et Jardins Botaniques de Nancy	42	10	32
MNHN (Jardin des Plantes Paris & Arboretum Chevreloup 28, Menton 9, MNHN Seed Bank 1, La Jaysinia 1, Harmas de Fabre 1)	40	13	27
Jardin Botanique de la Ville de Lyon	36	9	27
Conservatoire Botanique National de Brest	25	1	24
Jardin botanique de la Ville de Paris	19	6	13
Conservatoire Botanique National de Mascarin	16	1	15
Jardin Botanique de l'Université de Strasbourg	14	5	9
Les Jardins Suspendus (Le Havre)	12	2	10
Jardin Botanique de la Ville de Caen	9	5	4
Jardin des Plantes de l'Université de Montpellier	7	5	2
Conservatoire Botanique Pierre Fabre	7	4	3
Jardin Botanique et Arboretum Henri Gaussen	4	1	3
Jardin Botanique Yves Rocher	3	1	2
Jardin Botanique de Marnay sur Seine	3	1	2

Table 2: Census of threatened taxa of Mayotte and Reunion in French *ex situ* collections (IUCN status EN, CR, EX EW, RE)

Mayotte
Census of Taxa in INTERNATIONAL *ex situ* collections
IUCN Status EN, CR, EX EW, RE

INSTITUTION (229)	COUNTRY	Nb TAXA (38)
Royal Botanic Gardens Kew	UK	15
Singapore Botanic Gardens	SINGAP	11
Botanic Garden Meise	BELG	10
Atlanta Botanical Garden	USA	10
Fairchild Tropical Botanic Garden	USA	9
Marie Selby Botanical Gardens	USA	9
Multiplant International Medicinal Conservation	KENYA	9
Multiplant International Medicinal Conservation-Seed Bank	KENYA	9
Montreal Botanical Garden / Jardin botanique	CANADA	9
Royal Botanic Gardens Sydney	AUS	8
Conservatoire et Jardin botaniques de la Ville de Genève	SWI	8
Bishop Museum	USA	8
Honolulu Botanical Gardens System	USA	8
United States Botanic Garden	USA	8
Kirstenbosch, NYBG, USDA, Brisbane, Xishuangbanna	-	7
and: **5** (6 taxa), **13** (5 taxa), **15** (4 taxa), **20** (3 taxa), **45** (2 taxa), **105** (1 taxon)		

Table 3: Census of threatened taxa of Mayotte in International *ex situ* collections (IUCN status EN, CR, EX EW, RE)

representation. Some taxa are frequently present in the different Conservatoires or Jardins botaniques, whereas other species are only represented by a small number or even a single accession (data has been obtained but is not shown in the tables). Furthermore, the percentage of availability of these taxa for recovery and restoration programs has not yet been evaluated in the present study. This shows that the objectives are not yet achieved and that there are efforts still to be made, at least by 2020, to achieve the conservation of these sensitive species outside of their territory of origin.

CONCLUSION

As a response to its international commitments to safeguard and preserve plant biodiversity, France has developed a series of appropriate structures, tools, measures and action plans. There is still great scope for progress with respect to the challenging extent and variety of France Overseas Departments, Countries and

Reunion
Census of Taxa in INTERNATIONAL *ex situ* collections
IUCN Status EN, CR, EX EW, RE

INSTITUTION (301)	COUNTRY	Nb TAXA (94)
Royal Botanic Gardens Kew	UK	33
Royal Botanic Garden Edinburgh	UK	20
Royal Botanic Gardens Sydney	AUS	18
Botanic Garden Meise	BELG	17
Bishop Museum	USA	16
Marie Selby Botanical Gardens	USA	16
Botanical Garden, Natural History Museum of Denmark	DEN	15
Botanic Gardens of South Australia	AUS	14
Singapore Botanic Gardens	SINGAP	14
National Tropical Botanical Garden	USA	14
Botanische Gärten der Universität Bonn	GER	13
Conservatoire et Jardin botaniques de la Ville de Genève	SWI	13
The New York Botanical Garden	USA	13
Waimea Valley Arboretum and Botanical Garden	USA	13
Tartu, Bayreuth, Dresden, Osnabrück, Kirstenbosch, Main Russia, Shanghaï Chenshan	-	12
and: **3** (11 taxa), **12** (10 taxa), **3** (9 taxa), **5** (8 taxa), **12** (7 taxa), **9** (6 taxa)		
19 (5 taxa), **20** (4 taxa), **26** (3 taxa), **59** (2 taxa), **112** (1 taxon)		

Table 4: Census of threatened taxa of Reunion in International *ex situ* collections (IUCN status EN, CR, EX EW, RE)

Mayotte and Reunion Isl.

Taxa not represented in *ex situ* collections
IUCN Status EN, CR, EX EW, RE

Mayotte (29)

EN	Adiantum flabellum
EN	Begoniacomorensis
EN	Chadsia coluteifolia
EN	Diplazium arborescens
EN	Lagrezia comorensis
EN	Medinilla tuberosa
EN	Oncostemum ankifiense
EN	Platylepis polyadenia
EN	Rapanea comorensis
EN	Rinorea auriculata
CR	Amyrea humbertii
CR	Antrophyum immersum
CR	Aristogeitonia monophylla
CR	Cassipourea ovata
CR	Chionanthus cordifolius
CR	Dalbergiacomorensis
CR	Foetidiacomorensis
CR	Ivodea choungiensis
CR	Leersiaperrieri
CR	Monoporus bipinnatus
CR	Ocotea comoriensis
CR	Peponidium humbertianum
CR	Pisonia sechellarum
CR	Psiadia pascalii

Réunion (104)

EX EW	Claoxylon grandifolium
EX EW	Ferneliapedunculata
EX EW	Mucuna pallida
RE	Adenostemma mauritianum
RE	Amauropelta oppositiformis
RE	Angraecum palmiforme
RE	Asplenium bipartitum
RE	Badulacrassa
RE	Cerastium indicum
RE	Dennstaedtia anthriscifolia
RE	Disperis discifera
RE	Gouania tiliifolia
RE	Grammitis pygmaea
RE	Hymenophyllum balfourii
RE	Hypolepissparsisora
RE	Launaea sarmentosa
RE	Lomariopsiscordata
RE	Lomariopsisvariabilis
RE	Mariscus sumatrensis
RE	Megalastrum lanuginosum
RE	Nerviliabicarinata
RE	Ophioglossum convexum
CR	Alysicarpus bupleurifolius
CR	Amauropelta tomentosa
CR	Angraecum corrugatum
CR	Angraecum viridiflorum
CR	Asplenium petiolulatum
CR	Chamaesyce goliana
CR	Christella gueinziana
CR	Cynorkis cadetii
CR	Cynorkis peyrotii
CR	Cyperus expansus
CR	Eleocharis minuta
CR	Eulophia borbonica
CR	Glinus oppositifolius
CR	Heliotropium foertherianum
CR	Heterochaenia fragrans
CR	Hypolepis goetzei
CR	Indigofera diversifolia
CR	Lepechina chamaedryoides
CR	Liparis hidlebrandtiana
CR	Lomariopsis mauritientis
CR	Ludwigia jussiaeoides
CR	Najas madagascariensis
CR	Nesogenes orerensis
CR	Persicaria poiretii
CR	Pisonia lanceolata
CR	Potamogeton thunbergii
CR	Pseudophegopteris aubertii
CR	Pteris croesus
CR	Pteris nevillei
CR	Pteris pseudolonchitis
CR	Pyrostria commersonii
CR	Senecio ptarmicifolius
EN	Adiantum hirsutum
EN	Aeranthes adenopoda
EN	Angraecum tenuifolium
EN	Antrophyum immersum
EN	Bathiorchis rosea
EN	Chamaesyce viridula
EN	Cheiroglossa malgassica
EN	Claoxylon racemiflorum
EN	Coptosperma borbonica
EN	Crepidomanes frappieri
EN	Cyperus stoloniferus
EN	Dombeya blattiolens
EN	Dombeya umbellata
EN	Doryopteris pedatoides
EN	Droguetia gaudichaudiana
EN	Dryopteris antarctica
EN	Eulophia versicolor
EN	Fimbristylis sieberiana
EN	Gladiolus luteus
EN	Gleichenia polypodioides
EN	Grammitis poolii
EN	Habenaria undulata
EN	Heterochaenia borbonica
EN	Huperzia saururus
EN	Hydrocotyle grossularioides
EN	Liparis bernieri
EN	Liparis punctilabris
EN	Megalastrum canacae
EN	Melicope segregis
EN	Nesaea triflora
EN	Phragmites mauritianus
EN	Pilea cadetii
EN	Polyscias borbonica
EN	Polyscias sessiliflora
EN	Psiadia rivalsii
EN	Pyrostria orbicularis

Table 5: Census of threatened taxa of Mayotte and Reunion not represented in International *ex situ* collections (IUCN status EN, CR, EX EW, RE)

Territories, but different schemes are being deployed gradually outside Metropolitan France to safeguard their biodiversity.

Progress is still slow but steady, from the launch of the French National Biodiversity Strategy in 2011 to the elaboration of Regional Biodiversity Strategies, as in Reunion and Mayotte, to the extension of the network of protected areas and to the inventory of species with threatened status.

With regard to the deployment of *in situ* and *ex situ* measures concerning overseas rare and threatened species, two new Conservatoires Botaniques Nationaux are in the pipeline in Guadeloupe and Martinique; they will join in the work with the first overseas Conservatoire Botanique National de Mascarin in Reunion Island, created in 1986. The JBF network is aiming at developing concerted actions for the *ex situ* conservation of species listed in the appendices to the international conventions and not yet or insufficiently represented in the *ex situ* collections at a global level. Twinning programs are also being developed between Metropolitan and Overseas French Botanic gardens.

Lastly, with the launch of the French Agency for Biodiversity in 2017, which now groups four previous agencies, the Agency of marine protected areas, the Technical workshop of the natural spaces, the National office of water and aquatic environments and the French National parks, a new impetus has been given to allow the implementation of the different strategies and action plans.

As for the ODCT, the French Agency for Biodiversity (AFB) is building partnerships with local authorities and stakeholders in order to implement its strategy. Thus, the AFB wants to mobilize and federate all the stakeholders acting for the biodiversity in the French ODCT around a common project: reconciling preservation of these exceptional reservoirs of biodiversity and endogenous development of the human activities (Agence Française pour la Biodiversité, 2018).

REFERENCES

Amann C., G., Arhel R., Guiot V., Marquet G. (2011) *'Plantes de Mayotte'.* Les guides naturalistes, Naturalistes, environnement et patrimoine de Mayotte, 366 p.

Barbé, M., Fenton, N., Lavergne C., Le Péchon, T., Baider, C., Gigord, L. (2015) *'Changes in lowland dry-forest native and alien plant communities on Réunion Island (Indian Ocean) over 16 years'.* Botany 93, 12 (843).

Baret, S., Rouget, M., Richardson D.M., Lavergne C., Egoh D., Dupont J., Strasberg D. (2006) *'Current distribution and potential extant of the most invasive alien species on La Réunion (Indian Ocean, Mascarene Islands)'*. Austral Ecology 31: 747-758.

Baret S., Fontaine C., Lavergne C., Saliman M., Herman S., Triolo J., Bazil S., Sertier J.C., Lequette B., Gigord L., Lucas R., Picot F., Muller S. (2012) *'Une méthodologie concertée pour la sauvegarde des plantes menacées de l'île de La Réunion'.* Revue d'Ecologie (Terre & Vie), supplément 11, 85-100.

Barthelat F. (2007) *'Flore et végétation de Mayotte, une histoire naturelle'*. Univers Mahorais, 6: 22-35 & 7: 38-48.

Barthelat F., M'Changama M., Ali Sifari B. (2006) *'Atlas illustré de la flore protégée de Mayotte',* version provisoire, 53 p.

Barthelat F., Viscardi G. (2012) *'Flore menacée de l'île de Mayotte : importance patrimoniale et enjeux de conservation'.* Revue d'Ecologie (Terre & Vie), supplément 11: 15-27.

Beauvais M.-L., Coléno A., Jourdan H. (2006) Les espèces envahissantes dans l'archipel néo-calédonien: un risque environnemental et économique majeur. IRD Editions, Paris.

Blanchard F. (2000) *'Guide des milieux naturels. La Réunion-Maurice-Rodrigues'.* 384 p. Ulmer, Paris.

Boullet V. (2007) *'Éléments pour le dossier UNESCO: habitats, végétation et flore. Habitats, flore et végétation : diversité et originalité.'* Dossier de candidature du dossier « pitons, cirques et remparts de l'île de La Réunion » au classement au Patrimoine Mondial de l'UNESCO : Partie Biodiversité. Rapport d'expertise non publié, Parc national de la Réunion, 53 p. Online : http://www.regionreunion.com/fr/spip/IMG/pdf/CNBM_UNESCO.pdf

Boullet V. et al. (2005) *'Mayotte biodiversité et évaluation patrimoniale, Contribution à la mise en œuvre des ZNIEFF'*. CBNM, juillet 2005, 324 p.

Boullet V. (2006a) *'La flore vasculaire de l'île de la Réunion'.* Ethnopharmacologia 38: 13-23.

Boullet V. (2006b) *'Notice de l'Index de la Flore vasculaire de la Réunion'.* Version 2006.1.

Cadet T. (1974) *'Étude sur la végétation des hautes altitudes de l'île de la Réunion'*. Vegetatio 29(2): 121-130.

Cadet T. (1977) *'La végétation de l'île de La Réunion: Étude phytoécologique et phytosociologique'.* Thèse de Doctorat d'état, Université Aix Marseille III, 2 vols, I Texte: 362 p., II Annexes [Réimpression 1980, Imprimerie Cazal, Saint-Denis de la Réunion].

Carié P. (1927) *'Végétation caractéristique et biogéographie des Massifs montagneux des Iles Mascareignes'.* Compte Rendu Sommaire des Séances de la Société de Biogéographie 32: 96-97 (4ème année).

Conservatoire Botanique National de Mascarin (Boullet V. coord.) (2007) *'Index de la flore vasculaire de la Réunion (Trachéophytes): statuts, menaces et protections'.* Version 2007.1.

Donlan C.J., Wilcox C. (2008) *'Diversity, invasive species and extinctions in insular ecosystems'*. Journal of Applied Ecology 45: 1114-1123.

Dupouey J.-L., Cadet T. (1986) *'Subdivisions de la forêt de bois de couleur à l'île de la Réunion'.* Annales des sciences forestières 43(1): 103-113.

Fadul R. (2010) *'Le Baobab Malgache – Adansonia madagascariensis Baillon – Plan Directeur de Conservation: outils d'aide à la conservation des espèces végétales menacées d'extinction'.* Version décembre 2010. Conservatoire Botanique National de Mascarin, Saint-Leu (Réunion), 69 p.

Fadul R. (2011) *'Typologie descriptive des habitats naturels de Mayotte – Outil de connaissance et de conservation du patrimoine naturel végétal'.* Rapport final pour le compte de la DEAL de Mayotte, CBNM, Décembre 2011, 87 p.

Fonty E., Sarthou C., Larpin D., Ponge J.-F. (2009) *'A 10-year decrease in plant species richness on a neotropical inselberg: detrimental effects of global warming?'* Global Change Biology 15:2360–2374.

Frenot Y., Chown S.L., Whinam J., Selkirk P., Convey P., Skotnicki M., Bergstrom D. (2005) *'Biological invasions in the Antarctic: extent, impacts and implications'.* Biological Review 80: 45-72.

Gargominy O. (ed.) (2003) *'Biodiversité et conservation dans les collectivités françaises d'outremer'.* X et 246 p. Collection Planète Nature. Comité français pour l'UICN, Paris, France.

Gigord l., Hivert J., Cuidet Y. principal authors (2013) *'Conservatoire Botanique National de Mascarin. Flore et végétations des îles Éparses'.* Online: http://ileseparses.cbnm.org/

Guiot V. (2011) *'Les zones humides de Mayotte'*. Volume 1: rapport & annexes, CBNM, Ministère de l'Ecologie et du Développement durable et de la Mer, 514 p. (35 p. + fiches descriptives).

Kiehn M. (2011) *'Invasive alien species and islands'*. Pp 365-384 In Bramwell D, Caujapé-Castells J (eds) The Biology of Island Floras, Cambridge University Press, Cambridge.

Kueffer C., Lavergne, C. (2004) '*Case studies on the status of invasive woody plant species in the Western Indian Ocean. Réunion'.* FAO. 37 p.

Kueffer C., Daehler C.C., Torres-Santana C.W., Lavergne C., Meyer J.-Y., Otto R., Silva L. (2010) *'A global comparison of invasive plant species on oceanic islands'.* Perspectives in Plant Ecology, Evolution and Systematics 12: 141-165.

Larpin D., Joly E., Delmas M. (2011) *'A New Caledonian Glasshouse in Paris – Challenges and Opportunities'.* Sibbaldia 9:55-76.

Lavergne C., Rameau C., Figier J. (1999) *'The invasive woody weed Ligustrum robustum subsp walkeri threatens native forest on La Reunion'.* Biological Invasions 1: 377-392.

Lindeman, J. C., Mori S.A. (1989) The Guianas. In: Campbell, D.G., and H. D. Hammond (eds.). *'Floristic inventory of tropical countries'.* New York Botanical Garden, New York, USA.

Loppe L.L., Mueller-Dombois D. (1989) *'Characteristics of invaded islands, with special references to Hawaii'.* Pp. 257-280 In: Drake J.A., Mooney H.A., Di Castri F., Groves R.H., Kruger F.J., Rejmanek M., Williamson M. (eds) Biological Invasions: a Global Perspective, John Wiley and Sons, Chichester.

Mac-Donald I.A.W., Thébaud C., Strahm W.A., Strasberg D. (1991) *'Effects of Alien Plant Invasions on Native Vegetation Remnants on La Reunion (Mascarene Islands, Indian Ocean)'*. Environmental Conservation 18: 51-61.

Meyer J.-Y. (2004) *'Threat of invasive alien plants to native flora and forest vegetation of Eastern Polynesia'.* Pacific Science 58:357–375.

Meyer J.-Y., Florence J. (1996) *'Tahiti's native flora endangered by the invasion of Miconia calvescens DC. (Melastomataceae)'.* Journal of Biogeography 23: 775-781.

Meyer J.-Y, Claridge E.M. (Eds) (2014) *'Terrestrial Biodiversity of the Austral Islands, French Polynesia'.* Muséum national d'Histoire naturelle, Paris, 224 p. (Patrimoines naturels; 72).

Muller S. (2011) *'La toundra artico-alpine de l'archipel de Saint-Pierre-et-Miquelon face au changement climatique: mise en place de dispositifs de suivi de la végétation'*. Revue Forestière Française, 62 (3/4): 477-484.

Muller S., Meyer J.Y. (2012) '*Les enjeux de la conservation de la flore et des habitats naturels menacés de l'outre-mer français'*. Revue d'Ecologie (Terre & Vie), supplément 11, 7-14.

Muller S., Etcheberry R., Abraham D. (2012) *'Les plantes vasculaires rares et menacées de l'archipel de Saint-Pierre-et-Miquelon'.* Revue d'Ecologie (Terre & Vie), supplément 11, 47-55.

Pascal O. (2002) *'Plantes et forêts de Mayotte'.* SPN, IEGB - Muséum national d'Histoire naturelle, Paris, 116 p. (Patrimoines naturels; 53).

Pascal, O., Labat, J.-N., Pignal, M., Soumille, O. (2001) *'Diversité, affinités phytogéographiques et origines présumées de la flore de Mayotte (Archipel des Comores)'* 1101-1123. In: Jardin botanique national de Belgique (eds.). Systematics and Geography of Plants. Vol. 71, No. 2, Plant Systematics and Phytogeography for the Understanding of African Biodiversity, Meise.

Rivals P. (1952) *'Études sur la végétation naturelle de l'île de la Réunion'.* 214 p. Les Artisans de l'Imprimerie, Toulouse.

Rolland R. & V. (2005) *'Mayotte: biodiversité et évaluation patrimoniale, contribution à l'inventaire ZNIEFF'.* Rapport DAF de Mayotte (Service Environnement Forêt) et Conservatoire Botanique National de Mascarin, 328 p.

Strasberg D., Dupont J., Rameau J.-C. (2000) *'Typologie des milieux naturels et des habitats de la Réunion'.* DIREN/Université de la Réunion, 19 p.

Strasberg D., Rouget M., Richardson D.M., Baret S., Dupont J., Cowling R.M. (2005) 'An assessment of habitat diversity and transformation on La Réunion Island (Mascarene Islands, Indian Ocean) as a basis for identifying broad-scale conservation priorities'. Biodiversity and Conservation 14: 3015-3032.

Actu-Environnement (2017). Online: https://www.actu-environnement.com/ae/news/nouvelle-reserve-naturelle-nationale-mayotte-29567.php4

Agence Française pour la Biodiversité (2018). Online: https://www.afbiodiversite.fr/fr/actualites/seminaire-outre-mer-du-09-au-11-avril-2018

CBN Mascarin (2018). Online: https://www.cbnm.org

Chiffres clés de la biodiversité en France (2018). Online: https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2019-02/datalab-48-cc-biodiversite-les-chiffres-cles-edition-2018-decembre2018a.pdf

Conservatoire du littoral (2019). Online: http://www.conservatoire-du-littoral.fr/

Conservatoire du littoral de la Réunion (2016). Online: http://www.reunion.developpement-durable.gouv.fr/le-conservatoire-du-littoral-r259.html

French policy on biodiversity (2019). Online: https://www.diplomatie.gouv.fr/en/french-foreign-policy/sustainable-development-environment/french-policy-on-biodiversity/france-s-contribution-to-the-protected-areas/

IUCN Country Focus, Mayotte (2019). Online: https://www.iucn.org/regions/europe/resources/country-focus/mayotte-france

IUCN, Mayotte's flora and forests – a threatened heritage (2013). Online: https://www.iucn.org/content/mayotte%E2%80%99s-flora-and-forests-%E2%80%93-threatened-heritage

Ministère de la Transition Ecologique et Solidaire (2019a). Online: https://www.ecologique-solidaire.gouv.fr/aires-protegees-en-france

Ministère de la Transition Ecologique et Solidaire (2019b). Online: https://www.ecologique-solidaire.gouv.fr/biodiversite-presentation-et-enjeux

Ministère des Outre-Mer (2019). Online: http://www.outre-mer.gouv.fr/

Observatoire National de la Biodiversité (2018). Online: http://indicateurs-biodiversite.naturefrance.fr/

Protected areas in France (2013). Online: http://uicn.fr/wp-content/uploads/2016/08/Espaces_naturels_proteges-EN-ok.pdf

Stratégie biodiversité pour le développement durable de Mayotte (2014). Online: https://uicn.fr/wp-content/uploads/2016/09/Strategie_Biodiversite_Mayotte.pdf

Stratégie de conservation de la flore et des habitats de la Réunion. Online: http://www.reunion.developpement-durable.gouv.fr/IMG/pdf/SCFHR-web_cle013cee.pdf

Stratégie réunionnaise pour la biodiversité (2014). Online: http://www.reunion.developpement-durable.gouv.fr/IMG/pdf/SRB-2013-2020_cle093a71.pdf

The Conservatoire Botanique National de Mascarin (2001). Online: http://www.bgci.org/worldwide/article/0126/

The Flora of Reunion Island at Risk (2010). Online: https://www.iucn.org/content/flora-réunion-island-risk-one-three-species-are-threatened-extinction

The IUCN Red List of Threatened species (2017). Online: https://www.iucnredlist.org/

Zoological Park of Paris (2014). Online: https://www.parczoologiquedeparis.fr/sites/parczoologiquedeparis/files/documents/dp-pzp-gb-mars_2014.pdf

LIVING COLLECTIONS OF TROPICAL PLANTS AS NATIONAL HERITAGE COLLECTIONS OF UKRAINE

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ABSTRACT

Ex situ conservation of tropical plants threatened with extinction within their native ranges is one of the highest priorities on the research agenda for the botanic gardens of Ukraine. The most numerous living plant collections have been accumulated at the O.V. Fomin Botanic Garden, the Botanic Garden of Ivan Franko National University of Lviv and the M.M. Gryshko National Botanic Garden of NAS of Ukraine (NBG). All of them have the status of National Heritage Collections of Ukraine.

Since the publication of the Global Strategy for Plant Conservation (GSPC) in 2002, this strategy has been implemented at the botanic gardens of Ukraine with a particular focus on Target 8 (*ex situ* conservation), which proposes that by 2020 at least 75% of threatened plant species will be present in *ex situ* collections, and that at least 20% will be available for recovery and restoration programs. Therefore, it was important to assess the taxonomic diversity of living plant collections of tropical plants maintained at various botanic gardens focusing on the main plant groups that are of the highest priority for *ex situ* conservation. Field expeditions in tropical regions of the world (Vietnam, Madagascar, Costa-Rica, South Africa, Reunion) were undertaken to assess the main threats to tropical plants and to prioritize the plant groups to be the main focus for in-depth investigations aimed at long-term conservation under *ex situ* conditions.

Current research activities at our botanic gardens are focused on the following issues: studies of developmental biology of plants under glasshouse conditions; investigation of structural adaptations and life histories of orchids, succulents, cycads to survival under a wide range of different habitats; development of in vivo and in vitro propagation procedures. To date, many native orchid species from South-East Asia and South America have been propagated at the NBG through asymbiotic seed germination and tissue culture procedures. Recent research on cryopreservation has focused on practical procedures for genebank storage of orchid pollinia.

Plant exhibitions created at the botanic gardens of Ukraine highlight the diversity of tropical plants, their uniqueness, the plant adaptations to the ecological conditions of the tropical forest, and plant–animal relationships, providing education in issues connected with global climate changes and the urgent necessity of conserving species that support human needs and well-being worldwide. Finally, living plant collections are used as valuable sources of material for diverse scientific, conservation and educational projects.

KEYWORDS

Global Strategy For Plant Conservation, Botanic Gardens, *Ex Situ* Conservation Approach, Cycads, Orchids, Succulents

INTRODUCTION

The problem of biodiversity conservation of tropical floras with global ecological, economic and social importance, has already exceeded the boundaries of individual countries. Tropical ecosystems are exceptionally rich and encompass much of the biodiversity on Earth (Sodhi et al., 2004). However, rapid losses and alarming destruction of natural habitats in the tropics are causing drastic declines and extinctions of native biotas, including angiosperms (Sodhi, 2008). It has been assessed that the most significant threat processes comprise land conversion to agriculture and aquaculture, biological invasions, the unsustainable collection of biological resources for horticultural trade and private ornamental collections (Goettsch et al., 2015). To date, species and populations are disappearing at a greatly accelerated rate as a result of habitat loss, fragmentation, and isolation of suitable habitat, as well as competition from invasive plant species (Guerrant et al., 2014).

Successful conservation actions require joint efforts of scientists at the local, national, regional, and international levels (Wyse Jackson & Sutherland, 2000). The importance of *ex situ* plant conservation approach has long been recognized and widely discussed globally (Maunder et al., 2001; Guerrant et al., 2004; Cavender et al., 2015). Botanic gardens have traditionally been the main places for tropical plants research, horticulture and education. Originally, scientific research, collections and horticulture of many plant groups derived from tropical biomass were instigated by botanic gardens (Monteiro-Henriques, Espírito-Santo, 2011; Edwards et al., 2015; Pedersen et al., 2018). Botanic gardens conserve plant diversity *ex situ* and can prevent extinction through integrated conservation action. In addition, Botanic gardens are the best places to raise public awareness about conservation and biodiversity. With climate change, *ex situ* conservation is becoming important to store plant biodiversity (Donaldson, 2009). As was pointed out by many authors (Griffith et al., 2015; Pence, 2013; Volis, 2017a, b), the fundamental contribution of botanic gardens in biodiversity conservation remains through the cultivation of living plant collections of critically endangered species or species extinct in wild which cannot be conserved through seed- or tissue-banking protocols. Nevertheless, living plant collections in botanic gardens are underutilized worldwide resource for plant conservation (Cibrian-Jaramillo et al. 2013).

In general, it has been estimated that species from tropical regions are about twice as likely to be threatened, compared with species from temperate regions (Brummitt et al., 2015). This discrepancy may be partly explained by the fact that many temperate species have naturally larger ranges (Stevens, 1989) and, consequently, are less severely affected by localized threats. On the other hand, Brummitt et al. (2015) have suggested that other factors contributing to the marked contrast in proportions of threatened species between temperate and tropical regions may include the greater rate of land conversion occurring in the tropics.

Interestingly, most of the *ex situ* protocols about sampling procedures, gene bank standards and storage techniques were prepared by the agricultural sector and then adapted by the wild plant sector, predominantly by botanic gardens (Volis, 2017b).

In Ukraine, the loss and erosion of biodiversity and urgent need to handle the problem of climate change has led to increased governmental interest in issues related to plant biodiversity worldwide. Diverse studies aimed at protection of rare species are carried out at our Botanic garden with focuses on various plant groups.

At the present time, the most numerous living plant collections have been accumulated at O.V. Fomin Botanic Garden, Taras Shevchenko National University of Kyiv, Botanic Garden of Ivan Franko Lviv National University and M.M. Gryshko National Botanic Garden (NBG). All of them have the status of National Heritage Collections of Ukraine. The list of National Heritage units, including the most important science and arts collections, is designated by relevant ministries and agencies and approved by the Cabinet of Ministers of Ukraine.

Our gardens belong to different agencies: Gardens of Lviv and Kyiv Universities belong to the Ministry of Education and Science of Ukraine, while M.M. Gryshko National Garden belongs to the National Academy of Sciences of Ukraine. Nevertheless, we work within the same plant conservation network with specific conservation priorities.

MATERIAL AND METHODS

We focus our research on the three collections of tropical plants accumulated in three botanic gardens of Ukraine, the O.V. Fomin Botanic Garden, Taras Shevchenko National University, the Botanic Garden of Ivan Franko National University of Lviv and the M.M. Gryshko National Botanic Garden, National Academy of Science of Ukraine, in order to discuss how botanic gardens in Ukraine contribute to achieving target 8 of the Global Strategy for Plant Conservation (2010). Various databases available for searching collections of living plants and confirming taxonomic identity have been used, e.g. World Checklist of Orchidaceae (Govaerts et al., 2018), International Plant Names Index, The Plant List, the IUCN Red List (IUCN, 2013).

Living plant collections of tropical plants were replenished and managed taking into consideration the International priorities in the Garden's policy of collection development as outlined in the International Agenda for Botanic Garden in Plant Conservation, Global Strategy for Plant Conservation (2010) and CITES Orchid Checklists (Roberts et al., 1995, 1999, 2001; Smith et al., 2006; Oldfield, McGough, 2007); CITES Cactaceae Checklist (Hunt, 2016). The NBG's collection of tropical orchids was registered at the Administrative Organ of CITES in Ukraine (Ministry of Environment, registration No. 6939/19/1-10, 23 June, 2004). The basic asymbiotic seed germination techniques and tissue culture procedures (including cryopreservation of orchid pollinia and seeds)

for the propagation and long-term conservation of plants from various angiosperm families both in in vitro culture and under glasshouse conditions have been used. Development of propagation methods for numerous species of tropical orchids in the NBG was preceded by long-term observations and dedicated studies in their reproductive biology (duration of anthesis, terms of pollination of flowers, and duration of fruit maturation).
To assess the effect of breeding systems on fruit set and seeds viability, of orchids in particular, artificial self-pollination (induced autogamy) and artificial cross-pollination (induced xenogamy) treatments were performed (Dafni, 1992).
To achieve successful acclimatization of orchid plants, we tried to meet ecological requirements of each species under glasshouse conditions. To accommodate successfully studied plants to suitable glasshouse conditions, first of all we have used the data on ecological requirements of particular species known from literature sources, as well as the data from our own field observations. Excellent papers and comprehensive monographs, published recently (Cribb, 1998, Averyanov et al, 2003), highlighted the precise data on ecological requirements of many orchid species, particularly, slipper orchids.
The field expeditions in tropical regions of the world (Vietnam, Madagascar, Costa-Rica, South Africa, Reunion) were undertaken to study the ecological preferences of various plant species and to assess the main threats to tropical plants and to prioritize the plant groups to be the main focus for an in-depth investigations aimed at long-time conservation under *ex situ* conditions.
Various strategies for conservation of living plant collections have been employed at our botanic gardens, predominantly living plant collections maintenance and in vitro propagation.

RESULTS

At present, there are 30 botanic gardens and 19 arboreta in Ukraine. At a national level, existing plant conservation activities of botanic gardens and arboreta that contribute to the achievement of a Global Strategy for Plant Conservation are regulated by the Council of Botanic Gardens and Arboreta of Ukraine.
The principal policy of the Botanic Gardens and Arboreta in Ukraine is the maintenance of living plant collections, study of indigenous plant species and those outside their natural habitats, assessment of their conservation status and potential economic use, as well as development of research, conservational and educational programs.
The Garden's collections in Ukraine comprise about 20,000 species and cultivars, including outstanding collections of woody and shrubby temperate plants, annual and perennial ornamentals, medicinal plants, as well as tropical plants.
In botanic gardens in Ukraine, large collections of rare and threatened plants derived from tropical biomass have been established and maintained. Living collections of tropical plants in the botanic gardens of Ukraine vary in number from a few hundred to several thousand different species, depending on institutional affiliation and an institution's objectives, as well as the available financial and scholarly resources. Consequently, considerable experience in the *ex situ* conservation of the tropical flora has been accumulated.
The first glasshouses in the Botanic Garden of V. N. Karazin Kharkov University were built in 1808. Unfortunately, at the time of October Revolution, in 1917, all glasshouses buildings were destroyed.
O.V. Fomin Botanic Garden, founded in 1839, is known to be one of the oldest in Ukraine. Its living collection of tropical plants comprises more than 4,200 taxa, representing 830 genera and 180 families. The greenhouse, which was built for the largest and the oldest palm trees in Northern Eurasia, is among the highest in the world. It is noteworthy that more than 60 % of collected samples represent plants with «succulent syndrome» which is considered to be one of the most remarkable examples of convergent evolution within the plant kingdom (Ogburn, Edwards, 2010).
Additionally, collections include the representatives of other tropical plants representing various ecological and taxonomic groups, e.g. monocots (13%); hydrophytes and carnivorous plants (12%); ferns and gymnosperms, including cycads (7%) and others (8%).
An overview of species richness of tropical plant collections in the O.V. Fomin Botanic Garden by the end of XIX century can be obtained from the inventory manuscript of the Taras Shevchenko National University of Kyiv (former Saint Vladimir Royal University of Kiev). Archival papers indicate that the succulent collections are more than 100 years old. The outstanding examples of *Agave americana* var. *marginata* (1923), *Dasylirion glaucophyllum* Hook. (1928), *Euphorbia alcicornis* Baker (1932), *Aloe camperi* Schweinf. (1933), *Cereus repandus* (L.) Mill. (1938), *Aloe arborescens* Mill. (1942) were maintained until now. Nevertheless, this collection was drastically increased in number about 60 years ago.
The *Cactaceae* family is the largest plant taxon evaluated to date under the International Union for Conservation of

Nature (IUCN) Red List Categories and Criteria (Goettsch et al., 2015). It revealed that cacti are among the most threatened taxonomic groups assessed to date, with 31% of the 1,478 evaluated species threatened, demonstrating the high anthropogenic pressures on biodiversity in arid lands (Goettsch et al., 2015). The family Cactaceae, being one of the most popular horticultural plant groups, is considered the fifth most threatened large taxonomic group in the world (Novoa et al., 2017).

The assessment of succulent collections with IUCN Categories and Criteria revealed that representatives of 19 families and more than 1,200 species are included in the IUCN Red List and are regulated by CITES:

Cactaceae – >1000 species, *Aizoaceae* – 87 species, *Asphodelaceae* – 62 species, *Crassulaceae* – 38 species, *Apocynaceae* – 19 species.

Research on succulent species is one of the most important activities at the O.V. Fomin Botanic Garden. Research on these plants is conducted on phenological observations, studying the reproductive biology and vegetative architecture, seed germination and viability testing, assessment of various plant adaptations to arid climate, propagation methods development.

Our own field observations conducted in the natural habitats of rare succulent species, e.g. in Ibity Massif, a quartzitic massif located 25km southwest of Antsirabe, in 2013, have shown that many species of succulent plants such as *Aloe* spp. and *Pachypodium* spp., as well as *Orchidaceae* species (*Angraecum* spp.), are harvested by local people and this kind of activity is considered as a direct threat for these species.

Succulent plants are grown in 6 glasshouses, occupying 750m². Nevertheless, the majority of plant specimens are kept in pots. Two exhibitions represent the diversity of unusual succulent plants derived from both America and Africa.

Collections of tropical and subtropical plants, accumulated at the Botanic Garden of Ivan Franko Lviv National University are one of the oldest in Ukraine. Founded in 1852, it is home to 1,700 taxa of tropical plants belonging to 475 genera and representing 136 families from various tropical biomes of the world.

In 2002 the collection was designated as the National Heritage Collection of Ukraine.

The most valuable part of this collection is comprised of “living fossils” cycads (*Dioon edule* Lindl., *Cycas* L. and *Ceratozamia* spp.). Cycads are long-lived perennial plants, most of which are considered as threatened, rare or endangered and are listed in the IUCN (2004) Red List (Octavio-Aguilar et al., 2008). The Botanic Garden of Ivan Franko Lviv National University is an example of a botanic garden that uses cycads as a major research and display resource (Prokopiv, 2009).

Previously, it was shown that *ex situ* collections are especially important to the survival of *Cycadaceae*, because low germination rates, low seedling survival rates, and long generation times can make recovery of a cycad population *in situ* slow (Griffith et al., 2015).

Palms also comprise a valuable part of the collection established at the Botanic Garden of Ivan Franko Lviv National University. The ages of these plants vary within the range of 80–125 years, including *Syagrus romanzoffiana* (Cham.) Glassman (syn. *Arecastrum romanzoffianum* (Cham.) Becc.), *Phoenix canariensis* Hort. ex Chabaud, *Ph. reclinata* Jacq., *Livistona australis* (R. Br.) Mart., *Sabal minor* (Jacq.) Pers., *S. mexicana* Mart. and *S. palmetto* (Walter) Lodd. ex Schult. & Schult.f., *Howea belmoreana* (C. Moore et F. v. Muell.) Becc., *H. forsteriana* (C. Muell.) Becc., *Phoenix rupicola* T. Anderson, *Ph. theophrasti* Greuter, *Washingtonia filifera* (Rafarin) H.Wendl. ex de Bary.

Beside, the unique relict plants of *Araucariaceae* family, *Agathis macrophylla* (Lindl.) Mast. (160 years old) (categorized in the IUCN Red List as an endangered species) and *Araucaria bidwillii* Hook., are maintained at the collection.

Living collections in botanic gardens and arboreta are particularly important for preserving critically endangered species or species extinct in wild. The assessment of conservation status of species accumulated in the collections of the Botanic Garden of Lviv National University has revealed that it includes 85 species in 60 genera from 38 families that are conserved at international level.

Besides, many tree species, such as *Quercus ilex* L. (Fagaceae), *Magnolia grandiflora* L. (Magnoliaceae), *Pimenta dioica* (L.) Merr., *Eucalyptus pulverulenta* Sims (Myrtaceae), *Swietenia mahogani* (L.) Jacq. (Meliaceae), *Pinus roxburghii* Sarg. (Pinaceae), *Chrysophyllum imperiale* (Linden ex K.Koch & Fintelm.) Benth. & Hook.f. (Sapotaceae) were saved from the pre-war collections, i.e. since the time the Second World War had begun.

Founded in 1935, the M.M. Gryshko Botanic Garden (NBG), National Academy of Sciences of Ukraine, is one of the top botanic research institutions and botanic garden in Ukraine.

At present the NBG living collection of tropical plants contains about 4,200 taxa representing approximately 900 genera and 164 families. The orchid plants have been a main focus of the Garden’s Living Collections (Table 1).

Ex situ conservation of tropical orchids threatened with extinction within their native ranges, assessment of unexploited properties of various orchid species are among the highest research priorities at NBG (Cherevchenko et al., 2007).

Because of biological peculiarities of orchids (obligate/ facultative dependency from mycorrhizal fungi, complicated life cycles and highly specialized pollination syndromes, habitat specificity, and limited ranges), representatives of *Orchidaceae* family often belong to the most vulnerable species, that are extremely sensitive to environmental changes (Swartz, Dixon, 2009). The main factors, resulting in drastic decline in natural orchid populations ranges, are the global changes of climate (Seaton et al., 2010), natural habitats loss due to anthropogenic pressure, as well as unregulated large-scale collections of orchids as ornamental and medicinal plants.

NN	Family	Genera number	Species number
1.	*Orchidaceae*	146	450
2.	*Cactaceae*	80	400
3.	*Apocynaceae (inc. Asclepiadaceae)*	47	333
4.	*Araceae*	38	309
5.	*Crassulaceae*	22	243
6.	*Asphodelaceae (inc. Aloaceae)*	7	156
7.	*Amaryllidaceae*	23	150
8.	*Euphorbiaceae*	9	150
9.	*Bromeliaceae*	21	134
10.	*Moraceae*	4	90
	Total	397	2415

Table 1: The most representative families in the NBG's living tropical plant collections

Orchids are also widely and illegally harvested from the wild for local, regional and international trade (Hinsley et al., 2017). Moreover, scarce ecological studies suggest that epiphytic orchids exhibit a low tolerance to harvesting (Mondragyn, 2009). Noteworthy, orchids constitute > 70% of CITES-listed species (Hinsley et al., 2017).

At present, the NBG's living collection of tropical orchids contains about 4,500 plants representing approximately 170 genera and 450 species, which are native to South-East Asia, South and Central America, with a few genera originating inAfrica. The NBG's collection is taxonomically representative; it includes the taxa belonging to four out of five currently recognized subfamilies of Orchidaceae family (*Cypripedioideae, Vanilloideae, Orchidoideae*, and *Epidendroideae*). While creating the collection, the strategic goal was to represent most widely the floristic, ecological and morphological diversity of Orchidaceae, with an emphasis on rare and vulnerable orchid species.

The oldest samples are cultivated at NBG's orchid unit glasshouses since the 70th years of the 20th century (*Coelogyne cristata* Lind., *C. tomentosa* Lindl., *Anguloa clowesii* Lindl., *Ansellia africana* Lindl. *Calanthe vestita* Lindl., *Guarianthe bowringiana* (J.H. Veitch ex O'Brien) Dressler & W.E. Higgins. Artificial pollination treatments have shown that majority of these plants after more than 40 years of cultivation under glasshouse conditions were able to produce fruits with viable seeds.

The most valuable part of the orchid collection is represented by orchid species of the flora of Vietnam. This collection was developed due to scientific collaboration between NBG and the Center for Biodiversity Conservation and Development of the Institute of Tropical Biology of Vietnam. Since 1989 within the framework of partnership between NBG and ITB five expeditions have been carried out, which resulted in new accessions to the living orchid collection (Cherevchenko et al., 2007). In 2013, the samples of 45 orchid species of Vietnamese flora, maintained and propagated at NBG, were translocated to the Institute of Tropical Biology for Biodiversity Conservation Center with potential of re-introduction and strengthening the wild orchid populations.

Therefore, it would be reasonable to suggest, that many restrictions considered as those limiting the importance of living collections *ex situ* can be applied to the orchids to a lesser extent. An availability of the aggregated pollen (so called "pollen dispersal unit" (Pacini, Hesse, 2002), or pollinia/pollinaria) diminishes or makes impossible spontaneous hybridization which threatens the loss of species genetic identity during long-time *ex situ* cultivation. Moreover, the possibility of adult individuals of epiphytic orchids with sympodial shoot branching pattern to survive in cultivation is apparently unlimited.

DISCUSSION

The Global Strategy for Plant Conservation highlights that a minimum of 75% of threatened plant species should be conserved within *ex situ* collections, with at least 20% available for recovery and restoration (Wyse Jackson & Kennedy, 2009).

The results of current study allow us to suggest that botanic gardens in Ukraine, in particular, those maintaining the National Heritage Collections of tropical plants have long been involved in *ex situ* conservation, maintaining living plant collections, in vitro germplasm collection and actively participating in the conservation of threatened species (Cherevchenko et al., 2007). Usually, it is emphasized that the establishment and maintenance of living plant collections deriving from the same region where the garden is located (regional living plant collections) is of crucial importance, because it would be reasonably to expect the greater success in the species maintenance. This practice is encouraged by the Global Strategy for Plant Conservation (Monteiro-Henriques, Espírito-Santo, 2011).

However, today it is widely discussed that *ex situ* collections have numerous limitations that restrict their utility for conservation. Usually, among the main limitations the small sample sizes of *ex situ* collections, the loss of genetic variation, a rapid increase in the level of inbreeding depression are specified (Volis et al., 2009, 2017 a, b; Young-Bi Fu, 2017).

Undoubtedly, sustainable conservation measures require an "ecosystem approach" to ensure the preservation of various natural habitats of orchids along with other organisms associated with orchids during their life cycles (mycorrrhizal fungi, pollinators) enabling the orchids survival under natural habitats (Seaton, 2007; Pemberton, 2010). Nevertheless, developing and managing an *ex situ* collection in botanic gardens can be viewed as an essential additional component of an integrated approach to orchids conservation (Swarts, Dixon, 2009). It is assumed that annuals and short-lived plants are more subjected to the loss of genetic variability than long-lived plants.

In this regard, orchids with inherited long life spans are well adapted for long time cultivation under glasshouse condition. Our findings suggest that, orchids as long-lived plants are more suitable for long-term conservation than the plants from any other group. Many limitations which are considered to restrict applicability of an *ex situ* approach to conservation, such as loss of species integrity through spontaneous hybridization, are not so crucial in this case. The tiny seeds are well suitable to be seed-banked (Seaton, 2007; Seaton et al., 2010), the sympodial pattern of regeneration makes orchids suitable for endless vegetative regeneration under glasshouse cultivation.

Botanic gardens maintaining collections of tropical plants are responsible for their long-term persistence and sustainability, which is extremely topical at present, when there are strict legal limitations as a result of CITES regulations concerning sampling plants from natural habitats (CITES Orchid Checklists) and their transfer across national boundaries.

The transferring of orchids of the flora of Vietnam, propagated at NBG, to the Institute of Tropical Biology we consider as integration of *ex situ* and *in situ* approaches, the usefulness of which was recognized more than four decades ago (Maunder et al., 2001; Volis, 2017 a, b).

At present, the protection of biodiversity of rare tropical orchid species *ex situ* should not be limited by listing the specimens of rare and vulnerable species maintained in greenhouses of botanic gardens of the temperate zone climate. It requires a fundamental understanding of factors controlling plant development and acclimatization/adaptation in artificially created conditions using different experimental methods.

From our standpoint, in order to be successful the protection of rare tropical orchid species *ex situ* requires a fundamental understanding of factors and mechanisms underlaying orchid reproduction systems *in situ* and *ex situ*, seedlings development and adaptation both under glasshouse conditions and in in vitro culture. On the other hand, studying these subjects is a prerequisite for development of techniques for propagation and cultivation.

First of all, we consider studying the reproductive biology of rare tropical orchids as an important background and for any conservational project *ex situ*.

During more than three decades of orchids investigations in cultivation, the flowering phenology of approximately 350 tropical orchid species was studied. Extended hand-pollination treatments (artificial self- and cross-pollinations) have been used to evaluate the reproductive strategy and breeding systems of these plants. It was shown that the majority of orchids studied are self-compatible but not autogamous (Buyun, 2011).

In addition, the impact of different factors, including flowering longevity after pollination, pollinated flower position within inflorescences, resource status on reproductive success of orchid species *ex situ* has been analyzed for many orchid species maintained under glasshouse conditions (e.g., *Angraecum eburneum* Bory, *Cymbidium dayanum* Rolfe, *Guarianthe bowringiana*).

To date, many native orchids species from South-East Asia and South America have been propagated at the NBG through asymbiotic seed germination and tissue culture procedures (Buyun et al. 2004; Cherevchenko et al. 2007; Ivannikov, 2012). Recent research on cryopreservation has focused on practical procedures for genebank storage of orchid pollinia (Ivannikov, 2012). Undoubtedly, the use of glasshouse collections of living plants grown under artificial climate conditions in the temperate zone cannot ensure conservation of the whole genetic diversity of any group of plants. Whereby, the relatively small samples that can be grown in botanic gardens generally offer a very slender basis for the survival of the species in the future.

This way of conservation of tropical plants can be viewed instead as urgent measures because when rare species are poorly sampled often only a small portion of their actual genetic diversity is preserved. In addition, the plant samples are often borrowed from living collections of other botanic gardens after long-term cultivation under glasshouse conditions (Cherevchenko et al., 2007). The majority of specimens in botanic gardens are cultivated out of the range country and not contributing to a specific conservation project (Maunder et al., 2003). To date, many critical issues linked with long-term conservation of diverse germplasm, including *ex situ* living plant collections, have emerged (Yong-Bi Fu, 2017; Pedersen et al. 2018). Vulnerability of genebanks and the risk of genetic erosion through genetic drift, artificial selection and spontaneous hybridization affecting genebank sustainability are considered as a serious counter argument against usefulness *ex situ* approach for biodiversity conservation (Maunder et al., 2001; Volis et al., 2009; Yong-Bi Fu, 2017). Additionally, Pedersen et al. (2018) have suggested that the limited intraspecific genetic variation in traditional collections, orchids in particular, may clearly represent a serious limitation of the extent to which propagated plants can potentially be used for genetically sustainable recovery programs in the wild.

It is well known that certain botanic gardens are very rich in some collections while deficient in others (Hultine et al., 2015), therefore collaboration among botanic gardens would enrich the quality of any type of conservation project undertaken at botanic gardens, in Ukraine in particular.

Due to space limitations, and because collecting and regenerating seed samples are costly, botanic garden living collections cannot often accommodate sufficiently large population samples (Volis, 2017a). High maintenance costs is one of the major limitation of *ex situ* maintenance collection of tropical plants. Moreover, it reasonable substantiated that botanic gardens in richer countries have more species in their botanic garden's collections (Golding et al., 2010). Due to the limited resources many gardens can invest in the conservation of only a few or even just one target species (Cavender et al., 2015).

Therefore, prioritizing species for conservation in particular botanic gardens in Ukraine, which doesn't belong to the countries with the highest economical level of development and considering above-mentioned limitations, we should carefully assess the existing collection, available resources and space, experience in collection management, scientific expertise available, regional climate (and predicted future climate) as it was pointed out by Cavender et al. (2015).

Additionally, living plant collections are used as valuable sources of material for diverse scientific, conservational and educational projects.

Plant exhibitions created at each of the botanic gardens highlight the diversity of tropical plants, their uniqueness, providing education in issues related to conservation of plant species suffered through over-collecting, global climate changes and irreversible loss of their natural habitats.

CONCLUSIONS

In our opinion, botanic gardens in Ukraine can be considered as a global conservation resource with a long heritage in conservation science, education and horticulture, and they remain at the national level as the main institutions involved in tropical plant conservation and reintroduction programs. Botanic gardens in Ukraine, especially those maintained the National Heritage Collections Unit, play a central role in the *ex situ* conservation and exploration of the global plant biodiversity.

National Heritage Collections of tropical and subtropical plants, which are held at three of the botanic gardens of Ukraine, serves several functions: 1) as an approach to assure long-term conservation under glasshouse conditions in case of extinction in the wild; 2) as source of material for research, educational and environmental programs which can contribute to the conservation of a species; 3) as a source of germplasm both in vivo and in vitro, including in vitro cryopreserved propagules, available for potential reintroduction projects.

Current research activities at our botanic gardens are focused on the following issues: studies of developmental biology of plants under glasshouse conditions; investigation of structural adaptations and life histories of orchids, succulents, cycads to survival under a wide range of different habitats; development of in vivo and in vitro propagation procedures. Today, our botanic gardens maintain both large living collections of tropical plants and conduct active research programs.

Finally, the currently existing collections having the status of National Heritage Collections of Ukraine are maintained and replenished '...with the gardens' focus on the most threatened, endemic and adapted to the local climate species...' (Volis, 2017b) that is consistent with recently proposed an approach for management and use of botanic garden living collections worldwide (Cibrian-Jaramillo et al. (2013).

In order to maximize the success of the conservation living collections in botanic Gardens of Ukraine, our efforts should be cooperative, while one of the most important task to be resolved remains the appropriate standard of collections' maintenance and incorporation of collections of tropical plants into world database resources.

REFERENCES

Averyanov L., Cribb Ph., Phan Ke Lock, Nguyen Tien Hiep (2003) *'Slipper Orchids of Vietnam'*. Portland, Oregon: Timber Press.

Brummitt N.A., Bachman S.P., Griffiths-Lee J., Lutz M., Moat J.F., Farjon A. et al. (2015) '*Green Plants in the Red: A Baseline Global Assessment for the IUCN Sampled Red List Index for Plants'* PLoS ONE 10(8): e0135152

Buyun L.I. (2011) *'Tropical orchids (Orchidaceae Juss.): reproductive biology, structural and functional adaptations, ex situ conservation'* A. manuscript. Thesis for Doctor of Science degree in Biology. Kiev (in Ukrainian).

Buyun L., Lavrentyeva A., Kovalska L., Ivannikov R. (2004) *'In vitro germination of seeds of some rare tropical orchids'.* Acta Universitatis Latviensis, Biol. 676: 159–162

Cavender N., Westwood M., Bechtoldt C., Donnelly G., Oldfield S., Gardner M., Rae D., McNamara W. (2015) *'Strengthening the conservation value of ex situ tree collections'*. DOI: 10.1017/S0030605314000866.

Cherevchenko T.M., Buyun L.I., Kovalska L.A., Vu Ngoc Long (2007) *'Ex situ conservation of tropical orchids in Ukraine'.* Lankesteriana 7(1-2): 129–133

Cibrian-Jaramillo A., Hird A., Oleas N., Ma H., Meerow A.W., Francisco-Ortega J., Griffith M.P. (2013) '*What is the conservation value of a plant in a botanic garden ? Using indicators to improve management of ex situ collections'.* The Botanical Review 79:559-577

Cribb P. (1998). *The genus Paphiopedilum*. Kota Kinabalu: Natural History Publications.

Dafni A. (1992). *'Pollination Ecology: a Practical Approach'.* Oxford: IRL Oxford University Press.

Donaldson J. (2009) *'Botanic gardens science for conservation and global change'.* Trends Plant Sci. 14:608–613

Edwards C.E., Bassüner B., Birkinshaw C., Camara C., Lehavana A., Lowry II P.P., Miller J.S., Wyatt A., Wyse Jackson P. *'A botanical mystery solved by phylogenetic analysis of botanical garden collections: the rediscovery of the presumed-extinct Dracaena umbraculifera'.* Oryx, 49(3):416-424

Goettsch B., Hilton-Taylor C., Cruz-Piñón G., Duffy J.P., Frances A., Hernández H.M., Inger R.,...Taylor N.P. et al. (2015) *'High proportion of cactus species threatened with extinction'.* Nat. Plants 5; 1:1-7

Golding J., Güsewell S., Kreft H., Kuzevanov V.Y., Lehvävirta S., Parmentier I., Pautasso M. (2010) *'Species richness patterns of the living collections of the world's botanic gardens: a matter of socio-economics?'* Ann. Bot. 105:689–696

Govaerts R., Bernet P., Kratochvil K., Gerlach G., Carr G., Alrich P., Pridgeon A.M., Pfahl J., Campacci M.A., Holland Baptista D., Tigges H., Shaw J., Cribb P., George A., Kreuz K., Wood J.J. (2018) *'World checklist of Orchidaceae'.* Kew: Facilitated by the Royal Botanic Gardens. Available at: http://apps.kew.org/wcsp/ (accessed July 27, 2018).

Hinsley A., de Boer H.J., Fay M.F., Gale S.W., Gardiner L.M., Gunasekara R.S., Kumar P., Masters S., Metusala D., Roberts D.L., Veldman S., Wong S., Phelps J. (2018) *'A review of the trade in orchids, and its implications for conservation'.* Bot. J. Linn. Soc. 186:435–455

Griffith, M.P., Calonje M., Meerow A.W., Tut F., Kramer A.T. et al. (2015) *'Can a botanic garden cycad collection capture the genetic diversity in a wild population?'* Int. J. Plant Sci. 176(1):1-10

Guerrant E.O., Havens K., Vitt P. (2014) *'Sampling for effective ex situ plant conservation'.* Int. J. Plant Sci. 175(1):11-20

Hultine K.R., Majure L.C., Nixon V.S., Arias S., Burquez A., Goettsch B., Puente-Martonez R., Zavala-Hurtado A. (2016) *'The role of Botanical Gardens in the Conservation of Cactaceae.'* BioScience, 66(12):1057-1065

Hunt D. (2016) '*CITES Cactaceae Checklist*' 3rd edition. Royal Botanic Gardens, Kew.
Ivannikov R.V. 2012. Reproductive biology of orchids in vitro. Thesis for Doctor of Science degree in Biology. Kiev, 48 p. (in Ukrainian).
Maunder M., Higgens S., Culham A. (2001) *'The effectiveness of botanic garden collections in supporting plant conservation: A European case study'.* Biodiversity and Conservation 10(3):383-401
Mondragyn D. (2009) *'Population viability analysis for Guarianthe aurantiaca, an ornamental epiphytic orchid harvested in Southeast Mexico'.* Plant species biology 24(1): 35-41
Monteiro-Henriques T., Espírito-Santo M.D. (2011) *'Climate change and the outdoor regional living plant collections: an example from mainland Portugal'*. Biodivers. Conserv. 20: 335-343
Novoa A., Le Roux J.J., Richardson D.M., Wilson J.R.U. (2017) *'Level of environmental threat posed by horticultural trade in Cactaceae'.* Conserv. Biol. 31(5):1066-1075. doi:10.1111/cobi.12892
Octavio-Aguilar P., González-Astorga J., Vovides A.P. (2008) *'Population dynamics of the Mexican cycads Dioon edule Lindl. (Zamiaceae): life history stages and management impact'.* Bot. J. Linn. Soc. 157: 381-391
Ogburn M.R., Edwards E.J. (2010) *The Ecological Water-Use Strategies of Succulent Plants'*. Advances in Botanical Research. 55: 179–225
Oldfield S., McGough N. (Comp.) (2007). '*A CITES manual for botanic gardens'.* Second edition. Botanic Gardens Conservation International, Richmond, United Kingdom.
Pacini E., Hesse M. (2002) *'Types of pollen dispersal units in orchids, and their consequences for germination and fertilization'*. Ann. Bot. 89: 653-664
Pedersen H. Æ., Find J.I., Petersen G., Seberg O. (2018) *'On the "Seidenfaden collection" and the multiple roles botanical Gardens can play in orchid conservation'*. Lankesteriana. 18(1):1-12
Pemberton R.W. (2010) *'Biotic resource needs of specialist orchid pollinators'.* The botanical review 76(2): 275-292
Pence V. (2013)*'In Vitro Methods and the Challenge of Exceptional Species for Target 8 of the Global Strategy for Plant Conservation'.* Annals of the Missouri Botanical Garden 99(2): 214-220
Prokopiv A.I. (2009) *'Form variability and various approaches to classification of Cycadopsida'* Biodiversity conservation of tropical and subtropical plants: International conference proceedings (10-13 March, 2009). Kiev: 75–79 (in Ukrainian)
Seaton P. T. (2007) *Orchid conservation: where do we go from here?* Lankesteriana7(1–2):13–16
Roberts J.A., Beale C.R., Benseler J.C, McGough H.N. & Zappi, D.C. (1995) *'CITES Orchid Checklists'.* Vol. 1. Royal Botanic Gardens, Kew.
Roberts J.A., Allman L.R., Beale C.R., Butter R.W., Crook K.R. & McGough H.N. (1997) *'CITES Orchid Checklists'*. Vol. 2. Royal Botanic Gardens, Kew
Roberts J.A., Anuku S., Burdon J., Mathew P., McGough H.N. & Newman A. (2001) *'CITES Orchid Checklists'.* Vol. 3. Royal Botanic Gardens, Kew
Seaton P.T. (2007) '*Orchid conservation: where do we go from here?'* Lankesteriana 7(1–2): 13–16
Seaton P.T., Hu Hong, Perner H. [et al.] (2010) *'Ex situ conservation of orchids in a warming world'.* The botanical review 76(2):193–203
Smith M.J., Brodie C., Kowalczyk J., Michnowicz S., McGough H.N. & Roberts J.A. (2006). *'CITES Orchid Checklists'.* Vol. 4. Royal Botanic Gardens, Kew
Sodhi N.S., Lian Pin Koh, Brook B.W., Ng P.K.L. (2004) *'Southeast Asian biodiversity: an impending disaster'.* Trends in Ecology and Evolution 19(12):654-660
Sodhi N.S. (2008) *'Tropical biodiversity loss and people—a brief review'.* Basic Appl. Ecol. 9:93–99. doi: 10.1016/j.baae.2007.11.001
Stevens GC. (1989) *'The latitudinal gradient in geographical range: how so many species coexist in the tropics'*. The American Naturalist 133(2): 240–256
Swarts N.D., Dixon K.W. (2009b) *'Perspectives on orchid conservation in botanic gardens'.* Trends Plant Sci. 14:590–598
Volis S., Blecher M., Sapir Y. (2009) *'Complex ex situ- in situ approach for conservation of endangered plant species and its application to Iris atrofusca of the Northern Negev'.* BioRisk 3:137–160. doi: 10.3897/biorisk.3.5
Volis S. (2017a) *'Complementarities of two existing intermediate conservation approaches'.* Plant Diversity 39:379-382
Volis S. (2017b) *'Conservation utility of botanic garden living collections: Setting a strategy and appropriate methodology'.* Plant Diversity 39(6):365-372
Wyse Jackson P.S., Sutherland L.A. (2000) *'International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International'*, U.K.
Wyse Jackson P.S., Kennedy K. (2009) *'The Global Strategy for Plant Conservation: a challenge and opportunity for the international community'.* Trends Plant Sci. 14(11):578-80
Yong-Bi Fu. (2017) *'The vulnerability of plant genetic resources conserved ex situ'*. Crop. Sci. 57:2314-2328

FROM SINGLE INDIVIDUAL CONSERVATION TO THE RESTORATION OF NATURAL POPULATIONS OF CRITICALLY ENDANGERED FERN SPECIES

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ABSTRACT
Among 424 endangered or threatened Hawaiian plant taxa (USFWS 2015), 236 taxa are known from fewer than 50 individuals (PEP 2018). Because of their rarity, there is not enough detailed information about biology-ecology-life-strategy and reproductive biology of these species. For this reason, research on different aspects of their life strategy is inseparable from other conservation activities. The long term research (1999–2018) on three critically endangered endemic to Kauai (Hawaiian islands) fern species *Asplenium dielpallidum* N. Snow, *Asplenium dielmannii* Viane and *Asplenium diellaciniatum* Viane resulted in the return of *ex situ* propagated plants to their natural habitat in their country of origin. Simultaneous to the population studies of the target (their biology and ecology, dynamics, adaptations to local climate pattern, habitat conditions, dispersal and distribution pattern, potential source populations) tests were conducted on different methods of restoring populations (reducing the competition with non-native species, availability of soil spore bank, sowing in to the habitat, tolerance to replanting and translocation, population reinforcement). Detailed laboratory studies at Tallinn Botanic Garden on gametophyte generation and propagation provided a lot of relevant information (perennial life strategy of gametophytes, duration of developmental stages and transitions, obligatory of out-crossing, good capability for vegetative and regenerative growth), also the plants for restoration. Planting ferns to their natural habitat began in 2016 and continued in 2017-2018.

KEYWORDS
Research On Population Biology, Conservation Methods, Reinforcement, Artificial Establishment Of Populations

INTRODUCTION

Among 1,386 Hawaiian vascular plant taxa (Imada 2012), 424 taxa are listed as Endangered or Threatened (USFWS 2015), and approximately 236 species of these are known from fewer than 50 individuals (PEP 2018). Although close to extinction, very little is known about the life span, reproductive cycle, breeding type, growth pattern, dispersal factors, habitat requirements, limiting factors or threatening factors of such rare and endangered species. The fern flora of Hawaiian Islands consists altogether of 222 taxa of ferns. Of 167 taxa of native ferns. 132 are endemic (Vernon and Ranker 2013). Among other vascular plants, Pteridophytes are a complicated group to study for their conservation because of their separate independent generations of gametophytes and sporophytes, with important life cycle stages and events taking place in both generations. Regardless of good capability for long-distance dispersal, the recruitment of sporophytes depends on species specific mating compatibility type of gametophytes (Raghavan 1989).

For successful reintroduction/reinforcement/ restoration of the species, the research on different aspects of their life strategy and habitat are inseparable from other conservation activities. For preserving critically endangered species, the minimum information immediately needed is as follows:

- their historical and current distribution;
- population size and condition;
- population structure (age, life-stage, genetic, spatial);
- population dynamics;
- spore source, spore bank;
- breeding system;
- duration of life-stages;
- timing and duration of dispersal;
- factors influencing the dispersal;
- factors influencing the survival;
- tolerance to the stress and disturbance;
- structure and condition of natural community;
- habitat requirements of the species;
- habitat quality;
- availability of suitable habitat patches on the landscape.

At Tallinn Botanic Garden, the research on endangered plant species is focused on selected, locally or globally endangered fern species. It is conducted by:

- *in situ* population monitoring for condition assessments and research on species ecology;
- *ex situ* study of reproductive biology and *ex situ* propagation for reinforcement, reintroduction and restoration;
- artificial establishment of populations both *in situ* and *ex situ*.

Since then, the most far-reaching has been the research on three IUCN Critically Endangered fern species endemic to the island of Kauai (Hawaiian Islands) - *Asplenium dielpallidum* N. Snow; *Asplenium dielmannii* Viane and *Asplenium diellaciniatum* Viane. It was started with condition assessments and population studies, and continues with the efforts on artificial establishment of sub-populations on the landscape within their historical distribution range.

METHODS

At the beginning of the research, the whole population of *Asplenium dielpallidum* consisted of 15 reproductive individuals in two locations. After not having been found for more than 100 years, *A. diellaciniatum* was relocated in 2001 by K. Wood and S. Perlman (NTBG) and *A. dielmannii* in 2002 by L. Arnold (KRCP). Their natural habitats were heavily disturbed by introduced ungulates or overgrown by non- native species.

The research was started by population surveys with the aim to gather information about species distribution and biology, population structure and dynamics in the habitat. Simultaneous, small scale pilot tests were conducted on different potential methods of improving the condition of extant populations:

- reducing competition with non-native species (2002-2005) with the aim to test if removing highly competitive non-native species on recent extinction location would help the target species to recover via spores in the soil of the habitat;
- sowing spores in to the habitat (2002-2004; 2013-2015) with the aim to test the possibility of self-recovery in the habitat;
- soil spore bank analyses (2008-2009) with the aim of learning if target species could have a soil spore bank and could be recovered from this, what are the species represented in the soil of the habitat and how long may their spores stay viable;
- testing the planting tolerance (2002-2005) with the aim to learn if target species would tolerate any re-planting/relocation and which would be the preferred life-stages for the re-planting;
- *ex situ* boosting of rescued sporelings (2006-2007) with the aim of testing if rescued sporelings could be used for growing plants for population reinforcement and restoration;
- experimenting with population reinforcement (2007-2011), with the aim to increasing the spore source of the habitat and testing if establishment of experimental populations within fenced exclosures would affect the dispersal of the species via colonization of new patches of suitable habitat;
- laboratory experiments on reproductive biology and propagation at Tallinn Botanic Garden (2011-2015) with the aim of learning about specific life-strategies of gametophytes and working out propagation protocols for conservation.

Based on the information gathered, it was planned to initiate gradual out-planting of *ex situ* propagated plants during several consecutive years. The ultimate aim was to reinforce the species by artificial establishment of sub-populations in protected sites by fencing locations within their historical range.

RESULTS

The study of population structure and dynamics revealed that target species had seasonal growth with germination peaks during rainy periods. Natural recruitment was cyclical according to the ENSO climate pattern of longer periods of wetter and drier years. Stage transition monitoring demonstrated that the relative amount (the number) of transitions to premature stage could possibly indicate population condition and trend. The survival rates of newly established individuals were very low, as a result of heavy disturbance in the habitat caused by introduced and feral ungulates. It was learned that dynamic sub-populations, if immediately protected, could serve as source populations for recovery and restoration of the species.

Reducing competition with non-native species Although the exact location of previously extinct individuals was known and weeding regularly conducted, the target species did not recover during the study period of 2002-2006. Eventually, this experiment had to be finished as non-native plants species became replaced by native species (*Luzula hawaiiensis, Bidens sandwicensis, Rumex albescens, Doryopteris decipiens, Poa* sp., *Carex* sp., *Acacia koa*) on the study plots.

Sowing spores to the habitat was conducted twice. The first test (2002-2004), with the spores of unknown quality collected from a single individual of A*splenium dielpallidum*, did not result with the establishment of gametophytes or sporophytes of the species. It was learned that the erosion caused by over-population of ungulates was one major limiting factor against natural establishment for the species with spores or small seeds. The second test (2013-2015) was made by sowing a mixture of fresh spores of different individuals of *Asplenium dielmannii* into the protected area at the previous location. The establishment of gametophytes and sporophytes was not documented during that period, but it was learned how important it is to consider the role of heterogenity of microhabitats.

Soil spore bank analysis 2007-2009
From repeated tests it was learned which species were represented in the soil and how long they stayed viable in the soil of this particular habitat. The target species was not separated from gametophyte cultures grown from soil samples. Most of native species that germinated during the test were less abundant, their germination and development of the gametophytes much slower than that of non-native species. The tests revealed that the soil spore bank was dominated by fast growing non-native species (Aguraiuja, Urman 2008; Urman 2009).

Testing the planting tolerance (2004-2006)
Damaged and thus close to death individuals of different life stages (sporeling, premature, mature) were used for *in situ* testing planting or relocation tolerance. It was experienced that the target species of interest were tolerant to replanting, but it became evident that the current stage of the degradation of the habitat was a limiting factor for replants. The survival rates and life span of mature replants was longer, they recovered and produced lots of spores during their life time.

***Ex situ* boosting of rescued sporelings at NTBG (2006-2007)**
The condition of damaged and uprooted (by feral ungulates) sporelings and premature individuals recovered, and in stable nursery conditions most of them transitioned into the mature stage within a year. It was learned that gametophytes and sporelings rescued from heavily disturbed habitats, used to boost *ex situ* holdings, could be returned to the habitat and used for population reinforcement in protected areas (Aguraiuja 2010).

Experimenting population reinforcement (2007-2011)
Translocation from stable nursery conditions back to the wild places transplants under great stress, although it could be mitigated by growing plants in hardening conditions. Reversal from mature spore-producing to vegetative premature looking conditions is a clear sign of stress in case of ferns. The number of individuals in the reproductive stage decreased consistently during the years. For 2018, the size of the experimental population became equal with the size of the natural population. This first test of population reinforcement on these fern species reminded us of the importance of considering the microsite conditions and habitat quality.

Laboratory tests on reproductive biology and propagation at Tallinn Botanic Garden (2011-2015) provided information about:

- the perennial life strategy of gametophytes;
- the duration of developmental stages of gametophyte and the timing of transitions as an adaptation to seasonality in habitat conditions;
- the obligatory nature of out-crossing, and
- the good capability of gametophytes for vegetative and regenerative growth.

It was also learned that gametophyte cultures of these species could serve well for preserving the genepool for *ex situ* research and propagation for restoration. The full cycle from the spore to mature spore-producing individual took 4-5 years in cultivation (Aguraiuja 2014). Eventually, thousands of individuals were grown from the laboratory experiment material. As a scientific donation, altogether 13 thermoboxes with 1,790 specimens were translocated from Estonia to Hawaiian islands and received alive by the National Tropical Botanical Garden (NTBG), where they were replanted, and later on, relocated to Kauai Mesic Elevation Nursery in Kokee for further acclimatization to the local natural climate (Aguraiuja 2017).

Gradual out-planting to the natural habitat, within their historical distribution area, started in 2016 and continued in 2017-2018. Since then altogether 575 individuals were planted to a natural habitat in five locations within fenced exclosures:

- *Asplenium dielpallidum* - 343 individuals in two locations in Kuia Natural Area Reserve, survival

91,6% after the first year in the habitat;

- *Asplenium dielmannii* – 164 individuals in two location, in Na Pali Kona Reserve and Kokee State Park, 96,5 % alive after the first year in the habitat;
- *Asplenium diellaciniatum* – 78 individuals in one location, in Na Pali Kona Reserve, all alive after the first year in their new location.

Although the numbers of spore-producing individuals has increased remarkably, comparative monitoring of reintroduced and natural sub-populations will continue.

CONCLUSIONS

Although first year survival rates of transplants were relatively high, the effect of microhabitat selection started to occur on the 3rd year of the first test of population reinforcement. For the species which have slow developmental rates in gametophyte generation, the recruitment of new sporophytes in the habitat, could possibly be expected at least 3-5 years after out-planting to the natural habitat (Aguraiuja 2014). Reintroduction could be assessed as successful at the moment when natural regeneration appears (Godefroid et al. 2011). At least 10 years of monitoring would be critical for estimating if the reintroduction effort has been successful in mitigating against the extinction of the fern species.

This research confirmed that reinforcement, restoration or re-establishment of new populations could be possible in the case of certain endangered species. The prerequisite for step by step success is a thorough knowledge about species life strategy and habitat requirements. Species requirements should be set as a priority for reaching the improvement of their condition. The management and conservation actions should be planned and timed in accordance to the species needs, and methods applied as soon as they are proved to be useful for improving the condition of the species.

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REFERENCES

Aguraiuja, R. (2010) *´Reinforcement of the populations of critically endangered endemic fern Diellia pallida (Aspleniaceae), Kaua'i, Hawaiian Islands, U.S.A.´* In: Soorae P.S. (ed.) IUCN Global Re-introduction Perspectives: 2010. IUCN/SSC Re-introduction Specialist Group: 319 – 323

Aguraiuja R. (2014) *´The germination tests of three critically endangered fern species: Asplenium dielapllidum, A. dielmannii and A. diellaciniatum´*. Hawaii Conservation Conference, July 15-17, 2014, Hawaii Convention Center; Honolulu

Aguraiuja R. (2017) *´Restoring critically endangered fern species´*. BG Journal. Journal of Botanic Gardens Conservation International. Volume 14, Number 2: 38-39

Aguraiuja R., Urman K. (2008) *´The fern spore bank as a predictor for possible changes in the community?´* 2nd World Botanic Garden Scientific Congress, Delft, Netherlands, 2008.

Godefroid S., Piazza C., Rossi G., Buord S., Stevens A.-D., Aguraiuja R., Cowell C., Weekley C.W., Vogg G., Iriondo J., Johnson I., Dixon B., Gordon D., Magnanon S., D., Valentin B., Bjureke K., Koopman R., Vicens M., Virevaire M., Vanderborght T. (2011) *´How successful are plant species reintroductions?´* Biological Conservation 144: 672- 682.

Imada T.C. (2012) *Hawaiian Native and naturalized Vascular Plant Checklist 2012.* Hawaii Boiological Survey, Bishop Museum Technical Report 60, Honolulu

PEP Species list (2018)

Raghavan V. (1989) *Developmental Biology of Fern Gametophytes.* Cambridge University Press

Rattur M., Aguraiuja R. (2015) *´Artificial habitat for ex situ and in situ conservation - case study on Asplenium septentrionale and Woodsia ilvensis in Estonia´*. 6th World Conference on Ecological Restoration, Manchester, 23-27 August, 2015

Urman, K. (2009) *´The experimental study of natural spore bank of rare forest communities of Kauai (Hawaiian Islands): could it be used for the conservation of the fern species?´* Fifth European Botanic Gardens Congress EuroGard V. Botanic Gardens in the Age of Climate Change. Helsinki, June 8 – 12, 2009

USFWS Endangered Species List (2015)

Vernon L.A, Ranker A.T. (2013) *´Current Status of the Ferns and Lycophytes of the Hawaiian islands´* American Fern Journal 103(2):59-111

BOTANICAL RESEARCH OF PRAGUE BOTANICAL GARDEN IN SOUTHERN VIETNAM

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INTRODUCTION

The mountains of southern Vietnam shelter high plant diversity and are not yet fully explored. Hon Ba Nature reserve and BiDoup-Nui Ba National Park are the areas with the highest botanical species richness in the region. Our aim was to contribute to knowledge of local vegetation and to characterize the distribution of selected plants in these areas.

STUDY AREA

The Hon Ba Nature Reserve was established in 2005 with a strictly protected zone of 10 448, 2 ha covering a mountain massif lying 20 km westwards from Nha Trang City, being the easternmost projection of the Lang Biang Plateau, which continues on to National Park Bidoup – Nui Ba. The eastern slopes of Hon Ba are under constant influence of their proximity to the sea, exposed to winds and humidity. Here, the warm and humid air flowing from the sea meets the cooler mountain air; this causes a specific microclimate with frequent mists and high air humidity. The highest peak of Hon Ba mountain ridge reaches a height of 1,567 m a.s.l.
BiDoup - Nui Ba National Park was established in 2004 and is named after the two highest peaks of the Lang Biang plateau: Bidoup (2,287m) and Nui Ba (2,167m), the former is the second highest peak of southern Vietnam. The total area of 70,038 ha makes the park one of five largest national parks in Vietnam.
Four expeditions to Hon Ba and Bidoup were undertaken, based on a Memorandum on Cooperation agreed and signed between the Botanical Garden of Prague and the Institute of Tropical Biology. The first part of joint field work was implemented in June – July 2011, followed by a second field trip carried out in February – March 2012 and the last trip was undertaken in January 2013. Bidoup-Nui Ba National Park was explored in March – April 2017.

RESULTS

The joint team in Hon Ba confirmed *in situ* 1,200 taxa, among this number are many species listed in the Red Data Book of Vietnam and IUCN Red List. Some records seem to be the first confirmation of their occurrence in Vietnam. An interesting feature of the area is the mixture of northern floral elements such as *Acer, Carpinus, Quercus, Salix, Anemone, Viola* and tropical elements such as palms like *Pinanga, Plectocomia*, but also families as *Ancistrocladaceae, Balanophoraceae, Gleicheniceae, Lecythidaceae* and *Zingiberaceae*. The main focus of the work was on herbs of the forest floor and on epiphytes. Some new species were recognized and subsequently scientifically described – *Arisaema claviforme, Cleisostoma yersinii, Vanilla atropogon* and *Zingiber discolor.* From Bidoup-Nui Ba National Park, new species of gingers (*Zingiberaceae*), *Meistera caudata* and *Meistera sudae* were prepared for publication and one Aspidistra species is in the process of being described. Numerous plants deserve further study and consultation with specialists from Vietnam or abroad to provide an accurate determination. However, it is certain that the number of vascular plants of Hon Ba Nature Reserve is at least a multiple of the previously existing official list. The majority of the data were collected in the field, but selected plants (mostly gingers, ferns, orchids and gesneriads) were brought to Prague Botanical Garden (with all necessary permits) and are part of its tropical collections. Results are being provided to the relevant Vietnamese authorities to allow for more efficient protection of the local flora.

Gingers

The whole plateau is very rich in gingers and it is highly predicted that there are still some species unknown to science that remain to be discovered. In Hon Ba area, 11 different taxa from six genera were collected. Except for the new species mentioned above as our new discoveries, it is worthy of mention that a member of rare genus *Siliquamomum*, *S. oreodoxa* was described also from the area of BiDoup.

Orchids

So far we have recorded more than 90 species of orchids from this region. Some species are restricted to a single location, while others are present in large areas. Some of our findings were quite surprising. For example, we discovered one plant of *Dendrobium farinatum*, originally described in 2004 from cultivated material in Germany, which originated from an unknown place in Vietnam. Some others are new to science (e.g. *Cleisostoma yersinii, Vanilla atropogon, Bulbophyllum* aff. *umbellatum, Zeuxine „honbaensis"* sect. *Psychechilos*). Four species represent the first record for Vietnam (*Appendicula ovalis, Cephalantheropsis halconensis, Hetaeria finlaysoniana* and *Lecanorchis nigricans*).

All of the five main currently accepted subfamilies of the Orchidaceae were found to be present in the Hon Ba reserve. The most important of these is subfamily *Apostasioideae*, which is a very rare and ancient (basal-most) orchid group that survives up to the recent period in tropical Asian forests only. Three species were found in the Hon Ba reserve, while two of them could not be determined because we found only sterile individuals. Based on leaf characters, these species could be some other newly discovered species.

Conifers

Conifers are an important vegetational component in both research areas. Altogether, 10 species in 7 genera from 4 families were recorded, indicating a high diversity of conifers in the mountains of southern Vietnam. Rare species worthy of mention, such as *Pinus krempfii, Fokienia hodginsii* and *Nageia wallichiana* were recorded. The first one mentioned has the major part of its distribution in the study area and it is a remarkable dominant of some parts of the mountainous forest, especially on mountain ridges. In Hon Ba area, just the last 22 mature trees are present, but there are places in the BiDoup-Nui Ba area with numerous mature trees.

CONCLUSIONS

Research of mountainous areas in southern Vietnam has brought a new insight into plant diversity of this area. Although botanical exploration has to some extent dated back for more than a century, there is still potential for new discoveries to be made and six newly described species are a clear proof of this statement.

URBAN HABITAT SURVEY IN PORTO BOTANICAL GARDEN

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ABSTRACT

The Botanical Garden of the University of Porto is a designed outdoor space of ecological, aesthetical and historical interest. It is a place rich in landscape settings, stories and memories, where the eclectic interventions of the end of 19th century and first half of the 20th century stand out. The proximity of the Atlantic Ocean, tempered by the Gulf stream and a granite substrate, create favourable conditions for the cultivation of a varied, robust and multi-layered plant community, integrating species from various bioclimatic regions.

It is laid out on three main levels, establishing a mosaic of spaces, habitats and plant groups, full of diversity and surprise effect. At the higher level, an almost flat terrace accommodates the main house, the entrance woodland gardens and the formal gardens enclosed by high Camellia japonica clipped hedges, mainly of Portuguese cultivars created by the end of the 19th century; the intermediate levels are mainly occupied by the cacti collection and the greenhouses; the lower level is dominated by a small arboretum. In its four hectares, the Botanical Garden reveals a relatively rich assemblage of cultivated habitats, with diverse spatial arrangements and multiple vegetation layers.

These habitats of human origin have been surveyed in a research project on urban biodiversity undertaken in the city of Porto between 2009 and 2013. The habitat identification, description and representation were done through the adaptation to the urban landscape of an already established method developed by the European Biodiversity Observation Network. Such procedure allowed the development of new habitat survey method dedicated to artificial ecosystems, particularly occurring in the urban context, named Urban Habitat Biodiversity Assessment (UrHBA).

UrHBA describes the urban habitats based on Raunkiaer life forms, land cover, dominant species, site descriptors and vegetation layers. The method is strongly grounded on spatial narrative and representation, easy to understand by non-specialists. The resulting habitat maps communicate with the general public and are complemented with detailed plant species inventories for each habitat.

Like other urban green spaces, the habitat characterization of the Botanical Garden of Porto using this method suggested that it can make a relevant contribution for researching and knowing more about urban biodiversity, its opportunities and problems, and the importance to conserve, promote or create conditions to improve its quality in densely humanized areas.

KEYWORDS

Cultivated Biodiversity, Designed Spaces, Habitat Assessment

INTRODUCTION

The Botanical Garden of the University of Porto constitutes a special, unique and referential space in the context of the city and academia. It is a designed outdoor space with significant landscape quality, with high artistic and symbolic relevance, historical interest and rich in biodiversity. It also stands out due to its public access and the opportunities it generates in terms of conservation, recreation, education and research.

The garden and its house form a complex with important historical, cultural and natural value. This value stems from its origin at the end of the 19th century, as an affluent private eclectic space, and by its evolution into a public space, in the second half of the 20th century, for teaching and learning in the fields of Botany and Landscape Architecture. The space is also profoundly associated with the lives and works of the writers Sophia de Mello Breyner Andresen and Ruben Andresen Leitão.

Porto Botanical Garden is situated on the southern area of the city, on a flat promontory over Douro River (373 m away), close to the Atlantic Ocean (2,277 m away), between 58.84 m and 72.81 m above sea level, and with a dominant slope of 0-3%, achieved mainly with terrain levelling (41.153138° N, 8,642676° W; Figure 1).

The influence of the Atlantic Ocean, tempered by the Gulf Stream, and a granite substrate, create very favourable conditions for the development of a diverse, robust and multi-layered plant community, integrating species from various bioclimatic regions. It is laid out on three main levels, establishing a mosaic of spaces, habitats and plant groups, full of diversity and surprise effect (Figure 2). At the higher level, an almost flat terrace accommodates the main house, the entrance woodland gardens and the formal gardens enclosed by high *Camellia japonica* clipped hedges, mainly of Portuguese cultivars created by the end of the 19th century; the intermediate levels are mainly occupied by the cacti collection and the green houses; the lower level is dominated by a small arboretum.

These habitats of human origin have been surveyed in a research project on urban biodiversity, accomplished in the city of Porto between 2009 and 2013 (Farinha-Marques et al., 2014).

MATERIAL AND METHOD

The habitat identification, description and representation were achieved with a new habitat survey method dedicated to artificial ecosystems, particularly occurring in the urban context, named Urban Habitat Biodiversity Assessment (UrHBA; Farinha-Marques et al., 2015). This method resulted from the adaptation to the urban landscape of an already established method, developed by the European Biodiversity Observation Network (Bunce et al., 2011).

With UrHBA, habitats are mapped and described based on several attributes (Farinha-Marques et al., 2017):

1. Urban Habitat Categories are determined by the most prevalent land cover in the area. Urban habitats dominated by vegetation are classified according to Raunkiaer plant life forms of the dominant species (Table 1—Life form categories). Artificial elements and sparsely vegetated areas are included as non-life form categories (Table 2 – NLF categories).
2. Site Descriptors are intended to provide a common name for each type of habitat, linking ecological and landscape approaches and aiding the perception of the space. Some examples of Site Descriptors are: “Tree alley”, “Open wood”, “Closed wood with understory”, “Hedge”, “Lawn”, “Tank”, “Building” or “Path”.
3. Vegetation Layers are determined through the analysis of the vegetation and visual estimation of plant height, as indicated in Table 3. This attribute is recorded as a combination of layers, including all plant layers with more than 30% cover.

The detailed steps of the methodological procedure can be conferred in Farinha-Marques et al., 2015 and Farinha-Marques et al., 2017.

These attributes are good indicators of habitat structure and environmental conditions, making this methodology particularly useful for biodiversity studies (Bunce et al., 2011).

RESULTS AND DISCUSSION

About 83% of the area of the Botanical Garden is occupied by trees and shrubs above 5m (forest phanerophytes), forming habitats of “closed woods” (Figure 3 and Figure 4). These occur mainly at the edges of the property, creating a protective frame to the formal gardens of the central level. In the northern area, near the main entrance and around the house, four habitats were identified: 1) “closed woods” of deciduous and evergreen forest phanerophytes, with American sweetgum (*Liquidambar styraciflua*), Japanese maple (*Acer palmatum*), European oak (*Quercus robur*), Japanese camellia (*Camellia japonica*) and rhododendrons (*Rhododendron* spp.); 2) “closed woods” of deciduous and coniferous forest phanerophytes, dominated by cedars (*Cedrus* spp.), Araucaria (*Araucaria* spp.) and linden (*Tilia* spp.); 3) “closed woods” of evergreen forest phanerophytes, with Canary Island date palm (*Phoenix canariensis*), New Zealand Christmas tree (*Metrosideros excelsa*) and several cultivars of *Camellia japonica*; 4) “closed woods” of evergreen and coniferous forest phanerophytes, with Southern magnolia (*Magnolia grandiflora*) and Lebanon cedar (*Cedrus libani*).

In its small-scale complexity, the “multi-layered border” of autochthonous inspiration, constitutes a habitat of evergreen low phanerophytes, dominated by lavender (*Lavandula* spp.), sage-leaved rock rose (*Cistus salviifolius*), curry plant (*Helichrysum italicum*) and *Halimium umbellatum*.

As complex glades, the “formal gardens” are formed by several habitats whose dominant plant species do not grow above the average height of human vision. They can be described as: 1) habitat of evergreen low phanerophytes, dominated by different species and cultivars of boxwood (*Buxus* spp.); 2) habitat of deciduous and evergreen, with several cultivars of hybrid tea roses (*Rosa* spp.) and English lavender (*Lavandula angustifolia*); 3) habitat of leafy and caespitose hemicryptophytes, with *Festuca arundinacea* and *Lotus pedunculatus*.

In the arboretum, there are two dominant habitats: 1) "closed woods" of deciduous forest phanerophytes, with London plane (*Platanus* × *acerifolia*), silver birch (*Betula pendula*), black gum (*Nyssa sylvatica*), hornbeam (*Carpinus betulus*) and copper beech (*Fagus sylvatica* f. *purpurea*); and 2) "closed woods" of coniferous forest phanerophytes, where several species of fir (*Abies* spp.), spruce (*Picea* spp.), arborvitae (*Thuja* spp.) and false cypress (*Chamaecyparis* spp.). Also relevant in this area, but with a reduced spatial extension, there are patches of "closed woods" of evergreen forest phanerophytes, with cork oak (*Quercus suber*), and "closed woods" of evergreen and coniferous forest phanerophytes, with blue gum (*Eucalyptus globulus*) and California redwood (*Sequoia sempervirens*).

The cacti and succulent "botanical collection" includes two types of habitats: 1) evergreen and non-leafy evergreen mid phanerophytes, with *Aloe* spp., *Agave* spp., *Cereus* spp. and *Opuntia* spp.; and 2) evergreen forest phanerophytes, marked by the presence of cabbage tree (*Cordyline australis*).

The few "short meadows" are habitats of caespitose hemicryptophytes dominated by *Festuca rubra, Dactylis glomerata* and *Lolium perenne*.

The main habitats dominated by water take the form of "pods", "tanks" and "fountains". These constructed elements integrate water and vegetation and are important for the stimulation of amenity, sensorial quality of the place and for biodiversity, as they create favourable and attractive conditions for wildlife. The larger ones are dominated by species and cultivars of water lilies (*Nymphaea* spp.), papyrus (*Cyperus papyrus*) and duckweed (*Lemna minor*).

The complexity and richness of the vegetation structure of the Botanical Garden are strongly evidenced by the presence of several vegetation layers (Figure 5). In a sample of 29 parks, gardens and green squares of Porto, analysed with the same method (UrHBA; Farinha-Marques et al., 2015), the Botanical Garden revealed the highest combination of vegetation layers – 16 combinations, out of a total of 31 possible combinations. Most of the garden is occupied by two dominant layers, generally tall trees over groundcovers, low shrubs or medium shrubs.

CONCLUSION

The characterization of urban habitats constitutes an important contribution to the knowledge of the urban biodiversity, that is currently fundamental for the planning and management of the city, following models and strategies that promote higher environmental and landscape quality. UrHBA methodology has a high spatial expression, allowing an easy graphical representation and a strong communicative effect for specialists and the general public.

In its four hectares, the Botanical Garden reveals a relatively rich assemblage of cultivated habitats, with diverse spatial arrangements and multiple vegetation layers.

The Porto Botanical Garden is nowadays a medium-scale green space, that is perceived and experienced as a cultural landscape, intensely designed and ordered. It constitutes a multidimensional arrangement, with high spatial diversity, rich in cultivated plant biodiversity and very relevant in the historical and cultural context of Porto and Portugal. Its open relationship with the public makes it one of the most accessible and friendly gardens in Porto.

REFERENCES

Bunce R.G.H., Bogers M.M.B., Roche P., Walczak M., Geizondorffer I.R., Jongman R.H.G. (2011) *'Manual for Habitat and Vegetation Surveillance and Monitoring. Temperate, Mediterranean and Desert Biomes'*. Wageningen: Alterra (report 2154)

Farinha-Marques P., Fernandes C., Lameiras J.M., Silva S., Guilherme F. (2014) *'Morfologia e Biodiversidade nos Espaços Verdes da Cidade do Porto - Livro 1: Seleção das áreas de estudo - 2ª Edição, revista e aumentada'.* Porto: Research Centre in Biodiversity and Genetic Resources, University of Porto. ISBN 978-989-98732-2-3. Online: http://bio-diver-city.fc.up.pt/index.php/book-i-selection-of-the-study-areas-portuguese-2nd-edition

Farinha-Marques P., Fernandes C., Guilherme F., Lameiras J.M., Alves P., Bunce R. (2015) *'Morphology & Biodiversity in the Urban Green Spaces of the City of Porto. Book II - Habitat Mapping and Characterization'.* Porto: Research Centre in Biodiversity and Genetic Resources, University of Porto. ISBN 978-989-98732-4-2. Online: http://bio-diver-city.fc.up.pt/index.php/

book-ii-habitat-mapping-and-characterization
Farinha-Marques P., Fernandes C., Guilherme F., Lameiras J.M., Alves P., Bunce R.G.H. (2017) *'Urban Habitats Biodiversity Assessment (UrHBA): a standardized procedure for recording biodiversity and its spatial distribution in urban environments'.* Landscape Ecology 32(9):1753-1770. doi: 10.1007/s10980-017-0554-3

TABLES AND FIGURES

Super-categories	Categories	Sub-categories
TRS Trees and shrubs	DCH Dwarf chamaephytes SCH Shrubby chamaephytes LPH Low phanerophytes MPH Mid phanerophytes TPH Tall phanerophytes FPH Forest phanerophytes GPH Mega forest phanerophytes	DEC Winter deciduous EVR Evergreen CON Coniferous NLE Non-leafy evergreen SUM Summer deciduous
HER Wetland herbaceous	SHY Submerged hydrophytes EHY Emergent hydrophytes HEL Helophytes	
HER Terrestrial herbaceous	LHE Leafy hemicryptophytes CHE Caespitose hemicryptophytes THE Therophytes GEO Geophytes HCH Herbaceous chamaephytes CRY Cryptogams	

Table 1: Life form categories. Urban Habitat Categories can be classified as a single life form category or a combination of two life form categories (from Farinha-Marques et al., 2015).

Super-categories	Categories	Sub-categories
ABE Artificial built structures	STR Built structure AQE Aquatic element PAV Pavement RUB Rubbish SEA Sea AQU Aquatic ICE Ice and snow TER Terrestrial LIT Organic litter	VGT With vegetation NVG Without vegetation
SPV Sparsely vegetated	ROC Bare rock BOU Boulders STO Stones GRV Gravel SAN Sand EAR Earth	

Table 2: Non-life form categories. Urban Habitat Categories can be classified as a single non-life form category or a combination of two non-life form categories (from Farinha-Marques et al., 2015).

Vegetation layers	Plant height
Tall trees	Over 5 m
Tall shrubs and small trees	Between 2 m and 5 m
Medium shrubs and tall herbaceous plants	Between 60 cm and 2 m
Small shrubs and medium herbaceous plants	Between 30 cm and 60 cm
Groundcovers and aquatic plants	Lower than 30 cm

Table 3: Vegetation Layers (from Farinha-Marques et al., 2015).

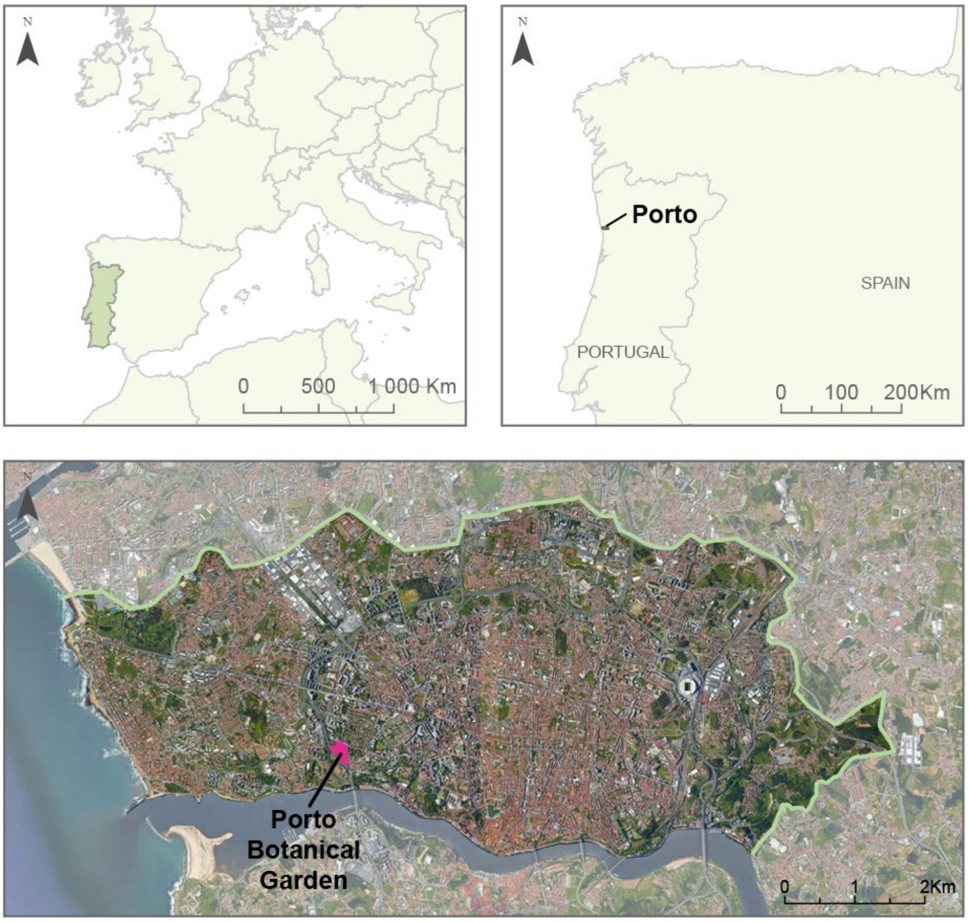


Figure 1: Location and context of Porto Botanical Garden.

Figure 2: Perspective of Porto Botanical Garden (©Google Earth) and overall ambience of the main areas.

Figure 3: Urban Habitat Categories of Porto Botanical Garden.

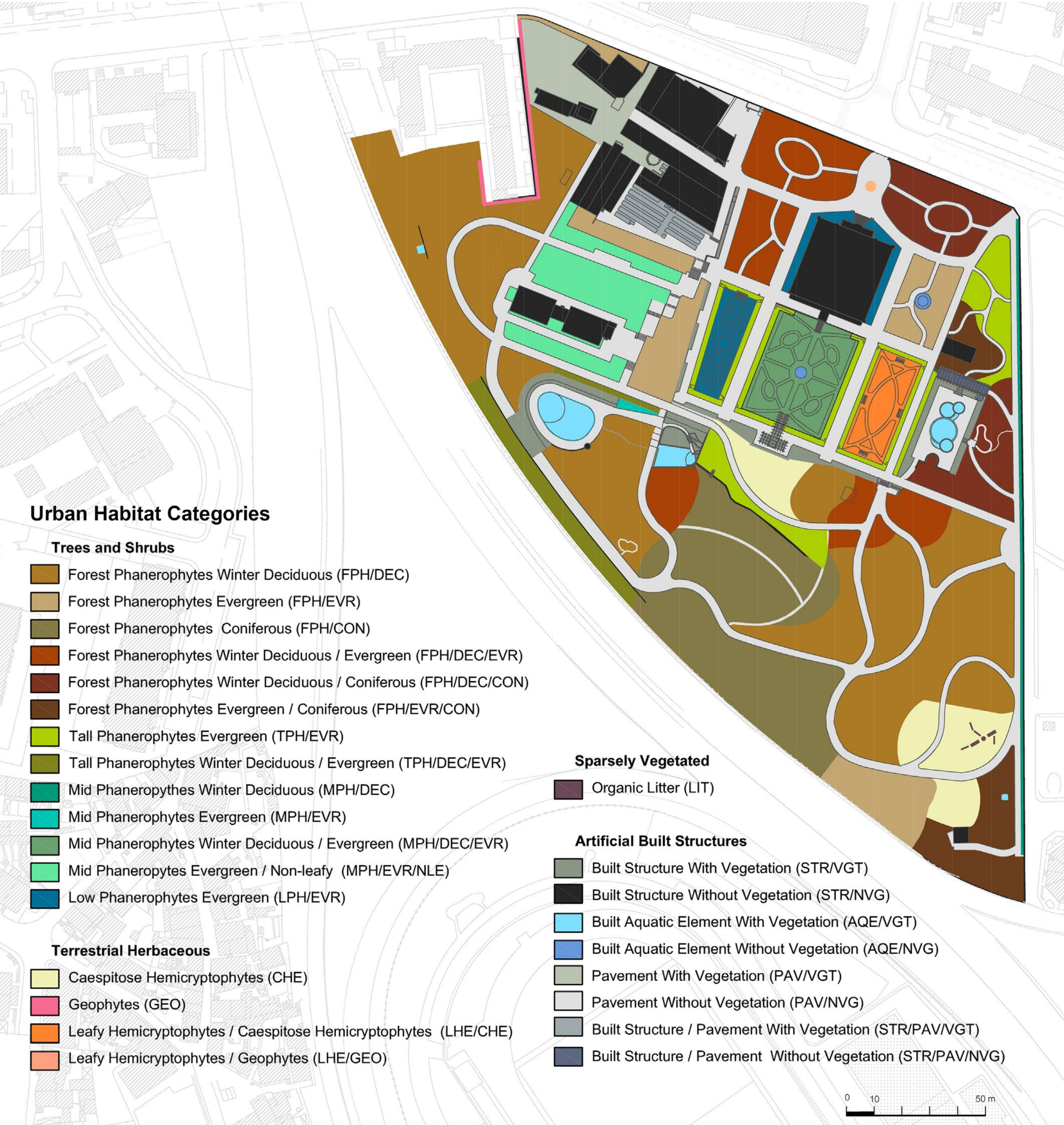


Figure 4: Site Descriptions of Porto Botanical Garden.

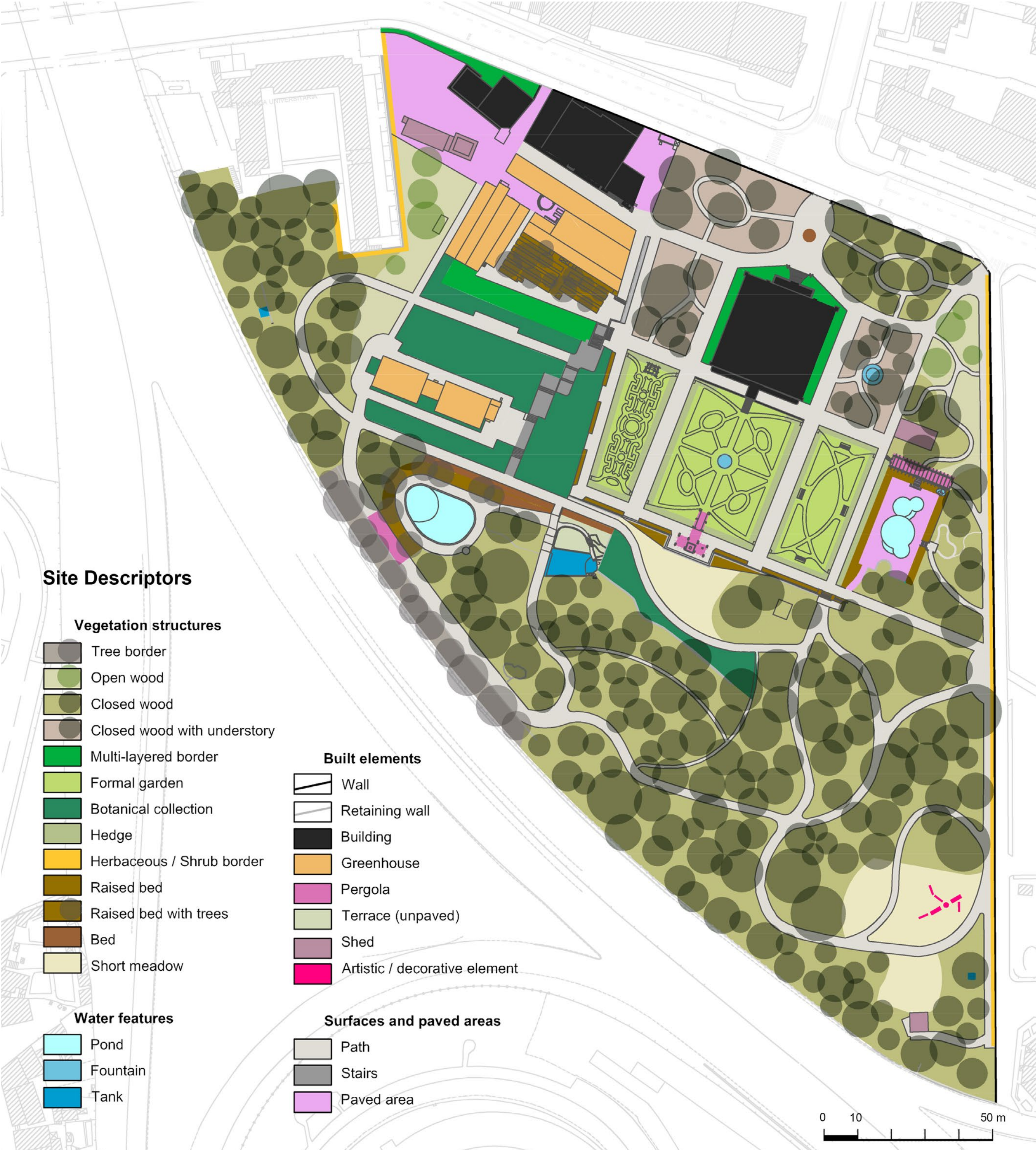
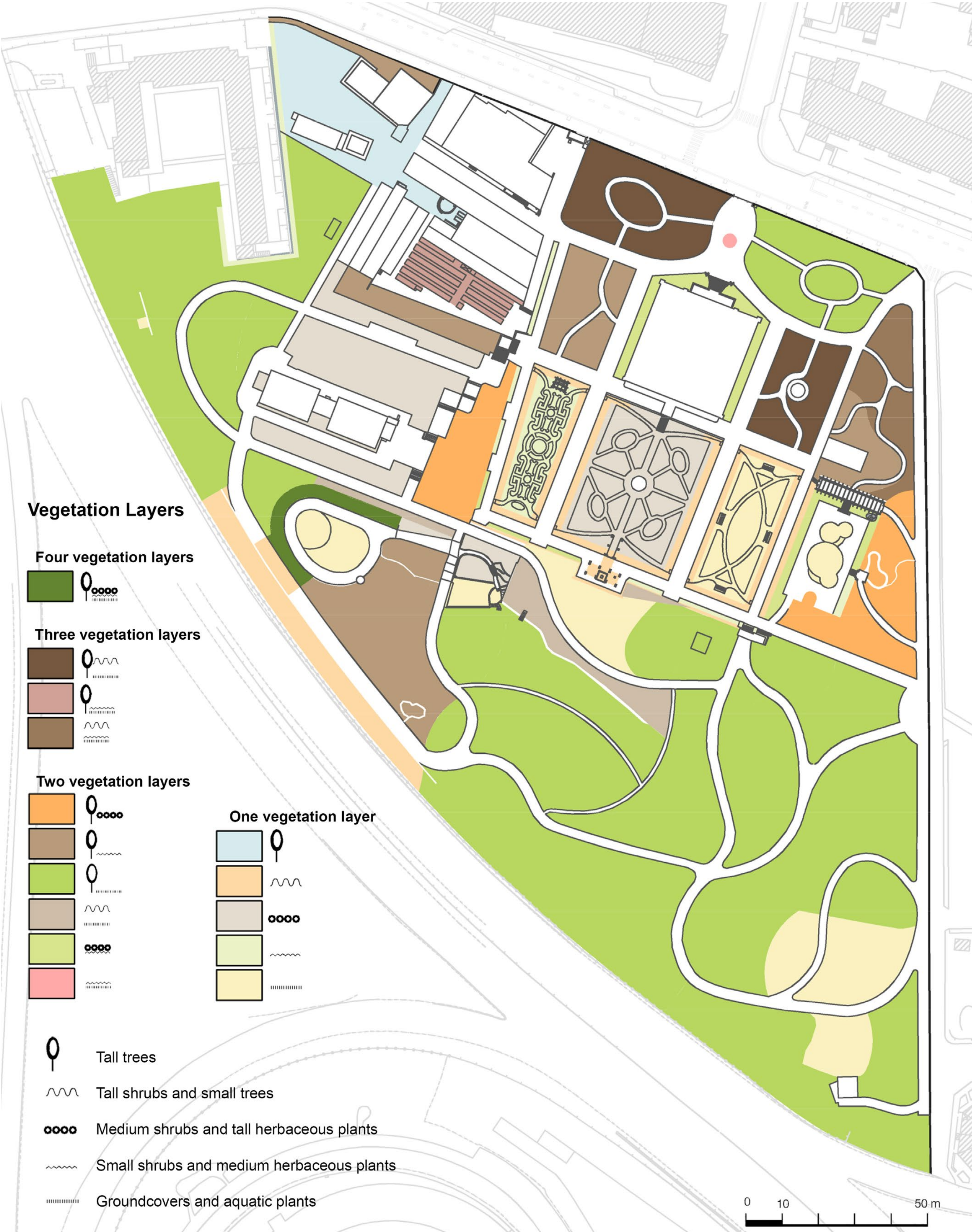


Figure 5: Vegetation Layers of Porto Botanical Garden.



ASEXUAL PROPAGATION OF FOUR THREATENED ENDEMIC PLANTS OF GREECE MAINTAINED AT THE BALKAN BOTANIC GARDEN OF KROUSSIA FOR *EX-SITU* CONSERVATION AND SUSTAINABLE USE

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ABSTRACT
The Balkan Botanic Garden of Kroussia (BBGK), N. Greece is dedicated to the *ex situ* conservation of native plants of Greece and the Balkans. The BBGK has formulated a conservation strategy for the collection and documentation of wild plant material for sustainable utilization, prioritizing firstly the Greek endemic, rare and threatened (critically endangered, endangered and vulnerable) plants found in different regions of Greece and secondly other socio-economic valuable plants with aromatic-medicinal properties or edible parts. Its aim is to contribute to the implementation of Targets 8 and 9 of the Global and European Strategies for Plant Conservation at local, regional and international scales. In this framework, plant material originating from wild populations of distant areas of Greece and maintained at the Laboratory of Conservation and Evaluation of Native and Floricultural Species was used for asexual propagation with softwood tip cuttings. The species studied are the endangered *Erysimum krendlii* Polatschek and *Thymus plasonii* Adamović, the vulnerable *Centaurea paxorum* Phitos & Georgiadis and the rare *Erysimum naxense* Snogerup; all are range-restricted, local Greek endemics with small populations in the wild, therefore with conservation priority, showing also potential commercial interest (aromatic-medicinal properties, edible parts or as pot plants for gardening). The effect of the immersion of the base of the cuttings for 1 minutes in liquid solutions of IBA at different concentrations (0, 2000 and 4000 ppm for *E. naxense* and *E. krendlii*; 0, 1000 and 2000 ppm for *T. plasonii* and *C. paxorum*) on root formation was tested for all species. A peat moss (Terrahum): perlite soil substrate in a 1:3 ratio was used for the experiment. The rooting percentage, the number of roots and the root length were analyzed in order to develop special propagation protocols for each species. *E. krendlii* showed better results with the use of 4000 ppm IBA showing 100% rooting, 30.86 roots/cutting and 3.71 root length after 5 weeks of maintenance in the mist. Respectively, by the use of 2000 ppm IBA *T. plasonii* cuttings performed similar root lengths (1.74-2.15 cm), increased rooting percentage up to almost 86% and number of developed roots up to 12 roots/cutting within a period of seven weeks. Rooting of C. *paxorum* cuttings was successfully performed under mist in a period of three weeks exhibiting 100% rooting percentage, 47.86 roots/cutting and 2.61 cm root length with the use of 1000 ppm IBA. *E. naxense* gave 85.71% of rooting, 19 roots/cuttings and 3.06 cm root length under the effect of 4000 ppm IBA for eight weeks. All the young individuals produced were transplanted in trays and latter in bigger pots (0.33 and 1Lt) until their final transplanting pot size (2.5Lt), each time in an enriched peat moss (TS2): perlite: soil substrate in a 2: ½ : ½ ratio, for their subsequent growth under unheated greenhouse conditions. The successful asexual propagation of the studied species allowed the creation of mother plants for each of them and facilitated the *ex situ* conservation and the domestication process of these wild species. This process may currently permit the mass production of plant material for the sustainable exploitation of these valuable and unique genetic resources of Greece.

KEYWORDS
Cuttings, Greek Flora, Aromatic And Medicinal Crops, Rooting, Propagation Protocols, *Erysimum* Spp., *Thymus Plasonii*, *Centaurea Paxorum*

INTRODUCTION

Plant diversity in Greece and the Balkans is exceptionally rich and unique, presenting a higher degree of endemism in relation to surface than any other comparable area of Europe or the Mediterranean region (Phitos et al., 1995; Strid and Tan, 1997). 22% of the plant taxa (species and subspecies) found in Greece are unique

(Dimopoulos et al. 2013, 2016), found nowhere else in the world (Greek endemics). (Akeroyd and Heywood, 1994). The uniqueness and rarity of the Greek and the Balkan flora demands effective conservation efforts as it is under increasing threat from climatic change, fires, land reclamation, overgrazing and urban and tourist development (Krigas et al. 2014). Botanic gardens play a key role in ensuring that plant resources are not only conserved *ex-situ* but are also used sustainably for the benefit of all people, in order to improve human well-being (Wyse Jackson and Sutherland, 2000; GSPC, 2002). The Balkan Botanic Garden of Kroussia (BBGK) has formulated a conservation strategy (Maloupa et al., 2008) and has adopted the Mission Statement to "support research, maintenance, propagation, evaluation, conservation and sustainable use of the native plants of Greece and the Balkans, combined with raising the environmental awareness of the public".

In the context of the global efforts to halt biodiversity loss by 2010 and beyond, emphasis is also given to the creation of a link between the *ex situ* and the *in situ* conservation actions regarding the IPS of Greece and the Balkans. Consideration has also been given by adjusting BBGK's individual conservation actions in light of the targets of the Global Strategy for Plant Conservation (GSPC, 2002) and the European Plant Conservation Strategy (EPCS, 2002). With this in mind, the BBGK has undertaken initiatives and has developed a strategy for the maintenance of extensive mother plantations, development of protocols for large-scale propagation and cultivation, estimation of the market potential for possible introduction of new products in ornamental floriculture and horticulture, cosmetology, pharmaceuticals, food flavourings, and landscaping (Maloupa et al., 2008a).

Current scientific literature regarding the biology of many European threatened plant species is quite limited. The same applies for the rare and threatened Greek endemic species investigated in this study, viz. *Erysimum naxense* Snogerup and *Erysimum krendlii* Polatschek (*Brassicaceae*), two species of section *Cheiranthus* (L.) Wettst. and *Erysimum* L., respectively (Gkika et al. 2013). Both of the studied *Erysimum* species (*E. naxense, E. krendlii*) are local endemics of Greece that are restricted to a single island of the Aegean Archipelago (Naxos and Samothraki, respectively). *E. naxense* is nationally (Snogerup, 1995) and globally (Walter and Gillett, 1998) considered "Rare" and is protected by the Greek Presidential Decree 67/1981, while *E. krendlii* is nationally assessed as "Vulnerable" (Krigas, 2009a). *E. naxense* is a perennial plant (rarely biennial) growing mainly as a rock-dweller at 100-500(-800) m above sea level (Snogerup, 1995); *E. krendlii* is a biennial (or short-living perennial) plant growing in phrygana, roadsides, and rocky areas from 250-1,000(-1,500) m (Krigas, 2009a).

Thymus plasonii is assessed as Endangered due to small area of occupancy, small population size (<8000 individuals) and high probability of habitat alteration / destruction imposed by human activities and many alien plants (Krigas, 2009b).

Centaurea paxorum is assessed as Vulnerable due to restricted range (single-island endemic to Paxoi-Antipaxoi), small population size (<5000 individuals), chasmophytic, high probability of habitat alteration / destruction imposed by natural phenomena and human activities (Krigas, 2009c).

Cuttings are still one of the most important means of plant propagation. Many new plants can be created in a limited space from a few stock plants. Greater uniformity is obtained and plants are usually reproduced with virtually no genetic change (Hartmann et al., 1997). The aim of the present study was to produce species-specific asexual propagation protocols by cuttings for the four rare and threatened Greek endemic plants as a means to contribute to their *ex-situ* conservation and sustainable utilization.

MATERIALS AND METHODS

Plant Material

Plant material was collected from the natural habitats of the selected species as a result of botanic expeditions conducted at floristically important areas (e.g., National Parks, NATURA 2000 sites and other protected areas). For each species collected, site specific information was kept (location, region, altitude, longitude and latitude) as well as a detailed habitat description. All plants collected, received immediate care in the nursery since they recover from transplantation shock (Fig. 1).

Asexual Propagation

Research on the asexual propagation of the four species was conducted. Softwood tip cuttings of 1.5-6 cm were taken during early-mid autumn from mother plants developed inside the greenhouse (1.5-2.5 cm for *E. naxense*, 2-4 cm for *E. krendlii*, 3-5 cm for *T. plasonii* and 5-6 cm for *C. paxorum*). The effect of the auxin indole-3-butyric acid (IBA) at three different concentrations (0, 1000 and 2000 ppm for *E. naxense* and *E. krendlii*;

0, 1000 and 2000 ppm for *T. plasonii* and *C. paxorum*) on root formation was tested. After immersion for 1 min in solutions of different IBA concentrations, the cuttings were placed in propagation trays in a substrate of peat (Terrahum) and perlite (Geoflor) (1:3 v/v) and maintained at bottom heat benches in a plastic greenhouse. Soil temperature was kept at 18-21°C, while air temperature was 15-25°C depending on weather conditions. Relative humidity was approximately 70-85% (mist). Experiments lasted for 8 weeks for *E. naxense*, 5 weeks for *E. krendlii*, 7 weeks for *T. plasonii* and 3 weeks for *C. paxorum*, followed a randomized design with 7 replications per treatment for the 3 following species (*E. naxense, E. krendlii* and *T. plasonii*) and 8 replications per treatment for C. paxorum. At the end of the experimental period per species, the number of roots per rooted cutting and root length were measured. Rooting was expressed as percentage (%). Produced rooted plants from all four species were then transplanted in pots of 0.33 L (8x8x7 cm) and subsequently in 2.5 L containing a mixture of peat (Klasmann, TS2), perlite and soil (2:1:1 v/v). Plants were maintained at the nursery with the aim of creating adequate initiation material for future experiments on sexual or asexual propagation.

Statistical analysis

Analysis of variance was performed with the SPSS 17.0 statistical package and mean separation with Duncan's Multiple Range Test. Significance was recorded at $P \leq 0.05$.

RESULTS

Vegetative propagation of *E. naxense* by cuttings was successfully achieved within 8 weeks. IBA (2000 and 4000 ppm) increased the number (19-26.75) and length of roots/rooted cutting (2.15-3.21 cm) compared to the control (2 roots 0.39 cm long). Rooting was highest (85.71%) and almost doubled when cuttings were treated with 4000 ppm IBA with respect to the IBA-untreated cuttings (42.86%). (Fig. 2, 3).

In *E. krendlii* cuttings, rooting was optimum with 2000 and 4000 ppm IBA. Root length (4.28 cm) was higher with 2000 ppm IBA and root number with 4000 ppm IBA. Rooting was 100% in all IBA treatments, compared to the control (85.71%) (Fig. 4, 5).

Regarding *T. plasonii*, the best rooting treatment of cuttings within 7 weeks was 2000 ppm IBA (8.67 roots 1.78 cm long, 85.71% rooting percentage). Root length was not affected due to increasing IBA concentrations (1.78-2.01 cm) in comparison to the control (1.74 cm) (Fig. 6, 7).

Asexual propagation of *C. paxorum* cuttings was successfully performed within 3 weeks. IBA (1000 and 2000 ppm) positively affected rooting (100%) giving 45.75-47.86 root number, while the control exhibited 71.43% rooting with 17.4 roots. Cuttings treated with 1000 and 2000 ppm IBA gave similar root lengths (2.61-2.67 cm) to the control (2.44 cm) (Fig. 8, 9).

DISCUSSION

Considering the recent challenges in regional conservation planning, it becomes apparent that there is an urgent need for increased applied research in order to develop propagation and cultivation protocols for target plants threatened with extinction, towards species recovery and populations' reinforcements (Maunder et al., 2001; Sarasan et al., 2006; Bunn et al., 2011).

In the present study with *E. naxense*, best rooting results were obtained when cuttings treated with 4000 ppm IBA. It has widely been documented that auxins promote adventitious root development of stem cuttings through their ability to promote the initiation of lateral root primordia (Leakey et al., 1982).

In the other studied *Erysimum* species (*E. krendlii*), the auxin hormone IBA had a significant effect on rooting performance of cuttings with 2000 and 4000 ppm concentrations to be the most effective. Enhancing rate of adventitious roots development with auxin application has been found to increase the number of roots initiated per rooted cutting in a number of species (Aminah et al., 1995).

The exogenous application of IBA generally improves rooting in *Thymus* species (Iapichino et al., 2005). In the current study with T. *plasonii*, IBA (1000 and 2000 ppm) resulted in increased rooting percentage. According to a previous research study conducted by Krigas et al. (2010), asexual propagation of softwood cuttings of *Thymus holosericeus* was successfully performed in 15 days where 0.2% IBA gave 80% rooting percentage with 13.1 roots/cutting and 1.5 cm root length. In the present experiment regarding *T. plasonii* cuttings, 80 – 85.71% were the higher rooting percentages obtained after a 7-week period in early-mid autumn. However, the combination of GIS data with previous experience on rooting of other species of the same genus raised propagation success of *T. holosericeus* nearly by 90% (from 45 to 80% rooting) revealing that early spring

was the appropriate season for the rooting trials since greenhouse temperatures emulate those in its natural environment (Krigas et al. 2010).
With respect to studying *C. paxorum*, the application of 1000 and 2000 ppm IBA caused a 3-fold increase in root number whereas IBA, irrespective of concentration led to 100% rooting. Increased number of roots is important for the plants to increase their ability to exploit soil water and nutrients, which in turn increases their overall growth (Ozel et al., 2006). The same authors reported that juvenile C*entaurea tchihatcheffii* cuttings treated with 500 ppm IBA for 10 min gave the highest frequency of rooting, root number and root length along with normal flowering (Ozel et al., 2006).
Additional research is needed on the rooting mechanism and to know the functions of adventitious roots in the functional biology of the plant. Knowledge of the behavior and relative contribution of these to the total performance of the plant would be beneficial.

CONCLUSION

All four Greek endemic species (*E. naxense, E. krendlii, T. plasonii* and *C. paxorum*) were successfully propagated and effective species-specific protocols have been produced for their asexual propagation (rooting: 85-100%) to back up their *ex situ* conservation at the Balkan Botanic Garden of Kroussia and to facilitate their sustainable exploitation. This study presents a facilitated asexual propagation by cuttings protocol for the *ex-situ* conservation of the four rare and threatened local endemic plant species of Greece contributing to the implementation of Target 8 of the Global Strategy for Plant Conservation (http://www.cbd.int/gspc/).
It was shown that there is a species-depended correlation between optimum rooting performance and IBA concentration. The concentration of IBA must be carefully chosen in order to avoid induced after effects, depended on plant species. This study is a step forward towards the regeneration, sustainable utilization and conservation of these rare and threatened Greek endemic plants.

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REFERENCES

Akeroyd J.R., Heywood, V.H. (1994) Regional overview: Europe. pp. 39–54 In: Davis, S.D., Heywood, V.H., Hamilton, A.C. (eds), Centres of Plant Diversity: A Guide and Strategy for Their Conservation, vol. 1 (Europe, Africa, South West Asia and the Middle East). The World Wide fund for nature (WWF) and IUCN-The World Conservation Union, Oxford, UK.
Aminah H., Dick J.M.C.P., Leakey R.R.B., Grace J., Smith R.I. (1995) *'Effect of indole butyric acid (IBA) on stem cuttings of Shorea Leprosula'.* Forest Ecology and Management 72:199–206
Bunn E., Turner S.R., Dixon K.W. (2011) *'Biotechnology for saving rare and threatened flora in a biodiversity hotspot'.* In Vitro Cellular & Developmental Biology-Plant 47(1): 188-200
Cox D.A. (1988) *'Production of Centaurea montana for early spring sales'.* Research Report Series-Alabama Agricultural Experiment Station, Auburn University 5:13-14
Davis E.S., Fay P.K., Chicone T.K., Lacey C.A. (1993) *'Persistence of spotted knapweed (Centaurea maculosa) seed in soil'.* Weed Science 41(1):57-61
Dimopoulos P., Raus Th., Bergmeier E., Constantinidis Th., Iatrou G., Kokkini S., Strid A. & Tzanoudakis D. 2013: Vascular plants of Greece: An annotated checklist.– Berlin: Botanic Garden and Botanical Museum Berlin-Dahlem; Athens: Hellenic Botanical Society. – [Englera 31].
Dimopoulos P., Raus Th., Bergmeier E., Constantinidis Th., Iatrou G., Kokkini S., Strid A. & Tzanoudakis D. 2016: Vascular plants of Greece: An annotated checklist. Supplement. – Willdenowia 46: 301 – 347.
Economou K.D., Oreopoulou V., Thomopoulos C.D. (1991) *'Antioxidant activity of some plant extracts of the family of Labiatae'.* Journal of the American Oil Chemists' Society 68:109-113.

Ekim T. (1994) *'Centaurea tchihatccheffii Fisch. and Mey, Yanardöner Asteraceae'.* Karaca Arboretum Magazine 2(3):137-138

EPCS (2002) *'European Plant Conservation Strategy'.* Council of Europe and Planta Europa Secretariat, London, UK.

Gkika P.I., Krigas N., Menexes G., Eleftherohorinos I.G., Maloupa E. (2013) *'Effect of temperature and light on seed germination of Erysimum naxense and Erysimum krendlii'.* Central European Journal of Biology 8(12):1194-1203

GSPC (2002) Global Strategy for Plant Conservation. Secretariat of the convention on biological diversity & botanic gardens conservation international, Kew, UK.

Hartmann H.T., Kester D.E., Davies F.T., Geneve R.L. (1997) *'Plant Propagation: Principles and Practices'.* Prentice Hall, Inc., New Jersey.

Iapichino G., Arnone C., Bertolini M., Amico Roxas U. (2005) '*Propagation of three thymus species by stem cuttings: Thymus capitatus L., Thymus serpyllum L., Thymus vulgaris L.'* Acta Horticulturae 723.

Karimi M., Berrichi A., Boukroute A. (2014) *'Study of vegetative propagation by cuttings of Thymus satureioides'.* Journal of Materials and Environmental Science 5(4):1320-1325

Kokkini S., Vokou D., Karousou, R. (1989) *'Essential oil yield of Lamiaceae plants in Greece'.* In: Bhattacharya S.C., Sen N., Sethi K.L. (Eds.), Essential Oils, Fragrances and Flavors. 3. Biosciences. Oxford & IBH Publishing, New Dehli, pp. 5-12

Krigas N., Maloupa, E. (2008) *'The Balkan Botanic Garden of Kroussia, Northern Greece: a garden dedicated to the conservation of native plants of Greece and the Balkans'.* Sibbaldia 6:9–27

Krigas N. (2009a) *'Erysimum krendlii Polatschek, Vulnerable (VU)'.* In: Phitos D., Constantinidis Th., Kamari G. (Eds.), The Red Data Book of Rare and Threatened Plants of Greece, Vol. 2 (E-Z), Hellenic Botanical Society, Patras

Krigas N. (2009b) *'Thymus plasonii Adamović, Endangered (EN)'.* In: Phitos D., Constantinidis Th., Kamari G. (Eds.), The Red Data Book of Rare and Threatened Plants of Greece, Vol. 2 (E-Z), Hellenic Botanical Society, Patras

Krigas N. (2009c) '*Centaurea paxorum Phitos & Georgiadis, Vulnerable (VU)'.* In: Phitos D., Constantinidis Th., Kamari G. (Eds.), The Red Data Book of Rare and Threatened Plants of Greece, Vol. 2 (E-Z), Hellenic Botanical Society, Patras

Krigas N., Mouflis G., Grigoriadou K., Maloupa E. (2010) *'Conservation of important plants from the Ionian Islands at the Balkan Botanic Garden of Kroussia, N Greece: using GIS to link the in situ collection data with plant propagation and ex situ cultivation'.* Biodiversity and Conservation 19:3583–3603

Krigas, N., Bandi, A. & Vokou, D. (2014). Identified threats and proposed protection measures for the Rare and Threatened Plants of Greece: classification, ranking and mismatches. – Pp. 43-52 in: Krigas, N., Tsoktouridis, G., Cook, C.M., Mylona, Ph. & Maloupa, E. (Eds.), Botanic Gardens in a Changing World: insights into Eurogard VI, Botanic Gardens Conservation International (http://www.botanicgardens.eu/eurogard/eurogard6/krigas_threatened.pdf).

Leakey R.R.B., Chapman V.R., Longman K.A. (1982) *'Physiological studies for tropical tree improvement and conservation. Factors affecting root initiation in cuttings of Triplochiton scleroxylon. K. Schum'.* Forest and Ecology Management 4:53–66

Maloupa E., krigas N., Grigoriadou K., Lazari D., Tsoktouridis G. (2008a) *'Conservation strategies for native plant species and their sustainable exploitation: case of the Balkan Botanic Garden of Kroussia, N. Greece'.* pp. 37–56 In: Teixeira da Silva J.A. (Ed.), Floriculture Ornamental Plant Biotechnology: Advances and topical issues. vol. 5 (1st edn.). Global Science books, Isleworth, U.K.

Maloupa E., Grigoriadou K., Papanastassi K., Krigas N. (2008b) '*Conservation, propagation, development and utilization of xerophytic species of the native Greek flora towards commercial floriculture'.* Acta Horticulturae 766:205–213

Maunder M., Higgens S., Culham A. (2001) *'The effectiveness of botanic garden collections in supporting plant conservation: a European case study'.* Biodiversity and Conservation 10:383–401

Okay Y., Demir K. (2010) *'Critically endangered endemic Centaurea tchihatcheffii Fisch. and Mey. and its propagation possibilities'.* African Journal of Agricultural Research 5(25): 3536-3541

Phitos D., Strid A., Snogerup S., Greuter, W. (1995) *'The Red Data Book of Rare and Threatened Plants of Greece'*. WWF, Athens.

Rey C. (1992) *'Selection of thyme (Thymus vulgaris L.) for extreme areas'.* Acta Horticulturae 306:66-70.

Sarasan V., Cripps R., Ramsay M.M., Atherton C., McMichen M., Prendergast G., Rowntree J.K. (2006) *'Conservation in vitro of threatened plants—progress in the past decade'.* In Vitro Cellular and Developmental Biology- Plant 42:206–214

Selaru E., Draghici M. (1989) *'Research on developing a technique for greenhouse culture of Centaurea moschata var. imperialis'.* Lucrari Stiintifice, Institutul Agronomic 'Nicolae Balcescu', Bucuresti, Seria B, Horticultura 32(1):93-103

Snogerup S. (1995) *'Erysimum naxense Snogerup, Rare (R)'.* In: Phitos D., Strid A., Snogerup S., Greuter W. (Eds.), The Red Data Book of Rare and Threatened Plants of Greece. WWF, Athens

Strid A., Tan K. (1997) *'Flora Hellenica.'* Vol. 1. Koeltz Scientific Books, Koenigstein, Germany

Walter K.S., Gillett H.J. (1998) 'The 1997 IUCN Red List of threatened plants'. Gland, Switzerland and Cambridge, The World Conservation Union

Wyse Jackson P.S., Sutherland L.A. (2000) *'International Agenda for Botanic Gardens in Conservation'.* Botanic Gardens Conservation International, Kew, UK

TABLES AND FIGURES

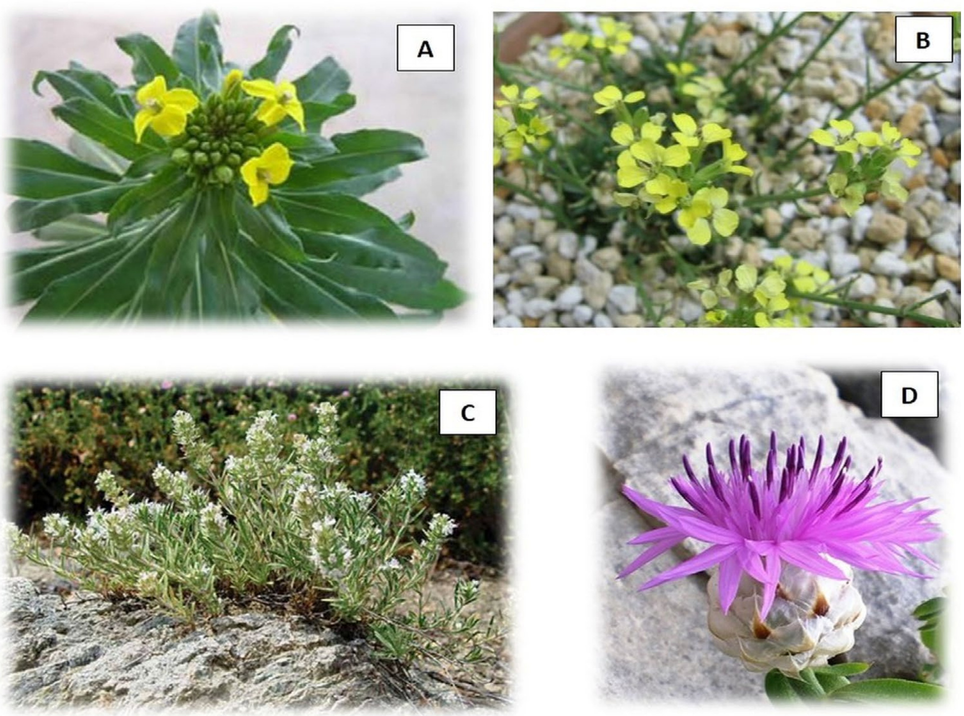


Figure 1: Adult plants of four studied species in their natural habitats in Greece: (A) *Erysimum naxense* (Naxos Island), (B) *Erysmum krendlii* (Samothraki Island), (C) *Thymus plasonii* (Mt Chortiatis) and (D) *Centaurea paxorum* (Paxi Island)

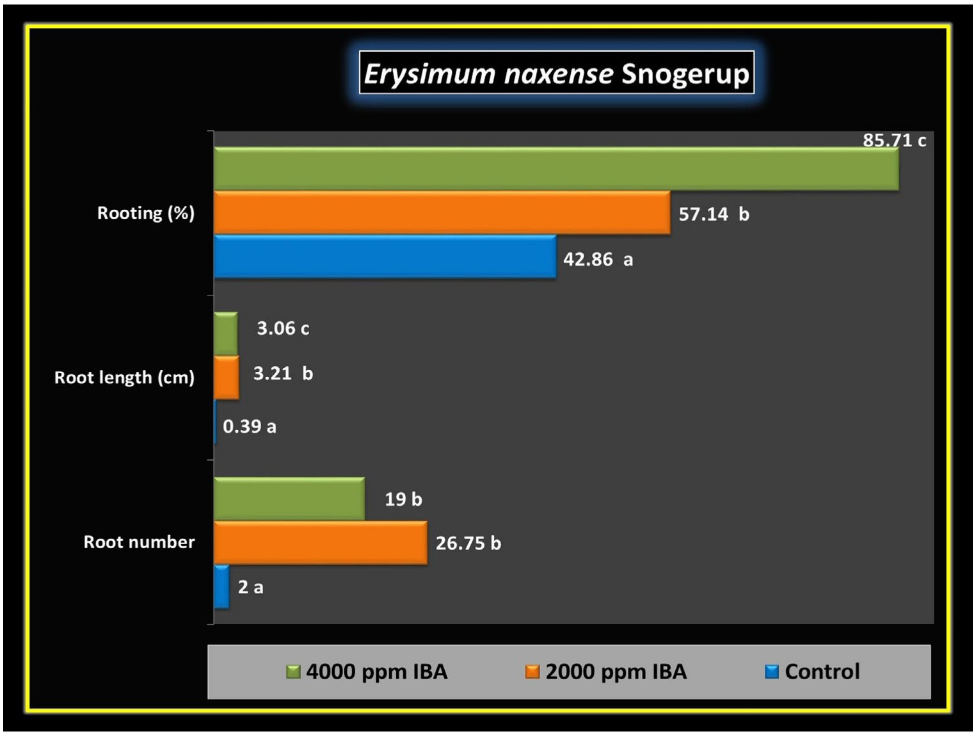


Figure 2: Effect of IBA concentration (0, 2000, 4000 ppm) on root number/ rooted cutting, root length and rooting percentage in *E. naxense* cuttings after 8 weeks

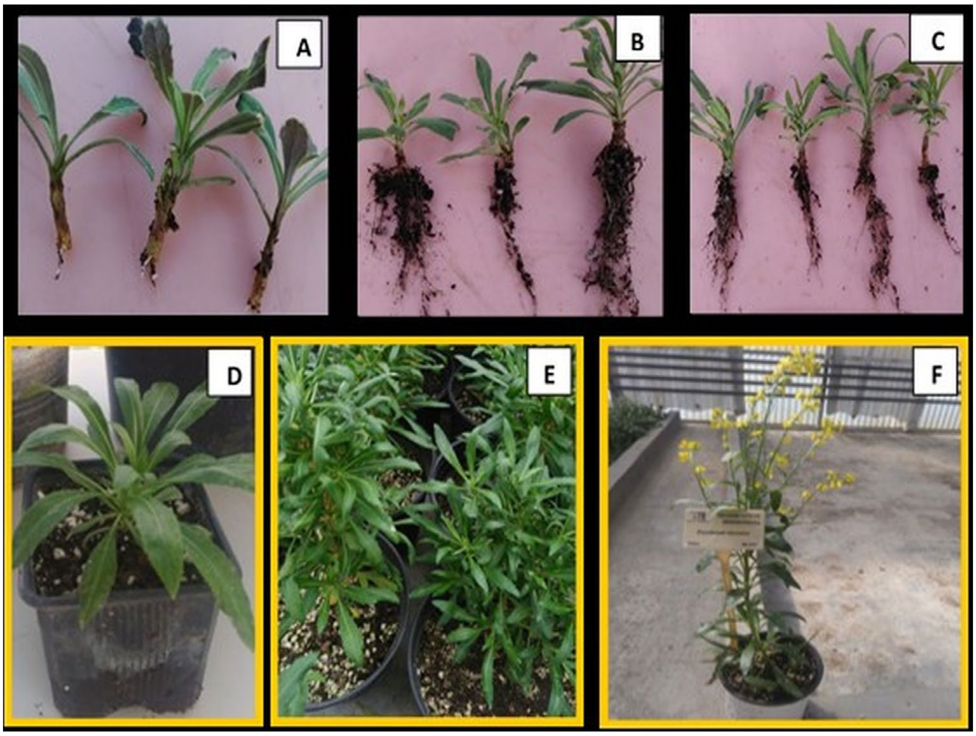


Figure 3: Asexual propagation of *E. naxense* cuttings: (A) Control, (B) 2000 ppm IBA, (C) 4000 ppm IBA, (D) Transplantation and vegetative growth of rooted cuttings into 0.33 and 2.5 L pots after 10 weeks, (E) 16 weeks, and (F) 5 months

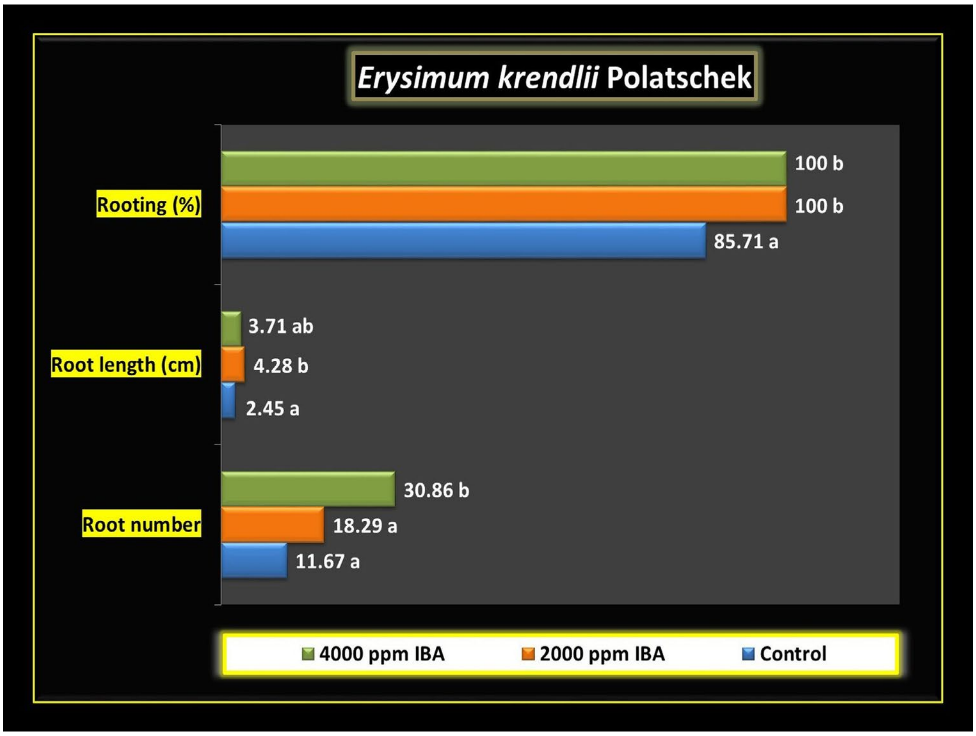


Figure 4: Effect of IBA concentration (0, 2000, 4000 ppm) on root number/ rooted cutting, root length and rooting percentage in *E. krendlii* cuttings after 5 weeks

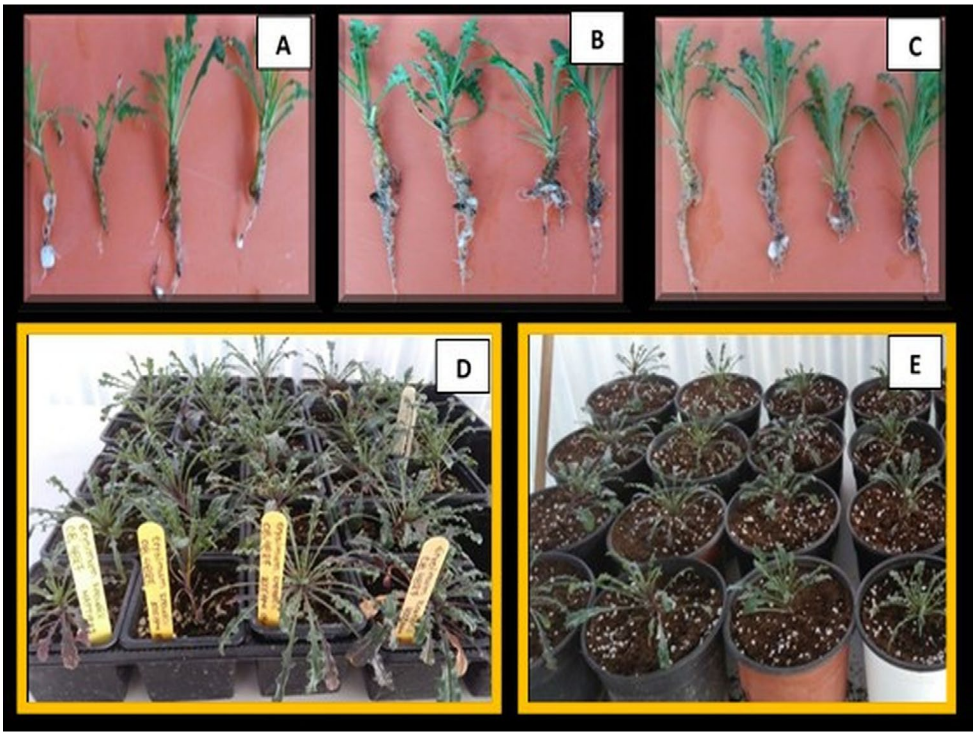


Figure 5: Asexual propagation of *E. krendlii* cuttings: (A) Control, (B) 2000 ppm IBA, (C) 4000 ppm IBA, (D) Transplantation and vegetative growth of rooted cuttings into 0.33 L pots after 4 weeks and (E) 2.5 L pots after another 4 weeks.

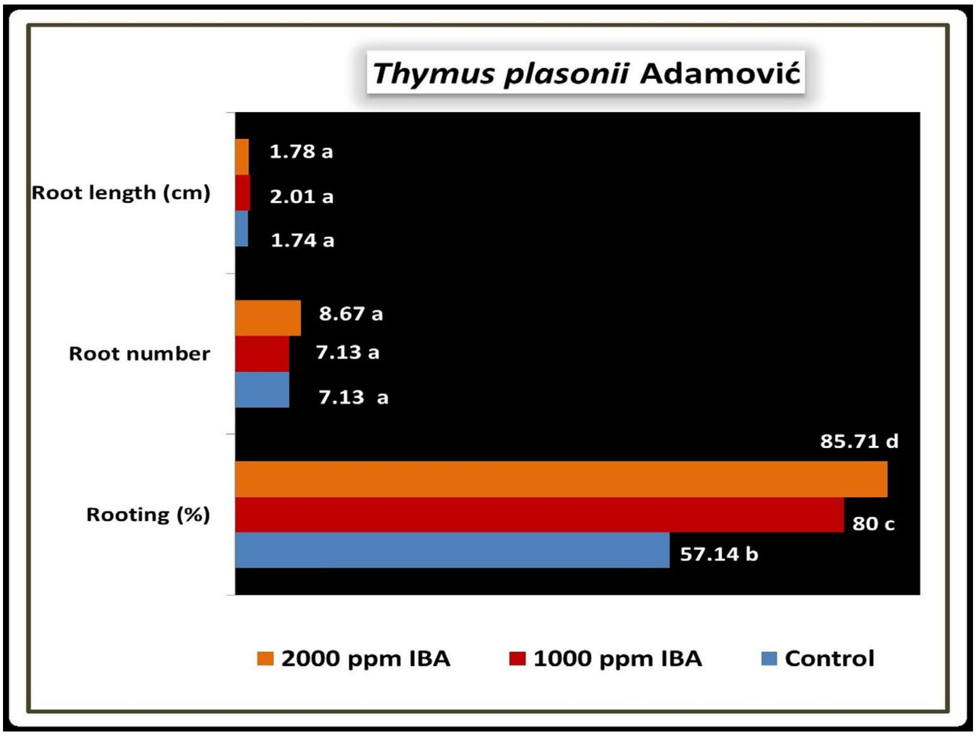


Figure 6: Effect of IBA concentrations (0, 1000, 2000 ppm) on root number/ rooted cutting, root length and rooting percentage in *T. plasonii* cuttings after 7 weeks

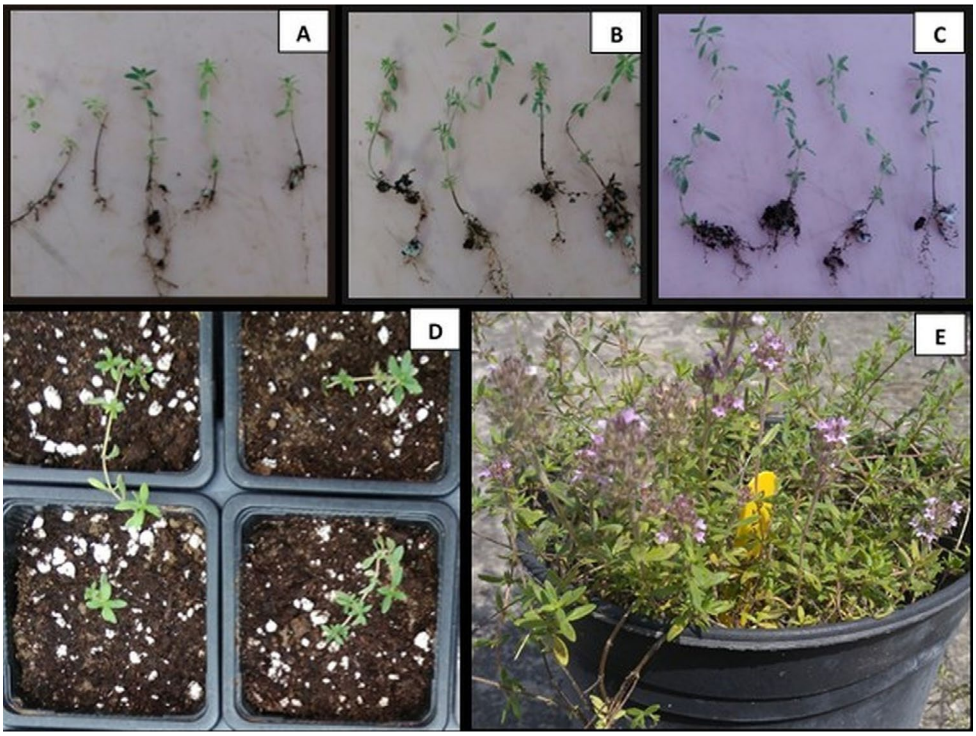


Figure 7: Asexual propagation of *T. plasonii* cuttings: (A) Control, (B) 1000 ppm IBA, (C) 2000 ppm IBA, (D) Transplantation and vegetative growth of rooted cuttings into 0.33 L pots after 3 days in the greenhouse bench and (E) 2.5 L pots after 5 months in natural conditions, outside greenhouse

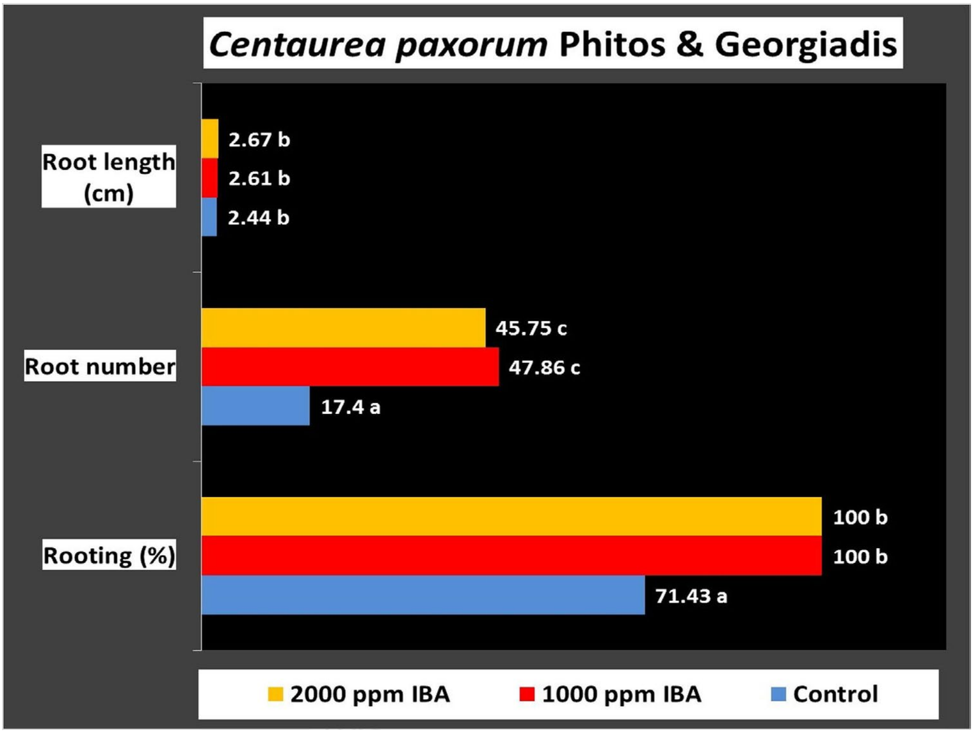


Figure 8: Effect of IBA concentrations (0, 1000, 2000 ppm) on root number/ rooted cutting, root length and rooting percentage in *C. paxorum* cuttings after 3 weeks

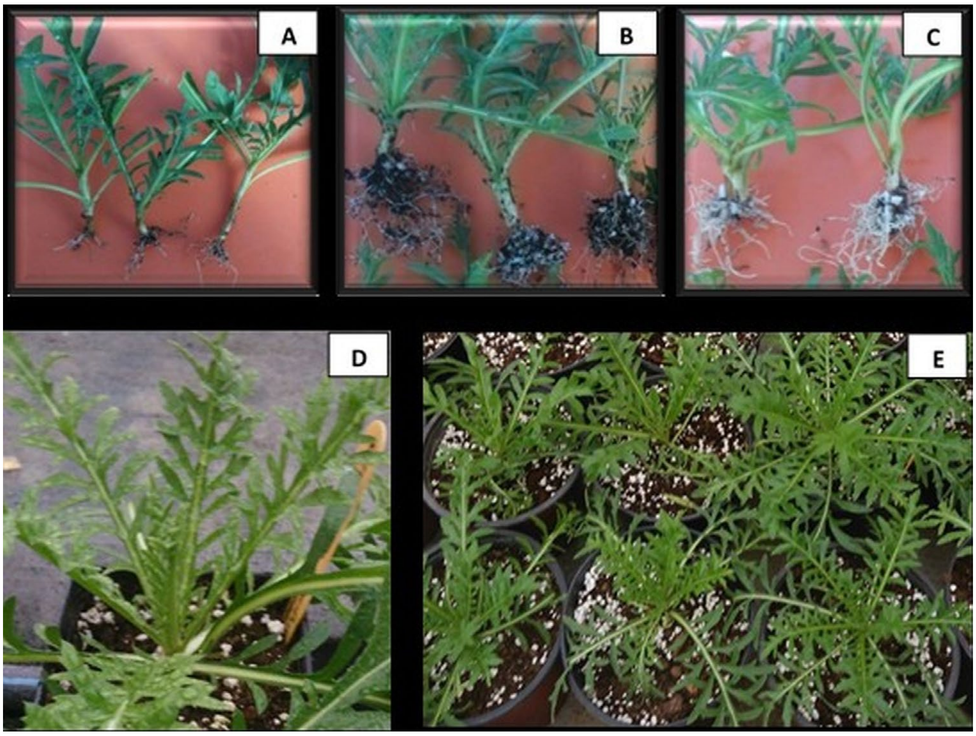
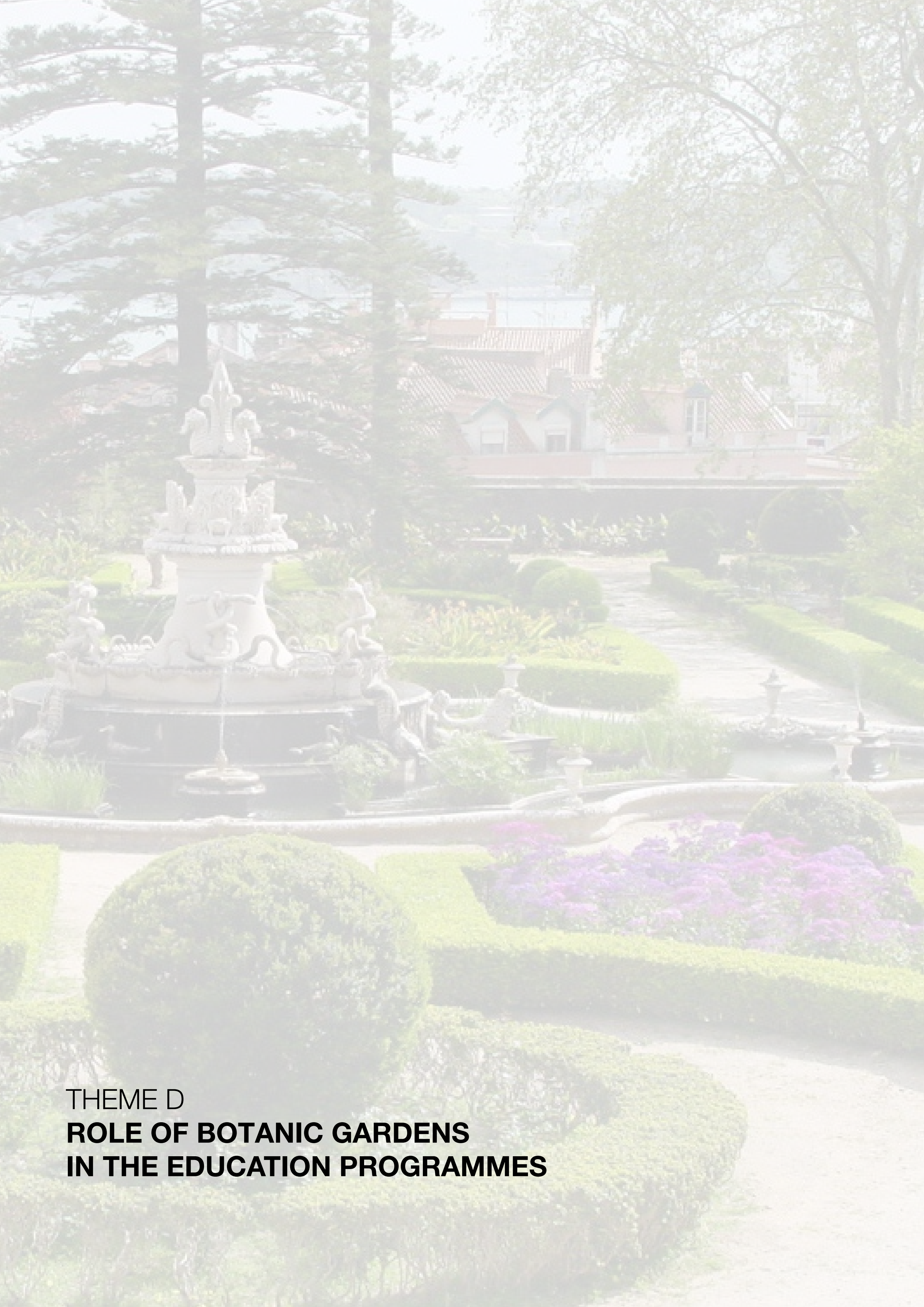


Figure 9: Asexual propagation of *C. paxorum* cuttings: (A) Control, (B) 1000 ppm IBA, (C) 2000 ppm IBA, (D) Transplantation and vegetative growth of rooted cuttings into 0.33 L pots after 4 weeks, (E) 2.5 L pots after another 8 weeks



THEME D

ROLE OF BOTANIC GARDENS IN THE EDUCATION PROGRAMMES

THE BOTANICUM: NEW OPTIONS FOR SCIENCE EDUCATION AND PUBLIC OUTREACH AT THE BOTANICAL GARDEN OF THE UNIVERSITY OF VIENNA

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ABSTRACT

The Green School Program at the Botanical Garden of the University of Vienna has been established more than 25 years ago. From the beginning onwards the program was developed with the intention to combine the potentials, options and needs of university education for biologists and future biology teachers with the demands for educative activities at the garden.

The present paper describes the history, the rationales and the ideas behind the development of different kinds of activities of this program and its interactions with a diversity of target audiences in an academic and non-academic context. It also refers to scientific research projects incl. bachelor-, master-, diploma- and PhD-theses connected with them. In addition, options for future developments opening up now because of the construction of the Botanicum, a building especially devoted to the program, are presented. This building will, for the first time, allow to offer public outreach and education activities the whole year around.

The processes of and the ideas behind the development of the program to be relaunched now are also laid out. This program will focus on three target groups: (1) children and school classes, (2) (future) teachers and educators, and (3) the general public. It also will continue to explore synergies with teachers´ and scientists´ education at the university in accord with the relevant curricula. The new program will, in part, be developed in consultation and collaboration with other stakeholders.

Scientific evaluation of the program will continue, aiming at getting better insights into backgrounds, demands, needs and interests of different types of visitor groups of the garden. These studies shall increase the general knowledge about successful incentives for different target groups in creating an "environment of curiosity and interest" in a "natural laboratory", and shall help to further optimize the education and outreach programs, approaches and tools.

KEYWORDS

Green School Program, Science Education, Science Communication Research, Didactics Of Botany

INTRODUCTION

Since its establishment more than 25 years ago the „Green School Program" at the Botanical Garden of the University of Vienna (Hortus Botanicus Vindobonensis, HBV) has been aiming to trigger curiosity and excitement about natural sciences, addressing target audiences of all ages and social backgrounds. The activities organized by the HBV have been designed to get insights into the world of plants, and to gain first hand experiences about the beauty and the importance of biological diversity. As a green oasis in the city centre the Botanical Garden provides options for expeditions into the world of plants and for scientifically based studies on all kinds of biological questions.

As part of the celebrations of its 650th anniversary in 2015 the University of Vienna decided, with support of a sponsor, to build a special facility for the Green School at the garden: the Botanicum. This building will allow to widen the scope of topics offered to different potential users and provides new options for education and public outreach at the HBV the whole year around.

The "Green School" program has been developed in parallel to the needs of a university education for biologists and future biology teachers (Pass & al. 2005). These synergies are currently further explored, and will, if possible, be expanded in accord with the relevant curricula (Kiehn 2016a).

Courses and programs and the interactions with the target groups have already been subject of evaluation and research. This way, interests of different audiences and the effectiveness of the offered programs can be assessed. Such studies shall be continued and shall further support a permanent optimization of programs, approaches and tools of the Green School.

MATERIAL AND METHODS

Based on the personal experience of the first author, internal documents and reports of the Green School Program and the Botanical Garden over the last 25 years, and by evaluating relevant publications, conference presentations and students´ theses, the paper provides insights into the developmental processes of the different Green School activities at the HBV for the last 25 years. It describes the interactions between the creation of curricula for biology and teachers´ education at the University of Vienna and the Green School programs developed for the public outreach to different groups of garden visitors. Accompanying science education research projects are exemplified and put into a broader theoretical frame. Based on these multi-facetted experiences of more than 25 years, the paper presents strategies for a future oriented development of the public outreach and education activities incorporating the options now provided by a Green School building allowing activities the whole year around.

RESULTS AND DISCUSSION

With more than 11.500 species in its collections (Kiehn 2016b) the HBV harbours a species-rich collection of taxa from temperate to tropical regions. Many of these plants are on view to the circa 150,000 visitors annually coming to the garden (Knickmann & Kiehn 2015), and many are used in the teaching of university courses in biology and pharmacy and in research projects. Thus the Botanical Garden is a valuable source of material for studies at the university.

However, there were no university courses directly connected with the collections of the HBV when the first author of this paper was appointed as curator in 1991. Also, there was no program to cover the demand for guided tours for school classes in the garden. Within the following years, an integrated approach was applied to change this situation in a synergetic way:

a) Development of new university courses especially designed to improve students´ involvement with and knowledge of the Botanical Garden and its collections: Between 1991 and 1995, two new types of courses were designed to fit to the curricula of the University of Vienna. One course especially addresses future teachers and students interested in science communication. It uses the garden and its plants to improve students´ skills in developing appealing and short program units on plants and/or environmental sciences for defined target groups. This type of “science education” course is an opportunity for practical training and has therefore become very popular with the students. With some modifications, it now is an obligatory part of the curriculum for future teachers.

The second type of courses is placed in the Bachelor- and Master-curricula and is directed towards students interested in botany and conservation. Here, the students get insights into the collections and are encouraged to develop short information leaflets or presentations on topics specifically relevant for the Botanical Garden, mainly for the general public. Ideally these leaflets are suited for being displayed in the garden. Sometimes, such courses also resulted in scientific publications (e.g., Kiehn & Rayner 2001), exhibitions (e.g., Kiehn & al. 1996, Kiehn 1997, Kaar 2001, Dostal & al. 2006), or in Master or Diploma theses (e.g., Winding 2001, Kogler 2012). Students having passed these types of courses successfully are invited to actively participate in the Green School.

b) Creation of an organisational structure to handle the requests for guided tours: Initially, the first author of this paper handled the whole organisation of the guided tours himself and also guided most of the tours. This limited the number of possible activities. With the availability of dedicated students this situation changed, and the need for an organisational structure became evident. With support of the Vice-Rectorate of the University of Vienna responsible for teaching, a part time position for a coordinator of the program was created. The Association of the Friends of the Botanical Garden secured some funding for students working as guides. This way, the annual number of guided tours for school classes in the context of the Green School Program increased from 60 (in the 1990s) to 240 (in 2006, Dostal & al. 2006b). Actually, more than 6,000 people are participating every year in c. 300 different outreach activities of the garden. Since 2016, the coordination of the Green School is placed at the Event Management of the University of Vienna, and the whole program is official part of the public outreach activities of the University.

c) Options for students´ theses on topics of relevance for the outreach programs: As a follow-up of the participation in the above mentioned courses students were encouraged to prepare diploma theses directly connected with the garden and its outreach programs. More than 30 theses have been successfully finished so far. Subjects covered by such theses range from topics related to plant systematics, morphology or functional traits (e.g., Graf 2008, Hölbling 2009, Hölzl 2013, Mayr 2016, Mutlular 2016, Teubert 2013), geographical ranges, soil conditions or uses (e.g., Pfannhauser 2010, Pumpler 2016, Sales-Reichartzeder 2008, Satzinger 2015), to characterization or revitalization of certain areas in the garden (e.g., Berner 2013, Lämmerhirt 2001, Amelin 2013). Some theses even "go beyond the garden walls", as restoration plans for a school garden (Müllern 2008), of a monastery garden with touristic potential (Weis 2016) or with practical ideas for green school programs at other gardens (Aichinger 2017). As added value, all these theses provide new materials and tools to be used in the outreach programs of the HBV.

d) Development of materials and templates for guided tours and programs incl. training sessions: The materials and programs developed in the context of the university courses and theses provide a wealth of practical tools useful for guided tours and programs. Quite often, such materials were practically tested by the authors in the garden. In addition, information packages were developed especially designed for certain types of programs (e.g., on useful plants, trees, plant animal interactions). Relevant materials have been prepared for different topics (e.g., flower models, chemicals, or lenses) and are stored to be used by the guides if needed. All the accompanying texts, explanations and background information are digitally available at a computer accessible for all guides. Guides have the possibility to gain experiences by joining other more experienced guides and by attending training courses offered on a regular basis for selected topics. Some of the tools and the rationales behind them have meanwhile also been published in international journals or conference proceedings (Lampert & al. 2012, 2015).

e) Establishment of evaluation tools:
As the whole program is embedded in the teachers´ education activities at the University of Vienna, this offered a possibility to develop research and evaluation tools to accompany the development and to test the effectiveness of certain programs. Major fields of activities relate to counteract 'plant-blindness' (a common perception that plants are uninteresting or boring, and they are often overlooked in everyday life; Wandersee & Schussler 2001, Hershey 2002), to the question which plants are interesting for certain target audiences and to the creation of scientifically correct perceptions about pollination and dispersal of plant diaspores (Lampert 2012, Mayr 2016). A number of courses were developed for groups of all ages but mostly for school pupils between 6 and 18 years old, as their visit to the Botanical Garden is often their first conscious contact with nature and especially with living plants.
Some of the studies were based on the observation that the usefulness of plants seems to be an important criterion for children for arranging plants in groups (Krüger & Burmester 2005). Therefore one approach was to identify 'flagship-species' amongst useful plants for capturing childrens´ attention, as interest has significant influence on the motivation to gather new knowledge (Hidi & Baird 1986). In addition, the questions whether interest in useful plants is evenly distributed within the target groups, whether interest in plants changes with age, and whether there are some areas of knowledge which are 'sexier' than others have been dealt with. A series of studies on these topics started in 2008 and is still ongoing, with the aim of developing an educational concept devoted to the useful plants group (Sales-Reichartzeder & al. 2011, Auleitner 2014, Lörnitzo 2015, Pany & Heidinger 2015a, 2015b, Pany 2016, Pany & al. 2017). Consequently the Botanical Garden participates in the current EU-funded project BigPicnic (https://www.bigpicnic. net/).

f) Consequences:
Based on different studies mentioned above, several new educational concepts have been proposed and partly initiated at the Botanic Garden to optimize arrangements and presentations of a number of plant groups, especially of the useful plants. In the context of the BigPicnic project, e.g., a display with raised beds for food plants was established as joint effort of trainees and staff of the Botanical Garden, project collaborators and school kids. This project is also presented to the garden visitors and is documented by a bachelor thesis.
Elements of the Green School Program meanwhile have been "exported" to other locations and organisations in Austria, e.g., as courses of the Childrens´ University in Vienna or in Steyr (Upper Austria), or at the Kinderuniversum in Waidhofen a.d. Ybbs (Lower Austria).

CONCLUSION

The Botanicum building will provide new options for science education at the Botanical Garden of the University of Vienna, as it will allow to link indoor and outdoor activities and to operate during the whole year. It also provides the space for training courses and seminars in need of presentation facilities or technical equipment like microscopes. This will considerable expand the potential scope and improve the effects of the future program.

An evaluation of the whole range of the current activities including the different guided tours and projects and the accompanying tools and materials has been started, aiming at streamlining these activities for the new opportunities provided by the possibility of indoor activities.

The new program will continue to benefit from the synergies with the teachers´ and scientists´ education at the university. Based on the experiences from over 25 years and from studies about visitors´ compositions and interests (e.g., Pfannhauser 2010, Pany 2016), and taking the increasing demand on "lifelong-learning" opportunities into account, it will be designed to explicitly serve three target groups: children and school classes, (future) teachers and educators, and the general public. In consultation and collaboration with other stakeholders, e.g., the Austrian Education Competence Center at the University of Vienna, other universities, teachers´ organisations, or school boards of the Austrian Federal States, also programs for post-graduate university courses and professional development of teachers are planned.

Because of the many different types of visitors, the garden is a perfect place to continue testing a variety of teaching and public outreach methods. Therefore the scientific evaluation of the program will continue, aiming at getting better insights into backgrounds, demands, needs and interests of different types of visitor groups of the garden. Presentations and publications of the results of such studies (besides students´ theses also in form of scientific papers), will be prepared to reach a wide audience of science educators, scientists and botanical garden staff.

In addition, the practical activities of the students and guides in the framework of the program and the success of interactions with different target groups shall strengthen the knowledge base, competence and qualification of (future) teachers and educators to create curiosity and to deliver scientific content as appealing as possible.

ACKNOWLEDGMENTS

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The staff of the Botanical Garden always was extremely supportive of all outreach activities in the garden and many staff members actively took and still take part in the program.

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REFERENCES

Aichinger E. R. (2017) ´*Entwicklung von Materialien zur zielgruppengerechten Vermittlung botanischer Themen im Botanischen Garten der Stadt Linz.*´ Diploma thesis. Vienna: University of Vienna.

Amelin N. (2013) ´*Konzept zur Revitalisierung der pflanzengeographischen Abteilung im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Auleitner, L. C. (2014) ´*Schülervorstellungen zu Drogenpflanzen.*´ Diploma thesis. Vienna: University of Vienna.

Berner B. (2013) ´*Charakterisierung der Rasen- und Wiesenflächen im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Dostal D., Henner J., Kiehn M. (eds.) (2006a) ´*Pflanzen, Bäume und Früchte in der Bibel. Ausgewählte Pflanzen der Bibel. Begleitheft zur Ausstellung.*´ Vienna: Österr. Bibelgesellschaft

Dostal D., Schumacher F., Kiehn M. (2006b) ´*Education at the University of Vienna Botanical Garden.*´ In Willison J., Kneebone S. (eds.): ´*The Nature of Success: Success for Nature. The 6th International Congress on Education in Botanic Gardens. Congress Proceedings.*´ Kew: BGCI and Oxford: Univ. of Oxford Botanic Garden

Graf S. (2008) ´*Die systematische Abteilung des Botanischen Gartens der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Hershey D. (2002) ´*Plant Blindness: 'We have met the enemy and he is us'.*´ Plant Science Bulletin 48 (3): 78–84.

Hidi S., Baird W. (1986) ´*Interestingness – a neglected variable in discourse processing.*´ Cognitive Science 10: 179–194.

Hölbling M. (2009) ´*Das System der einkeimblättrigen Pflanzen im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Hölzl M. (2013) ´*Didaktische Überlegungen zur Präsentation blütenbiologischer Phänomene im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Kaar M. (2001) ´*Mensch und Pflanze vom 16. Jahrhundert bis heute - zur Biologie, Kulturgeschichte und Nutzung ausgewählter Pflanzenarten des "Hortus Eystettensis" : Datenerhebung und Erstellung von Materialien für zielgruppenorientierte Präsentationen.*´ Diploma thesis. Vienna: University of Vienna.

Kiehn M. (ed.) (1997) ´*Condimenta. Gewürzpflanzen in Koch- und Backrezepten aus der römischen Antike.*´ Wien: Institut für Botanik und Botanischer Garten, Universität Wien.

Kiehn M. (2016a) ´*Case study 7.2.7. Hortus Botanicus Vindobonensis: a training and education resource for university students.*´ P. 196 in Gratzfeld J. (ed.). ´*From Idea to Realisation – BGCI's Manual on Planning, Developing and Managing Botanic Gardens.*´ Richmond, UK: Botanic Gardens Conservation International.

Kiehn M. (2016b) ´*The plant collections of the Botanical Garden. Pp. 41-47 in Feigl C.(ed.): ´Academic showcases. The Collections at the University of Vienna.*´ Wien, Köln, Weimar: Böhlau.

Kiehn M., Lassnig P., Liebhart T., Schembera E., Walter J. (1996) ´*Giftpflanzen. Katalog zur Ausstellung im Institut für Botanik und Botanischen Garten der Universität Wien, Juni bis September 1996.*´ Wien: Institut für Botanik und Botanischer Garten, Universität Wien.

Kiehn M., Rayner K., (2001) ´*Mahagoni - wertvolle Tropenhölzer der Alten und Neuen Welt.*´ Palmengarten 65/1: 40-45.

Knickmann B., Kiehn M. (eds.) (2015). ´*Der Botanische Garten.*´ Wien: Botanischer Garten, Universität Wien.

Kogler E. (2012) ´*Blütenbewegungen bei Bulbophyllum lobbii – Analyse des Bewegungsmechanismus.*´ Master thesis. Vienna: University of Vienna.

Krüger D., Burmester A. (2005) ´*Wie Schüler Pflanzen ordnen.*´ Zeitschrift für Didaktik der Naturwissenschaften 11: 85-102.

Lämmerhirt A. (2001) ´*Konzept zur Umgestaltung der "Genetischen Gruppe" im HBV nach wissenschaftlichen, didaktischen und gärtnerischen Gesichtspunkten.*´ Diploma thesis. Vienna: University of Vienna.

Lampert P. (2012) ´*Blüten und Bestäuber.*´ Diploma thesis. Vienna: University of Vienna.

Lampert P., Pany P., Kiehn M. (2012) ´*Durch die Blume: Blüten und ihre Bestäuber.*´ Unterricht Biologie 375, 11-16.

Lampert P., Rose M., Kiehn M. (2015): ´*Building models to build up unterstanding.*´ Pp. 118-138 in Irwin Z., Hobson C., Prasadh Selvam R., Derewnicka L. (eds.) ´*The Proceedings of the BGCI 9th International Congress on Education in Botanic Gardens. Biodiversity for a Better World. Wild Ideas Worth Sharing*´. Richmond, Surrey: BGCI.

Lörnitzo A. (2015) ´*SchülerInnen-Interessen zum Thema Gewürzpflanzen und der Einsatz von forschendem Lernen im Biologieunterricht.*´ Diploma thesis. Vienna: University of Vienna.

Mayr J. (2016) ´*Ausbreitungsbiologie bei Pflanzen.*´ Diploma thesis. Vienna: University of Vienna.

Müllern K. (2008) ´*Revitalisierung eines Schulgartens – wissenschaftliche Grundlage und didaktische Konzepte für einen Nutzpflanzengarten.*´ Diploma thesis. Vienna: University of Vienna.

Mutlular J. (2015) ´*Botanische Charakterisierung und Dokumentation der Baumarten des Botanischen Gartens der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Pany P. (2016) ´*Schüler_innen-Interessen an Nutzpflanzen.*´ PhD thesis. Vienna: University of Vienna.

Pany P., Heidinger C. (2015a) ´*Nutzpflanzen als „Türöffner" für die Vermittlung botanischer Inhalte - Häufigkeitsverteilungen von Interessenprofilen als Hilfe für die Planung von Botanik-Unterrichtseinheiten.*´ Erkenntnisweg Biologiedidaktik 13: 25-40.

Pany P., Heidinger C. (2015b) ´*Uncovering patterns of interest in useful plants - Frequency analysis of individual students' interest types as a tool for planning botany teaching units.*´ Multidisciplinary Journal for Education, Social and Technological Sciences 2(1), 15-39.

Pany P., Heidinger C., Kiehn M. (2017) ´*T6 P1352; The potential of useful plants as flagship species to counteract plant blindness.*´ P. 479 in Abstracts Book II. Posters and Abstracts. XIX International Botanical Congress 2017. Shenzhen, China: IBC.

Pass G., Kiehn M., Lang I., Reininger-Cetin C., Aigner-Breuss E. (2005) ´*Fachdidaktik "Biologie und Umweltkunde" an der Universität Wien: Evaluierung von Organisationsstrukturen; Kooperationsformen mit Schulen und methodischen Innovationen in der Lehre.*´ Pp. 61-96 in Ecker A. (ed.) ´*Fachdidaktik im Aufbruch. Zur Situation der Lehramtsstudien an der Universität Wien.*´ Frankfurt/M., Berlin, Bern, Bruxelles, New York, Oxford, Wien: Peter Lang.

Pfannhauser M. (2010) *Die Pannonische Gruppe im Botanischen Garten der Universität Wien*. Diploma thesis. Vienna: University of Vienna.

Pumpler P. (2016) ´*Die Serpentingruppe im Botanischen Garten der Universität Wien Geobotanische und pflanzenökologische Aspekte von Lebensräumen über Serpentinit.*´ Diploma thesis. Vienna: University of Vienna.

Sales-Reichartzeder J. (2008) ´*Die Nutzpflanzengruppe des Botanischen Gartens der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Sales-Reichartzeder J., Pany P., Kiehn M. (2011) ´*Opening the window on 'plant-blindness'.*´ Roots 8, 2: 23-26.

Satzinger V. (2015) ´*Fachbotanische Beschreibung der Nutzpflanzen im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Teubert F. M. (2013) ´*Diasporenökologie im Botanischen Garten der Universität Wien.*´ Diploma thesis. Vienna: University of Vienna.

Wandersee J. H., Schussler E. (2001) ´*Toward a theory of plant blindness.*´ Plant Science Bulletin, 47(1): 2-9.

Weis M. (2016) ´*Hofgarten Seitenstetten: Evaluierung der Potenziale für Vermittlungsprogramme sowie Entwicklung von Infrastruktur und Medien.*´ Diploma thesis. Vienna: University of Vienna.

Winding G. (2001) ´*Lebende Fossilien im HBV.*´ Diploma thesis. Vienna: University of Vienna.

FROM BOTANIC GARDEN TO THE SCHOOL: NATURAL SCIENCES WITH THE IBSE METHODOLOGY OUTSIDE CLASSROOM

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ABSTRACT

Non-formal educative settings, such as gardens and museums, as well as the Inquiry-based Science Education (IBSE), a multifaceted and student-centered methodology, play an essential role as tools for Education. Based in the educative experiences in a Botanic Garden, our aim is to study the integration of IBSE outside classroom in a formal Portuguese school context. The goal is to understand the impact of this methodology in Natural Sciences learning, and in the opinions and educative products of 10 to 12 years old students.

Within a partnership with a School and a Science Teacher of the Portuguese 5th year level, and trained in IBSE, seven thematic classes on biodiversity and sustainability were taken from an Educational Program developed in Coimbra Botanical Garden. Fulfilling the curricular demands these lesson plans were integrated in the classes during the three school periods and adopted and adjusted to the existing conditions and resources.

The cognitive learning of the students in the Natural Sciences topics, and their opinions, were regularly monitored, validated and statistically evaluated by seventy-two pairs of pre and post-questionnaires and also analyzed in a semi structured interview with the teacher.

The results proved a cognitive improvement of the students in all curricular themes evaluated, as referred elsewhere. The emphasis is now to highlight the positive feedback from students and their teacher view on the work developed. After completing the innovative approach in class, the motivation involved 92% of the students, responses in 99% of them and new learning felt by all; 89% of the students showed satisfaction in the activities experienced and in the documents produced. Favoring questioning, both the teacher and the students want to continue this teaching and learning format at School, as an enlarged and creative alternative for Natural Sciences understanding. Moreover, lesson plans, new botanic thematic and the resources produced are replicable by other educational communities and diverse stakeholders, directly, or as ideas to new activities for schools.

Applying those educative strategies on a regular basis outside classroom, either in a museum, a botanic garden or a school garden, will improve knowledge, encouraging imagination and a stronger sensitivity for nature, plants and their importance for life.

KEYWORDS

Active Learning, Curricular Innovation, Experimental Practices, Non-Formal Educative Settings

INTRODUCTION

Conceptual framework - WHY this research

The educative processes with IBSE lessons outdoors, being or not guided by a formal curricula, are flexible and adapt to the needs and interests of the students, who can gain a human-nature connection and develop greater environmental awareness. Being an active, experimental and student-centered educative methodology, IBSE imitates the scientific research and it is characterized as a multifaceted activity. Students use the same skills as the scientists, like questioning, data collection, reasoning, proof review in the light of what is already known, drawing conclusions and discussing the results (Artigue et al., 2012).

IBSE means that students progressively develop key scientific ideas by learning how to investigate and build their knowledge and the understanding of the world around, based on the students' work and physical and mental realities and background. Put a question, find an answer, go further, and grow. If you ask, you want to know. The more I know, the more there is to learn: this is the attitude of a scientist (Tavares, Silva, & Bettencourt, 2015). IBSE is based in a constructivist

cognitive development model where the construction of knowledge implies hands-on, heart-on and minds-on stimulation, increasing the students' curiosity and creativity (Tavares, 2018).
Also, non-formal education environments, such as gardens or museums, are especially relevant in Science Education, for the construction of knowledge is enhanced when using these educative settings, typically outside classroom (Ainsworth & Eaton, 2010; ASE OSWG, 2011). It is known that these outdoor experiences are positively reflected on the academic performance of each student, increasing awareness to new options, in a transversal way: as an apprentice, for professional career, as political and socially active citizen (Beatty & Schweingruber, 2017; Matteman & Damsa, 2017).
Natural Science with IBSE outside classroom stimulates a first-hand experience, the appreciation of nature as a whole, a tighter relationship, promoting greater motivation and engagement for action and knowledge and environmental reflection (Tavares et al., 2015). Going to Nature as a starting point, and using it as a practice of daily life, combines with the main characteristics of IBSE methodology, which values pre-existing knowledge and a new perspective of open and team-social teaching, where the individualities of students and teachers must be taken into account, respecting each singularity (Malm, 2009; Pessoa, 2013). The two components - an environment outside classroom and a student-centered methodology - facilitate and improve the educative process (Tavares et al., 2015), where storytelling is an important tool to consider (Bedford, 2001; Tavares, 2017).

WHAT to investigate

A project promoted by the Centre for Studies in Human Development, Faculty of Education and Psychology of the Catholic University (Porto) to understand the impact of IBSE outside classroom in a real School context with young students (10 to 12 years old - 5th grade) and concerning three main levels: cognitive learning, opinions and attitudes and the work produced.

MATERIAL AND METHODS

HOW to implement

By a partnership with a School and a Science Teacher trained in IBSE and the students of the 5th grade (first year of the second cycle of basic education): a sample of 75 students of the 3 classes- A (25), B (26) and C (24). Fulfilling the curricular program (Caldas & Pestana, 2010), seven topics on biodiversity and sustainability (Table 1) were taken from the Educational Program developed in Coimbra Botanic Garden (Tavares, 2015) and adjusted to the school resources and conditions.

Timetable

The educative project was developed during three phases of a complete scholar calendar: 1st- partnership and arrangements of themes in school (April and May, previous to the project implementation at school); 2nd- application, monitoring, collection of results, and evaluation (September to July); 3rd- organization of the documents produced (June and July).

Assessment Tools and Procedure for Students' opinions and attitudes:

A-Students' Questionnaires

Regular evaluation of 72 valid pair of pre (1st term) and post (2nd term) questionnaires with five question, anonymous, were answered within 15 minutes. The 1st and 2nd questions were closed and the last three were open questions. The answers' contents were grouped by similar subjects in a maximum of 8 items, and assessed by simple statistical analysis.
There were five main items for students' opinions and attitudes: 1- Motivation for learning; 2- Actions generated in the students or the students 'proactivity; 3- Impacts on learning in general; we want to know if students think they learn more; 4- The degree of satisfaction with the methodology; if they liked to work in this way and why; 5- Suggestions for other improvements in the classes.

B- The work produced

During the three school terms of the project implementation, the students developed their work following the seven curricular topics, as referred in table 1.

C- Interview with the teacher

To understand the lived experience and the opinion of the teacher on the impact of the IBSE outdoors classes in the students' feelings and learning, a semi-structured interview (Amado, 2013) was implemented with her, at the end of the scholar year and the project implementation.

Seven curricular topics /nº of IBSE sessions
1st Term: 4 themes/10 sessions
1- Plant diversity. *The algae who wanted to be a flower*/2
2- The leaves. ***The Autumn color's in the garden leaves*** /3
3- The flower *is also a mother* /3
4- Stems, form and function of the plant organs. *Shall we hug the trees?* /2
December: Revisions; discussion of the students' projects on plant diversity; storytelling; exchange of books. Christmas homework: to write lyrics for a song on plants evolution.
2nd Term: 3 themes /10 sessions
5- The cells and DNA. *The beginnings of life* /5
6- Classification and taxonomy. *Plants have a family too*/ 3
7- Explorers. *Scientists in the school*/2
3rd Term
Exhibition of the students' texts and drawings on the *"Algae-flower"* story. Composition of the song "the alga's dream" with the music teacher, based on the verses written by the students. Helping 6th graders students learn the song. Competition for the best plant label made for the school gardens. Celebration of Earth day (May 22nd): the students place the labels in the garden plants. *"The algae's dream"* song performance at the end-of-the-year school ceremony (https://www.youtube.com/watch?v=SDypuKHtzRs - 27th May2016), interacting with the audience, all educative community (students, parents, friends, teachers and school staff).

Table 1: School chronogram of the 5th grade curricular topics and IBSE sessions

RESULTS

Concerning the cognitive learning there was a good level of knowledge in all curricular topics reflected in a change from 0% correct answers in the pre questionnaire to 70-90% in the post questionnaire, as referred elsewhere (Tavares, 2017).

This paper focuses students' opinions and attitudes (A) the work produced (B), expressed from Figures 1 to 11, respectively, and the reflections within the teacher interview (C).

A-Results in the questionnaires on students' opinions and attitudes are as follows

Comparing the questionnaire's results on question 1 (Fig.1), the motivation of students was already high (85%) during the launch of the project, in the 1st term, and was even greater at the end of the 2nd term, with 92% of them. All students were willing to collaborate, showing total enthusiasm, good will and motivation either for the activities developed or for the fulfillment of the questionnaires.

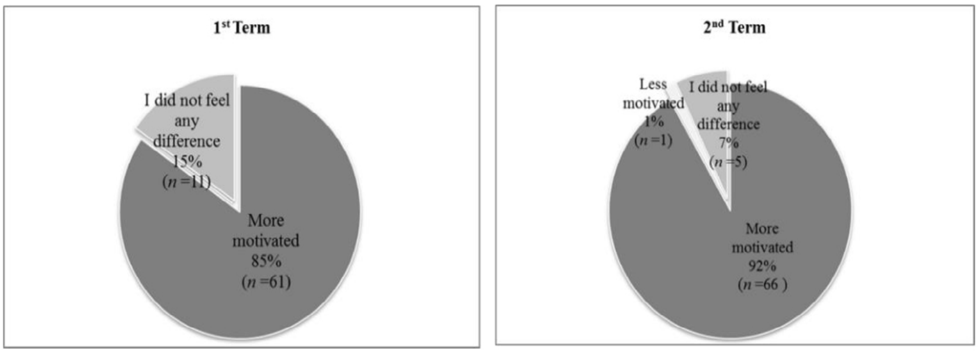


Figure 1: Results on Question 1: Motivation for learning

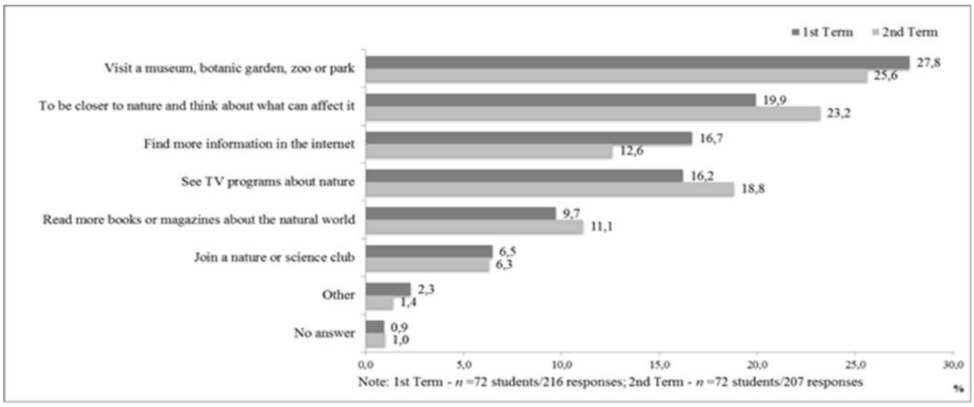


Figure 2: Results on Question 2: Impact in the students 'proactivity'

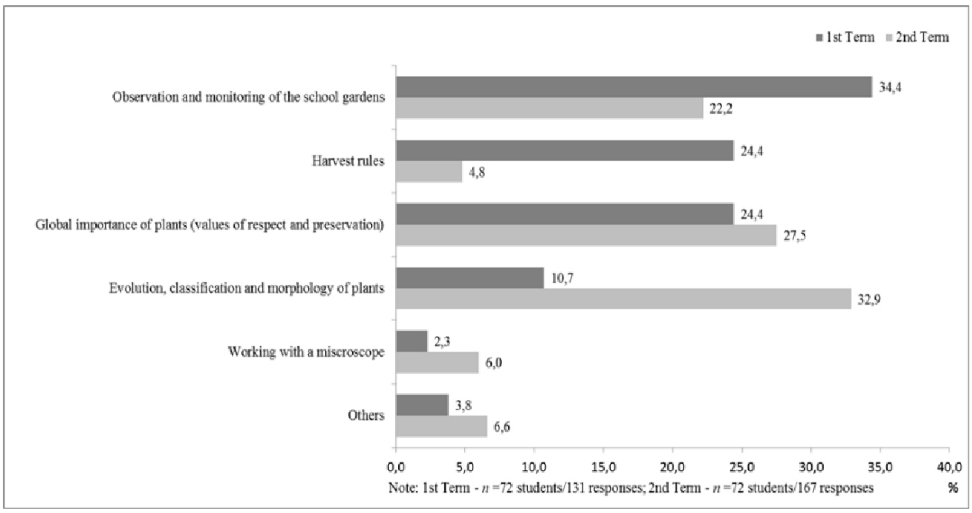


Figure 3: Results on Question 3: Impact in the student learning.

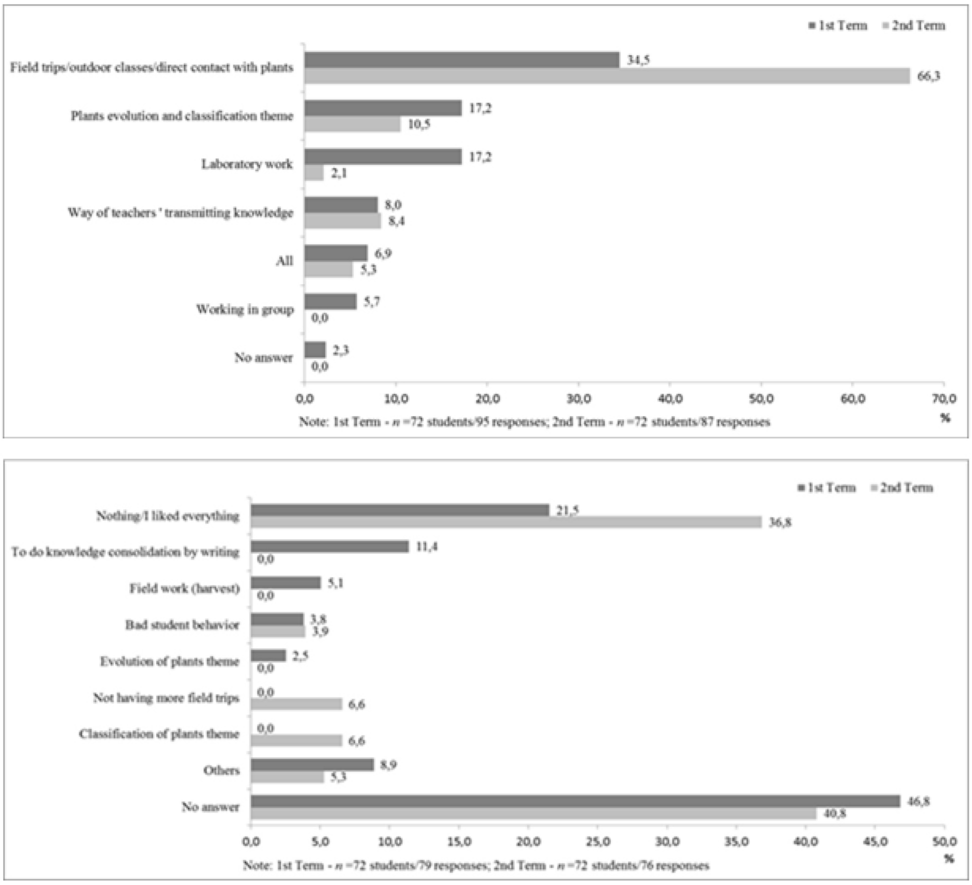


Figure 4: Results on Question 4: Satisfaction with the methodology. 4.1 - Positive points and 4.2. - Negative points

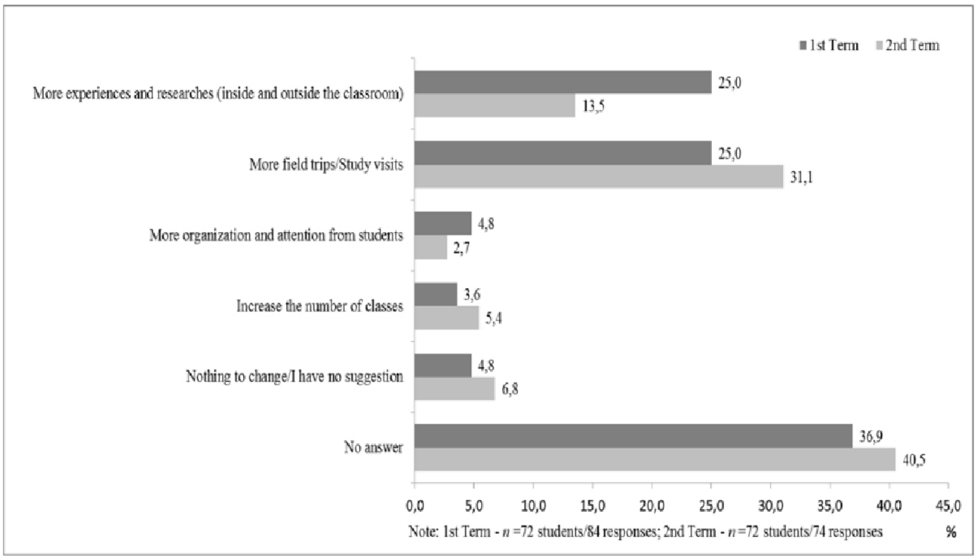


Figure 5: Results on Question 5: Improvement suggestions

The impacts and evidence of proactivity are visible with 99% of the students, as shown in Figure 2, and new learning convictions with thematic specification were revealed by 100% of them in Figure 3.

As Figure 3 reveals, the evolution of plants was an item learned represented a new approach achieved with success, and not previewed by the curricula, as is also corroborated by the answers in Figure 4.

The results of Figure 4 show complementarity of the questions in 4.1 and 4.2., showing high level of satisfaction of the students in the different items expressed and performed. As shown in Figure 5 there were 89% of students that demonstrated satisfaction in the activities experienced, in the classes' format, the products created

B- Examples of the Work produced by the 5th grade students on the seven curricular topics and IBSE sessions

Figure 6: Work produced on Topic 1: Plant diversity outside and inside classroom

Figure 7: Work produced on Topic 2 and 3: The leaves and the flowers outside and inside classroom

Figure 8: Work produced on Topic 4: Stems, form and function of the plant organs, outside classroom.

Figure 9: Work produced on Topic 5: The cells and DNA extraction, at the lab

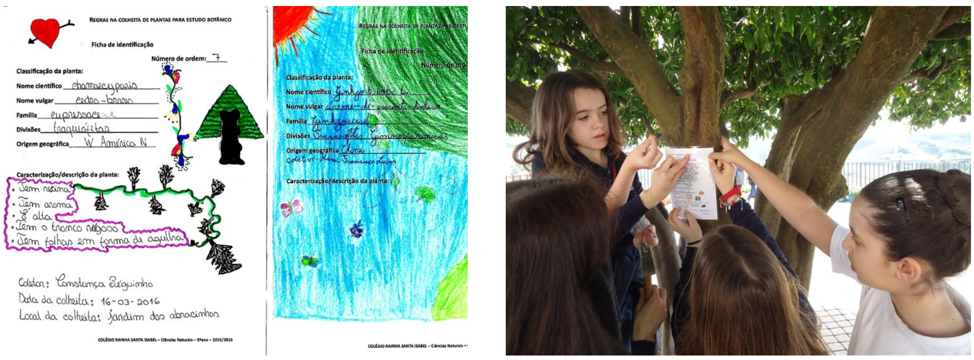
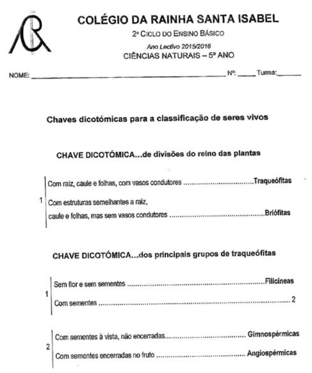


Figure 10: Work produced on Topic 6: Classification and taxonomy outside classroom.


COLÉGIO DA RAINHA SANTA ISABEL
2º Ciclo do Ensino Básico
Ano Lectivo 2015/2016
CIÊNCIAS NATURAIS – 5º ANO

NOME: ______________________ Nº: _____ Turma: ______

Chaves dicotómicas para a classificação de seres vivos

CHAVE DICOTÓMICA...de divisões do reino das plantas

1	Com raiz, caule e folhas, com vasos condutores	**Traqueófitas**
	Com estruturas semelhantes a raiz, caule e folhas, mas sem vasos condutores	**Briófitas**

CHAVE DICOTÓMICA...dos principais grupos de traqueófitas

1	Sem flor e sem sementes	**Filicíneas**
	Com sementes	2
2	Com sementes à vista, não encerradas............	**Gimnospérmicas**
	Com sementes encerradas no fruto	**Angiospérmicas**

Figure 11: Work produced on Topic 7: Explorers outside classroom and the construction of a dichotomous key for plants

and would like to have continuity in this type of classes during the next years to come. Students' perceptions were very positive in all fields, by the general high marks achieved in the answers 'percentages, and the outcomes produced, as will be supported by the next examples.

C- Teacher's Interview

The teacher's opinion on the educative experience was expressed in the final interview. Generally, the considerations related to the maintenance and obedience to the curricular programs and only a change in the usual sequence of the program items, linking to daily reality. Teacher commented that there was a better use of the school resources (e.g.- monitoring of the cycle evolution and morphology of plants in the gardens) with the great opportunity to share experience and knowledge with the other teacher partner. Also, a good and enriching collaboration in the educative process was expressed by improvement of the student's satisfaction and the learning achieved, as this format was well received by them and generated a differentiated and enthusiastic response enhancing them to learn willingly. The new educative tools and strategies constitute very positive points as there was creativity in the work produced and that is reproducible, being these considered one of the best educative attainments.

On this experience, the teacher could consider three main points: a professional improvement; a creative, complete and innovative alternative for Natural Sciences in Primary Education; and new educative products to be functional in further classes.

CONCLUSION

The novelty of this study relies on a plan integrated during one complete scholar calendar in the current Portuguese school format, not disturbing the organization of the lessons neither in terms of time nor curriculum accomplishment. It was possible to empower the students, making them the main protagonists of the education process by a day-to-day discovery of meanings, interpretation, understanding and assessment of the case-studies at school, according to the curricula targets.

By using and exploring the "nature reality" expressed in the gardens, laboratories and resources of the School, knowledge was stimulated, and also the fascination and awareness for the importance, diversity and sustainability of all living organisms. An important emphasis and an innovation for the plant's knowledge was undertaken as crucial, as sometimes this is an item under consideration by the educative community.

Reinforcing and refreshing the formal context of the school, this research in partnership on educational practice of the Portuguese educative systems, could link the universities with school, teacher, students and all the school community, producing professional satisfaction and innovation for the teacher and the school, and a global preparation of the students. Regarding the everyday family collaboration in the home-work and cultural and social practices within the school community and the final year party (Table 1), besides amplified emotional engagement with science by new interactions with students (Aunola et al., 2013; Fleer et al., 2016), could linked wiliness and partnership to learn and to achieve tasks, empowered by a group team work efforts, a positive point refer also by students in Figure 4.

As our practices evidences reveal, the current education system allows integrating non-formal and informal elements that should be gradually incorporated by formal education, so as continually to meet the needs of student and teacher, and of the individual and society realities. Teachers did not feel reluctant to use outdoor resources as a teaching environment, as well as the students. On the contrary, they always felt very comfortable and enthusiastic any time they went out of the classroom, a particularly efficient action when students produce the labelling of the school gardens (Table 1; Figures 3, 4, 6 and 10). Similarly, this case study points to the current and real positive possibility of crossing non-formal Science classes outdoors with IBSE, respecting the formal curricular development. The teacher stated that the formalisms was relevant to organize, to plan and monitoring the state of the students' knowledge, as much as non-formal features adoption, like alteration of the order in the curricula items presentation, being all decisions made to make Science lessons more compatible with alive outside resources, that is to say, with world reality outdoors.

As futures perspectives the Science museums, botanic gardens or school gardens are paramount as outside classroom settings for Natural Science teaching and learning practices. The lesson plans and resources produced are replicable and instruments to other educational communities and the achieved outcomes even justify the proposal for a new curricular unit on botany, at first grade primary school level, on simple concepts of the differentiation and the evolution of the plants. Finally, and as both the teacher and the students referred, Science outside classroom with IBSE should be adopted on a regular basis at School.

An open system with different environment arrangements can and should be adopted to allow the "entrance" of more creativity and a diversity of thinking, opinion and points of view, dealing with IBSE methodology indications, empowering the initial interest level and motivation of students. To use the gardens of the school, for the study and understanding of plants' morphology and diversity, adapting the circumstances and educational models to the concepts to be taught, was an example to meet their expectations and needs and provide them the more adequate institutional support and resources. Relaying into the natural resources and "tools'' of the "real world" around us, changing every day, reality is a true question to follow and new Nature interpretations and meanings can achieve relevant answers to real problems.

The students are by nature curious and eager for news, ready for the curiosities around them, and for the moment. Why not use the powerful changing reality that nature permanently gives us every moment, to know, to interpret and to found knowledge? By awakening and building tastes and trends for their paths, students draw their personal tendencies early on in their careers for the future.

REFERENCES

Ainsworth, H. & Eaton, S. (2010) *Formal, non-formal and informal learning in the sciences*. Calgary, AB: Onate Press and Eaton International Consulting Inc.

Amado, J. (2013) *Manual de Investigação Qualitativa em Educação.* Coimbra: Imprensa da Universidade de Coimbra.

Artigue, M., Dillon, J., Harlen, W. & Léna, P. (2012) *Learning Through Inquiry – Background Resources for Implementing Inquiry in Science and Mathematics at School.* The Fibonacci Project. Final Version. Scientific Committee of Fibonacci.

ASE OSWG (2011) *Association for Science Education. Outdoor Science Working Group. Outdoor Science.* Shrewsbury: Field Studies Council and King's College of London.

Aunola, K., Viljaranta, J., Lehtinen, E. & Nurmi, J. (2013) The role of maternal support of competence, autonomy and relatedness in children's interests and mastery orientation. *Learning and individual differences.* 25: 171–177. doi.org/10.1016/j.lindif.2013.02.002

Beatty, A. & Schweingruber, H. (2017) *Seeing Students Learn Science: Integrating Assessment and Instruction in the Classroom.* THE NATIONAL ACADEMIES PRESS:

Washington, DC. Online: http://www.nap.edu/23548 (accessed December 28, 2017).

Bedford, L. (2001) Storytelling: The Real Work of Museums. ***Curator. The Museum Journal.*** 44(1):27–34.

Caldas, I. & Pestana, I. (2010) ***Ciências da Natureza (5º ano). Projeto Desafios.*** Carnaxide: Santillana Constância Editores.

Fleer, M., Adams, M., Gunstone, R. & Hao, Y. (2016) Studying the landscape of families and children's emotional engagement in science across cultural contexts. I*nternational Research in Early Childhood Education*. 7(1): 183–201.

Malm, B. (2009) Towards a new professionalism: enhancing personal and professional development in teacher education*. Journal of Education for Teaching*, 35 (1): 77-91.

Matteman, Y. & Damsa, W. (2017) Research-minded education in Science Museums. ***Spokes.*** 27:1-14.

Pessoa, P. (2013) ***Ensaios de voos-metamorfoses pessoais e profissionais.*** Tese de Mestrado em Ciências da Educação. Porto: Universidade Católica Portuguesa.

Tavares, A.C. (2015) ***Educação em Jardins Botânicos: 16 anos de experiência.*** Málaga: Online: http://www.eumed.net/libros-gratis/2015/1442/index.htm. (accessed December 28, 2017). Edition by author, 2016. University of Coimbra Libraries: Coimbra.

Tavares, A.C. (2017) ***Metodologia IBSE no ensino-aprendizagem das Ciências da Natureza: casos de estudo em espaços exteriores à sala de aula.*** Relatório de Pós-doutoramento, apresentado à Faculdade de Psicologia e Educação da Universidade Católica do Porto, Centro de Estudos em Desenvolvimento Humano. On-line: http://www.eumed.net/libros/libro.php?id=1666 (accessed December 28, 2017). Edition by author, Universities of Coimbra and Porto Libraries: Coimbra, Porto.

Tavares, A.C. (2018) Diálogo museológico interdisciplinar em prol da biodiversidade: um evento performativo. ***Aula, Museos y Colecciones de Ciencias Naturales.*** In press.

Tavares, A.C., Silva, S. & Bettencourt, T. (2015) Advantages of Science Education Outdoors through IBSE Methodology. In P. Blessinger, J. M. Carfora (Eds.), I*nquiry-Based Learning for Science, Technology, Engineering, and Math (Stem) Programs: A Conceptual and Practical Resource for Educators,* Vol. 4 (pp.151–169). Bingley: Emerald Group Publishing Limited. doi/10.1108/S2055-364120150000004010

BEYOND PLANT BLINDNESS: SEEING THE IMPORTANCE OF PLANTS FOR A SUSTAINABLE WORLD – AN OVERVIEW OF PRELIMINARY FINDINGS

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ABSTRACT
Humans are becoming an urban species. Living in large cities can reduce intimate contact with the natural world thus placing greater emphasis on 'presented nature' settings, such as zoos, botanic gardens and natural history museums. Botanic gardens provide opportunities for aesthetic interactions with the plant world. However, previous research has demonstrated that 'plant blindness' can inhibit human perceptions of plants. Increased extinction levels mean the world can no longer afford our citizens to see 'nothing' when they look at plants, the basis of most life on earth. Despite a key educational role identified in the Global Strategy for Plant Conservation 2011–2020, botanic gardens, and allied settings, have received limited research attention. Given the critical role of plants in ecosystem resilience it is imperative to motivate teaching and learning that can move beyond 'plant blindness' towards experiences in which teachers and learners see the importance of plants for a sustainable world. Contemporary research sources suggest that multimodal and sensoric experiences in 'presented nature' settings might create shifts away from plant-blindness towards reading the importance of plants. The paper presents an overview of preliminary key findings from a recently completed three-year interdisciplinary research study 'Beyond Plant Blindness – seeing the importance of plants for a sustainable world', funded by The Swedish Research Council (Dnr 2014-2013). The everyday life of a plant can appear to be static and silent to human perception. And yet, modern science tells us that plants live in complex, and often social, worlds. Removing plants from the human view makes it easier for us to exploit them but reduces our ability to see into their worlds; how might taking a different view improve our understanding and sensitivity to the lives of plants? In this paper we demonstrate the value of connecting with plants through sensory interactions with living specimens, artistic and scientific narratives and affirm the importance of visual methods of communication. Moreover, we show the power of memories and emotions in building personal connections between plants and people, and the strength of aesthetic reasons for connecting with a favourite plant, thus we provide possibilities for planning future visitor interactions with botanical collections.

KEYWORDS
Online Survey, Artistic and Scientific Narratives, Emotions, Memories, Fascination

INTRODUCTION

The sample of research participants in this three-year study focuses on student teachers studying at Gothenburg University and everyday visitors to the two institutions Universeum Science Centre and Gothenburg Botanic Garden. The main research question was: what impacts do presented nature settings a) with animals b) without animals have on plant-based learning experiences? This question was investigated *in situ* in the two aforementioned 'presented nature' sites. Three sub-questions underpinned these main questions:

1. How might plant-based sensoric experiences influence human perceptions of plants?
2. How might story-based scientific narratives concerning individual plants impact on 'plant-blindness' in didactical situations?
3. By 'looking through an artistic lens' is it possible to appreciate/identify plants in new ways?

Our working hypothesis was that multimodal and sensoric experiences in ´presented nature' environments will create shifts in perception away from ´plant blindness´ towards seeing the importance of plants for a sustainable world.

MATERIAL AND METHODS

The research team brings together specialists in education, taxonomic science and art-based research. This interdisciplinary focus is considered a critical element of our approach, which is centred on the notion of reading the story of "Life as Plant" and included art-based research installations in Gothenburg Botanic Garden. Our study draws on qualitative and quantitative data from four different research methods:

- An online survey
- Mapped conversations in two scientific education centres
- Recorded impressions at three specific art installations constructed by artist members of the research team
- Written responses to three science posters developed by the scientist member of the research project.

Swedish was the main language used in the research interactions, although, in the case of some everyday visitors and the scientific posters English was the language used. Table 1 shows the participant samples involved in each strand of the study.

Scientific themes

Six themes with special emphasis on 'plantness' (Darley, 1990) were selected: reproduction, longevity, symbiosis (narrow sense), competition, defence, and facilitation (Fig. 1). The overall purpose of the scientific narratives is to mediate the fact that plants, despite their seemingly sessile and silent nature, are indeed living organisms that have behaviours comparable to those of animals.

For a first presentation of the scientific narratives, posters highlighting the themes reproduction, longevity and competition were produced (Fig. 2). The heading of each poster was phrased as a question, in order to create interest by the reader, and the heading was followed by a preamble (Table 2). The posters were illustrated with 4–5 photographs of the organisms used as case studies. Figure captions counted 5–65 words, in total 40–65 words for each poster. The explanatory texts associated with each case study counted 50–150 words, in total 440–490 words per poster. Figure 2 shows the most popular poster.

Three artwork installations

The artwork connects to two of the scientific themes; reproduction and competition. In Gothenburg Botanic Garden the artists (Snæbjörnsdóttir/
Wilson) made three art-based installations http://snaebjornsdottirwilson.com/category/projects/beyond-plant-blindness/. The first installation was situated in a gallery in which photographs, using scanning electron microscope images, of detailed structures of seeds were foregrounded over their adult forms with their human collector's story becoming a footnote. These seed biographies occupied one wall of the gallery. In the same room the growing form of each seed was presented; textual connections between the living plant and represented seeds visitors met on the wall of the gallery were offered by the plant labels in the growing seed containers. In the second installation, placed in a large wooden barn-like building, one specific seed, Stipa pennata, was magnified, through the use of a scanning electron microscope. The printed seed image was suspended over a large area of the building exposing its complex form to public scrutiny only to vanish in a richly coloured meadow in the next, and final, installation occupying a rain shelter. Thus, reproductive structure and adaptation were focused on in installations one and two whilst the plant's competitive struggle amongst many plant forms was in focus in installation three.

RESULTS

As this is a presentation of preliminary key findings from a substantial three-year study we do not present a full body of results here, but highlight those seen to be of particular relevance to the botanic garden community. Thus we focus on two particular questions in the online survey, an overview of responses to the botanic garden artworks and a summary of responses to the scientific posters. Further analysis and dissemination work by the research team members is in progress.

Online Survey

Favourite Plants

Two hundred and two student teachers participated in an online survey using "Survey Monkey". The survey took place over a period of two years. The open-ended questions on favourite plant and favourite animal sought students' views on favourite plant among all plants and favourite animal among all animals rather than a simple head to head comparison (e.g. Kinchin, 1999). A greater number of plants were chosen as a favourite choice than animals. This finding counters previous studies of preferences among school students (e.g. Wandersee, 1986). One student teacher in our study noted that they "did not like plants", three student teachers "could not choose" and eleven student teachers did not have a favourite plant. Among the remaining students plants chosen as favourite appear to form three distinct groupings:

1. Generic forms
2. Named Plants
3. Specific structural features

The group chosen by eight students we have defined as 'generic forms' in which we have placed responses such as "bush", "tree", "grass" and "palm". This first group is closely followed by the group we have named 'specific structural features', in which, seven students chose "flowers" as their favourite plant. The largest group by far is the one we have defined as 'named plants': a group of twenty-two named plants. In this last group favourite plants mentioned by more than ten students were *Tulip* (21), *Rose* (20), *Orchid* (16) and *Wood anemone* (12). We suggest there is an interesting relationship emerging between the top three choices of named plants, all of which have a high diversity of floristic features and colours, and the choice "flowers".

Reasons for choosing favourite plant

The teacher students who chose the top three named plants and those that chose "flowers" align with beauty being given as a prime motivator for student plant choice. This, in some ways, mirrors Haywood's study (Haywood, 2018) of families visiting the Royal Botanic Garden, Kew in London, UK. Her work illustrates how purposefully developed interpretative materials that inspired families to engage with taxonomic labels connect the families with the aesthetic beauty of plants through to learning about science. In addition we found symbolic meaning to be a key motivator. This category included aspects of seasonality, for example students choosing Wood anemone citing it being a "herald of Spring" after the long dark Swedish winter, thus their motivation is culturally embedded (Balding and Williams, 2016) in their experience of living in a country where the number of sun hours in winter is low and the arrival of Spring is to be celebrated. Likewise, students remembered being with plants at certain times of the year in their childhood.

Comparisons with favourite animal choices and their motivation

When the same question was asked for animals the overwhelming choice fell on dogs, cats and horses. To a minor extent, students mentioned dolphins, elephants, and lions. When asked for the reason why, three answers stood out as different from those given for plants: that the animals had human characteristics, that there were special memories associated with them, and that they were considered fascinating. Evidently, it is difficult to make plants anthropomorphic, but it is definitely possible to work more on the other two issues. Botanical gardens play a key role in making sure that people 'meet plants' and create good memories with them. Furthermore, we should highlight interesting narratives that make people attend to the plant world.

Summary of Responses to science posters

The student teachers found the questions and preambles fascinating, for example 'how old do plants get?' However, the vast majority wanted more and larger illustrations and less text. The students said they lost interest when they had "too much to read". Another reason why the students found it difficult to comprehend the messages in the posters is that they were presented in English, and that the students' vocabulary in this language is not adequate for understanding scientific terminology. Many of the students wished the posters had had a more overall approach instead of explaining issues in depth. They "could just as well read their text book" if they wanted details. We are planning to produce more posters in response to their comments and will make them in both Swedish and English. They will be tested with the student teacher community and responses collected and analysed.

Key Responses to art works

The diverse representations of plants presented in each installation provoked different responses in the student teachers and everyday visitors (Table 3). In relation to categories of responses we found both similarities and differences as demonstrated by table 3.

DISCUSSION

In the data presented it is clear that aesthetics and emotions play a key part in our student teachers feelings about, and connections to, plants. The responses to the online survey demonstrate that in our community of student teachers there is a self-expressed connection to a rich group of plant species. However, colourful, flowering plants found in homes and gardens dominate i.e. orchids, tulips and roses followed by a woodland plant commonly found in Sweden and seen as a "herald of Spring" upon its flowering. Thus, from this preliminary data we can see that flowers draw human attention. And yet, in counterpoint so do the artistic narratives focused on seed diversity and one plant's journey to survive. Table 3 demonstrates that the three installations in Gothenburg Botanic Garden brought to life an often hidden narrative, the story of seeds and their diversity. In the responses collected from student teachers and everyday visitors at installation one we found connections to "nature's beauty" and recognitions of "biological diversity" through the seeds' stories, but in their engagement with the seed biographies some respondents voiced an encounter with "the otherness of plants". This point relates to the online survey and how, in their reasons for choosing favourite animals student teachers were motivated by anthropomorphic reasoning; a motivation totally absent from their favourite plant choice. This does not mean we need to encourage anthropomorphic routes into "plantness" (Darley, 1990) but rather find the narratives that make public the "Life as Plant" story without negating the attributes that make plants and their lives "other" in the eyes of human audiences. Installation Two in its rendition of one seed made large and public demonstrated "nature's beauty" and the seed's "naked vulnerability" but also caused, in the representational change of scale, misconceptions of whether it was a plant, and if it was, what part of the plant. Thus, scale appears to matter. The final installation encouraged closer looking and created reflections on seasonality. It also inspired emotions.

It is obvious that text-rich posters are not the medium of choice for young adults. The texts in each poster consist of less than 500 words but it was still considered "too much". We suggest that the cultural trend in society is a turn to the visual. Several students noted that they would rather see a movie or perhaps have someone tell them what the posters were mediating to them. Considering that botanical gardens traditionally display most information in poster format, this is an interesting result. Personal interaction works better but is less cost-efficient. More research is needed in this area.

CONCLUSION

Our preliminary findings demonstrate the value of connecting with plants through sensory interactions with living specimens, artistic and scientific narratives, and the importance of visual methods of communication. Moreover, we show the power of aesthetic attributes, personal memories and emotions in building connections between plants and people. Plant stories are interesting but it matters how you tell them; bring fascinating stories to your visitors through various media narratives. Offer visitors time to look at, and be with plants, through diverse representations of "Life as Plant".

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REFERENCES

Balding M., Williams K. J. H. (2016) *'Plant blindness and the implications for plant conservation'.* Conservation Biology 30:1192–1199. DOI: 10.1111/cobi.12738
Darley W.M. (1990). *'The essence of "Plantness"'.* The American Biology Teacher 52:354–357
Haywood N. (2018). *'Beauty in the foreground, science behind the scenes': families' views of science learning in a botanic garden'.* Environmental Education Research. DOI:10.1080/13504622.2018.1469116
Kinchin I. (1999). *'Investigating Secondary-School Girls' Preferences for Animals or Plants: A simple "head to head" comparison using two unfamiliar organisms'.* Journal of Biological Education, 33:95–99
Wandersee J. (1986). *'Plants or animals? Which do junior high school students prefer to study?'* Journal of Research in Science Teaching 23:415–426

FIGURES AND TABLES

Figure 1: The six scientific themes related to plantness.

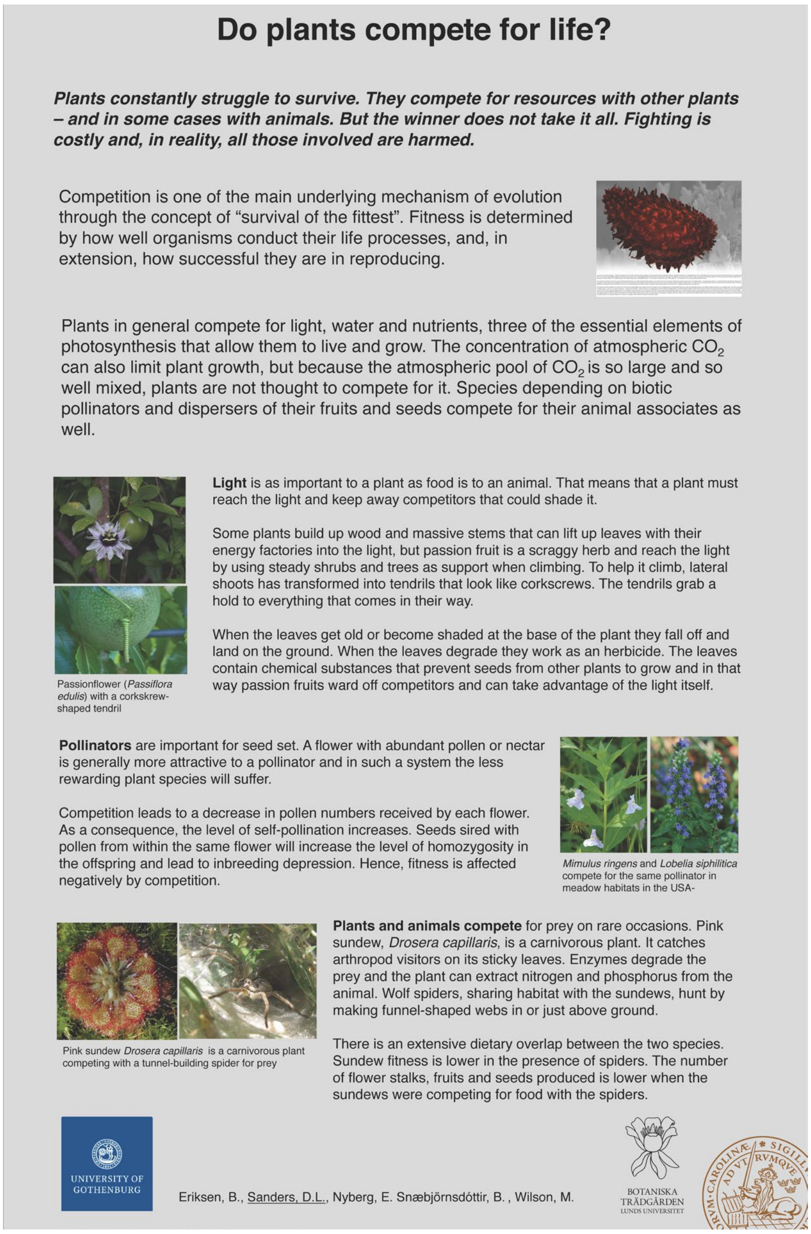

Figure 2: Example of a scientific poster highlighting the theme competition. This poster was rated best of the three by the students.

	Online Survey	Mapped Conversation: Botanic Garden	Mapped Conversations: Universeum	Recorded Impressions at Art Installations	Written Responses to Science Posters
Student teachers	202	41	53	30	11
Everyday visitors	0	13	21	7	0

Table 1: Participant sample in research study.

	Question	Preamble
Reproduction	Do plants reproduce sexually?	Sexual reproduction is essential for adaptability and long-term persistence in all species, including plants. Mixing of genes from two adults generates genetic variability in the offspring on which evolution can act
Longevity	How old can plants get?	Maybe you have asked yourself if you would like to live forever? No matter what the answer is, humans will not live much longer than 100 years. But plants – they are practically immortal!
Competition	Do plants compete for life?	Plants constantly struggle to survive. They compete for resources with other plants – and in some cases with animals. But the winner does not take it all. Fighting is costly and, in reality, all those involved are harmed

Table 2: Questions and preambles for the three posters presented to the student teachers.

Installation 1	Installation 2	Installation 3
Nature's Beauty	Scaling up leads to misconceptions: Is it a whole plant? An animal?	Seasonality
The Seed's Story	Beautiful Picture	Emotions
Colour and Scale	Naked vulnerability and yet strong	The more you look the more you see
Biological Diversity		
The 'otherness of plants'		

Table 3: Summary of Key Responses to artworks.

NATIONAL BOTANIC GARDEN OF LATVIA – STRATEGY OF ENVIRONMENTAL EDUCATION

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ABSTRACT
The National Botanic Garden of Latvia (NBG) was founded in 1956 as a scientific institution (one of the scientific institutes of the Academy of Sciences), focused on research in botany, plant physiology and breeding. At this time education and public engagement were less important. In 2006 the Garden was handed over to the Ministry of Environment Protection and Regional Development (MEPRD), making the goals of biodiversity conservation and public education more pronounced. An essential part of the NBG mission today is to educate visitors about the environment and biodiversity conservation issues. That is why we have worked out the strategy of environmental education.
As a result of a SWOT analysis of the existing situation and potential possibilities of NBG in environmental education (plant expositions, exhibitions, guided excursions, school educational program, lessons, events, information panels, homepage and accounts in social networks, press releases, booklets and popular science issues), the conclusion was made, that essential growth of audience can be achieved by creation of special infrastructure – the Centre of Environmental Education and Information (CEEI). The establishment of such Centre is planned in the framework of a larger project of the MEPRD, which is financially supported by European Cohesion Fund (CF), and will last until 2021. The CEEI should facilitate awareness of processes occurring in nature in attractive, intelligible and entertaining form, facilitate interest in plant life and educate about necessity and means of environment protection and nature conservation; as well as to enhance NBG educational capacity, to broaden its audience and to increase the number of visitors. The main audience should be groups of children from 5 years of age till the end of high school and families with children, the secondary – all other garden visitors. The CEEI exposition should be placed in a two-storeyed building in the place of the former NBG main office. The structure of exposition: Introduction (plant's importance for life on the planet); Roots, Trunk, Leaf, Flower, Fruits and Seeds, Final exposition (ecology, global environment problems, biodiversity conservation etc.).

KEYWORDS
Awareness, Community Engagement, Biodiversity Conservation, Nature Protection, School, Children

INTRODUCTION

The Botanic Garden in Salaspils was founded in 1956. Nevertheless, its roots date back to 1836, when the gardener Christian Wilhelm Schoch created a gardening company in Riga. The nursery was transferred to Salaspils in 1898. This was the beginning of the Garden.
On the 1st of September, 1956, the Botanical Garden of the Academy of Sciences was founded in Salaspils, using the rich plant collections and the heritage of the past gardening traditions. It was a scientific institution, focusing on research in botany, plant physiology and breeding. Education and public engagement were less important.

After the re-establishing of Latvian independence, in 1992 the garden obtained the status of a National Botanic Garden. Since 2006, when the garden was handed over to the Ministry of Environment Protection and Regional Development, its focus shifted to biodiversity conservation and public education. The essential part of National Botanic Gardens mission today is to educate visitors about the environment and biodiversity conservation issues. That is why we have to work out the strategy of environmental education.

MATERIAL AND METHOD

To create the Strategy, we had to define the institutions' mission, goal, functions and legal base, as well as analyse present possibilities and experience, using method of SWOT analysis.

Mission

National Botanic Garden of Latvia is governmental institution keeping scientifically documented collections of living plants with a goal to use them for biological diversity conservation, scientific research, education and community information in nature protection and gardening areas. National Botanic Garden represents Latvia in areas of its competence and is one of the state's scientific and cultural symbols.

The essential part of the National Botanic Garden's mission today is to educate visitors about the environment and biodiversity conservation issues, to let them *„relax while learning and to learn while relaxing ".*

The goal and functions

The goal of the National Botanic Garden is to maintain living plant collections and Latvian plant genetic resources, to expand connections between science and national economy in areas of its competence, to carry out community awareness and education in issues related to the environmental challenges of the 21st century, especially in plant conservation and careful use of natural resources, as the base of sustainable development.

To reach that goal, the NBG performs these functions: administration and management of the protected nature area "National Botanic Garden of Latvia"; maintaining living plant collections for research, education, tourism and recreation purposes; conservation *ex situ* genetic resources of cultivated and wild plants of Latvia; development of theoretical and methodological base for conservation and propagation of rare and endangered, as well as economically useful plant species and cultivars of local provenience; scientific research in biology (plant physiology, botany, biodiversity conservation), agriculture (gardening, plant breeding), as well as other scientific branches connected with plants; education in plant biology, environment protection and biodiversity conservation; cooperation with the world's botanic gardens and other institutions and organisations in plant gene fund conservation; keeping living plant specimens that are confiscated according to Washington Convention on International Trade of Endangered Wild Plant and Animal species (CITES) until decision of competent institutions; functions of the competent institution of the EP and EC Regulation 511/2014 "On compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union"; development and modernisation of biodiversity research and conservation infrastructure.

NBG functioning is based on 13 international legal documents [1-13], as well as 23 national legal documents. Education of the public and raising awareness are some of the core functions of NBG. Almost all NBG specialists are somewhat involved in it, but the main responsibility is on the Department of Education and Information.

Main directions of the NBG environmental education are: to provide information about plants' functions, composition, and role in provision of existence of all world's organisms by using contemporary tools and comprehensive language; to form awareness of connections between everyday things and life processes in plants, the place of plants in history, culture and religion; to inform about direct and indirect impact of human everyday activities on the natural resources of the planet; to promote renewable energy resources and sustainable resource management; to diversify school environmental education program with field and laboratory research possibilities, supporting comprehensive education process; to create lifelong education programs for different age and social groups in issues of gardening, history of park and garden art, nature conservation and environment protection issues; in context of community integration – to prepare lessons and expositions about aspects of ethnobotany, including national minorities living in Latvia as well as states and nationalities of European Union.

The area of the NBG is 1,29 x 10^6 m^2, it contains a wide diversity of natural biotopes and plant collections, being an excellent environment for school children learning expeditions in nearly natural but secure conditions, providing possibilities to research self-collected living material.

Using financial support of EU programs and capacity of NBG researchers and education specialists, it is possible to develop informal education programs turning NBG to one of the leading institutions in Latvian environmental education. Since opening of the new orangery in April 2015, the yearly number of visitors has at least doubled (from 25-30 to 60-65 thousand). The demand for attractive educational activities, as well as additional rooms for learning and storage has grown greatly.

Present situation in NBG environmental education (SWOT analysis)

1. Plant collections and expositions. NBG keeps one of the largest plant collections in Northeast Europe: about 13600 taxa of living plants, including 2500 indoor, 5400 woody, 4520 herbaceous, 1100 utility plants, 135 species of rare and endangered plants of Latvia. That gives wide possibilities to use them for environmental education.

New open area and orangery expositions were created recently. NBG Conservatory, constructed with support of ERDF, opened for visitors in 2015. Its common area is 3300m²; including 4 orangery halls open for visitors and

9 conservation halls. To mark 100-th anniversary of Latvia (celebrated in 2018), NBG arranged a special exposition – a bed of perennial ornamentals with an accent on the cultivars of Latvian breeding. To extend natural science education, exposition of Latvian rocks and minerals was created, arranged in order of geological age and accompanied by information about their properties and use.

Strengths: NBG permanent expositions are formed using the richest plant collections in Baltic States, labelled with Latin and Latvian plant names and proveniences. Expositions are enriched by information panels with interesting data about individual plants or parts of exposition.

Weaknesses: The huge NBG collection is only partially labelled. Information panels do not provide enough coverage and are prone to decay under open skies.

Opportunities: Enhancing the amount and quality of labels and panels should augment the usability of collections for educational purposes.

Threats: Labelling the most valuable specimens can attract the attention of thieves.

2. Thematic exhibitions. Since the new Conservatory was built, it's "inside gallery" is used for exhibitions. In addition to displays of flowers, seeds and fruits, art exhibitions – from children's drawings to professional artwork and photography, are organized during the year.

Strengths: Diversity of exhibitions is broadening the audience; it is an essential contribution to the educational and recreational function of NBG.

Weaknesses: Growing educational demand outpaces the availability of in-door space and human resources of NBG.

Opportunities: Permanent environmental education exposition would essentially improve accessibility of service. Additional exhibition rooms could improve usability of the NBG collections and intellectual potential.

Threats: Exhibitions of valuable works of art and rare specimens need additional security measures.

3. Guided excursions. In the NBG, several educational excursion programs are developed depending on audience and season. Duration of standard excursion is from 1 to 2 hours.

Strengths: Guides of NBG are highly qualified – with PhD or master's degree in biology, additional special education, practical experience, that gives a high level of information.

Weaknesses: Demand of excursions depending on the season. When large groups (40-50 people) are coming, it is not always possible to supply an optimal number (15-25) visitors per group. As a result, suffers from perceiving information. Sometimes (school groups) the guide has to deflect attention from the content of excursion to the children's behaviour that diminishes the amount and quality of given information.

Opportunities: Use of volunteer guides could be considered, to provide growing demand for NBG excursions. There is a reason to consider the possibility to make a treaty with the schools where the school guarantees the behaviour of the children.

Threats: Possibility of conflicts cannot be excluded in direct communication.

4. School educational program. In 2016 seventeen kinds of workshops for primary, secondary and high school were worked out. Some workshops are proposed in Russian and English as well. The link (in Latvian): http://nbd.gov.lv/lv/skolām. Pupils become not only listeners, but also researchers, which significantly enhances educational impact. About 2/3 of school groups now prefer workshops, not just excursions.

Strengths: The garden is an excellent "Learning room" to familiarize with plant diversity, breeding, conservation, etc. The NBG school education program corresponds with the Latvian education standard, it is a good supplement to the usual school learning process and gets popularity both in Latvia and in the neighbouring countries. There are specialists, experience, equipment.

Weaknesses: One school group spends 3-4 hours in the garden, so it is possible to arrange 2 workshops per day, but the school demand is wavelike. Thus at present the request of workshops is more than we can satisfy. There is an actual lack of rooms.

Opportunities: By arranging special learning rooms, the growing demand of workshops for school children could be satisfied, and their possibilities broaden.

Threats: Workshops have lower effectiveness without participation of the biology teacher(s) of the respective school.

5. Thematic lessons and excursions. Thematic lessons and excursions are organised during NBG events (plant fairs, thematic days), in frameworks of seminars for teachers etc. The themes: "Conservation of local flora", "Ethnobotany for teachers", "A look into the world of plant aromas", The ABC of conifers" "The story about the Noah's ark"; "Roses and their breeding in the NBG", "Find and familiarize!", etc.

Strengths: In the NBG there are high qualified specialists – biologists and gardeners, their given information in areas of plant growing and in scientifically popular themes usually is paid by high attention.

Weaknesses: Preparing lessons asks for a lot of intellectual, creative and work contribution. Highest demand of the lessons is usually in the period of most intensive garden work when the specialists are most busy.
Opportunities: Availability of rooms for lessons would improve both quantity and quality of activities, especially in bad weather conditions.
Threats: Attendance of open-air activities depends on weather, which is an unavoidable factor.

6. Public events. Seven thematic plant fairs per season are organized in the NBG ("Skylark Day", "Fascination of Plants Day", "Rose Day", "Harvest Fest" and other), during them also lessons of local or invited lectors, lessons-excursions of garden's specialists ("Rose growing", "American cranberry growing", "Traditional dying plants of Latvia"), creative workshops for families and children ("Plant your plant", "Making Christmas decorations"), charity actions, concerts, etc. are organized.
Regular tradition is "Scientist's night" in September, as well as active participation in the events organized by Salaspils local government, like the fest of Salaspils parish, Salaspils half-marathon "Catch the wind", botanic orientation competitions and other public events. Also, some private events, like weddings, are provided.
Strengths: Thematic events enhance public awareness about NBG.
Weaknesses: NBG staff is employed in areas which are not the primary tasks of their work. Some public events are giving more in financial incomes than in solving essential for botanic gardens tasks like conservation and education.
Opportunities: Additional rooms could essentially grow NBG potential in organizing different events, including as much as possible tasks of nature protection and environmental education.
Threats: Too much public during the mass events can cause technical threats to the infrastructure, collections and expositions.

7. Interactive information panels. In the Conservatory 5 digital information panels are placed, giving information about the NBG in general, with a special accent to the Conservatory plants and the role of botanic gardens in plant conservation.
Strengths: Interactive information panels are provoking a special interest, especially from school children.
Weaknesses: The amount of given information is not enough. There is no local IT specialist to solve technical problems quickly.
Opportunities: A growing amount and diversity of information is accessible in interactive form could essentially grow the NBG capacity in the area of environmental education.
Threats: Interactive panels are digital devices which degrade in time. They can be damaged both mechanically and electrically, when exposed to the public.

8. NBG homepage. Content of the NBG homepage (http://www.nbd.gov.lv) is regularly actualized. The official homepage is an essential, primary source to get the most correct information about the NBG actual news. By growing interest in Botanic gardens, it also grows the actuality of the homepage. The functional activity of the homepage essentially facilitates information circulation in both potential audience and NBG staff.
Strengths: The homepage is the most operative and effective tool of information circulation about the NBG actualities, as well as to build the feedback with the audience.
Weaknesses: This information source is not available for social groups that are not using computers. Being the official homepage of the state institution, NBG homepage has to have structure and content mandatory for such a state institution- that is not entertaining enough to attract youth.
Opportunities: Another homepage with the separate web address, specially designated for children and youth audience, could be the place for more entertaining information.
Threats: Possibility of hacker attacks.

9. Accounts in the social networks. NBG is keeping its accounts in the social networks: Facebook, Draugiem.lv, Twitter
Strengths: One of the promptest communication forms. Possibility to use social accounts as effective advertisement tools, as well as providing feedback with the community.
Weaknesses: Need to provide a timely reaction to the incoming communication. Thus, somebody must permanently "be online" for that we are not ready with existing human resources.
Opportunities: Making information circulation in social accounts more intense and regular, social networks can be an effective form of connection with the community.
Threats: Social networks can be used also for NBG image denigration.

10. Press releases. Information about NBG actualities is regularly sent to the mass media in the form of press releases.
Strengths: Media are often publishing positive information, such a way equalizing the amount of negative news. It provides accessibility of NBG information and reduces the amount of paid advertisement.

Weaknesses: Coverage of printed media is declining, as a result declining also the number of information recipients.
Opportunities: Printed media stay to be the main communication form with the rest of the community not using computers and Internet.
Threats: Sometimes as a result of incompetent edition of the press releases by journalists can be published incorrect or false information.

11. Printed booklets. Periodically informative booklets are issued, used in advertisement events and shared free to visitors.
Strengths: A booklet is an information source reminding about the visit and promoting coming again, also it may be used as educational material.
Weaknesses: Publishing is expensive. Often visitors are taking the free booklet just because of "nice pictures" or "it is for free", and, possibly, it never will be read.
Opportunities: Booklets on natural historic themes can be effective learning materials, simultaneously following up engagement functions. Such information practically does not go out of date.
Threats: Changing information can go out of date, and some amount of printed material becomes unusable that is an uneconomical waste of resources.

12. Popular scientific issues. Many NBG specialists are authors of the hundreds of scientifically popular articles in the journals and newspapers, as well as the books.
Strengths: NBG specialists are high authorities in Latvia in their area of competence. Their articles are taken in Latvia with more trust than translated articles of foreign authors which may be not adequate to the local climatic conditions.
Weaknesses: Not always authors can present the content in easy and entertaining form.
Opportunities: We must improve the style, making popular scientific issues not only informative, but also entertaining, including those for children and teenagers, because those issues are one of the first sources, forming the interest in the themes that are actual for us.
Threats: Printed literature is in an unfavourable situation in comparison with Internet resources and other media.

RESULTS

Analysis of existing possibilities and experience of NBG in environmental education showed that existing infrastructure is not enough to perform planned work directions and activities effectively. To develop the potential of environmental education an establishment of special infrastructure – the Centre of Environmental Education and Information (CEEI) is necessary. It would ensure the formation of environmental thinking for sustainable development and community education about the ecological and economical role of plants, biodiversity conservation, environmental technologies, using diverse informal methods. The Centre of Environmental education could become an entertaining tool in popularization of knowledge in areas of nature and environment, as well as for the community engagement in solving environmental problems.

CEEI would be a separately functioning object in the NBG with the permanent exposition, capable to receive both organized groups and individual visitors. For that goal, the former administrative house and old conservatory will be reconstructed and bound in a joined building.

DISCUSSION

Basic attributes of the CEE

Audiences: primary - children and teenager in age from 5 years to the end of high school (in groups); families with children; adults of all ages who aren't lost their "inside child", who like discover the nature and spent their free time interestingly; secondary - the guests of NBG events; common excursions (groups of retired people, tourists etc.).
Languages: primary - Latvian, English, Russian (texts in the exposition); secondary: Estonian, Lithuanian, German (booklets, homepage).
Message: life on the Earth depends on plants. Through the plant's micro parts to understand the global importance.
Goals: to promote understanding of the processes going on in the nature; to awake interest in plant life by entertaining and surprising with the different facts and effects; to educate about environment protection and conservation issues; to enhance National Botanic Gardens educational capacity; to scale the number of NBG visitors at last for 20%.
Place in the NBG structure: Centre of Environmental Education should be a part of the Department of Education and Information.

Estimated content of exposition of the CEE

Common principles. Placement of living plants in the exposition is not planned. Living plants and processes connected with them should be demonstrated in the

greenhouse. In each part of exposition, some products made in Latvia should be shown according to the subject. Some themes of expositions should be explained in the form of imaginative fairy tales.
The story of exposition should be supplemented with the contemporary visual, audial and interactive effects, involving all senses.

Main parts of exposition

1. *Entrance* (Introduction). The global importance of plants should be accented, the explanation about the common build of the plant, that is connected with the general layout of exposition. The place for changing information about the exhibitions, workshops and other events in the Garden should be provided.
2. *Root* – the underground life of plants. Impression of being underground, mysterious, but active and important must be generated.
Themes to be covered: types of roots – (the game - which root fits to which plant); root functions – support, nutrition, transport, with examples; plant requirements on soil pH (some examples of wild and cultivated plants); plant underground parts which are not roots (bulbs, gums etc.); root nodule bacteria of the leguminous, their role in the soil fertility; mycorrhiza – relationships between plants and fungi; use of the roots (food, medicinal, economic, etc.); root's friends, neighbours and enemies; section of compost heap; soil pollution attempt on the roots (salt, waste, over fertilization), organic, integrated, conventional farming.
3. *Stem* - Impression about plant diversity and greatness must be generated.
Themes to be covered: physiology of the stem, including circulation of sap, the process and rules of sap extraction traditional in Latvia; forest levels: in Latvian forests (30m); in tropical forests (80m); the tree trunk is our home: inhabitants of tree trunks in Latvian and in tropical forests; anatomy of the trunk: longitudinal and cross-sections, information we can get from it, including collection of wood samples; economic importance and use of parts of the trunk: wood, resin, bark, fibre; papyrus and bamboo.
4. *Leaf.* The impression of feeling like being inside in the foliage must be generated.
Themes to be covered: diversity of leaf forms, surfaces, and colours; leaf modifications (needles, spines etc.); leaf physiology, photosynthesis; leaves of different species with the plant names; carnivorous plants; "leaves are our food": plant pests - the most wide-spread leaf pests, biological methods of pest control; economic importance of leaves – leaf vegetable, aromatic, medicinal, dye plants, etc.
5. *Flower* - the most beautiful part of the plant, colourful, diverse and aromatic.
Themes to be covered: composition of flower and inflorescence, methods of plant taxonomy, large scale flower models; pollination, macro pictures of pollen, how insects see flowers; how to make "butterfly garden", "bee garden"; flower scents; beauty of flowers; economical use of flowers – medicinal, edible flowers, spice flowers etc.; Latvian floriculture and breeders.
6. *Fruits and seeds*. Plants are the only on the Earth, who are producing, using the energy of the sun. The other inhabitants of the planet are using their products.
Themes to be covered: "pregnancy of the flower" (how from the flower fruits and seeds are forming), kinds of seeds (gymnosperms, monocotyledonous and dicotyledonous plants); vegetative propagation of plants, including in vitro propagation; food aspect of fruits and seeds: seeds as the basic source of food; edible/inedible wild plants of Latvia; economic importance and use of fruits and seeds; ways of semination; bionics – use of the forms and principles of the nature in the technologies; why some fruits are poisonous, seeds have hard covering etc.; cones, their kinds and use, collection of cones (more as 100 specimens).
7. *The final part of exposition*. Includes the rest and waiting space, as well as the place for changeable expositions and events.
Themes to be covered: ecology, global environmental problems; biological diversity, including mission of botanic gardens; plants in the coats of arms (as the entertainment); professions where you can use knowledge about the living nature, as well as different hobbies connected with the nature, the list of the educational institutions etc.

Infrastructure and resources necessary for the EEC are: rooms where to place the exposition and to ensure quality of visitation; learning rooms suitable for the age of participants and specifics of workshops (the room for the children with the furniture of suitable high, the laboratory room with sinks and special table; laboratory equipment; the greenhouse and bio composting laboratory: study of the bio composting cycle helps to understand the metabolic processes in the nature, attracts attention to the problem of recycling; "the wormery", to demonstrate the process of bio humus production; storage rooms for learning materials, tools and books; the infrastructure of roads and paths must be reconstructed; at last 6 additional staff positions must be generated: service specialist of technical information equipment – 1; communication staff – 2; education staff – 2; caretaker – 1.

Necessary maintenance expenses (heating, electricity, salaries, technical maintenance etc.) is planned to reimburse from the state dotation and NBG incomes.

CONCLUSION

Analysing existing possibilities and experience of NBG the necessity of establishment of special infrastructure – the Centre of Environmental Education and Information (CEEI) is stated.

CEEI should be a separately functioning object in the NBG with the permanent exposition, dedicated primarily for the children and teenagers.

Potentially accessible results of creation of CEEI should be:

1. development of the interactive exposition with the goal to improve environmental awareness in the society by sharing knowledge and understanding about the environment and its protection issues, developing necessary abilities and skills as well as responsible attitude and motivation;
2. development of the learning base as a support for the common education in areas of biology, gardening, nature protection, sustainable use of natural resources etc.
3. development of the greenhouse with the bio composting laboratory, promoting understanding about the importance of recycling;
4. promoting the process of lifelong learning;
5. promoting community integration;
6. developing the base for the workshops, summer camps and other environmental education activities;
7. ensuring the possibility for environmental education for all NBG visitors, which number at present is over 60 thousand per year.

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REFERENCES

Convention on biological diversity. Rio de Janeiro, 05.06.1992.

Global Strategy for Plant Conservation. Decision IV/9. Secretariat of the Convention on Biological Diversity, 2002;

COP 10 *Decision X/17. Consolidated update of the Global Strategy for Plant Conservation* 2011-2020. Conference of the Parties to the Convention on Biological Diversity 10-th meeting, Nagoya, Japan, 18-29 October 2010;

Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilization to the Convention on Biological Diversity. I. Convention on Biological Diversity (1992). Protocols, etc., 2010 Oct. 29. II. Conference of the Parties to the Convention on Biological Diversity (2010: Nagoya, Japan). III. United Nations. K3488. A48 2011;

Regulation (EU) No 511/2014 of the *European Parliament and of the Council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union.* Online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R0511 (accessed April 10, 2018)

European Plant Conservation Strategy. Council of Europe and Planta Europa, 2002.

International Agenda for Botanic Gardens in Conservation. Botanic Gardens Conservation International, 2000;

Convention on access to information, public participation in decision-making and access to justice in environmental matters. Aarhus, Denmark, 25.06.1998.

Convention on International Trade in Endangered Species of Wild Fauna and Flora. Washington, 3.03.1973.

International Treaty of Plant Genetic Resources for Food and Agriculture. 03.11.2001. FAO, 2009.

Conservation of forest genetic resources. Ministerial Conference on the Protection of Forests in Europe, Strasbourg (1990) resolution 2 (S2). Online: http://foresteurope.org/wp-content/uploads/2016/11/Commitments_all.pdf (accessed April 10, 2018)

General Guidelines for the Conservation of the Biodiversity of European Forests. Ministerial Conference on the Protection of Forests in Europe, Helsinki (1993) Resolution 2 (H2). Online: http://foresteurope.org/wp-content/uploads/2016/11/Commitments_all.pdf (accessed April 10, 2018.

Forestry Cooperation for the Countries with Economics in Transition. Ministerial Conference on the Protection of Forests in Europe, Helsinki (1993) resolution 3 (H3). Online: http://foresteurope.org/wp-content/uploads/2016/11/ Commitments_all.pdf (accessed April 10, 2018)

THE WORLD NEEDS MORE GARDENERS – USING THE BARROCAL BOTANIC GARDEN TO PROMOTE SUSTAINABLE GARDENS IN THE ALGARVE

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ABSTRACT

Although much conservation work is the responsibility of government agencies and global organizations, local associations also have a huge part to play. The Global Strategy for Plant Conservation 2011-2020, and the Nagoya Protocol of 2010, makes special mention of the role of gardeners in plant conservation and species recovery.

The Barrocal is one of three ecological areas of the Algarve (Serra, Barrocal and Litoral). It has natural conditions of high scientific interest and biodiversity. It is urgent to share with all those involved with management and conservation knowledge about the flora of this special territory. The Barrocal has a well documented flora of 1001 species, 461 genera and 101 families. The area runs along the length of the Algarve between the Serra and the coastal strip and comprises an extensive range of mesozoic carbonated soils.

The strong desire to see plant life continue and thrive needs the support of individuals. The Mediterranean Gardening Association promotes links between knowledgeable gardeners, academics and professionals in horticulture. Since its start in 2016, the Barrocal Botanic Garden project has attracted interest across the botanical and horticultural community. There is also an economic case to be made based on the benefits of botanic and demonstration gardens in this region as it already attracts a high number of tourists and is seeking to expand the ´out of season´ visitor opportunities. Our links to organizations also dedicated to Mediterranean gardening and landscapes present an opportunity to share this resource internationally.

Our chosen site has been abandoned land for many decades, allowing native plants to recover and with the typical vestige woody plants of carob, almond and olive trees present. The land currently involved in this project (approx. 1,000 sqm) is part of a larger area in secure private ownership with existing demonstration gardens. The prospect of *in situ* conservation of a rich natural plant community is a remarkable opportunity in a region under enormous pressure from tourist and other developments. The challenges of restoration ecology, pressure on water supplies and habitat loss are all present in the Mediterranean climate zones, and the Algarve is no exception. The promotion of sustainable gardening knowledge and skills using native plants is an urgent and necessary task.

KEYWORDS

Education, Building Skills, Gardens, Gardeners, Native Plant Gardening, Multi-Disciplanary Approach

INTRODUCTION

It should be more generally accepted that, as native plants have been evolving over millennia in specific climatic and topographical conditions, their contribution, together with the fauna that coexists with them, should provide a blueprint for the sustainable development of land in any area. Unfortunately, as in many other parts of the world, people in the Algarve region largely did not always recognise or acknowledge the significance of this fact.

It is therefore urgent to:

- recognise the floristic options existing within the native species,
- accept them as an element of identity,
- recognise a regional heritage that it is vital to preserve,
- utilise plants adapted to the climate and in particular with minimum water requirements,
- integrate elements that guarantee biodiversity.

MATERIAL AND METHOD

MGAP (Mediterranean Gardening Association Portugal) hopes that the Barrocal Botanic Garden will play a contributing role to these aims by promoting the recognition of the place of native plants in garden design and landscape recovery, and by so doing minimize pressure on scarce and precious resources such as water. It is felt that it is important to highlight the crucial balance of the natural landscape with its chromatic seasonal components and its rich diversity, as opposed to the alien monoculture as represented by a golf course or a lawn.

It is recognised that there is still a long way to go to persuade local authorities to accept sustainable planting as is evident in the use of water dependent exotic plants in public spaces. However, while it is accepted that much conservation work should be the responsibility of government agencies and global organizations, local associations also have an important part to play. Petitions, publicity, and social media campaigns have highlighted the special importance of small areas with highly diverse populations of shrubs, trees, bulbs and orchids. This type of action is important as the Algarve is particularly rich in endemics in some highly specialized habitats, such as high cliffs and the humid zones on the west coast[1].

A full annual calendar of MGAP gardening related events initiated since 2004 has proved that there are high levels of interest in learning more about sustainable gardening, as well as more about the native plants of Portugal and more about the management techniques for such gardens. The MGAP programme has always included practical skills workshops and visits and has involved small specialist plant nurseries in our plant fairs. In fact it is a key aim and objective of the MGAP Statutes to support local nurseries and encourage them to grow the plants needed to make and repair sustainable gardens. There is also an active publications programme with books for sale on Mediterranean gardening, wildflowers and orchids of the Algarve, in both English and Portuguese. All these activities bring together horticultural professionals, academics and practical amateur gardeners by showing them the beauty of sustainable gardens using native and climate-appropriate plantings.

The strong desire to see plant life continue and thrive needs the support of individuals. Encouragement for our botanic strategy was received from the Nagoya Protocol of 2010, and the Global Strategy for Plant Conservation 2011-2020, which makes special mention of the role of gardeners in plant conservation and species recovery. The Protocol also recognizes the importance of the economic value of ecosystems and biodiversity, together with providing access to traditional knowledge and essential cultivation skills.

The GSPC 2011-2020 goes further and provides targets for

- understanding, conserving and documenting plant diversity
- education and awareness about plant diversity
- building capacity for public engagement

Role of Gardeners in Plant Conservation and Species Recovery

Gardeners have always played a role in plant conservation and species recovery. International examples abound, such as national plant collections schemes in UK, France, Germany and USA which promote gardening skills and knowledge to provide conservation through cultivation[2].

A local example of plant conservancy are the fruit collections held at Tavira on the Algarve[3]. Local species and varieties of several different fruit trees are held on secure land and well documented. Varieties that might not be as productive as new varieties, but which are important to ensure disease resistance and the genetic biodiversity of those already adapted to local conditions.

The intensive use of weed killers and the pressure for new houses and resorts are a threat for more and more plants. An analysis of Red data list threatened plants in UK National Plant Collections showed that over 1200 red list plants were held in collections. By sharing access to the Red Data list and the plants in it, MGAP makes sure that more and more people realize how threatened these plants are.

Botanic gardens in Portugal with exotic plant collections from 18th and 19th centuries, in some cases now extinct in their native habitats, are important to understand how the Portuguese expansion brought a new world of plants to Europe. There are cases of plants being propagated from seeds from Botanic Garden collections and reinstated into wild habitats[4].

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[1] https://algarvedailynews.com/cases/salgados/2659-protected-rare-plant-may-save-salgados
[2] http://www.nccpg.com National Plant Collections UK
[3] Coleções de Fruteiras DRAP Algarve www.drapalg.min-agricultura.pt
[4] http://ser-insr.org/news/2017/10/3/botanic-gardens-and-native-seed-production

Guiding Gardeners towards sustainable Gardening

MGAP feels that we have a role to play by demonstrating to all sections of the population the beauty of native plants by growing them in a garden setting. This means that demonstration gardens should be encouraged and established with an accessible programme of workshops. Topics include plant identification, propagation, seasonal interest, hands on sessions for planting, pruning and other management techniques[5]. MGAP has a unique role in bringing a multidisciplinary approach to promoting the role of native plants in garden design, landscape recovery, and the sustainable use of water to minimize pressure on scarce resources.

Educating garden owners includes showing them the value and diversity available in local flora, drought, fire and disease resistance as well as seasonal interest, in return for minimum inputs. Integration with native plants from other Mediterranean climate zones adds to the sustainable plant palette available.

Through plant identification workshops and by demonstrating the special plant communities of the Algarve, many new garden owners have been shown that their land and gardens contain important biodiversity which encourages wildlife, insects and birds into their gardens. However they need help and encouragement as, although many people are becoming aware that diversity is a good thing, they do not necessarily know how to develop it on their own. It is therefore increasingly important to include young professionals in our activities, implementing sustainable practices with suitably trained gardeners.

Threats to Mediterranean zones with particular reference to the Barrocal - Algarve

The Mediterranean climate zones of the world face many challenges in common but threats from burgeoning tourist facilities, housing estates and golf courses are probably the most threatening to maintaining diversity. This is also very true of the Algarve.

The Botanic Garden lies in that part of the Algarve which is known as the Barrocal. The Barrocal is one of three ecological areas of the Algarve (Serra, Barrocal and Littoral) and runs along the length of the Algarve between the Serra and the coastal strip. It comprises an extensive range of mesozoic carbonated soils and has conditions which are of great scientific interest. It has a rich flora of 1001 taxa, 461 genera and 101 botanical families which has been well-documented. It is therefore worth sharing the knowledge of the particular and unique flora of the Barrocal with the wider public as well as those involved with its management and conservation.

The continuing pressure for development in the littoral with its highly seasonal tourist activity ignores the year round attraction for visitors of the local flora and fauna. There are lots to be discovered away from the coast in unspoiled areas such as the Barrocal, not least the very diverse and glorious wildflowers in the spring. Acknowledged biodiversity hot spots already exist but more areas need to be evaluated and to be protected. Turismo da Natureza attracts more and more tourists that want to be away from the busy resorts but there is very little information for such visitors on the official Tourist Information sites. This is surprising as for example recent bird watching festivals on the Algarve have attracted visitors out of season and seem to have astonished the Tourist Authority by the interest they receive.

MGAP promotes wildflower walks which are well attended, and include visitors that happen to be in Portugal and know of these events from local publicity.

Economic Benefits of Nature and Garden Tourism

Garden tourism[7] is a largely untapped resource in mainland Portugal but there is a strong economic case to be made based on the benefits of botanic and demonstration gardens in this region as it already attracts the interest of a number of tourists. Garden tourism in other European countries provides steady income streams for the employment and training of gardeners. As a result many agencies are seeking to expand the ´out of season´ visitor opportunities. Our links to other international organizations also dedicated to Mediterranean gardening and landscapes present an opportunity to share this resource globally. Visiting gardens is one of the most popular tourism activities today, the value in the UK is estimated at £200m per annum and there are currently over 150,000 gardens to visit in the UK. The UK provides a significant percentage of visitors to the Algarve and they are looking for gardens to visit.

Since its formation in 2016, the Barrocal Botanic Garden project has attracted interest from both amateurs and professionals across the botanical and horticultural community. Sustainable tourism is an integral part of the holiday decision-making process for many (especially experienced, educated and mature travellers from developed countries) and – for those destinations that can demonstrate their sustainability credentials through good quality experiences rather than green brands – the

[5] http://newsandevents.mediterraneangardeningportugal.org/2015/10/propagation-workshop-with-plants-seeds.html

future is bright.
Interest in the medicinal properties of many Mediterranean natives has benefitted the conservation of species used for their health benefits. This interest is also a useful way of integrating inherited local knowledge into plant choices. Gathering information on which plants are used locally and using them in a demonstration garden is an important means of communicating their value and preventing their disappearance. At our events we often integrate talks by specialists on using aromatic, medicinal and culinary herbs and they are usually the best attended talks during the day.

DISCUSSION

Our Approach

Our chosen site for the Botanic Garden has been created on abandoned land left for many decades, allowing native plants to recover and with the typical vestige woody plants such as carob, almond and olive trees present. The land currently involved in this project (approx. 1,000sq m) is part of a larger area in secure private ownership with existing demonstration gardens. The prospect of *in situ* conservation of a rich natural plant community is a remarkable opportunity in a region under enormous pressure from tourism and other developments.
Following seasonal surveys of the large variety of existing plants in the botanic garden we are enriching it with specimens which are found in the Barrocal but which are not presently represented in the garden. Creation and maintenance of accurate plant records for the site is ongoing.
Planting commenced in February 2017 and will continue. An official launch took place in May 2017[6]. Approximately 650 plants have been added to the garden with an ongoing programme including bulbs, annuals and trees.
As we believe conservation horticulture will be of increasing importance, we aim to provide a training ground for those seeking the opportunity to acquire or develop their skills. The promotion of sustainable gardening knowledge and skills using native plants is an urgent and necessary task.
Aims of the Barrocal Botanic Garden

- Demonstrate the enormous potential for using the native plants of the Barrocal.
- Provide a resource for environmental education and skills training in the gardening/landscaping/ horticultural industries on the benefits of using native plants.
- Link Government, academic and training institutions to pass up-to-date knowledge onto the next generation.
- Demonstrate the use of native plants to deliver beauty and diversity with minimum interventions and low to nil water use.
- Engage all ages and nationalities in the life of the garden, throughout the year, through various activities including workshops, guided walks, planting and open days and identification sessions.

REFERENCES

Flora e Vegetação Barrocal Algarvio, Tavira – Portimão, Carlos J Pinto Gomes, Rodrigo J P Paiva Ferreira. CCDR Alg 2005 ISBN 972 957 349 2
Available online: www.ccdr-alg.pt/site/sites/ccdr-alg.pt/files/publicacoes/livro_flora.pdf
Árvores e Arbustos do Barrocal, João A. Santos and Filomena Campos, Almargem 1999
Plantas do Algarve com interesse ornamental / Algarve Plants with Ornamental Interest,Fernando Santos Pessoa, José Rosa Pinto & José Rocha Alexandre. CCDR Alg 2007
ISBN: 978 972 36 0715 4
Flora do Algarve, Serra do Caldeirão e Barrocal, José Rosa Pinto/Sebastião Pernes
ISBN 9789898472038
Plant Conservation- Why it Matters and How it Works, Timothy Walker. Timber Press 2013
ISBN 978 1 60469 260 0
Algarve Plants and Landscape – Passing Tradition and Ecological Change, D J Mabberley and P J Placito Oxford University Press 1993, ISBN 0198587023
The listing for plants recorded in the Barrocal Botanic Garden area, Web site www.flora-on.pt
http://flora-on.pt/#/1nb31*nb31*silves

DEMONSTRATION GARDENS at Quinta da Figueirinha, Silves www.qdf.pt

- Drought-resistant plants
- Exotic fruit garden
- Cypress Plantations
- Experiences with oaks and other tree species

[6] http://newsandevents.mediterraneangardeningportugal.org/2017/05/the-launch-of-mgap-barrocal-botanic.html
[7] http://episode-travel.com/en/garden-tourism-in-portugal-blooming-attraction

GARDEN OF FLOWERING CARPET

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ABSTRACT
For the last few years University Botanic Gardens Ljubljana successfully collaborates with the Municipality of Ljubljana (Slovenian capital) where the Gardens are situated. As an institution with rich history and as an institution helping with advice and work at creation of green urban policy, Botanic Gardens has gained a good reputation. The result of this past fruitful collaboration was the transfer of municipal land near our Botanic Gardens into permanent and free-of-charge use, to University Botanic Gardens Ljubljana. The wish of Ljubljana Municipality was to design this area as a place constantly available to citizens and bringing an added value to the area itself. Based on this wish we created a so-called "Garden of flowering carpets", where beds with melliferous plants will interweave with autochthonous moor plant species. Aforementioned area is located on Ljubljana moor. We also created this new place in a way that it could be managed with low costs and minimal effort. In the first phase all invasive plant species and bushes were removed from the area. During the second phase beds for plants and grass paths have been arranged. This was followed by sowing of melliferous plants like *Melilotus albus, Onobrychis viciifolia* in *Trifolium incarnatum*. Melliferous plants beds will provide a bee pasture for urban bees. Furthermore, in that part of the area where water is stagnating, we planted moist meadow with autochthonous hydrophilic plant species, while on the other, dryer part drought-loving species were planted. At the border of the area there are water channels where autochthonous water and shoreline plants were planted. On those parts *in-situ* conservation of moor plants will be performed. In collaboration with Municipality of Ljubljana and Faculty of architecture also a learning bee-house has been placed in front of plant beds before the beginning of summer 2017. It will serve for the introduction of beekeeping to the public and for scientific purposes. Beside *in-situ* conservation of moor plants and growing melliferous plants, the "Garden of flowering carpets" will be a place for various events connected with beekeeping and ethnobotany.

KEYWORDS
Melliferous Plants, *In-situ* Conservation, Low Cost Management

INTRODUCTION

Nowadays, botanic gardens are not institutions that carry out their work only within the institute and behind the fence but spread their knowledge outward. They are facilitators of pure science with applied science and places which enables socializing and networking different disciplines that are at least a little involved in the world of plants, or they are interested in nature. No matter how big the gardens are, they act as binding forces and have an important educational role. They are connected with their surroundings ecologically, culturally and socially (Oldfield 2008). Botanic gardens, especially the elderly, are often part of the cities and make a significant contribution to the green city structure (Monem 2007). Especially in recent times, when urban planners are aware of the importance of greenery in cities, botanical experts with their extensive knowledge of plants and their ecology are very helpful. Thus, it is not surprising that many botanic gardens in the world are involved in various projects that are related to the urban environment and the culture of living. In the Bronx within the Bronx Green-Up project the New York Botanical Garden has changed 10,000 abandoned urban lands into parks and the community gardens together with the townspeople (Keller, 1994). Urban green areas were created which include playgrounds for children and urban gardens where citizens can produce food themselves. As many as 1,000 families participated in the co-creation. In Culiacán, Mexico, Jardín Botanico Culiacán participated in a project to involve the public in the arrangement of public green spaces and green spaces around schools (Vorgu et al, 2015). Through this engagement they wanted to prevent violence and drug abuse among young people. At the same time, they connected them with nature and encouraged them to protect it. In Brooklyn, the botanical garden participates in the Green Bridge project, promoting the greening of the urban environment with an emphasis on protecting plant species using native species in urban gardening (Vorgu et al, 2015). Cooperation with the city authorities in the management of the environment is especially important in large cities, which are spreading rapidly, and this way divert nature to the inhabitants. In such an environment green areas management is even more important. In the Australian city of Adelaide, the Botanic Garden is part of the Sustainable Landscapes Project. It represents a link between private and public institutions and has the role of educating the public in the design, construction and management of urban green spaces in a sustainable way. It participates in the selection of plant species and according to environmental requirements includes the best horticultural practice for those areas (Pitman, 2007). According to China's urban policy even every new emerging city or already existing city should have a botanic garden. With their knowledge botanic gardens would improve planting plans in the urban environment by providing new plant species, which are more suitable for local environmental conditions (Wen, 2008).

Also, the University Botanic Gardens Ljubljana includes in the city green policy with its knowledge and active work. For the last 15 years the connection between the University Botanic Gardens Ljubljana and the City of Ljubljana, in which the garden is located, is especially intense. The reason for fruitful cooperation is also the fact that the Mayor of the City of Ljubljana is aware of the importance of green spaces in the city for the environment itself and for the townspeople. In his decisions on management of public green areas he respects the opinion of the experts and at the same time he wants to cooperate with the profession. Finally, the cooperation between the profession and the green city policy brought Ljubljana the honorary title Green Capital of Europe in 2016. The beginning of the cooperation between the University Botanic Gardens Ljubljana and the City of Ljubljana began with the involvement of garden experts in the city public space committee in which various experts discussed solutions and a strategy of public space, a large part of which are green areas. In a major action in 2006 the Botanic Garden co-operated in the arrangement of one of the major urban parks, where degraded and illegal kitchen gardens have been replaced by park areas with fruit and other trees. City trees are those which occupy a special part of urban green areas and are often forgotten. For this purpose, the Botanic Garden together with other experts from the field of arboristics published a book on how to treat the city trees (Šiftar et al, 2011). Since then it has been involved in various urban forestry management projects or new planting projects. Major projects include the renovation of two main streets in the centre of the city where the Botanic Garden has been involved as a consultant in the selection of the most suitable tree species for planting. In 2015 it organized a seminar for supervisors of urban green areas maintainers with a practical workshop where participants learned how to manage green areas as sustainable as possible, how to preserve natural biodiversity, what are the problems of maintaining and how to deal with them as efficiently as possible. On this occasion, we presented the advantages of planting autochthonous plant species in the urban environment (Bavcon, 2017; Bavcon and Ravnjak, 2017 b). In the year of Ljubljana as the green capital of Europe on the initiative of the city we have greened the walls of the main presentation pavilion with indigenous plant species. In this way we presented to the citizens and tourists the plant variety of Slovenia (Ravnjak and Bavcon, 2017a, Ravnjak and Bavcon 2017b).

Due to the rapid response of the Botanic Garden to solving problems on green urban areas, its efficiency and knowledge, it is not surprising that the City of Ljubljana decided to deliver one of its surfaces to the Botanic Garden in Ljubljana. City's desire was to arrange a new green area for citizens and visitors of the garden for additional offers and education at the University Botanic Gardens Ljubljana.

MATERIAL AND METHODS

The land which the City of Ljubljana allocated to the University Botanic Gardens Ljubljana for use free of charge is located not far away from the site of the Botanic Garden. The land area is 0.7 ha, surrounded on three sides by private land and from one by railway (Bavcon & Ravnjak 2017 b). When the land was handed over to the Botanic Garden, it was overgrown with bushes and invasive plant species such as Japanese knotweed (*Reynoutria japonica*), Canadian goldenrod (*Solidago canadensis*), giant hogweed (*Heracleum mantegazzianum*), staghorn sumac (*Rhus typhina*) and manitoba maple (*Acer negundo*). Illegal kitchen gardens and illegally placed sheds were also there. We arranged newly acquired land in three phases: cleaning of the site, preparation of a design for arrangement, implementation of the design. Like the University Botanic Gardens Ljubljana, the land is located at the beginning of the Ljubljansko barje where the substrate is loam with a full moor soil underneath and is slightly acidic. During the precipitation, period ground is often dampened due to the moor soil, while in the summer period the soil is often dry. On the land, there are also two water canals, which serve to collect excess water at precipitation. Such a delineation of plots with water channels is characteristic of the Ljubljansko barje ever since the time of the settlement when people in this area began to deal with agriculture, but it was accelerated by the construction of the Gruber canal (1772- 1778), which runs along the Botanic Garden, and the colonization of Barje in the first half of the 19th century in places where the surfaces were to be converted into agricultural ones. (Melik 1946)

Cleaning of the site

In 2016, as soon as we received the land, we started to clean the location. Before we began removing unwanted plant species, we inspected all the plants at the site and selected the specimens that we wanted to preserve at the site (hazel, plum and an existing orchard with apple trees). We removed the shed, kitchen gardens and piles of remains of construction material. Then we ground all the remaining plants with a large mulcher. With a mulcher, we ploughed up the area and grind the sod and then settled the level of the land (Figure 1). Then followed the cleaning and deepening of already completely filled up and overgrown water channels, which did not serve their purpose.

Figure 1: Cleaning the area with a mulcher

Preparation of a design

The basic idea of the development plan was to arrange and maintain the site according to the principle of "low-cost management". The location will not be intensively cultivated and we have created a combination of natural habitats where we can carry out *in-situ* protection of plant species and larger garden beds with honey plants. Despite the fact that the site measures only 0.7 ha, its terrain is diverse and has a moor character of Ljubljansko barje. In the lower part, the water stagnates and the soil is wet, and on the higher part it is drier. That is why we decided that on the wet part we plant wet meadow species and on dry part species, characteristic for dry meadows. Water channels also represent an important living environment on the marshes, so we have planned to plant with aquatic plants and riparian vegetation, or we have left those indigenous species that have grown there. The rest of the site was arranged in larger beds with honey plants or a combination of honey plants and crops (Figure 2).

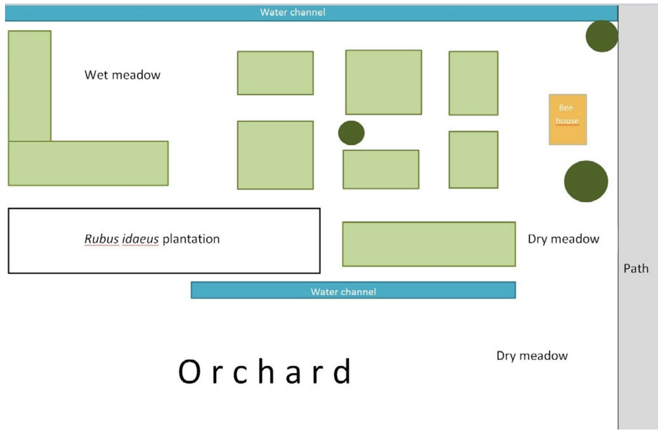

Figure 2: Design of the garden

Implementation of the design

With the help of the string, we laid out the garden beds and thoroughly ploughed up each of them. We then removed the larger remnants of organic material, grabbed the beds and edged them. Then followed the sowing of species on beds (for example *Linum usitatissimum, Melilotus albus, Trifolium incarnatum*...) and planting seedlings of dry and wet meadow area (Table 1). Intermediate spaces between the beds on the dry part were further sown with grass and hay residue derived from a dry meadow, where we perform *in-situ* protection of plant species. During the season we then mowed only the intermediate grassy paths between the individual garden beds and then the wet and dry meadows after the plants produced seeds (Bavcon & Ravnjak 2016 b, Bavcon & Ravnjak 2018 b). In the fields with some annual cultural plant species, for example *Linum usitatissimum*, we also sowed buckwheat in late summer (*Fagopyrum esculentum*). We also arranged a sandy path which links the new location to the Botanic Garden and built a fence along the path. In the spring of 2017 in cooperation with the City of Ljubljana and the

Faculty of Architecture, an educational bee house was placed on the northern part of the land by the connecting path. Educational bee house was a seminar work of students. According to our and the beekeeper's needs, it was designed in such a way that visitors from wooden landing and through a glass barrier can observe the work of the beekeeper. At the top of the bee house, there is a flat roof, planted with plants tolerant of drought, strong sunlight and shallow soil. In addition, we have planted one of the Slovenian endemic species, *Sempervivum juvanii* on the roof (Table2). The rooftop plant population will serve as an *ex-situ* space for growing seedlings for the protection previously mentioned species. In front of the bee house, we arranged three small gardens with honey herbs.

Wet meadows and channels	Dry meadow	Plant beds
Fritillaria meleagris	*Salvia pratensis*	*Centaurea cyanus*
Hottonia palustris	*Leucanthemum ircutianum*	*Dipsacus fullonum*
Lythrum salicaria	*Medicago lupulina*	*Fagopyrum esculentum*
Leucojum aestivum	*Ajuga genevensis*	*Helianthus annuus*
Lychnis flos-cuculi	*Echium vulgare*	*Linum usitatissimum*
Gladiolus illyricus		*Melilotus albus*
		Onobrychis viciifolia
		Papaver rhoeas
		Trifolium incarnatum
		Trifolium pratense
		Trifolium repens

Table 1: Plant list of meadows planted at wet meadow, water channels, dry meadows and on plant beds

Beds infront of beehouse	Roof garden
Allium ericetorum	*Ajuga genevensis 'Istra'*
Allium schoenophrasum	*Sedum acre*
Allium senescens	*Sedum album*
Hyssopus officinalis	*Sedum maximum*
Marrubium incanum	*Satureja montana*
Melissa officinalis	*Satureja subspicata*
Origanum vulgare	*Sempervivum juvanii*
Salvia officinalis	*Semprevivum tectorum*
Satureja montana	*Verbascum phoeniceum*
Sedum maximum	*Thymus sp.*
Thalictrum minus	
Thymus sp.	

Table 2: Plants planted on a roof of a bee house and in front of the bee house

RESULTS AND DISCUSSION

The 'Garden of flowering carpet' is an example of fruitful cooperation between the University Botanic Gardens Ljubljana and the City of Ljubljana, and an example of a fast-arranged garden with low costs and low input (Ravnjak & Bavcon 2017b). It was designed in such a way that large fields of flowering plants look like flowering carpets among which visitors could walk, while at the same time these plants would be ideal bee pastures. Like many other botanic gardens all over the world, the University Botanic Gardens Ljubljana faces the problem of and lack financial resources and lack of staff. Each additional cultivation area can, therefore, means the costs and a larger unit of effort. In spite of that fact in smaller gardens, each additional area represents more opportunities for activities and engagement of the Botanic Garden (Bavcon et al. 2012, Bavcon & Ravnjak 2015 a). In our case, a compromise was adopted. The new surface will be extensively regulated and it will still be interesting for visitors, but at the same time, it will serve for activities of the Botanic Garden. Already in the first year of landscaping we managed to remove all invasive plant species with intensive mowing of grassland. Similarly, in the first year along the water channels, the riparian species populated themselves, such as *Dipsacus fullonum, Mentha longifolia, Lythrum salicaria, Hypericum tetrapterum*, etc. On large beds where we planted honey plant species in combination with certain crops in the first year, there was a lot of weeds which we physically removed. With each subsequent year, the number of weeds decreased. On the garden bed where we planted wheat with mixed grain weeds from the first year onwards are successfully re-seeding itself the cornflower (*Centaurea cyanus*) and common poppy (*Papaver rhoeas*). In this location, the influence of the moor soil is visible as the soil is dry in the dry season and therefore the growth of the plants is worse, while in the years with the rainy spring the soil is soaked and therefore the plants are quite large and lush. Due to this during the growing season in the year 2018 the Melilotus albus species it was necessary to mow twice because the increase in precipitation in the warmest part of the year was higher than usual.

The newly arranged part of the Botanic Garden also presents a testing ground for students' education. From the very beginnings of the arrangement of the mentioned surface, we included students in the execution of the works as part of the educational process, among them also Erasmus students. They participated in sowing and planting of plant species as well as in building the bee house. We presented them with the concept of arranging the described part of the garden and practically demonstrated work on the field, where then they actively participated (Ravnjak & Bavcon 2017 b). The 'Garden of flowering carpet' was immediately included in the program of our activities. In the framework of regular guided tours of the garden, we present the Ljubljansko barje and the living environment of marsh plants and their *in-situ* protection (Bavcon 1997; Bavcon & Ravnjak 2016 a). By setting up an educational bee house the mentioned location gained a new subject of education, namely honey plants, and at the same time a new interest group - beekeepers. By planting autochthonous honey plants we want to present to the beekeepers the importance and advantage of autochthonous plant species in comparison with non-indigenous species and potentially invasive honey plants (Bavcon 2013; Bavcon & Ravnjak 2014, 2016 b; Bavcon et al 2015; Bavcon 2017; Bavcon & Ravnjak 2018 b; Ravnjak & Bavcon 2017 c). In 'The Garden of flowering carpet' we present to them indigenous honey species and teach them about their ecology and growing. The educational bee house serves both independent visitors and guided groups. While independent visitors visit the bee house on their own and on the information boards read the basic information about the bee house, within guided tours, we present beekeeping, the life of the honey bee and the connection between plants and bees. At the same time, the educational bee house serves as a learning and research tool for teaching beekeeping and studying the bees of the Department of Biology. In the future, a photovoltaic system will be installed on it, which will allow energy for cameras and scales placed in the beehives. With their help, it will be possible to monitor the happening in bee families. Our purpose is to research which native honey plants are most commonly collected by bees.

'The Garden of flowering carpet' will be in the future also intended for various events. In the autumn season in 2017, we prepared a presentation of some traditional farm tasks, such as milling of cereals and the preparation of sheaves for making a thatched roof from agricultural crop residues. At this location we can present in live species which were in the past crucial for survival, and how people used them. The location will serve us to represent ethnobotany (Bavcon & Ravnjak 2015 b, Bavcon & Ravnjak 2018 a). For the needs and purposes of ethnobotany in the future, we want to complement the existing orchard with some other indigenous varieties of fruit trees. Nowadays, some of these varieties have almost disappeared (Šiftar 2004), so the mentioned location can be an ideal place for displaying and preserving them. In times of climate change, these varieties will become even more important as they are adapted to the climatic conditions in which they were cultivated. On the first International Bee Day (May 20, 2018) we organized various workshops on the topic of bees and plants, the presentation of beekeeping and the autochthonous kind of honeybee *Apis mellifera carnica*.

The University Botanic Gardens Ljubljana received a new place with the donated location where additional educational and research activities can be carried out. The newly arranged area is intended for citizens and at the same time it is the confirmation by the City of Ljubljana that with our work in Botanic Garden we are on the right path.

REFERENCES

Bavcon J. (1997) *Vzgoja visokobarjanskih in nizkobarjanskih rastlin v kulturi: (Poročilo).* Ljubljana: Biotehniška fakulteta, Oddelek za biologijo, Botanični vrt, 1997. 23 str.
Bavcon J. (2013)*Naše rastline*. 1. izd. Celovec: Mohorjeva, 2013. 256 str., fotogr. ISBN 978-3-7086-0744-3.
Bavcon J. (2016) We brought nature into the heart of the city. V: Žirovnik, Karmen (ur.). *Ljubljana. For you. : report of the European Green Capital 2016 project.* Ljubljana: City. [2017], str. 15, ilustr.
Bavcon J., Marinček A., Ravnjak B. (2012) Novi tropski rastlinjak = The new tropical greenhouse. V: Bavcon J. (ur.). *Tropski rastlinjak v Ljubljani = The tropical greenhouse in Ljubljana,* (Index seminum, ISSN 1318-170X). Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2012, str. 7-79.
Bavcon J., Ravnjak B. (2014) *Projekt ozelenitve objekta Gimnazije Ledina.* Ljubljana: Botanični vrt Univerze v Ljubljani, Oddelek za biologijo, Biotehniška fakulteta, 11. 7. 2014. Ni pag. [5 f.], 2 pril. (načrt), tabela.
Bavcon J., Ravnjak B. (2015 a) Botanični vrt kot izvor šolskih vrtov = The botanical garden as the origins of the school garden. *Šolska kronika : zbornik za zgodovino šolstva in vzgoje*, ISSN 1318-6728, 2015, letn. 24 = 48, št. 3, str. 285-296, ilustr.
Bavcon J., Ravnjak B. (2015 b) Some traditional plant uses in Slovenia. V: Larpin, Denis (ur.). *Proceedings of the EuroGard VII Congress : European botanic gardens in the decade on biodiversity challenges and responsibilities in the count-down towards 2020*, EuroGard VII Congress, Paris, July 6-10, 2015. [S. l.: s. n. 2015], str. 109-118, ilustr. https://www.bgci.org/files/EUConsortium/EuroGard%20vii/EuroGardVII.pdf.
Bavcon J., Ravnjak B. (2016 a) *Ljubljansko barje : 16. november 2016, Botanični vrt Univerze v Ljubljani,* Ljubljana. 2016; Ljubljana.
Bavcon J., Ravnjak B. (2016 b) *Travniki - zelene površine ali pisani vrtovi? = Meadows - green surfaces or colorful gardens?.* E version. Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2016. 150 str., ilustr. ISBN 978-961-6822-37-4. http://www.botanicni-vrt.si/pdf/books/meadows-green-surfaces-or-colourful-gardens.pdf.
Bavcon J., Ravnjak B. (2017 a) *Botanični vrt v letu zelene prestolnice Evrope = Botanic gardens in the year of European green capital.* Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2017. 126 str., ilustr. http://www.botanicni-vrt.si/pdf/books/botanic-gardens-in-the-year-of-european-green-capital.pdf.
Bavcon J., Ravnjak B. (2017 b) Botanic gardens integration into city green policy. V: Autochthonous Plants in the urban environment : 112 pp
Bavcon J., Ravnjak B. (2018 a) Some traditional plant uses in Slovenia. V: Larpin, Denis (ur.). *Proceedings of the EuroGard VII Congress : European botanic gardens in the decade on biodiversity challenges and responsibilities in the count-down towards 2020,* EuroGard VII Congress, Paris, July 6-10, 2015. [S. l.: s. n. 2015], str. 109-118, ilustr. https://www.bgci.org/files/EUConsortium/EuroGard%20vii/EuroGardVII.pdf.
Bavcon J., Ravnjak B. (2018 b) *Die farbenfrohen Wiesen Sloweniens : Freisinger Gartentage*, 11. bis 13. Mai 2018.
Bavcon J., Ravnjak B., Bavcon D. (2015) *Travniška kadulja (Salvia pratensis L.) v Sloveniji = Meadow clary (Salvia pratensis L.) in Slovenia.* Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2015. 160 str., ilustr. ISBN 978-961-6822-26-8. http://www.botanicni-vrt.si/pdf/books/meadow-clary-salvia-pratensis-l-in-slovenia.pdf.
Keller T. (1994) Green-up! Roots 9: 19-21
Melik A. (1946) Ljubljansko mostiščarsko jezero in dediščina po njem. Ljubljana.
Monem N. K. (2007) Botanic Gardens a living history, London: Black dog publishing
Oldfield S. (2008) Urban botanic gardens – benefiting people and biodiversity. BGjournal 5,2: 3
Pitman S. (2007) Educating for sustainable urban landscapes. Roots 4, 2: 5-8
Ravnjak B., Bavcon J. (2017 a) Green walls as a natural display window. V: Autochthonous Plants in the urban environment : 112 pp
Ravnjak B., Bavcon J. (2017 b) Botanic gardens in the year of European green capital. Ljubljana, University Botanic Gardens Ljubljana: 126 pp
Ravnjak B., Bavcon J. (2017 c) *Predstavitev in pomen sajenja avtohtonih medovitih rastlin : Center kulture Španski borci,* 13. april 2017, Ljubljana.
Šiftar A., Maljevac T., Simoneti M., Bavcon J. (2011) *Mestno drevje.* Ljubljana: Botanični vrt, Oddelek za biologijo, Biotehniška fakulteta, 2011. 207 str.
Šiftar, A. (2004) Zimska hruška Pyrus nivalis Jacq. samonikla ali kultivirana drevesna vrsta v Sloveniji = Snow pear Pyrus nivalis Jacq. wild growth or cultivated tree species in Slovenia. V: Hudina, Metka (ur.). *Zbornik referatov 1. slovenskega sadjarskega kongresa z mednarodno udeležbo, Krško, 24.-26. marec 2004.* Ljubljana: Strokovno sadjarsko društvo Slovenije. str. 509-522.
Vorgu D. L., Moussouri A., Fernández Rodrigez T., Fernández Rodrigez A. (2015) Appropriate Green Space Project, Jardín Botánico Culiacán, Mexico. Caring for community, a manual for botanic gardens: 23
Wen X. 2008. The importance of botanic gardens in Chinese cities. Urban botanic gardens – benefiting people and biodiversity. BGjournal 5,2: 19-22

A NEW CONNECTIVE EDUCATIONAL TOOL FOR SCIENTIFIC INSTITUTIONS AND SCHOOLS, THE DISCOVERY PASSPORT

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ABSTRACT
Each year the botanical collections of the Hortus botanicus Leiden are visited by many schoolchildren of the Netherlands. They get to enjoy the tropical greenhouses, the monumental trees and our changing exhibits such as the carnivorous plant show. Often the learning stops after the trip as the experience is replaced with new impressions. Children can now continue the experience at home with the Discovery Passport. Eleven educational organisations from the Leiden area are collaborating in an innovative way to present regional primary schools with various classes on nature, science, technology and sustainability. To increase and extend learning about science, nature and technology, several organisations in the city of Leiden decided to work together to streamline their workshops for schools and families. A new online platform forms the connection between classroom and workshops from museums and botanical gardens with extended learning at home. The schools request a membership card for all the children in a class. The children can then visit any participating location, such as the Leiden Botanical Garden, with their school, and participate in an educational program. During this program they will be introduced to various subjects, which are discussed with the class. For the teachers at school, the Discovery Passport offers an overview of participating organisations to visit, depending on their preferred subject and activity. For children, it presents a new way to learn both at school and home in a playful manner with additional rewards when various parts such as treasure hunts are completed. Here the children process their experiences through various means of gamification. The Discovery Passport is not only made available for participating schools, but the website is publicly available. Currently, more than 400 events and workshops have been held and more than 50% of all elementary school children in Leiden have requested and received a Discovery Passport. Future projects aim to expand the participating organisations, the number of workshops and to include more schools outside the city of Leiden.

KEYWORDS
Botanical Gardens, Natural History, Online Teaching, Technology

INTRODUCTION

The inclusion of lessons on science and technology in elementary education in the Netherlands is currently limited. Schools often focus more on general subjects such as linguistics and mathematics while subjects such as biology, history, physics and technology are of less concern. The number of schools actively teaching these subjects is limited (SLO-National Expertisecentrum Leerplanontwikkeling 2016) and more than half of the involved teachers have mentioned how hard it is to include science and technology in their current curriculum (SLO Report 2016). However, several elementary schools in Leiden have expressed interest in getting support with science education (reported in the collaboration plan of the Discovery Passport; Samenwerkingsplan Verwonderpaspoort).

To enhance the current facilities for the education in science, a plan was developed to create the Discovery Passport, a new support tool for schools and various institutions. Several criteria and aims were established for this new tool:

1. Enthuse children for natural history and science and to stimulate their curious nature.
2. Contribute to enhancing the scientific knowledge, skills and education of our targeted groups: children (aged 4-12 years old) in the city of Leiden and the surrounding area.
3. Build a lasting collaboration between the participating organisations, including schools and offer joint education activities with the partners.
4. Better the quality of the currently offered curriculum.

5. Stimulate participation of our target group to educational activities by creating an attractive plethora of options that act on the curiosity and enthusiasm of children.

The Discovery Passport acts as a bridge between the participating organisations and elementary schools for education on nature, science, technology and sustainability. Teachers are able to simply select the type of subject and activity that best fits their class and schedule a particular workshop. The activities with the Discovery Passport were created to leave a lasting impression on the participants and bring children into contact with live objects and practicing scientists.

MATERIAL AND METHODS

Participating organisations

The Discovery Passport was created as a collaboration project between various organisations including Naturalis Biodiversity Center, Technolab, Junior Science Lab, Museum Boerhaave, Hortus botanicus Leiden, Universe Awareness, het Wetenschapsknooppunt Leiden, Duurzaam Leiden (sustainable Leiden) en de Pabo Leiden. All phases in the development of this tool were produced with the continuous support and participation with a number of elementary schools in Leiden. The natural history museum, Naturalis Biodiversity Center (Naturalis), was the largest contributor within the project and supervised the majority of the project and helped with the development of the digital world.

Technolab Leiden is an organisation focused on science education for students by having them work on experiments. The Junior Science Lab is a facility of the University of Leiden that aims at older children (grade 7-8, aged 10-12), which schools can ask for workshops on several scientific experiments. The Museum Boerhaave is specialized on the history of science and medicine and their aim is to inform the public on the importance of the natural sciences and medicine both in the past and present. Universe Awareness is an international project aimed at children that brings them into contact with astronomy. Duurzaam Leiden (Sustainable Leiden) is a governmental initiative to raise awareness in children on environmental issues and the importance of sustainability. Het wetenschapsknooppunt (scientific junction) is a collaboration project between the University of Leiden, the Technical University of Delft and the Erasmus University of Rotterdam, which uses several activities to stimulate the investigative attitude and creativity of students. Finally, the Pabo is the training for elementary teachers in Leiden, connected to the Leiden University.

Focus groups

This tool was developed to help science education in Dutch elementary schools (children aged 4-12 years old) in the city of Leiden with an expansion to the surrounding area in the future.

Tool development

The Discovery Passport was an initiative by Naturalis Biodiversity Centre in 2016. Several other institutions including the Hortus botanicus Leiden were contacted and asked to join in the development of this tool. During a span of two years, a new digital platform was created and the Discovery Passport was introduced. At the start of the project, a set of goals termed the "Big five" were adopted (they were in use at Naturalis) which became the ground rules for every participating institution (De Big Five van Educatie, Naturalis 2015). The initial setup of the digital world was outsourced by Naturalis. All partners developed individual programs which stimulate scientific literacy. This is the ability to ask questions about the world around you (fed by curiosity), to look for answers and to be critical of the answer and results. This helps introduce the scientific method of formulating questions, hypotheses and predictions and make critical decisions (De Jonge Akademie 2012).

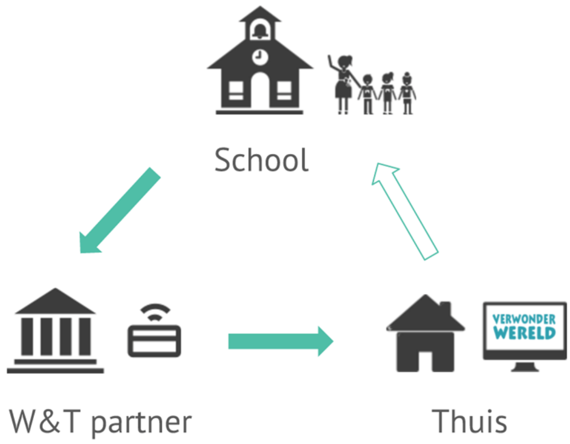

Figure 1: Diagram of the relations between schools, scientific institutes (W&T partner) and children's home.

At home, the digital world (Verwonderwereld) contains more information and games to continue the experience of a particular event hosted at the W&T partner. Interactions that are enhanced by the Discovery Passport in green. (Courtesy Naturalis Biodiversity Centre)

Availability

Teachers can apply for the Discovery Passport online and two cards will be supplied for every child. One card is used at the school, when the class visits a workshop that has been booked on a particular subject. These workshops come with preparatory material that can be used by the teacher at school to introduce the subject. During the workshops, the children are introduced to live materials on the subject and they can play a game or work on a scientific problem. The second card is to be used when someone is visiting any of the participating museums or gardens with their family. Each institute is provided with its own card scanner to unlock parts of the digital world after the children complete a specific challenge or treasure hunt. At home, the cards, together with an account gives access to a digital world with several islands (Fig. 1). Each island was created by a particular institution and contains various games and information to continue the learning experience at home in a playful manner.

RESULTS

Events were hosted between September 2016 and August 2018 (two school years). The second school year over half of all elementary school students in Leiden requested a Discovery Passport and more than 400 events were booked for educational activities on nature, science, technology and sustainability. The project started with nine organisations that offered activities, which increased to eleven during the year (Plan Verwonderpaspoort 2018-2022). Events were hosted at:

1. Naturalis Biodiversity Center
2. Rijksmuseum Boerhaave
3. Technolab Leiden
4. Hortus Botanicus Leiden
5. Wetenschapsknooppunt Leiden
6. Junior Science Lab
7. Sterrewacht
8. Gemeente Leiden
9. Naar Buiten!
10. Vereniging Leidse Schooltuinen
11. Het Bewaarde land

The Discovery Passport was mainly distributed in Leiden itself with plans to expand in 2018. In the Hortus botanicus Leiden, several hundred children visited the Discovery Passport activities.

DISCUSSION

The Discovery Passport project has given the Hortus botanicus the chance to be a part of the large network between different nature, science and environmental partners, while previously this was mostly with art museums. The project is still ongoing and further developments aim to expand the range of the project outside the city of Leiden and the use of the digital world. UUntil now, several evaluations have been made on the accessibility of the Discovery Passport and the experiences various users have had. This resulted in some modifications. The next step would include a new evaluation of the tool by all participating schools to see if the modifications have the desired results.

The Verwonderpaspoort concept won the prestigious Dutch National Museum education prize in November 2017. This enables us to distribute the project further beyond the borders of Leiden to neighboring cities. As the majority of visitors in the Hortus botanicus Leiden come from these neighboring areas, it is expected that the number of participants for this project will also rise. The organisation Naar Buiten!, has taken over the coordination of the project and is currently recruiting new schools.

Cooperation between the various partners has also resulted in the prospects on new projects for the Leiden botanical garden. This includes a project on pollination (the citizen science project, Nederland Zoemt) and presentations at schools and some public vegetable markets.

Over the next few years, we hope to expand this project, not only in the number of participating schools and students, but also in the number of available workshops created by each organization. The aim is to simplify the user interface for teachers and also create an open policy for new contributors to the project.

CONCLUSION

Where there has been a recent decline in the attention to general botany and in the number of students studying plant biology, we expect the Discovery Passport to create a renewed interest among younger generations. In this way we hope to encourage a long lasting relation between the participating children, science and botany.

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REFERENCES

De Jonge Akademie (2012) Tussen onderzoek en samenleving, Aanbevelingen voor optimale wetenschapscommunicatie (Acces via https://www.knaw.nl/nl/actueel/publicaties/tussen-onderzoek-en-samenleving_

Miller JD. (2004) Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. Public Understanding of Science, 13(3): 273-294.

Museum Boerhaave: Missie Museum Boerhaave. Accessed May 2018 from: http://www.museumboerhaave.nl/bezoekersinformatie/over-museum-boerhaave/missie/

Naturalis Biodiversity Center (2015) De Big Five van educatie: Leren bij Naturalis Biodiversity Center. Accessed May 2018 from: http://www.naturalis.nl/media/library/2015/07/Big_Five_DEF.pdf

Platform Onderwijs 2032: Over Ons. Accessed May 2018 from: http://onsonderwijs2032.nl/

Sarti, A., Dijkstra, C., Nury, E., Seidell, J. C., & Dedding, C. (2017). 'I eat the vegetables because I have grown them with my own hands': Children's perspectives on school gardening and vegetable consumption. Children & Society, 31, 429-440. doi:10.1111/chso.12214

SLO team (2016) Wetenschap & technologie in het basis en speciaal onderwijs. Accessed May 2018 from: http://downloads.slo.nl/Repository/wetenschap-en-technologie-in-het-basis-en-speciaal-onderwijs.pdf

STEM Funders Network: What are STEM ecosystems? Accessed May 2018 from: http://stemecosystems.org/what-are-stem-ecosystems/

Techniekpact: 12 doelen. Accessed May 2018 from:http://www.techniekpact.nl/doelen

Technolab Leiden: Website Technolab. Accessed May 2018 from:http://www.technolableiden.nl/

UNAWE: About Universe Awareness (UNAWE). Accessed May 2018 from: http://www.unawe.org/about/

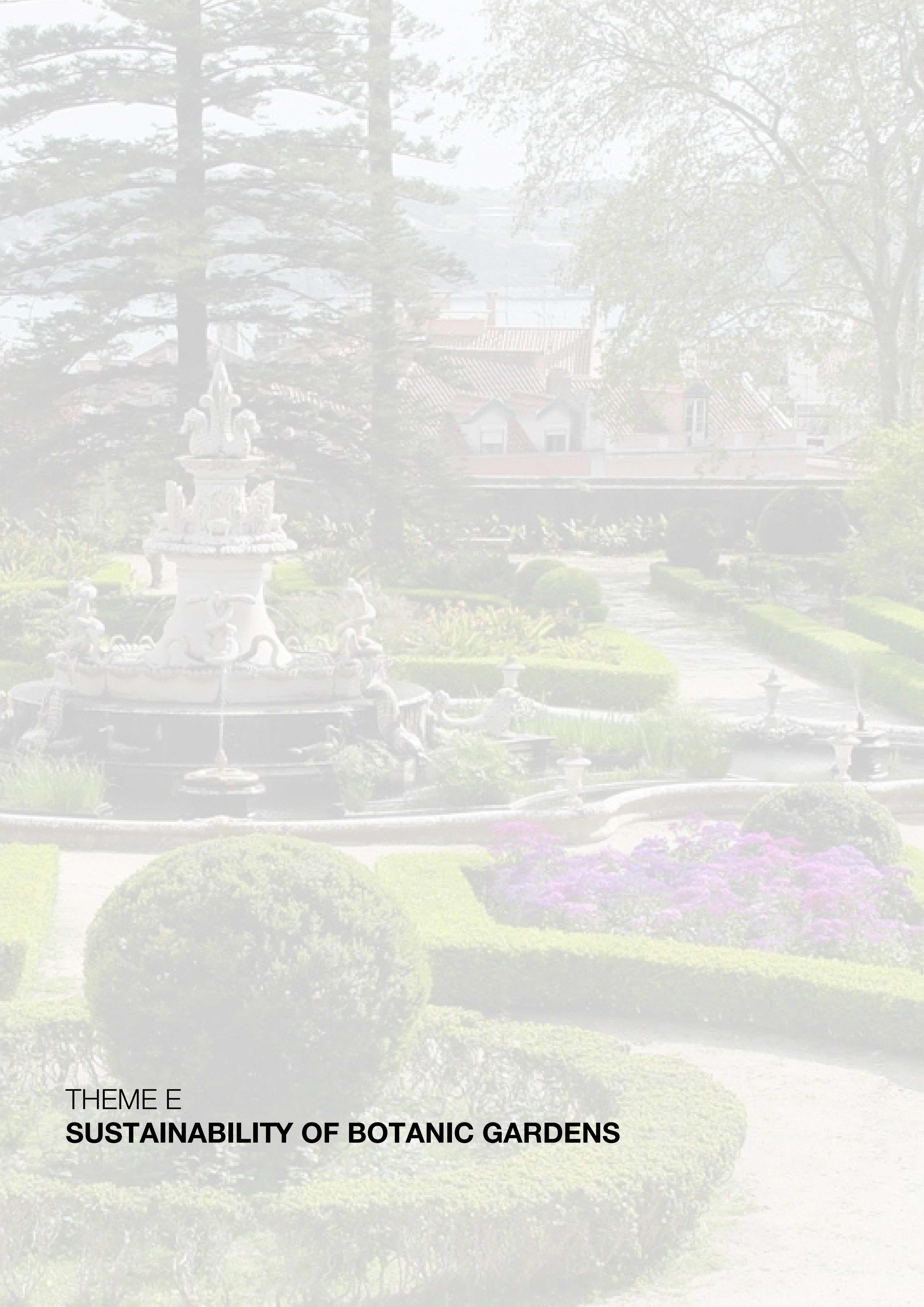
Universiteit Leiden: Hortus Botanicus Leiden. Accessed May 2018 from: https://www.hortus.leidenuniv.nl/

Universiteit Leiden: Junior Science Lab. Accessed May 2018 from:http://www.juniorsciencelab.nl/

Verkooijen L. Adviesrapport Gemeente Leiden: NME Basisonderwijs. Opgehaald van https://gemeente.leiden.nl/themas/duurzaam-leiden-nme/primair-onderwijs/

Wetenschapsknooppunt Zuid Holland: Over Ons – Missie en Visie. Accessed May 2018 from:http://www.wetenschapsknooppuntzh.nl/over-ons/missie-visie/

Wippoo, M. (2016). Draft partner strategies for co-creation.



THEME E

SUSTAINABILITY OF BOTANIC GARDENS

THE SUSTAINABILITY OF THE GLOBAL BOTANIC GARDEN ESTATE

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ABSTRACT

While much has been written about the various ways in which individual botanic gardens are adopting sustainable practices in their operations and are able to inform visitors about the nature of the sustainability message, through education and outreach programmes, little consideration has been given to the sustainability of the institutions themselves, individually, nationally or globally. Over the centuries, the roles of botanic gardens have changed and evolved. Many botanic gardens have come and gone as circumstances and demands have changed. In recent years, many of them have taken on responsibilities for issues such as *ex situ*, *in situ* conservation, reintroduction and ecological restoration. Today, many botanic gardens are in the curious situation of playing an important part in implementation of various fields of national policy, for example in helping meet their countries' obligations under the CBD and other environmental treaties such as CITES, contributing to some of the key Aichi targets and Millennium Development Goals, alleviating the impacts of climate change through understanding the mechanisms of adaptation of plants and their capacity to track the climatic shifts, yet few of them, including many that are state-run, receive any appreciable government or public support for these assumed mandates. In addition, there is a growing expectation that botanic gardens should be filling gaps in botanical capacity building and training in the light of the decline of botany in the university sector and in other public institutions. At the same time, public attitudes and expectations of the services that institutions such as botanic gardens should offer, have changed and have in many cases affected policy. A further complicating factor is that a considerable number of the world's botanic gardens are struggling to survive and are barely functional.

Among the questions that we need to address are:

- What capacity does the current estate of botanic gardens have to meet the challenges they have assumed?
- How do we match the demands to the available capacity, especially given the present highly skewed distribution of botanic gardens and its mismatch with the distribution of global plant diversity?
- How many botanic gardens do we need?
- Should we support failing botanic gardens, and if so how?
- Are the current models of botanic gardens suited for their present functions?
- Should we consider developing different models which are more suited to local conditions and requirements, rather than the current 'western' ones, as has recently been suggested?

Few countries have reviewed these issues and much more action is needed at a national and, where appropriate, regional level so that a global overview of capacity and needs can be obtained, recommendations prepared and plans made to address them.

KEYWORDS

Botanic Gardens, Capacity Building

INTRODUCTION

In line with many other kinds of organization, botanic gardens across the world have embraced the notion of sustainability, as a perusal of many of their websites clearly shows. The main areas of sustainability in which they are engaged are:

- The adoption of sustainable building design and maintenance practices
- Practising sustainable horticulture, recycling and reducing waste and energy and water consumption
- Adopting integrated pest management
- Furthering the sustainable use and harvesting of plants diversity
- Promoting sustainable landscaping both with in the garden and in the wider community

- Education programmes

These and related issues have been reviewed by several authors (e.g. Wyse Jackson, 2009; Arapetyan, 2015) However, little consideration has been given to the sustainability of botanic gardens themselves as institutions, individually, nationally or globally. The main exception is the recent attention being paid to developing strategies that will allow gardens to adapt to the impacts of global, and in particular, climate change and instability (Entwisle et al., 2017). An example of a botanic garden whose sustainability is already at risk because of changes in climate and land use is the Kongsvoll Alpine Garden, located in a subalpine, cultural landscape in Dovrefjell Mountains, southern Norway (Prestø, 2018). As Arias-Maldonado (2013) comments 'Sustainability is now relocated into the wider context of the social response to global warming'.

This paper addresses the sustainability of botanic gardens as institutions, individually, nationally or globally, and the viability of the global botanic garden estate. In addressing these topics, it is important to take note of the evolving debate on the nature of sustainability in the Anthropocene and its practices, policies and measurements, and its relationship to environmentalism (Arias-Maldonado, 2015); and the fact that the roles of botanic gardens are constantly changing as are public expectations of what they should offer.

A recent discussion by the directors of four UK National botanic gardens debated the question 'Are botanic gardens fit for purpose?' (https://www.bgci.org/news-and-events/news/0573/), including the following issues:

- How does a botanic garden differ from a public park, and how can the public and politicians be enthused by botanic gardens?
- How do botanic gardens balance their plant collection and plant conservation roles?
- Should botanic gardens focus more on socio-economically important plants or on wild species?
- What are the respective roles of botanic gardens and universities with regard to basic plant research?
- Is there a tension between the 'public good' role of botanic gardens in providing enjoyment, leisure and recreation for the public, and the more utilitarian roles of education, research and conservation?
- If a botanic garden is supported by public funds, should the public have a say in the ultimate 'purpose' of the botanic garden?

However, such matters are seldom discussed within the botanic garden community which in the face of the current environmental crisis and the continuing loss of biodiversity has understandably tended to focus most attention to exploring what botanic gardens can do to conserve plant diversity. But as we shall see later, adopting such a policy is only possible if a botanic garden itself is viable and the necessary resources and facilities are available for conservation actions, a situation that does not apply to many botanic gardens across the world. For many of them, sheer survival is the greatest challenge and increasingly gardens are becoming dependent on successful marketing, innovation, entrepreneurship and diversification so as to maintain income streams (Catahan & Woodruffe-Burton, 2017). On the other hand, as we shall see, despite these challenges, botanic gardens have collectively been able to make substantial contributions to science, plant conservation, environmental education and outreach and to the wellbeing of the local community.

NATURE, DIVERSITY AND SUSTAINABILITY OF THE BOTANIC GARDEN ESTATE

In looking at the sustainability of the global botanic garden estate, we need to consider the different stereotypes and models of botanic garden, their constantly changing missions and roles, how to define them and how many exist today.

Different botanic garden stereotypes

The conventional narrative is of an origin of botanic gardens from early physic gardens and university medicinal plant gardens in Europe which subsequently evolved into the western model as found in Europe and developed countries in other parts of the world. The western model usually involved landscaped areas, species-rich living collections both outdoors and under glass, thematic plantings including systematic beds, often a herbarium, library and museum and controlled public access. Many tropical botanic gardens, on the other hand, had their origins in the introduction of economically important plants, usually as part of colonial development by European powers (Heywood,1985). Their aim was to introduce into cultivation species of economic importance that could support the local economy and provide profits for the home country. Subsequently many of these botanic gardens have become tourist attractions while their economic role has been much reduced. But the distinction is far from clear as botanic gardens in various parts of the world, not just in the tropics but in Mediterranean and east

Europe for example, also had their origins in economic plant introduction, a role that goes back far into history (Heywood, 2011).

The early North American botanic gardens initially followed the European model but most of the pre-revolutionary gardens have not survived and in subsequent periods a large number of both public and private gardens were established; and in the 20th century many civic or municipal botanic gardens were developed in which horticultural and educational aspects were emphasized rather than scientific programmes (Heywood 1987; Watson et al., 1993) and the concept of public gardens evolved. The term public garden is used in the United States to cover the complete spectrum of gardens, including botanic gardens and they have been described as 'institutions using living plant collections fort public service through botany and horticulture' (Lighty 1982; see discussion in Watson et al., 1993). It is significant in this regard that that the American Association of Botanical Gardens and Arboreta (AABGA) had its origins in 1940 as an Affiliate of the American Institute of Park Executives, and in 2006, AABGA underwent a 'brand refresh' and became The American Public Gardens Association and now serves over 600 member institutions representing over 9,000 garden professionals in 14 countries.

The western model of a botanic garden was widely adopted in other parts of the world and adapted to local conditions but its relevance of is now being challenged in some part of the world such as the Middle East and south west Asia.

The changing roles of botanic gardens

The diversity of botanic gardens which exists today has evolved largely a response to different circumstances and demands (Heywood, 1987; Krishnan & Novy, 2016). Over the centuries, botanic gardens have occupied various roles, such as:

- study of medicinal plants
- horticultural excellence
- plant exploration
- plant introduction
- seed germination and propagation techniques
- plant and seed exchange
- acclimatation
- phenological observations
- public education and outreach
- environmental education
- horticultural training
- economic botany/ethnobotany
- taxonomic and floristic research
- provision of facilities for recreation and amenity
- displays of plant diversity in conservatories, ornamental gardens,
- native plant gardens
- managed natural vegetation with trails
- plant conservation
- ecological restoration
- seed banking
- tissue and cell culture
- reproductive biology
- adaptation to climate change
- urban greening

If one looks at the mission statements of botanic gardens today, a wide array of aims and aspirations is found (Box 1). Their mission statements often owe less to the CBD or other botanic garden strategy documents than to the need to satisfy the aspirations of the public or their patrons.

Box 1: Examples of botanic garden mission statements

'to promote research and education in horticulture, agriculture and forestry to benefit the people of South Carolina and beyond. The Moore Farms Botanical Garden in Lake City, SC, USA' http://moorefarmsbg.org/

'To build an understanding and appreciation of the botanical world', (BGSH, Adelaide, South Australia)

'To honor and preserve our connection with nature. Ours is a story of connecting people and plants', (San Luis Obispo BG, USA)

'environmental education and the conservation of native and endangered plants of Morocco', (Fez BG)

'...the study of the wild flora of the island of Elba', (Orto dei Semplici Elbano, Italy)

'A Living Museum for the Next Century', (Buffalo & Erie County BG, USA)

'to support, enhance and preserve [the Garden] as a serene, tranquil oasis for all to enjoy.
We develop and present educational programs for both adults and children, to better appreciate the natural world.' (Clark B.G., Albertson, USA)

'To conserve plants in Eastern China, discover sustainable ways of using them, and share our knowledge and enthusiasm with the public', (Shanghai Chenshan B.G., China)

'to conserve tropical and sub-tropical plants and maintain rich biodiversity on earth', (Dr. Cecilia Koo Botanic Conservation Center, Taiwan)

In the past three or four decades, conservation of plant diversity and environmental education have become common although by no means universal goals for botanic gardens (Smith & Pence, 2017). Thus, many of them today have invested effort in *ex situ* conservation, especially of native nationally threatened species, through their living collections, in seed banks or other forms of preservation; and some have taken on additional responsibilities for reintroduction and ecological restoration and a smaller number participate in species recovery and/or reintroduction programmes.

Botanic gardens do not have a formal mandate for plant conservation under any international treaty or agreement and so do not necessarily receive the funding needed to undertake it effectively (Heywood, 2009). At a national level, many of them, even including some that are state-run, do not receive any appreciable specific finance or government support or even recognition for this assumed mandate. As a result, botanic gardens are in the curious situation of playing an important part in implementation of various fields of national policy, for example in helping meet their countries' obligations under the CBD and other environmental treaties such as CITES, contributing to some of the key Aichi targets and Millennium Development Goals, alleviating the impacts of climate change through understanding the mechanisms of adaptation of plants and their capacity to track the climatic shifts, all without adequate funding or recompense. This of course limits their effectiveness as a major conservation instrument. There are of course notable exceptions, such as the dedicated state funding of botanic gardens for conservation actions include the 4-year project, funded by the Swiss Ministry of Environment, aimed at developing a conservation program for 100 Swiss priority species, which will include the preservation of genetic diversity of the species by storing seeds in the seed bank of the Jardin botanique de la Ville de Genève and establishing *ex situ* living collections that are replicated across Swiss botanic gardens and reintroducing or reinforcing wild populations (Ensslin et al., 2018); and the support of botanic garden development in China by both central and local government, for example the East China Wild Endangered Plant Conservation Centre of Shanghai Chenshan Botanical Garden, established with the support of the State Forestry Administration.

In addition to engaging in conservation, there is a growing expectation that botanic gardens should be filling gaps in botanical capacity building and training in the light of the decline of botany in the university sector and in other public institutions[1]. At the same time, public attitudes and expectations of the services that institutions such as botanic gardens should offer, have changed and have in many cases affected policy, with some gardens becoming increasingly like theme parks. As Rakow & Lee (2015) note, 'While botanical gardens are still built around plant collections, many are finding that the plants themselves are not enough to attract the size or diversity of audiences that they need to survive. More and more, gardens are embracing entertainment options to attract young professionals, families, and members of specific ethnic groups. These entertainment approaches and display functions vary from outdoor sculpture exhibits to concert series, themed festivals (chili peppers, pumpkins), cooking demonstrations, model trains, holiday light shows, and antique car rallies'. And as Krishnan & Novy (2016) suggest 'To become relevant in our current society, botanic gardens should evolve from the traditional models of cloistered research and horticulture, which have historically been perceived as being socially elite, to institutions that are more inclusive through adoption of socially relevant and diverse programs with broad nexus to society'.

Defining what is a botanic garden

An important question then that arises from the above discussion is 'What capacity does the current estate of botanic gardens have to meet the challenges they have been given or assumed?' To answer this, a number of issues must be addresses:

- How many gardens do we have?
- How many botanic gardens do we need?
- How do we match the demands to the available capacity, especially given the present highly skewed distribution of botanic gardens and its mismatch with the distribution of global plant diversity?
- Should we support failing botanic gardens, and if so how?
- Are the current models of botanic gardens suited for their present functions?
- Should we consider developing different models which are more suited to local conditions and requirements, rather than the current 'western' ones, as has recently been suggested?

As we shall see, there are no easy answers to these questions.

[1] In the United States, during the last 25 years, college courses and degree programmes in botany have declined by 50% (New England Wildflower Society, 2015)

The calculus of botanic gardens

How many gardens do we have? Although various figures have been suggested, it is remarkably difficult to ascertain how many botanic gardens exist, let alone how many are functional botanic gardens there are and what capacity they must meet the various demands placed upon them. Many botanic gardens have come and gone over the past 500 years and today a considerable number of the world's botanic gardens are struggling to survive and are barely functional.

A major obstacle to answering the question is the fact that the appellation 'botanic garden' carries considerable prestige and at present there is nothing to stop any garden calling itself one without any justification. A considerable number of gardens retain the title even when the functions are lost or have never been achieved. For example, a growing number of botanic gardens have lost or are at risk of losing their functional status because of policy changes made by their sponsors, notably university botanic gardens in Europe.

There is a good case to be made for restricting the use of the term botanic garden although gardens have generally been reluctant to submit themselves to any formal accreditation system with the exception of a few national schemes in Europe and a recently introduced standardisation system in China, as discussed below. A growing number of countries or regions have established a botanic garden association or network. While a few of these have put in place strict regulations that must be followed if an institution is allowed to become a member, in most botanic garden associations or networks, the requirements for membership are much less onerous. Yet the American Public Gardens Association Institutional Membership suggests on its website that many people regard membership as validation that they are operating with best practices and then notes that 'There are, some generally accepted criteria for defining the terms 'botanic gardens' or 'botanical gardens' that American Public Gardens Association asks our members to follow:

- The garden is open to the public on at least a part-time basis.
- The garden functions as an aesthetic display, educational display and/or site research.
- The garden maintains plant records.
- The garden has at least one professional staff member (paid or unpaid).
- Garden visitors can identify plants through labels, guide maps or other interpretive materials.

I proposed in 1985 (Heywood, 1985) that the most satisfactory approach to defining a botanic garden is to list a set of criteria which may be met in part or whole by individual gardens. Such an approach regards botanic gardens as a polythetic group that share many features, no single one of which is either essential for group membership or is sufficient to make an organism a member of the group but each member of the group must possess a certain minimal number of the defining characteristics. Having said that, the essence of a botanic garden is its living plant collections and so how the collections are sourced, cultivated, recorded, made available (and to whom) and monitored, and the use that is made of them, provide the defining criteria and largely describe the activities of botanic gardens. It is of course the living collections that give botanic gardens their name and they constitute in effect the only essential feature of a botanic garden but not sufficient in itself to define one. Thus, a botanic garden is a place with living collections that possesses a majority of the following attributes:

- A reasonable degree of permanence assured
- An underlying basis/rationale for the collections
- Proper documentation of the collections, including wild origin
- Adequate labelling of the plants at all stages
- Monitoring of the plants in the collections
- Open to the public on a regular basis
- Communication of information about the collections to the public, other gardens and other institutions though displays, education and outreach
- Exchange of material from the collections with other botanic gardens, arboreta or research institutions
- Developing expertise in introducing, growing and propagating plants
- Undertaking scientific, technical and horticultural research on plants in the collections
- Undertaking or participating with other appropriate centres in conservation and conservation biology programmes such as *ex situ*, *in situ*, recovery and restoration.

In addition to these attributes, others may be included for the purposes of, say, accreditation, although not otherwise essential as defining criteria, such as:

- Undertaking research in plant taxonomy in an associated herbarium
- Undertaking research in ethnobotany and medicinal and aromatic plants
- Development and maintenance of a seed bank
- Undertaking phenological observations

- Assisting and/or advising in urban greening programmes
- Acting as centres of information to support urban and peri-urban biodiversity
- Official centres for the implementation of conservation legislation and instruments
- Holders of special or national collections of particular groups
- Serving as a historical archive
- Practising ornamental horticulture and floriculture
- Training of professional and amateur horticulturists
- Maintenance and cataloguing of ornamental plant cultivars

All these activities make it very clear that botanic gardens are a very special kind of institution and without parallel. A recent international meeting that I attended in Selinunte, Sicily was entitled 'Botany at the intersection of Nature, Culture, Art and Science'[2] which is a very apt characterization if not definition of a botanic garden. Of course, such an array of possible objectives and uses of the garden can easily lead to a disharmony of function (Watson, et al., 1993)

An unfortunate consequence of the unique nature of botanic gardens, is that they are often not perceived of as museums or as scientific institutions and thereby often not eligible for funding streams available to such bodies. This has contributed to the financial difficulties in maintaining their core activities let alone expanding them.

Botanic gardens and arboreta

The distinction between botanic gardens and arboreta is another difficult area. Most lists of botanic gardens, including the IABG International Directory (Heywood & Heywood, 1990) and the BGCI Garden Search (https://www.bgci.org/garden_search.php) contain many arboreta.

The term arboretum was first used in modern times by the celebrated botanist and landscape and garden designer John Claudius Loudon to refer to a garden consisting of trees and shrubs that were collected for the purpose of scientific study, as in his proposed arboretum in the garden of the Royal Horticultural Society in London (Loudon, 1829) and in his monumental *Arboretum et fruticetum britannicum* (1838) although such collections of trees and shrubs were already known by then.

An arboretum conventionally refers to a scientific collection comprising mainly or exclusively trees. There are many kinds of arboretum and like botanic gardens they may play several different roles today – didactic, scientific and arboricultural research, ornamental, conservation, maintaining genetic diversity and increasingly recreational with some receiving very large numbers of visitors, thus sharing many features in common with botanic gardens. A typology of arboreta has been proposed by Gellini (1990) who recognizes: Collections arboreta, Mixed arboreta, Forestry arboreta, Ecological arboreta, Conservation arboreta, Specialized taxonomic arboreta, including clonal and seed arboreta.

The distinction between an arboretum and a botanic garden is thus not always clear, the main difference sometimes being whether or not there is a focus on trees and shrubs. While most arboreta are independent organizations, botanic gardens often have an arboretum included within them or in a separate location. For example, in the Royal Botanic Garden Edinburgh, the Arboretum refers the former grounds of Inverleith House, in the south west of the Garden where many of the trees in this area were initially planted to teach forestry students and are grouped by botanical families, although there are also other collections of trees in other parts of the Garden. In the case of Oxford University Botanic Garden, the 52ha Harcourt Arboretum is located at Nuneham Courtenay, some 12 miles from the Botanic Garden.

Dendrological Parks are a special kind of area related to both botanic gardens and arboreta and have some of the attributes of a protected area, nature reserve and arboretum as well possessing as other cultural values. They are often distinguished from arboreta but there is a degree of overlap. They are apparently restricted to Eastern Europe and former Soviet territories (such as Azerbaijan, Ukraine, Latvia, Poland, Romania etc.) although according to Pedrotti (2017), nearly all so-called arboreta in Italy correspond to dendrological parks. The Parcul Dendrologic Simeria in Romania is also known as the Simeria Arboretum! And in Germany there is the Botanic-Dendrological Garden Erfurt. In Ukraine, Sofiyivsky Park also known as Arboretum Sofiyivka is an arboretum ('type of botanical garden') and a scientific research institute of the National Academy of Sciences Uman, Central Ukraine. These dendrological parks are discussed in detail by Tamburelli (2007)

Calculus

In the light of the above discussion, it is evident that

[2] http://www.optima-bot.org/down/SELINUNTE_Program.pdf

until decisions are made on the criteria for inclusion or exclusion, it is impossible to give more than an approximation of the number of botanic gardens today. Even if one tries to apply the basic defining a botanic garden as 'a centre holding documented collections of living plants for a range of purposes such as scientific research, horticultural development, conservation, plant introduction, display, sustainability, education and outreach', there are very many borderline cases exist where it is difficult to reach a decision on their inclusion or not. For example, there are instances of institutions that are to all intents and purposes function as public parks or municipal garden but which have a small practical commitment to conserving a number of species. Another problem is that many large private gardens contain large and important collections of plants and while some of them merit being regarded botanic gardens, mostly they have too few of the attributes given in the above definition to be included.

Over the past three years, the IABG Secretariat, under Professor Hongwen Huang, has been critically reviewing the entries in the various listings of botanic gardens and is compiling a list of those institutions that *prima facie* meet the minimal requirements for recognition as a botanic garden, prior to preparing a new edition of the International Directory.

The list currently includes some 2,200 botanic gardens and arboreta[3]. It is currently undergoing a further process of screening and will then be put upon the IABG website so that all gardens will have an opportunity to confirm their entry or make a case for inclusion. If one includes functional arboreta, the total number is likely to be around 2,500 but it should be emphasized that they vary widely in their capacity to undertake the various actions attributed to them.

Botanic garden accreditation

No agency gives legal accreditation to botanic gardens. However, botanic gardens have generally been reluctant to submit themselves to any formal accreditation system apart from a few national schemes in Europe and a recently introduced standardisation system in China, as discussed below. IABG has been exploring the feasibility of introducing a global scheme for accreditation for botanic gardens since 2015 when the issue was raised at a meeting of the Advisory Committee of the Chinese Union of Botanical Gardens (CUBG) and the 2015 Annual Conference of Chinese Botanical Gardens, held at the Xishuangbanna Botanical Garden, Mengun, Yunnan in November 2015. It then commissioned a consultancy report on accreditation for botanic gardens in May 2216 which was discussed in detail at an IABG Accreditation Workshop held at in Shanghai Chenshan Botanical Garden in November 2016. Proposals to move the accreditation process forward were made at the workshop as well as a scheme for the definition of botanic gardens. It made the following recommendations:

- IABG should take the lead in developing a botanic gardens standards/accreditation program
- The IABG Asia Division should promote the standards/ accreditation idea more with the Chinese Union of Botanical Gardens and other relevant groups
- The standards and accreditation program could be first tested in China
- The criteria should continue to be developed in conjunction with the Standardization System of the Chinese A-Level National Botanical Gardens and other relevant programs around the world.
- The accreditation process should include a self-study and a peer review (with possibly international assessors)
- A fee should be applied/considered
- Once the draft standards are written, a meeting could be held for the Asia Region to further develop the ideas

The IABG Council agreed that a scheme for introducing an accreditation system should be developed and a second consultancy report was commissioned. An Information Paper outlining the issues and steps involved and possible options for introducing a global accreditation scheme was prepared (Richardson & Heywood, 2017). Subsequently, IABG convened an International Working Group on Botanic Garden Accreditation including representatives of APGA, BGANZ, CUBG, the European Consortium and BGCI, charged with exploring the issues involved and the feasibility of introducing a global accreditation scheme for botanic gardens. Due to subsequent developments (see below), the work of this group has been paused.

A few national accreditation programmes for botanic gardens have been introduced. An example is that of the Jardins botaniques de France et des Pays francophones (JBF), a professional association of botanic gardens of France and French-speaking countries. Its aims are to

[3] It is remarkable that in the early 1800s Jean Gesner, a Swiss physician and botanist, is said to have noted that by the end of the 18th century there were 1,600 botanical gardens in Europe (1911 Encyclopaedia Britannica vol. 4 Botany).

further the role and work of botanic gardens, improve knowledge, exchange ideas, experience and collections and to participate in the conservation of threatened plants and biotopes and it has developed a Charter of botanic gardens (La charte d'agrément) whose aim is improve the norms and professionalism of the botanic gardens in the network, and serve as a strategic tool for reinforcing their goals and ensure the relevance of research, conservation, education and awareness-raising activities and the quality of information for the dissemination of knowledge and data (Box 2).

Box 2: La charte d'agrément, Jardins botaniques de France et des Pays francophones: the process:
Applicant gardens must submit a letter of application, documentation about the garden and a letter(s) of support from local scientific authorities and a completed application form. If the administrative council of the JBF considers the application is then worth pursuing, it will make arrangements for the nomination of a Rapporteur and for two experts to visit the garden independently and submit their reports to the Rapporteur who will make a summary of the case and submit it to the administrative council for them to reach a decision. If the application is approved, and further appropriate documentation submitted, the garden will be registered as a Charter Member for a period of 7 years, renewable. If the application is rejected, the garden may apply for recognition as a supporting garden (Jardin parrainé).
Source: http://jbf-pf.org/images/agrements/CharteAgrementJBF.pdf

Botanic Gardens Conservation International announced in 2016 that it was planning to introduce an accreditation scheme for botanic gardens showing 'excellence in plant conservation practice'. In 2017 it made it known that it was broadening its accreditation scheme beyond conservation and outlined a scheme but later announced the launch of a substantially different international Botanic Garden Accreditation scheme at the Eighth European Congress of Botanic Gardens in Lisbon, Portugal in May 2018 as well as already listing the first seven accredited botanic gardens. The latest scheme appears to have embraced many features from the IABG information paper on accreditation (Richardson & Heywood, 2017) although it does not mention this or the IABG accreditation working group of which it is a member. It plans to offers three kinds of accreditation: BGCI Botanic Garden; BGCI Conservation Practitioner; and BGCI Advanced Conservation Practitioner, although the latter two are still under development despite accreditation for conservation being the aim of BGCI's original scheme.

From the information available, BGCI accreditation is very much less rigorous than some of the existing national schemes (Box 1; see examples in Richardson & Heywood, 2017) and appears to conflate recognition of botanic garden status with accreditation ('BGCI's accreditation scheme distinguishes botanic gardens from non-botanic gardens…' '…is aimed at botanical institutions wishing to establish their credentials as botanic gardens'[4]). In other relevant accreditation schemes, only a minority of eligible institutions seek or achieve accreditation but if they do not, this does not lead to their loss of institutional status. For example, in the case of the Jardins botaniques de France (JBF) currently (June 2018) there are 27 French, two Swiss and one Monegasque Accredited Gardens (Jardins botaniques Agréés) and six supporting gardens (Jardins parrainés) but a further 40 non-accredited gardens are members of the JBF.

The aim of accreditation is not to decide whether an institution merits the appropriate appellation (museum, botanic garden, etc) but to set and maintain professional standards and the rigorous evaluation of organizations that aim to meet these standards.

The BGCI accreditation scheme lacks transparency: it states that it 'was created through collaboration with a number of botanic gardens, experts and thorough a review of similar accreditation schemes' although no details have been revealed. Nor does it indicate under whose authority in BGCI accreditation is granted and it does not appear to have an approved commission or panel of experts to undertake the evaluation and recommend acceptance or rejection of applications; nor does there appear to be a reporting structure or an appeals mechanism.

How many botanic gardens do we need?

Given the many advantages that a botanic garden can provide to local communities as well as its scientific and horticultural activities, it would be easy to answer this question by saying 'as many as possible' but we need a much more nuanced approach. Each country is of course

[4] http://www.bgci.org/accreditation/ (accessed 25 June 2018)

free to create as many botanic gardens as there are available sponsors, both official and private, but there is also a global dimension to this question if botanic gardens are expected to contribute to meeting the various conservation and other targets that most countries have agreed to meet under the CBD. In terms of need, the current global number of functional botanic gardens and arboreta of around 2,500 is meaningless unless we have criteria against which to measure what is appropriate.

In most countries, the present botanic garden estate is not the result of any planning although some countries are beginning to adopt such an approach, for example, Indonesia where the establishment of new botanic gardens has been identified as one of the national priority programmes. It is planning to establish a new botanic garden in every province of the country, thereby creating 27 new botanic gardens (Widyatmoko & Risna, 2017).

What is concerning is the continuing dramatic mismatch between the distribution of botanic gardens and that of plant diversity (Box 3). Such a mismatch becomes a matter of concern in terms of capacity to undertake conservation actions in response to the international treaties such as CBD and its targets. Although it is not realistic to expect that any dramatic shift is possible in the balance between the number of botanic gardens in Europe and North America and those in tropical countries, we need to address this situation urgently and develop a realistic strategy both north-south and south-south so that conservation capacity can be enhanced in countries in South and Central America (Martins et al., 2017), Sub-Saharan Africa and South and Southeast Asia (Widyatmoko & Risna, 2017), including botanic gardens of various kinds, seedbanks and other *ex situ* facilities so as to support more effective plant conservation, recovery, reintroduction and ecological restoration.

Box 3: Location of botanic gardens: an example of the mismatch with plant diversity

It is well known that the great majority of botanic gardens are found in temperate areas of the world while a minority occur in tropical and subtropical areas. In the UK, for example, although up to 90 botanic gardens and arboreta have been recorded, a detailed review reveals that there are in fact about 32 functional botanic gardens (including at least eight borderline cases) plus seven arboreta. In terms of capacity for conservation, for example, all of them have documented living collections, some of them have seedbanks of various degrees of sophistication (including the unique Kew Millennium Seed Bank), a few are engaged in species recovery or other translocation projects, a few of them have conservation biologists on the staff and most of them are engaged in some form of education and/or outreach. With a vascular flora of some 1400 native species of which very few are endemic (apart from apomicts), there is clearly ample capacity available in UK botanic gardens if needed.

Compare the UK situation with that of a megadiverse country such as Bolivia, with a vascular flora 10 times the size of that of the UK. Bolivia has three functional botanic gardens (of the five recorded two are the same and one has been discontinued). They have some capacity for *ex situ* conservation and have some conservation collections of local flora. None has a seed bank. No conservation biologists are employed.

Determining capacity

It is necessary to determine the capacity of the botanic garden estate to undertake or participate in the various agreed activities to assess how far the demand (once that itself is assessed) can be met. Although some indicators have been proposed to assess botanic garden conservation performance (Havens et al., 2006; Smith & Harvey-Brown, 2017) they are not in common use although the recently launched BGCI-US and The American Public Gardens Association Plant Conservation and Biodiversity Benchmarking site should when fully functional and implemented 'provide the most comprehensive look at current plant conservation capacity for all public gardens throughout North America' via a Conservation and Biodiversity Self-audit worksheet including *in situ* and *ex situ* capacity, research and technical expertise, education and leadership[5]. Likewise, some limited surveys of conservation actions have been undertaken by BGCI (Smith & Harvey-Brown, 2017) but although highly informative, they apply to only less than 10% of botanic gardens and one cannot extrapolate global capacity from them.

Matching capacity to demand: seedbanks

The size of the demand is almost as difficult to assess as the capacity. If we take as an example, *ex situ* conservation

[5] https://www.publicgardens.org/sustainability-index/attributes/biodiversity-and-conservation

in seed banks, the GSPC revised target is at least 75% of threatened species in *ex situ* collections, and at least 20% available for recovery and restoration programmes by 2020. However, the total number of globally threatened species is not known. The IUCN Red List provides a global overview, although limited in value because of the poor level of sampling of most plant groups – with about 5-6% of plant species so far assessed. However, we can estimate with some degree of confidence the number of threatened species as 60-80,000 (Brummitt et al., 2015; Bachman et al., 2016; Heywood, 2009; Heywood, 2017). According to O'Donnell & Sharrock (2017) BGCI's databases indicate that there are at least 350 seed banking botanic gardens in 74 countries, most them are in Europe and the United States, with little capacity in plant-rich areas such as South America, Central Africa and South East Asia. Together they have banked 56,987, taxa, of which 37,000 are held in the Millennium Seed Bank (MSB) of the Royal Botanic Gardens, Kew[6].

Although considerable progress has been made by botanic gardens in contributing to meeting Target 8 of the GSPC, in some parts of the world such as Europe (Box 4) and North America where an analysis by Hird & Kramer (2013) found that approximately 35% of North America's nearly 5000 most threatened taxa are currently in *ex situ* collections, a great deal needs to be done but there is still a serious lack of capacity, especially in tropical countries. Riviere et al. (2018) present a priority-setting method designed to guide collecting strategies across Europe to meet the 2020 GSPC target 8.

THE NEED FOR A COMPREHENSIVE AUDIT

Although botanic gardens are the main institutions involved in the *ex situ* conservation of threatened plant species, many other institutions have seedbanks which include wild species. Globally, there are over 1,750 gene/ seedbanks (Hay and Probert 2013; FAO, 2014), many of which have accessions of wild plant species, maintained by local and national governments, NGOs, universities, commercial companies, the private sector, farmers and others in both the public and private sectors. These include national and regional environment institutes and agencies, agricultural and forestry institutes, specialist facilities such as the Hawaiian Rare Plant Facilities, the West Australia Threatened Flora Seed Centre, the Banco de Germoplasma Vegetal de la Universidad Politécnica, Madrid, the Xingu Seeds Network and the Amazon Portal Seed Network, Brazil. They house a diversity of types of collection, both long term and short term.

Most of the 1,750 gene banks are designed to conserve crop diversity but many of them also include substantial amounts of accessions of wild species, notably Crop Wild Relatives and medicinal and aromatic plants. According to FAO (2010), the nature of the accessions is known for about half of the material conserved *ex situ* and of these 17% are of wild or weedy species. This would appear to contradict the view that wild plants are generally not included in agricultural seed banks. What we don't know is how many of the wild species are threatened but of course they would still contribute to meeting target 9 of the GSPC (70% of the genetic diversity of crops, including their wild relatives and other socio-economically valuable plant species, conserved, while respecting, preserving and maintaining associated indigenous and local knowledge)

The gene bank system of the agricultural sector is well organized and includes the gene banks of the 11 CGIAR centres which manage seed and other germplasm collections on behalf of the international community. Then there are many other international and regional institutions such as the Nordic Genetic Resources Centre and the Southern African Development Community Plant Genetic Resources Centre. At a national level, major gene banks include those of the Institute of Crop Sciences (ICS) of the Chinese Academy of Agricultural Sciences. the China National GenBank (CNGB), the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) in Gatersleben, Germany, the United States National Plant Germplasm System, the N. I. Vavilov All-Russian Research Institute of Plant Industry, St Petersburg, and the National Bureau of Plant Genetic Resources (NBPGR), India.

A comprehensive audit is needed of the wild plant seed holdings of these gene banks so that a proper assessment can be made of the coverage and the gaps in the *ex situ* seed collections. Much closer cooperation should be encouraged between the agricultural, forestry and the biodiversity conservation sectors as I have previously advocated (Heywood, 1999a,b). As the Second Report of State of the World's Plant Genetic Resources for Food and Agriculture (FAO, 2010) notes, although in some countries, stakeholder consultations held to develop national responses to GSPC have been successful in

[6] Kew's Millennium Seed Bank partnership is the largest *ex situ* plant conservation project in the world.

bringing the botanical garden and environmental sectors together with the agricultural sector, 'in many countries cross-sectoral linkages remain poorly developed and botanical garden are not generally included national PGR programmes or networks.'

An example of a multisectoral approach to seed banking is the Hawai'i Seed Bank Partnership (HSBP)[7], a group of cooperating partners dedicated to the use of seed banking, based on scientific research, to preserve genetic diversity of native plant species for the purposes of conservation and restoration. The HSBP began in 2012 with four members and today, the HSBP has grown to include over 30 representatives from 15 organizations. Founding Partners of HSBP include representatives from Lyon Arboretum, O'ahu Army Natural Resources Program, National Tropical Botanical Garden, and Hawai'i Island Seed Bank, with support from research partners at the USDA's National Center for Genetic Resource Preservation. Current Partners also include representatives from US Fish & Wildlife Service, State of Hawai'i Department of Land & Natural Resources - Division of Forestry & Wildlife, Plant Extinction Prevention Program of Hawai'i, Pu'u Kukui Watershed Preserve, Wai'anae Mountains Watershed Partnership, Haleakalā National Park, Hawai'i Volcanoes National Park, UH Mānoa Department of Botany, UH Center for Conservation Research & Training, and Maui Nui Botanical Gardens.

This example highlights the value of adopting a broad approach to seed banking of wild species and the importance of looking out beyond the confines of the botanic garden and the conservation agency.

Seed banking in Europe

Compared with other areas of the world, the situation in Europe is well organized with a series of initiatives and networks for both wild and agricultural species (Box 4)

Box 4: Seed banking in Europe

In Europe, seed banking of both wild species and agricultural material is well organized. The European Native Seed Conservation Network (ENSCONET), a partnership of 31 organizations, including many botanic gardens, from 20 European countries operated from 2005 to 2009.

An important output was ENSCOBASE, the European Native Seed Conservation Database which contained 39,292 entries from 20 seed banks across Europe, representing accessions from 8,973 taxa native to Europe. At the end of the project the partners established the ENSCONET Consortium with the aim of maintaining significant levels of seed conservation activity across the continent. Seed banks belonging to the ENSCONET Consortium 'have made significant progress in the conservation, storage and dissemination of information of European native species, meeting targets 8b and 9 of the Global Strategy for Plant Conservation well in advance of the deadline' according to an analysis by Rivière & Müller (2017). A priority-setting method designed to guide collecting strategies across Europe to meet the 2020 GSPC target 8 was proposed by Rivière et al. (2018). They produced a country-based checklist of European threatened taxa to be collected and stored *ex situ* across the seed banks of the ENSCONET Consortium by 2020.

The European Cooperative Programme for Plant Genetic Resources (ECPGR) involving most European countries, aims at ensuring the long-term conservation and utilization of plant genetic resources in Europe. The Strategic Framework for the Implementation of a European Genebank Integrated System (AEGIS), is a platform connecting European gene banks under a common system for the long-term conservation of Plant Genetic Resources for Food and Agriculture (PGRFA), including wild species such as Crop Wild Relatives and Medicinal and Aromatic Plants.

In addition, the first European Community Exchange (ECE) on Seed Diversity and Access in Europe, with a focus on agrobiodiversity in local and regional seed banks, took place earlier this year (2018).

Seed banks in context

The accessions in seeds banks, along with living collections in botanic gardens, amongst other uses are important sources of material for species recovery and reintroduction programmes and for ecological restoration. Such programmes often require nursery and greenhouse facilities to produce the often very large numbers (as many as 500,000) of outplants required for translocation. So, to meet the requirements of species recovery and reintroduction programmes and the increasing emphasis on ecological restoration, we need

[7] http://laukahi.org/hawaii-seed-bank-partnership/

not only large amounts of seed and living collections as source material but nurseries, greenhouses, planting areas and skilled staff. No comprehensive assessment has been made of the existing capacity of botanic gardens to grow such quantities of material but it is certain that not many botanic gardens are able on their own to provide this because of the lack of available space and finance, although quite a number do so on a small scale.

This then raises the question of the need to develop specialized facilities to complement the efforts botanic gardens. In practice additional specialized conservation facilities have been created in several parts of the world such as the Rare Plant Facility in Hawai'i which comprises a range of nurseries, greenhouses and horticultural laboratories at several sites and the Native Plant Biodiversity Conservation Nurseries in North Caicos and Providenciales (Box 5). Other examples are the nurseries and other facilities provided by environment agencies and by forestry institutes.

The model of the Conservatoires botaniques nationaux in France is another approach to addressing the practical needs of plant conservation: the Fédération des Conservatoires botaniques nationaux (FCBN), is a network of 11 botanical conservatories (three in the Mediterranean region) aimed at the conservation of the wild plant species of France and its overseas territories. Under an agreement with the French Ministry of the Environment each Conservatoire is responsible for acquiring knowledge and undertaking conservation of the wild flora and natural and semi-natural habitats of a territory made up of a number of Departments with a biogeographical coherence. Their conservation programmes include *ex situ* (seed banking, cultivation of threatened species) and *in situ* actions in collaboration with protected area managers. Some are incorporated in an existing botanic garden.

Box 5: Non-botanic garden specialized conservation facilities

The Hawaiian Rare Plant Facilities

It has been estimated that there are c. 1,400 vascular plant taxa are native to the State of Hawai'i, nearly 90 percent of which are endemic to the state. 220 plant species have populations of fewer than 50 wild individuals remaining. The Hawaiian Rare Plant Facilities, are part of a state-wide programme Plant Extinction Prevention Programme (PEPP) committed to saving Hawai'i's rarest native plants from extinction by propagation and outplanting. They include four mid-elevation rare plant nurseries (at Volcano on Hawai'i Island, Pahole on O'ahu, Kōke'e on Kaua'i, and Olinda on Maui) and the Kealia rare plant nursery on Kaua'i.

Native Plant Biodiversity Conservation Nurseries in North Caicos and in Providenciales

The Department of Environment and Maritime Affairs has two native plant nurseries, located on Providenciales and North Caicos. Between them, over 110 species of native plants are propagated and research is undertaken to determine the best horticultural methods to grow them. Amongst the species recovered is the Caicos pine *Pinus caribaea* var. *bahamensis*.

The USAID and US Forest Service funded SEED project near Sabha, Jordan is training local women to collect and propagate native seeds, manage a local nursery, develop effective planting mediums, and manage all aspects of the nursery process. They grew and sold 94,000 seedlings their first year! This project is one of numerous local nursery programs designed to create a supply of native seedlings for restoration and conservation while also generating local economic opportunities by employing and training local people.

Are the current models of botanic gardens suited for present demands?

Do we need different models of botanic garden to accommodate the growing range of demands on them? How far does the current western model need to be supplemented by new types of specialized facility? Is the western model suitable for all countries or regions?

Many major well-funded gardens have been able to accommodate recent demands to take on responsibilities such as conservation when part of their present-day remit, but these are mostly located in temperate zones. More common is the situation of gardens with limited resources which are only able to undertake limited conservation, scientific and other activities.

Already many botanic gardens are departing in part at least from the western stereotype model. In term of conservation, there are botanic gardens that focus primarily on the cultivation and conservation of the local/regional flora such as the Jardín Botánico Canario 'Viera y Clavijo', and the Desert Botanical Garden, Phoenix, USA, devoted to education, research, exhibition and conservation of desert plants. The Andalusian

Network of Botanical and Mycological Gardens in Natural Spaces (Red Andaluza de Jardines Botánicos y Micológicos en Espacios Naturales – RAJBEN) initiated in 2001 comprises 12 botanic gardens located in natural vegetation communities in different biogeographic zones in Andalucía, Spain, and their role is the study, monitoring, cultivation, conservation, recovery and display of the flora and vegetation of the areas concerned, especially of rare and endangered plant species as well as environmental education and public outreach. They are provided with the infrastructure necessary to undertake these tasks and some have visitor or reception centres.

Some gardens are responding to public pressure for better visitor facilities such as the George Brown Darwin Botanic Gardens, Northern Territory, Australia which is about to undergo a $9.9 million facelift, with a new multi-purpose visitor and event centre to be built there as part of the Territory Government's $103 million Turbocharging Tourism stimulus package. According to the press release[8], the centre will be available for small conferences, weddings and community events, with interpretive materials leading visitors out into the beautiful gardens. The Bendigo Botanic Gardens, Victoria, Australia[9] which has adopted a master plan for the rejuvenation and extension of the garden, including a new contemporary Garden, The Garden for the Future, opened in May 2018, which is a multifunctional space, capable of holding an audience of well over 1000 people, .catering for public amenities, education and outdoor classrooms, as well as landscaping and collections planned for protected climate change, and seeking to connect people with plants in innovative ways (Creme, 2018). Broader objectives of the project were to improve the liveability, health, wellbeing and economy of the area.

Alternative models of botanic garden

In recent years, a range of innovative types or models of botanic gardens has been developed. Some examples are given in continuation:

- **The Chinese model**

China is engaged in a remarkable development of new botanic gardens (Fig. 1) over the past 30 years. Many of them are members of the Chinese Union of Botanical Gardens (CUBG) which is jointly sponsored by the Chinese Academy of Sciences, State Forestry Administration and Ministry of Housing and Urban-Rural Development. The CUBG provides a platform for Chinese botanic gardens to promote strategic cooperation, exchange of scientific and technical expertise, and information sharing

Because of strong national and local government support, some of these Chinese botanic gardens can include large scale research and conservation facilities such as those of Shanghai Chenshan Botanical Garden, South China Botanical Garden, Guangzhou and Xishuangbanna Tropical Botanical Garden, Yunnan. They also have a strong commitment to contribute to the local economy (Box 6).

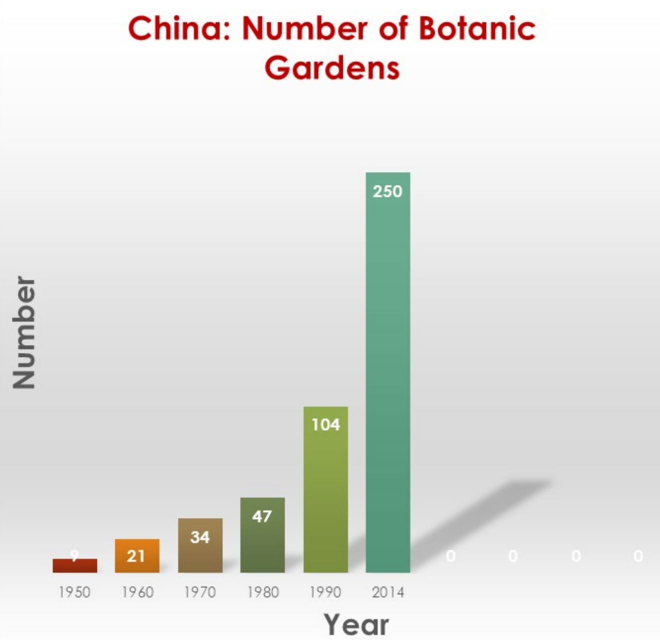

Figure 1: Growth of botanic garden numbers in China

8 http://newsroom.nt.gov.au/mediaRelease/24232
9 http://www.bendigobotanicgardens.com.au/

Box 6: Shanghai Chenshan Botanical Garden and sustainable development

The Chenshan Botanical Garden has contributed to the sustainable development of Shanghai City in the last six years and provides perspectives on future plant conservation and sustainable utilization. Sustainable economic growth is demanded by regions and countries with urbanization globally. Shanghai Chenshan Botanical Garden works closely with the local government in the 'City Green Master Plan' to increase plant diversity in rural park projects. It also provides technical support to city construction by introducing urban horticulture and phytoremediation. More than 20% of the plants in the most urbanized and industrialized areas in China are under threat. Chenshan has collaborated with the central government and the administration of local reserves in the conservation of 14 critically endangered plant species in East China. This has made the sustainable utilization of these plants possible. Chenshan also has a strategic vision to provide people with functional food. Secondary metabolism and gene-manipulating platforms have been already implemented to develop new varieties of plants to achieve this goal. As a botanical garden, Chenshan aims to attract and educate the public with its landscapes, seasonal flower shows, and cultural events. Chenshan helps visitors understand the condition of plants and the ways to protect them.

Source: Hu et al. (2017)

- **Other models**

Hippocrates Botanical Garden in Markopoulo Industrial Park, Attica, near Athens, Greece, was created in 2013 in the surrounding area and on the rooftops of the bioclimatic building of the cosmetics company APIVITA. It is a small botanic garden with 200 species from the Greek native flora and is part of a space for interactive contact with the native biodiversity that surrounds and complements the APIVITA factory.

New botanic garden at Taita research station, of the University of Helsinki, located in Wundanyi at the altitude of 1400 m in the center of the Taita Hills. In close vicinity to the station there is a three-hectare valley reserved for a new botanic garden. The plan for the garden includes solutions for local water management, agricultural test plots, and a native forest restored using plant material collected from local populations. The new garden would serve both the local community and students from all over the world by introducing them to the indigenous flora as well as showcasing sustainable agricultural practices and ethnobotanical heritage. The project will be carried out in close collaboration and interaction with the local authorities, NGOs and representatives of the neighbouring farmers. (Hyvärinen et al. 2018)

Lismore Rainforest Botanic Gardens (LRBG), NSW, Australia (http://www.friendslrbg.com.au/)

LRBG is an initiative of a non-profit group of volunteers working in conjunction with the Lismore City Council to establish, develop and maintain the Lismore Rainforest Botanic Gardens. The gardens have been established on waste land on the southern outskirts of Lismore and grows only native plants – mostly rainforest - endemic to an area within 200kms of the city of Lismore. One of the aims is preserve as many as possible of the species found in the rainforest. Their aim is summed up as follows: 'Being one of the new style botanic gardens we have few formal garden beds. We are instead working at creating an environment in which local indigenous plants will thrive in a natural environment. At the same time we have to develop a Botanic Garden and not just a regeneration site. Plants have to be accessible to the public and the site needs to be a beautiful place to visit'

Les Jardins Suspendus, Le Havre, France

The Hanging gardens are the latest French garden labelled as botanic by the association of the French and French speaking botanic gardens, in September 2017, simultaneously with the 500th birthday of the city of Le Havre. 'It is a garden, created in the city of Le Havre, Normandy in an ancient XIXth century fort, abandoned by the army in the 70's. Opened to the public in 2008 as a local park, it is still the main garden of its neighborhood, but moreover it has become one of the main touristic attraction of the city (150 000 visitors/year) as well as a recognized young botanic garden. Within its 10 ha, the garden tries to reveal the relationships between man, ocean and the plants by testifying how the main temperate regions of the word such as eastern north America and Asia or the austral regions, re-discovered by the Europeans during the last centuries, have successively enriched the gardens of western Europe.' Levain (2018)

Pha Tad Ke Botanical Garden, Laos

This is the first botanic garden in Laos. It is a regional research center in Luang Prabang, Laos and aims to bring 'a snapshot of the region's impressive biodiversity into the heart of the country's largest city by creating educational programs and acting as a tourist destination to promote the incorporation of edible and local plants into urban environments and to build awareness around local environmental preservation initiatives. Its mission is to 'develop educational programs for all age groups while conducting research into plant reintroduction, horticulture, ethno-botany and medicinal plants to address critical problems ranging from the management of local natural resources to conserving biodiversity worldwide. The natural setting of Pha Tad Ke Botanical Garden encourages contemplation, stimulation, and creativity. We believe that Art and Culture take a central place in our work to help with this consciousness shift for towards a more liveable world.

Nezahat Gökyiğit Botanic Garden, Istanbul

This garden developed in the loops of land in motorway junctions is not so much a new model of a botanic garden as a novel way of using land that is normally regarded as unsuitable. Despite its challenging location, a full-scale botanic garden with display, conservation collections, seed bank, herbarium, education and public outreach has been successfully developed.

- **Ancillary botanic gardens – the case of Lebanon**

'For botanic gardens to be established and sustained by Lebanon and the Lebanese, there is a need to deconstruct the traditional concepts of a botanic garden and recreate institutions based on new components that are culturally acceptable', Talhouk et al. (2014).

Because a botanic garden is not regarded in Lebanon as having sufficient priority to set aside land for it, given that it cannot compete with other more lucrative land use options, a proposed alternative is to look for lands where the options for urban and agriculture expansion options are restricted and where a botanic garden is one of the few possible land uses.

Ancillary botanic gardens (ABGs) are described as '… informal, deregulated gardens for the conservation of plant diversity and cultural plant knowledge; they are established by local communities in open sites which have existing levels of land protection owing to their primary purpose as archaeological sites, educational institutions, religious landholdings, private institutions and touristic sites'.

DISCUSSION

The global botanic garden estate is highly diverse and becoming more so in face of the pressures caused by the growing number of new demands on it. Prominent in these are undertaking plant conservation, a commitment that many botanic gardens have been encouraged to assume, and provision of quality facilities such as visitor and event centres as a means of attracting the public and increasing revenue. Related to this is the recognition of the importance of a playing a strong role in the affairs of the local community. Botanic gardens are adapting to these challenges in different ways and several new or modified models of garden are emerging which depart to a greater or lesser degree from the conventional western stereotype.

The diversity of ownership of botanic gardens is both a strength and a weakness: botanic gardens that are part of national or regional government networks, as in Australia and China, are often better resourced and able to meet a range of demands successfully, but the same is true of some privately funded gardens in the USA, for example. University botanic gardens, especially in Europe, often face severe challenges in maintaining their scientific role as botany loses its status as an academic subject. Several have closed and others are under threat. Municipal botanic gardens often have to prioritize enhancing the visitor experience at the cost of scientific activities to justify their existence. This diversity places great strains on the sustainability of the global botanic garden estate and it is to the great credit to the staff and leadership of the world's botanic gardens that they have collectively been able to make such major contributions to science and society in the past 30–40 years in which global change (including accelerated climate change) has transformed so much of our environment, society and socioeconomic structure.

The actual number of botanic gardens that meet the definition as 'a centre holding documented collections of living plants for a range of purposes such as scientific research, horticultural development, conservation, plant introduction, display, sustainability, education and outreach' is probably around 2,500 which is much lower than some current estimates. The criteria for inclusion are generally agreed but the problem is that there is no agreement on how many (or how few) of these criteria need to be met to achieve this. It would be helpful to have a thorough, wide-ranging and open debate on the issues involved and on the advantages and disadvantages of accreditation schemes for botanic gardens.

The historical imbalance in the distribution of botanic gardens remains a challenge, with most gardens in Europe and the USA. Given the multiple roles that botanic gardens can play and their increasing societal interaction, the creation of new ones, even in regions that are already well provided for, is to be encouraged.

How to increase the number of botanic garden regions of high plant diversity such as tropical America, southwest Asia, east Asia, and sub-Saharan Africa requires urgent political action and international cooperation and support. The fact that public expenditure related to the environment is not only decided nationally but is often devolved to subnational and local levels, can be both an advantage and a disadvantage. The growth and development of botanic gardens in China in the past 30-40 years largely supported by national and local government is a remarkable achievement.

The capacity of botanic gardens to undertake the various activities included in their remit has never been comprehensively assessed although various partial surveys have been undertaken. All these activities need skilled specialist staff and most botanic gardens have difficulty in making such provision. In many cases, the specialist staff such as conservation biologists, ecologists plant physiologists and geneticists are university staff with research and teaching commitments rather than fulltime botanic garden employees. As regards plant conservation, the main role played by botanic gardens is in maintaining well sampled and documented living collections of wild origin species and gene banks (mainly seed banks) which can provide material for use in various conservation actions such as species recovery (by population augmentation), reintroduction and ecological restoration. The horticultural skills and experience in germinating and growing a diversity of plants can be invaluable in conservation programmes although it must be recognized that there is a serious lack of conservation horticulturists in many parts of the world. For the successful delivery of species recovery and reintroduction programmes, multidisciplinary teams involving a range of institutions is necessary (Heywood et al., 2018) and botanic gardens can often form part of such consortia.

Although botanic gardens have made very considerable advances in in seed banking in recent years, they do not at present have the capacity needed to hold and maintain accessions of all known threatened plant species. Even with the addition of other seedbanks which hold accessions of wild seeds, there is still likely to be a substantial deficit. The situation is especially acute in many tropical countries where the numbers and functionality of seed banks containing wild seeds and their accessions are seriously inadequate and reliance on material from gene banks in other countries is only a poor and partial solution. It is unlikely that the additional capacity needed in these countries will be made available in the short term, especially in tropical countries.

For example, the situation of seed banking of wild species in Brazil has been analysed in several recent papers. According to Martins et al. (2017), currently only 20% of threatened species are in botanic gardens (Costa et al., 2016) and only 1.4% in seed bank collections (Forzza et al., 2016) and they conclude that the current scenario of *ex situ* conservation in Brazil suggests that Target 8 is an unachievable goal for 2020. Another study (Teixido et al., 2017), found that seeds of Brazilian species were banked to international conservation standard in only three institutions in Brazil – Genetic Resource and Biotechnology Center (CENARGEN-Embrapa), Porto Alegre Zoo-Botanic Foundation (FZB-RS) and Rio de Janeiro Botanical Garden (JBRJ) – and reported 'a noticeable gap of knowledge and practice of *ex situ* seed conservation of threatened species in Brazil'. Nonetheless, they considered that the relatively low economic costs estimated to attain the Target suggest meeting Target 8 is economically feasible in a short-term although unlikely to be achieved due to the lack of appropriate nationwide strategies and conservation policies. Likewise, In an assessment of the conservation capacity of Brazil's botanic gardens, da Costa et al. (2017) found that of the 26 (out of 36) gardens analyzed there were two with active seed banks: JBRJ with three species from the 2008 Red List and Jardim Botânico da Fundação Zoobotânica do Rio Grande do Sul (FZBRS) with six species from the Rio Grande do Sul state red list.

Similar challenges are faced by other megadiverse countries (see discussion by Maunder et al., 2004) and while there is little likelihood of GSPC target 8 being achieved by them by 2020, it should be a matter of priority that appropriate resources should be committed by the countries and donors to allow the necessary facilities and infrastructure to be put in place so that there is a realistic chance of any future post-2000 targets being met.

Botanic gardens are relative newcomers to seed banking. At the time of preparing the Botanic Gardens Conservation Strategy, in which *ex situ* conservation by botanic gardens is highlighted (Heywood 1989), and subsequently the establishment of the IUCN Botanic Gardens Conservation Secretariat (Later BGCI), many in the conservation community, including IUCN, were strongly opposed to the notion of *ex situ* conservation, ostensibly on the grounds that it would send out the wrong message and might encourage governments to reduce their efforts to conserve species *in situ* if they could be maintained more cost effectively in seed banks. Moreover, the conservation effectiveness of the *ex situ* approach was queried by many on technical and scientific grounds and both the CBD and the GSPC make it clear that *in situ* is the preferred approach and that *ex situ* plays a supporting role. A remarkable exception to this the negative view of the role of seed banks in wild species conservation was the creation by the Royal Botanic Gardens Kew of the Millennium Seedbank of the at Wakehurst Place in 1996 which later developed as an international Millennium Seed Bank Partnership and came to play a key role in the conservation of seed of wild plant species. It should also be noted that the Center for Plant Conservation (CPC), a network of US botanic gardens and arboreta, promoted and supported plant *ex situ* plant conservation since 1984 as well as supporting the concept of integrated conservation. One of the trilogy of books on plant conservation that was sponsored by the CPC is the volume '*Ex situ* Plant Conservation' (Guerrant et al., 2004) which remains a key reference.

Today, a more balanced view of *ex situ* conservation is generally adopted which recognizes the important role that *ex situ* collections plays as part of an integrated conservation strategy: as a source of material for use in species recovery and reintroduction and in ecological restoration; and as an insurance mechanism to provide germplasm for use in adapting to global change.

In fact, *ex situ* conservation by seed banking (and much of the technology and protocols) was pioneered by the agricultural sector to make provision for the storage of rapidly disappearing materials such as landraces and cultivars of crop species needed for plant breeding and development of new cultivars adapted to changing conditions. This led to the development of the genetic resources sector and the system of national, regional and international gene banks and the CGIAR Crop Centres and the subsequent establishment of IBPGR (Later Bioversity International) and the adoption of the International Treaty of Plant Genetic Resources for Food and Agriculture in 2001 (see Hawkes et al., 2000). It is not suggested that agricultural seed banks should be regarded as a model to be followed by botanic garden seed banks, given their different goals, and indeed Schoen & Brown (2001) cautioned against this. But there is much to be learned from each other and given the limited capacity of botanic gardens to provide the necessary seed banking and related facilities, much closer cooperation between botanic garden and other wild species seed banks and those in the agricultural sector is needed.

The global, regional and national organization of agricultural gene banks is highly effective although there are still gaps in coverage. It is doubtful, however, if the current informal organization of wild seedbanks is adequate to achieve the desired goals, as I have previously argued: 'This is a vast enterprise and not one that botanic gardens can or should attempt on their own' (Heywood, 2002). While countries may develop their own national strategies, a global strategy and mechanism for the *ex situ* conservation of wild species is needed. This could be a joint endeavour between the CBD/GSPC, CGIAR, FAO and other agencies (Laliberté, 1997; Heywood 2002, 2009).

CONCLUSIONS

The range of activities undertaken by botanic gardens today has highlighted the need for a serious and wide-ranging debate on the criteria that should be adopted for definition of a botanic garden and the desirability of introducing national or global accreditation schemes

Consideration should be given to the need for new models of botanic garden to meet changing public expectations.

A comprehensive audit of the capacity of botanic gardens to contribute to the relevant conservation goals of the CBD/GSPC and the Aichi targets, notably *ex situ* conservation, species recovery and reintroduction, should be undertaken.

Despite major advances in the past 30 years, the present distribution and capacity of botanic gardens for seed banking and related activities does not match the demand. Even considering the seed banking of wild species undertaken by institutions other than botanic gardens, there will remain a major deficit. The low number of botanic gardens and seed banks in many tropical countries is limiting factor that needs urgent national and international action if it is to be remedied.

The development of other types of specialized facility to complement the conservation capacity of botanic gardens should be encouraged.

If the targets for seed banking in present and future strategies are to be realized, a global action plan is needed that involves all the relevant sectors — biodiversity conservation and ecological restoration, forestry and agriculture. Is should involve the CBD, CGIAR, ECPGR, FAO, UNEP, IUCN, BGCI, IABG and other major botanic garden organizations such as BGANZ, CUBG, APGA, and the European Consortium.

It follows that all institutions and agencies involved in *ex situ* conservation need to work together. An integrated and cooperative approach to wild species seed banking between the various sectors and agencies concerned is needed.

REFERENCES

Arapetyan E. (2015) *'Botanical Gardens are the main base for education for sustainable development'* Thaiszia J. Bot. 25 (Suppl. 1): 7-11.

Arias-Maldonado, M. (2013) *'Rethinking Sustainability in the Anthropocene.* Environmental Politics 22: 428–446, http://dx.doi.org/10.1080/09644016.2013.765161

Arias-Maldonado, M. (2015) Environment and Society: Socionatural Relations in the Anthropocene (SpringerBriefs in Political Science. Springer)

Bachman S, Fernandez EP, Hargreaves S, Nic Lughadha E, Rivers M, Williams E (2016) *'Extinction risk and threats to plants'.* In: RBG Kew, state of the world's plants report-2016. Royal Botanic Gardens, Kew, pp. 58–63

Brummitt, N.A, Bachman, S.P., Griffiths-Lee, J, et al (2015) *'Green plants in the red: a baseline global assessment for the IUCN Sampled Red List Index for Plants'.* PLoS ONE 10(8): e0135152. doi: 10.1371/journal.pone.0135152

Catahan, N. & Woodruffe-Burton, H. (2017) Strategically Managing Sustainable and Innovative Business Development in Uncertain Times: An Exploratory Study of Botanic Gardens. The 50th Academy of Marketing Conference, Freedom Through Marketing: Looking Back, Going Forward., 3rd July 2017 - 6th July 2017, Hull University Business School, ISBN 978-1-5272-1271-8.

Costa, M. L. M. N., Bajgielman, T. (2016) Estratégia Nacional para Conservação *Ex Situ* de Espécies Ameaçadas da Flora Brasileira. Andrea Jakobsson Estúdio, Rio de Janeiro.

Creme, B. (2018) *'The Garden for the Future is open!'* THE BOTANIC GARDENer 50: 21–25.

Ensslin, A. Bürli, S., Fisher, N. (2018). *'Ex situ plant conservation and reintroduction by botanic gardens: establishing a programme to safeguard 100 priority species in Switzerland'.* EuroGard 8 Abstract volume p. 100.

Entwisle, T.J., Cole, C., Symes, P. (2017) *'Adapting the botanical landscape of Melbourne Gardens (Royal Botanic Gardens Victoria) in response to climate change'*. Plant Diversity 39: 338-347.

FAO (2014) Genebank Standards for Plant Genetic Resources for Food and Agriculture Revised ed. Food and Agriculture Organization of the United Nations, Rome

Forzza, R. C., Carvalho, A. Andrade, A. C. S. et al., (2016) Coleções biológicas do Jardim Botânico do Rio de Janeiro à luz das metas da GSPC/ CDB: Onde estaremos em 2020? Museol. & Interdiscipl. 9: 135–159.

Gratzfeld, J. (2018) *'Conservation horticulture in times of rapid change – a fundamental, yet underappreciated role of botanic gardens'.* EuroGard 8 Abstract volume p.49

Guerrant, E.O., Havens, K., Maunder, M. (2004). *Ex situ* Plant Conservation. Supporting species survival in the wild. Island Press, Washington DC

Heywood, V.H. (1985). *'Botanic gardens and taxonomy– their economic role'.* Bull Bot Survey India 25:134–147

Heywood, V.H. (1985) Botanic Gardens Conservation Strategy. First draft for WWF and IUCN prepared by Vernon H Heywood. WWF and IUCN, World Conservation Centre, Gland.

Heywood, V.H. (1999a) *'Trends in agricultural biodiversity'* in J. Janick (ed.) Perspectives on New Crops and New Uses, pp.2–14, ASHS Press, Alexandria, USA.

Heywood, V. H. (1999b). *'The role of botanic gardens in ex situ conservation of agrobiodiversity'.* In: Gass, T. Frese, L., Begemann, F. & Lipman, E. (eds), Implementation of the Global Plan of Action in Europe – Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture. Proceedings of the European Symposium, 30 June–3 July 1988, Braunschweig, Germany. International Plant Genetic Resources Institute, Rome, 1999, pp. 102–107.

Heywood, V. (2002). *'The future of botanic gardens – challenges and conflicts'.* In: Jardins Botânicos. Que perspectivo para o futuro? Actas VII Simpósio da Associação Ibero-Macaronésica de Jardins Botânicos. 24 a 26 Jilho 2002, Auditorio da Lagao Branca, Tapada da Ajuda, Lisboa, Instituto Superior de Agronomia, Lisboa, pp. 11–21.

Heywood, V. (2009) *'Botanic gardens and genetic conservation'* Sibbaldia guest essay. Sibbaldia. The Journal of Botanic Garden Horticulture No. 7, pp. 5–17.

Heywood, V.H. (2011) *'The role of botanic gardens as resource and introduction centres in the face of global change'*. Biodiversity and Conservation 20: 221-239.

Heywood, V.H. (2015) *'Mediterranean botanic gardens and the introduction and conservation of plant diversity'.* Flora Mediterranea 25 (Special Issue): 103-114 doi: 10.7320/FlMedit25SI.103

Heywood, V. Shaw, K., Harvey-Brown, Y. and Smith, P. (eds.) (2018) BGCI and IABG's Species Recovery Manual. Botanic Gardens Conservation International, Richmond, UK

Havens, K., Vitt, P., Maunder, M., Guerrant, E.O & Dixon, K. (2006). '*Ex situ* plant conservation and beyond'. BioScience 56: 525–31.

Hird, A., Kramer, A.T. (2013) *'Achieving target 8 of the global strategy for plant conservation: Lessons learned from the North American collections assessment'.* Annals Missouri Botanical Garden 99: 161-166. DOI: 10.3417/2011114

Hu, Y., Vincent, G., Chen, X. (2017) *'How can botanical* *gardens support sustainable urban development? A case study of Shanghai Chenshan Botanical Garden'.* Annals Missouri Botanical Garden 102: 303–308.

Hu, Y., Yang, S., Yang, J. (2017). *'Botanical gardens support urban sustainable development: a case study from the Shanghai Chenshan Botanical Garden'.* [J]. Biodiversity Science 25(9): 951-958.

Hyvärinen, M., Jovero, S., Pehkonen, P., Schulman, L. (2018) *'Conservation of Tropical Montane Forest in Taita Hills – How A Botanic Garden Could Make A Difference'.* EuroGard 8 Abstract volume pp. 82–83.

Krishnan, S., Novy, A. (2016). *'The role of botanic gardens in the twenty-first century'.* CAB Reviews Perspectives in Agriculture Veterinary Science Nutrition and Natural Resources 11:1-10.

Levain, A. (2018). *'The Hanging Gardens (jardins suspendus): in Normandy, the latest French botanic garden'.* EuroGard Abstracts volume p. 144.

Loudon, J.C. (1829). *'Arboretum in the Garden of the Horticultural Society'.* The Gardener's Magazine and Register of Rural & Domestic Improvement. 5: 344–348.

Martins, E., Loyola, R., Martinelli, G. (2017) *'Challenges and Perspectives for Achieving the Global Strategy for Plant Conservation Targets in Brazil'.* Annals Missouri Botanical Garden 102(2):347-356 https://doi.org/10.3417/D-16-00009A

Maunder, M., Guerrant, E.O., Havens, K., Dixonm, K.W. (2004) *'Realizing the full potential of Ex situ contributions to global plant conservation'*. In: Guerrant, E.O., Havens, K., Maunder, M. (2004). *Ex situ* Plant Conservation. Supporting species survival in the wild. Pp. 389–418. Island Press, Washington DC

New England Wild Flower Society. 2015) State of the Plants: Challenges and Opportunities for Conserving New England's Native Flora. Framingham, MA.

Opdam P., Verboom J., Pouwels R. (2003) *'Landscape cohesion: an index for the conservation potential of landscapes for biodiversity'.* Landscape Ecology 18:113–126.

Pedrotti, F. 2017. L'Arboreto dell'Università di Camerino. Collana *Natura e aree protette* No. 34. Tipografia Editrice TEMI, Trento.

Prestø, T. (2018). *'Should We Stay Or Should We Go? Land use, climate change and sustainability of an alpine Botanical Garden in Norway'.* EuroGard 8 Abstracts vol. pp.64–65. Biodiversity and Conservation

Rakow, D.A., Lee, S.A. (2015). *'Western botanical gardens: history and evolution'.* Horticultural Reviews 43: 269–311.

Rivière, S., Müller, J.V. (2017) *'Contribution of seed banks across Europe towards the 2020 Global Strategy for Plant Conservation targets, assessed through the ENSCONET database'.* Oryx 52: 464-470. doi:10.1017/S0030605316001496

Rivière, S., Breman, E., Kiehn, M., CartaJ, A., Müller, J V. (2018) *'How to meet the 2020 GSPC target 8 in Europe: priority-setting for seed banking of native threatened plants'.* Biodiversity & Conservation 27: 1873–1890.

Sharrock S, Jones M (2011) *'Saving Europe's threatened flora: progress towards GSPC Target 8 in Europe'.* Biodiversity & Conservation 20:325.

Smith, P. & Harvey-Brown, Y. (2017). BGCI Technical Review. Defining the botanic garden, and how to measure performance and success. Botanic Gardens Conservation International, Richmond.

Smith, P. and Pence V. (2017). *'The role of botanic gardens in ex situ conservation'.* Pp. 103–133. In: Blckmore, S. & Oldfield, S. (eds), Plant Conservation Science and Practice. Cambridge University Press, Cambridge.

Sustainable Sites Initiative (2014) Online: http://www.sustainablesites.org (accessed June 28, 2014)

Talhouk, S. N., Abunnasr, Y., Hall, M., Miller, T., Seif, A. (2014) *'Ancillary botanic gardens in Lebanon – Empowering local contributions to plant conservation'.* Siibbaldia: The Journal of Botanic Garden Horticulture 12: 111-129.

Tamburelli, G. (Ed.) 2008. Legal Systems for the Management of Protected Areas in Italy and Ukraine. Giuffrè Editore, Milan

Teixido, A.L., Toorop, P.E., Liu, U., Ribeiro, G.V.T., Fuzessy, L.F., Guerra, T.J., Silveira, F.A.O. (2017). *'Gaps in seed banking are compromising the GSPC's Target 8 in a megadiverse country'.* Biodiversity & Conservation 26: 703-706.

Widyatmoko, D. & Risna, R.A. 2017. A Role of Indonesian Botanic Gardens in Achieving Global Strategy for Plant Conservation Goals. Annals of the Missouri Botanical Garden 102(2):377-385. https://doi.org/10.3417/D-16-00006A

Wyse Jackson, P. (2009). *'Developing botanic garden policies and practices for environmental sustainability'.* BGJournal 6 (2): 3–6.

BOTANIC GARDENS AS "REGISTERED COLLECTIONS" UNDER THE EU ABS REGULATION: PAVING THE WAY FOR SUSTAINABILITY IN GREECE

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ABSTRACT

Being characterized as one of the most biodiverse countries in Europe, Greece constitutes a Mediterranean country with an unprecedented wealth of flora and a high level of endemism. Under international law, the *Nagoya Protocol* (NP) sets out a legally binding framework for conservation and sustainable use of biological diversity through the establishment of a system of access and benefit sharing (ABS). Pursuant to the *Aichi Targets* (Target 16) and the E*U Strategy for Biodiversity 2011-2020* (Target 6, Action 20),EU Regulation 511/2014 ("ABS Regulation") transposes the NP into European law and introduces the concept of due diligence in respect of the acquisition and utilization of genetic resources. *EU Implementing Regulation* 1866/2015 establishes an EU Register of collections ("the register"), laying down detailed rules as regards the monitoring user compliance and best practices. By consequence, users obtaining a genetic resource from a collection included in the register shall be considered to have exercised diligently. In this light, compliance with EU Regulations presumes that the goals of biological conservation and sustainable use are fulfilled. Taking into account that botanic gardens are generally defined as "documented collections of living plants" under the *International Agenda for Botanic Gardens in conservation*, EU botanic gardens could be classified as "registered collections" under the abovementioned EU Regulations. Greece has already developed a regulatory framework and related administrative practice acknowledging the multi-functionality of *ex situ* conservation, and especially the contribution of botanic gardens, streamlined with the *National Biodiversity Strategy and Action Plan.* Notwithstanding that EU Regulations constitute directly applicable law in EU Member States, domestic implementation is a challenging endeavor for Greece which undergoes a long period of economic austerity and disposes limited public funds. Despite the current problems concerning the progress of enforcement of and compliance with international and EU commitments, Greek Botanic Gardens may see the EU Regulations as an opportunity to create and/or strengthen national and international networks, as well as to support new initiatives for sustainable use and biodiversity conservation. The newly established Greek Botanic Gardens Network gives great momentum for the undertaking of all necessary preparatory steps towards compliance with international and EU law.

KEYWORDS

Genetic Resources, Sustainable Use, Due Diligence, Benefit Sharing

INTRODUCTION

With nearly 3,500 botanic gardens around the world maintaining approximately one third of all known plant species[1] botanic gardens (BGs) have a multidimensional function. Being defined as "institutions" of documented collections[2], their contribution to ex situ biodiversity conservation is indisputable. Furthermore, BGs foster scientific research and development through plant taxonomy and information-exchange, thereby serving as intermediaries between the "wild nature" and research institutions, scientific laboratories, or even the commercial industry.[3] In tandem, BGs are symbols of a country's cultural heritage and valuable educational hubs. Needless to say, BGs play a vital role in conservation and the sustainable use of genetic resources. Conservation

[1] Botanic Gardens Conservation International (BGCI),GardenSearchhttps://www.bgci.org/garden_search.php (accessed 16 March 2018).
[2] Botanic Gardens Conservation International (BGCI), International Agenda for Botanic Gardens in Conservation: 2nd ed. (Richmond, UK 2015) 148-156.
[3] K. Davis et al., 'An access and benefit-sharing awareness survey for botanic gardens: Are they prepared for the Nagoya Protocol?' (2015) 98 South African Journal of Botany.

and sustainable use are not antithetical, but inextricably linked, concepts. Sustainable use requires the adoption and enforcement of conservation measures, while it constitutes a *"valuable tool to promote conservation of biological diversity [...] because of the social, cultural and economic benefits that people derive from that use"*[4].

This paper aims to identify current challenges faced by Greek Botanic Gardens regarding implementation of the EU Regulation on Access and Benefit Sharing (ABS)[5] and to explore opportunities towards compliance. Section 1 explores the notion of sustainable development/use vis-à-vis BGs,while Section 2 reviews the international and European legal framework of ABS and presents BGs as registered collections under the EU ABS regulatory framework. The purpose of Section 3 is to highlight the linkage between the concept of due diligence and BGs. Finally, Section 4 presents national implementation of the EU ABS Regulation focusing on Greek BGs as a case-study. Concluding remarks are provided at the end of the analysis.

1. LINKING SUSTAINABLE DEVELOPMENT AND BGs

Notwithstanding that its legal normativity is debatable, sustainable development is defined as the *'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.*[6] Agenda 21[7] and the Johannesburg Declaration for Sustainable Development[8] further specify its content by recognizing three core dimensions of sustainable development, namely the economic, the environmental and the social. These elements are interconnected, and all are crucial for the well-being of individuals and societies.

Remarkably, the same approach of sustainable development is depicted in the so-called Sustainable Development Goals (SDGs) which are included in the recently adopted *United Nations 2030 Agenda for Sustainable Development[9]. The United Nations 2030 Agenda for Sustainable Development*[10] calls for the need to *'recognize the link between sustainable development and other relevant ongoing processes in the economic, social and environmental fields'* based upon the acknowledgement that *'social and economic development depends on the sustainable management of our planet's natural resources'*.[11] Even further, Goal 2.5 of the 2030 Agenda urges States to develop soundly managed and diversified seed and plant banks, aiming at the conservation of genetic resources, through the fair and equitable sharing of benefits arising from their sustainable utilization. Interestingly, the Agenda also highlights the role of data gathering to foster the implementation of the SDGs and better inform the measurement of progress[12].

In light of the above, BGs have the potential to contribute to sustainable development in many ways. Indisputably, BGs are centers of plant conservation hosting a wide and diverse range of plant species, including endangered or rare species. To this end, BGs have an accrued interest for scientists and researchers in various fields - from botanists to biologists and experts in biotechnology- while the utilization of genetic resources for scientific purposes can yield significant social benefits. On the other hand, the important role of BGs as educational tools must not be disregarded; public visits and organized tours in the auspices of BGs foster public participation, thereby developing a closer relationship between plants and people, culture, arts, religion, and tradition.[13] Even further, BGs constitute cultural monuments due to their landscape design, their historic trees and plantings, as well as the historic structures which have been preserved through time therein.

For their cultural and historical features, many BGs have already received legal protection, under the Convention Concerning the Protection of the World Cultural and Natural Heritage.[14]

[4] Ababa Principles and Guidelines for the Sustainable Use of Biodiversity (Annex I, Decision VII/12) (13 April 2004) (UN Doc. UNEP/CBD/COP/DEC/VII/12), para 2.
[5] Regulation (EU) No 511/2014 of the European Parliament and of the Council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union.
[6] UNGA Res 42/27, 'Our Common Future', Report of the World Commission on Environment and Development, Annex, para 27 (1987) (UN Doc. A/42/27).
[7] Agenda 21, adopted in United Nations Conference on Environment & Development Rio de Janeiro, Brazil, 3 to 14 June 1992.
[8] Johannesburg Declaration on Health and Sustainable Development 2002, adopted in the context of the preparations for the World Summit on Sustainable Development(WSSD).
[9] United Nations General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, Res A/70/1 (25 September 2015).
[10] United Nations General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, (25 September 2015) (UN Doc. A/70/1).
[11] A/RES/70/1, paras 55, 33.
[12] Ibid, para 57.
[13] Botanic Gardens Conservation International, https://www.bgci.org/public-engagement/1669/(accessed 19 March 2018).
[14] See for e.g. http://whc.unesco.org/en/list/1483.

2. INTERNATIONAL AND EU LAW FOR ACCESS AND BENEFIT SHARING OF GENETIC RESOURCES

Under international law, the core legally binding instrument for the protection of genetic diversity is the Convention on Biological Diversity (CBD).[15] CBD has a triple objective, i.e."*[t]he conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources […]*".[16] Entered into force in 2014, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (hereinafter the Nagoya Protocol)[17] operationalizes the third objective of the CBD through the creation of a transparent benefit-sharing mechanism for providers and users of genetic resources. The Nagoya Protocol is based on Prior Informed Consent (PIC) of the country providing the resources and Mutually Agreed Terms (MAT) on benefit-sharing, namely an agreement between the user and the supplier laying down the conditions for the utilization and sharing of the benefits of genetic resources. Furthermore, Member-Parties to the Protocol are required to adopt domestic benefit-sharing measures as well as to establish national focal points (NFPs) and competent national authorities (CNAs) to ensure that granting of access to genetic resources is monitored and based upon transparent criteria.[18] Apart from the CBD and its Protocol, noteworthy is the Strategic Plan for Biodiversity 2011-2020, which includes the so-called Aichi Biodiversity Targets.[19] Particularly relevant to genetic resources, Target 11 refers to the maintenance of "genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives".

Along the same lines, Target 6 (Action 20) of the EU Biodiversity 2020 Strategy stresses out the need for benefit-sharing of genetic resources.[20] Even further, implementing the Nagoya Protocol, the European Union adopted the EU Regulation 511/2014 (hereinafter EU ABS Regulation)and EU Implementation Regulation 1866/2015[21] (hereinafter Implementing Regulation). These two complemental legal instruments both contribute to the *'conservation of biological diversity and sustainable use of its components, in accordance with the provisions of the Convention on Biological Diversity'*.[22] The ABS Regulation applies only to genetic resources utilized for scientific and research purposes, providing that Member States are free to establish domestically access measures in order to comply with their obligation to ascertain whether genetic resources are accessed and utilized fairly and equitably. Entered into force in 2015, EU Implementing Regulation lays down detailed rules for the application of the EU ABS Regulation as regards the register of collections, monitoring user compliance and best practices, all of them being tools in assisting users to comply with their due diligence obligation.

3. DUE DILIGENCE AND BGs UNDER THE EU ABS REGULATION

Due diligence requires both the adoption and the vigilance enforcement of legislative measures.[23] Generally, due diligence is an obligation of conduct- not of result- namely a performance of "best possible efforts". In other words, it is commensurate with an obligation to meet a certain standard of care.[24]

Due diligence associated with "collections" under the EU ABS Regulation is accomplished through the establishment of the so-called Register, which is internet based and easily accessible to users. Notwithstanding that the establishment of the Register by the European Commission is mandatory, registration takes place on

[15] Convention on Biological Diversity, Rio de Janeiro, 5 June 1992; in force 29 December 1993) 1760 UNTS 79 [CBD].
[16] Ibid., Article 1.
[17] Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, opened for signature 29 October 2010; entered into force 12 October 2014).
[18] Ibid., Article 13.
[19] CBD COP X2, Strategic Plan for Biodiversity 2011-2020 (29 October 2010) (UN Doc. UNEP/CBD/COP/DEC/X/2)
[20] EU Biodiversity Strategy 2020, available at: http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm#stra.
[21] Commission Implementing Regulation (EU) 2015/1866 of 13 October 2015 laying down detailed rules for the implementation of Regulation (EU) No 511/2014 of the European Parliament and of the Council as regards the register of collections, monitoring user compliance and best practices (OJ 274/4).
[22] Ibid.,Preamble (1).
[23] European Commission, Guidance document on the scope of application and core obligations of Regulation (EU) No 511/2014 of the European Parliament and of the Council on the compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation in the Union, Commission Notice (OJ C 313/01).
[24] M J Olivia, 'Private Standards and the Implementation of the Nagoya Protocol: Defining and Putting in Practice Due Diligence in the EU Regulation on ABS' in B. CoolsaetImplementing the Nagoya Protocol comparing Access and Benefit-Sharing regimes in Europe (Brill Nijhoff, 2015), Ch 13 pp 295-297.

a voluntary basis.[25] In more detail, registration entails submission of a series of documents containing, inter alia, information about the holder of the collection and a description of the genetic resources included therein.[26] The national competent authorities verify the submitted information and decide upon whether a certain collection must be included in the Register.[27] Supplementary evidence with respect to the capacity of a collection to be registered with the Register constitutes, among others, the adoption by the collection of codes of conduct/guidelines and its participation in international certification schemes.[28] In simple words, a collection will be registered only if it applies standardised procedures for exchanging samples of genetic resources, as well as keeps records of all samples and relevant information.

It falls naturally, therefore, that BGs and the due diligence obligation under the EU ABS Regulations are closely related. On the one hand, under article 3 (9) of the ABS Regulation a "collection" is defined as *'a set of collected samples of genetic resources and related information that is accumulated and stored, whether held by public or private entities'.* On the other hand, under the EU Regulations BGs constitute *ex situ* collections of plants, i.e. of "genetic material"[29]. By logical implication, BGs fall under the meaning of "collections" and as such can apply for registration with the Register.

The *raison d' être* of the Register is to facilitate user compliance with the principal obligation of users, namely to ascertain that genetic resources are accessed and utilized in accordance with applicable access and benefit sharing legislation.What's imperative is that users who obtain GRs from a registered collection are considered to have exercised due diligence as regards the seeking of that information (art. 4 par. 7 of Regulation 511/2014 as well as preamble (2) of Regulation 1866/2015). In other words a presumption of users due diligence is introduced via both EU Regulations. It is crucial to note that due diligence is required not only at the stage of research funding but also in all cases where the user sells of transfers the result of the utilisation.[30] However, registration for small collections remains a difficult task. The shift of due diligence obligations from users to the registered collections reduces the administrative burden and compliance requirements on the latter, while at the same time collections are burdened with significant administrative costs. Certainly, collections with limited financial resources and staff are discouraged from pursuing registration.

Undoubtedly, though, registration of BGs entails many advantages. Principally, the Register constitutes a unified pool of documented genetic resources and helps genetic taxonomy, sample exchange and information storage in a centralised digital database. To this end, it ensures that the users have the ''necessary information'' and, consequently, become aware and respectful of the rights and obligations attached to genetic resources.[31] In this way, the standard of care on ABS can be reviewed by the European Commission and, concomitantly, increases the level of national compliance with the EU Regulations.[32]

4. CHALLENGES AND OPPORTUNITIES OF GREEK BGs

Being characterized as one of the most biodiverse countries in Europe, Greece constitutes a Mediterranean country with an unprecedented wealth of flora and a high level of endemism.

Under Greek law, the protection of the natural and cultural environment is recognised in article 24.1 of the Greek Constitution as a duty of the State and as a right of every citizen. The article's scope of protection is relatively broad extending to the protection of biodiversity, including genetic resources. Apart from the constitutional provision, specific forest laws as well as the Presidential Decree 67/1981 set the legal framework for the protection of forests and self-sown flora and wild fauna, while Law 1650/1986 constitutes the core legal instrument for all aspects of environmental protection. Along the lines of the aforementioned law, which also makes reference to the protection of self-sown flora and wild fauna, Presidential Decree 80/1990 introduces a set

[26] Ibid. 5, at Preamble (18).
[26] Ibid 11, at Annex I, Part A.
[27] Ibid. 5, at Article 5 para. 4.
[28] Ibid. 11, at Annex I, Part B.
[29] Ibid. 5, at Article 3.
[30] Implementation Regulation, paras 6, 9.
[31] U. Feit et al., First Meeting of the European Competent National Authorities Implementing the Nagoya Protocol and the Corresponding EU Regulation, Final Report 2017 Federal Agency for Nature Conservation, pp 86-87
[32] Ibid 22.

of rules particularly for the protection of plant genetic resources. In addition, Law 3937/2011 recognises genetic resources as a national heritage. Despite all the above legislative framework and the fact that there are clauses regarding access issues, the current legal framework does not regulate issues of benefit –sharing. However, the recent National Strategy for Biodiversity for 2014-2020 sets as a priority the amendment of the national access system to genetic resources and it also acknowledges the need for a regulatory framework on benefit sharing and on ABS in general.

Furthermore, the Greek legislation has still not aligned with the international and European ABS legislation. While it is true that Greece has not yet ratified the Nagoya Protocol (it is in the pipeline though[33]), EU Regulations apply to all Member States regardless of their transposition or not into the domestic legal order. Notwithstanding the "direct effect" of EU Regulations, the adoption of legislative measures at national level is necessary, together with the establishment of mechanisms to ensure their vigilant enforcement domestically. For the past decade, Greece has undergone a crisis era affecting its capacity to make public investments in environmental and conservation activities. Inevitably, many Greek BGs under-operate with little or no staff and scarce financial resources to function properly.

Nonetheless, recent efforts in establishing a network of Greek BGs for inclusion in the *European Botanic Gardens Consortium of the Botanic Gardens Conservation International* (BCGI) demonstrate the existence of an ignited interest for BGs. More specifically, Greek Botanic Gardens have recently launched the newly established Greek Botanic Gardens Network in an effort to strengthen Greek Botanic Gardens and to jointly address issues of common concern, namely to consider and decide the way forward on various aspects of compliance and to implement a common policy framework. To this end, the Network aims at promoting exchanges of genetic resources for non-commercial and commercial use, developing a tracking system and creating records of dates of acquisition, of seed lists, and of any official document (e.g. permits and certificates). Concomitantly, it may serve as the perfect place to achieve the EU ABS Regulation goal, which is the harmonized and uniform implementation by all Member States.

Towards the materialization of this goal, a first step could be the adoption of an national ABS Roadmap for BGs in consultation with stakeholders, including research institutions, Universities, plant scientists and the scientific community in general, non-governmental organizations (NGOs) and the public. Primarily, the Roadmap should determine a system for the recording of collections, i.e. species, plants, seeds and GR-related information, in conformity with the provisions of the EU Regulations. Furthermore, it should introduce assessment tools of BGs based on standardized procedures, which could be effectuated through the creation of a national register of BGs under the terms and conditions set forth in the Roadmap. In parallel, it is highly important that the linkages between national BGs and other national ex situ collections be strengthened with a view of creating a national Register of all *ex situ* collections (emphasis added). In this frame, registration of Greek BGs with the EU Register of collections upon decision of the National Competent Authority will be facilitated. At the same time, upgrade the role of BGs in Greece, i.e. by signifying their importance for sustainability and promoting their exposure to European and International established networks. Certainly, the level of success depends to a large extent on the political will of the country in spending public funds for the creation of a robust national mechanism in compliance with the regulatory requirements under the EU Regulations.

CONCLUSION

In all, botanic gardens conceptualize the holistic notion of sustainable development. The recognition of BGs as "registered collections" under the EU ABS holds multiple advantages with respect to achieving sustainability. At the same time, it provokes challenges, especially for small collections. Undoubtedly, the key for effective compliance with the EU ABS depends on national implementation to ensure that botanic gardens are legally protected and sustainably managed. In times of austerity and economic recession, sustainability is a challenging goal for Greece. Be that as it may, the development of a network of Greek BGs in compliance with the European ABS mechanism is a chance for the country to pave the way towards sustainability.

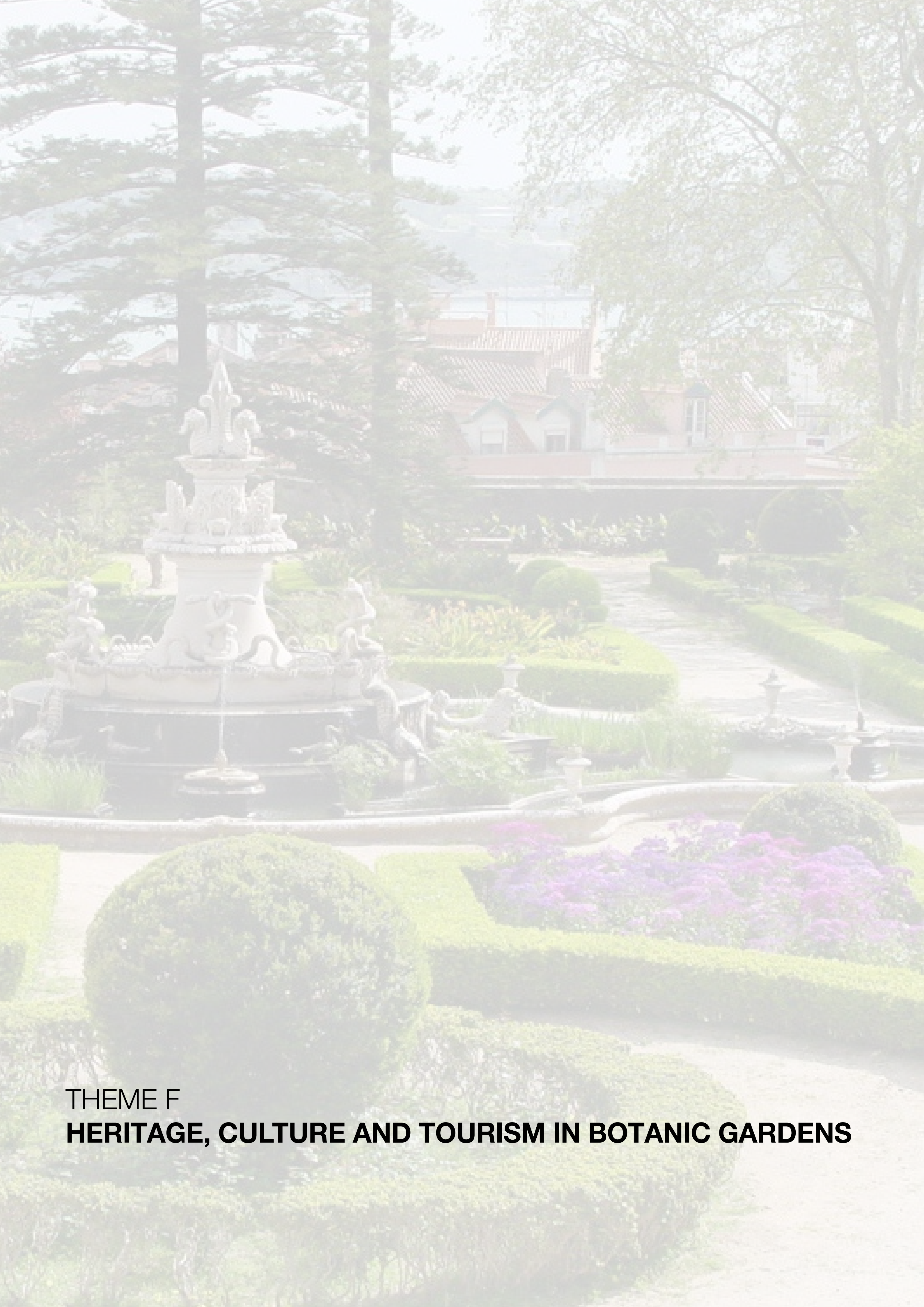
A National Roadmap on ABS and the development of a robust national mechanism on ABS in accordance with the EU commitments/standards can assist Greece

[33]This paper was presented and written in 2018 for the EUROGARD Conference. In the meantime until publication of this paper (2020) Greece has ratified the NP and has issued a Ministerial Decree on compliance measures with the EU ABS Regulation *(please contact the authors for more information and their recent publications on this issue).*

in achieving its sustainability goals, at least the ones regarding the sustainable use of genetic resources and biodiversity conservation. Indeed the newly established Greek Botanic Gardens Network gives great momentum for strengthening the dialogue between policy makers, BGs and other stakeholders aiming at developing a national ABS Roadmap in accordance with the Nagoya Protocol and EU Regulations.

REFERENCES

Ababa Principles and Guidelines for the Sustainable Use of Biodiversity (Annex I, Decision VII/12) (13 April 2004) (UN Doc. UNEP/CBD/COP/DEC/VII/12).
Botanic Gardens Conservation International (BGCI), International Agenda for Botanic Gardens in Conservation: 2nd ed. (Richmond, UK 2015).
Botanic Gardens Conservation International(BGCI), https://www.bgci.org/garden_search.php (accessed 16 March 2018).
Botanic Gardens Conservation International (BGCI), https://www.bgci.org/public-engagement/1669/ (accessed 18 March 2018).
CBD COP X2, Strategic Plan for Biodiversity 2011-2020 (29 October 2010) (UN Doc. UNEP/CBD/COP/DEC/X/2).
Commission Implementing Regulation (EU) 2015/1866 of 13 October 2015 laying down detailed rules for the implementation of Regulation (EU) No 511/2014 of the European Parliament and of the Council as regards the register of collections, monitoring user compliance and best practices (OJ 274/4).
Convention on Biological Diversity, Rio de Janeiro, 5 June 1992; in force 29 December 1993) 1760 UNTS 79 [CBD].
Davis K. et al., 'An access and benefit-sharing awareness survey for botanic gardens: Are they prepared for the Nagoya Protocol?' 98 South African Journal of Botany (2015).
EU Biodiversity Strategy 2020, available at:http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm#stra
United Nations General Assembly, Transforming our world: the 2030 Agenda for Sustainable Development, (25 September 2015) (UN Doc. A/70/1).
European Commission, Guidance document on the scope of application and core obligations of Regulation (EU) No 511/2014 of the European Parliament and of the Council on the compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilisation in the Union, Commission Notice (OJ C 313/01).
Feit U. et al., First Meeting of the European Competent National Authorities Implementing the Nagoya Protocol and the Corresponding EU Regulation, Final Report 2017 Federal Agency for Nature Conservation.
Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity, opened for signature 29 October 2010; entered into force 12 October 2014).
Olivia M.J., 'Private Standards and the Implementation of the Nagoya Protocol: Defining and Putting in Practice Due Diligence in the EU Regulation on ABS' in Coolsaet B. *Implementing the Nagoya Protocol comparing Access and Benefit-Sharing regimes in Europe* (Brill Nijhoff, 2015).
Regulation (EU) No 511/2014 of the European Parliament and of the Council of 16 April 2014 on compliance measures for users from the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization in the Union (OJ 150/59).
UNGA Res 42/27, *'Our Common Future',* Report of the World Commission on Environment and Development (1987) (UN Doc. A/42/27).



THEME F

HERITAGE, CULTURE AND TOURISM IN BOTANIC GARDENS

THE GENUS CITRUS (RUTACEAE) IN THE MEDITERRANEAN REGION IN ANCIENT TIMES

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ABSTRACT
This paper refers to and evaluates theories about the introduction history and presence of species of the citrus family (*Rutaceae*) into the Mediterranean world in ancient times. In particular it refers to sweet orange [*Citrus x aurantium* L. subsp. *sinensis* (L.) Engler], bitter orange (*C. x aurantium* L. subsp. *amara* Engler), lemon [*C. x limon* (L.) Burm.f.] and citron (*C. medica* L.). For each taxon all available sources from antiquity, their translations and their interpretations are taken into account. Recently published historical and (archaeo)botanical papers on *Citrus* are dealt with as well, especially if they provide new hypotheses on introduction times and pathways of different *Citrus* species into the Mediterranean area.
A number of wrong interpretations and assumptions are identified, especially in the newer literature. Besides mistakes in translations or perceptions of ancient texts and images, one of the identified reasons for these errors is a non-reflective citation of wrong "old" interpretations.In addition, some arguments are shown to be circular.
Based on the evidence from all the historical sources any speculations about the presence of sweet oranges and bitter oranges in ancient times in the Mediterranean region are wrong. A careful analysis of the different hypotheses about the introduction times and pathways of lemon (*C. x limon*) and citron (*C. medica*) into the Mediterranean reveals that postulated evidence for the presence of *C. x limon* in Roman times is not conclusive. This relates especially to interpretations of images in mosaics or wall paintings but also to archaeological and archaeobotanical findings. Theories proposing an introduction of *C. medica* across the Near East and the Eastern Mediterranean region are supported, while recently proposed connections between the introduction of this species and Phoenician trade appear very doubtful. Some confusions observed even in modern publications are caused by the fact that the name "citrus" in Roman antiquity was used not only for citrons, but also for the sandarak tree [*Tetraclinis articulata* (Vahl) Mast.] of the cypress family (*Cupressaceae*). They are shortly dealt with as well.

KEYWORDS
Citron, Lemon, Orange, *Tetraclinis*, Introduction History, Roman Times

INTRODUCTION

The native distribution area of *Citrus* is the Himalayan region from India to China. There the cultivation of *Citrus* species and the selection of cultivars have a tradition of several thousand years (Hui 1999, Schirarend 1996, Mabberley 2004). According to the standard reference literature (e.g., Gams 1979, Hui 1999, Mabberley 2004) oranges and lemons were introduced to the Mediterranean region not earlier than the 10th century AD, the sweet oranges even later. Only the citron (*Citrus medica*) was already present in antiquity.

But recent publications and books, some of them written by well-known historians or archaeobotanists, contain statements that sweet and bitter oranges and lemons did already occur in the Mediterranean in Roman times. Some of them additionally provide new hypotheses on introduction times and pathways for *Citrus medica*. Mainly based on archaeobotanical findings others argue that citrons and lemons had been in Italy much earlier than originally assumed.

Thus the question, when the most important *Citrus* fruits really reached the Mediterranean area for the first time, has become actual again. This shall be discussed below for sweet and bitter oranges, citron and lemon.

MATERIAL AND METHODS

The present paper is largely based on the PhD thesis of the author (Kiehn 2017). There, all available sources from antiquity, their translations and their interpretations were analysed. This includes all types of historical written sources as well as images. In addition, numerous recently published historical and (archaeo)botanical papers on *Citrus* were critically evaluated as some of them propose new hypotheses on the introduction of the different *Citrus* species into the Mediterranean area.

Due to the maximum lenght of contributions for this proceedings volume, the present paper can only summarize the most important results about the introduction history of *Citrus* into the Mediterranean region, and only will refer to a relevant and representative selection of all of the sources. A full bibliography and complete survey of the sources published before mid 2017 is provided by Kiehn (2017), the present paper additionally includes publications appeared until early 2018.

RESULTS AND DISCUSSION

Sweet (*Citrus* x *aurantium* ssp. *sinensis*) and bitter orange (*C.* x *a.* ssp. *amara*)

Oranges (*Citrus x aurantium*) are hybrids between the pomelo [*Citrus maxima* (Burm.) Merr.] and the mandarine (*Citrus reticulata* Blanco). They have different complex parental situations (see Luro & al. 2017) and have originated in China (Mabberley 2004).

Oranges present in the Mediterranean region in Roman times?

In the last decades several authors expressed the view that oranges (*C. x aurantium*) can be identified in texts or images from Roman times. Even if they give references for their statements (which is not always the case) it will be shown that their views are not at all based on or corroborated by ancient sources or images.

In his important university textbook Carcopino (1941) writes that brides in Rome weared orange flowers: *„ … she wore a veil of flaming orange … a wreath … of myrtle and orange blossom.“*. But no source for this statement is given or could be found in Roman texts. Orange flowers are also mentioned by Theroux (1996): the *“lovely orange blossom”* is attributed by him to Diana, the virgin goddess of hunting. However, there is no evidence for orange flowers or any similar white flower as a symbol or attibute for the godness Diana in the ancient sources. Bowe (2004) writes: *“... we know that oranges (Citrus aurantium), natives of the Far East, fruited in some imperial gardens“*. He also does not give a source for his statement. According to my studies (details see Kiehn 2017) no ancient literature about the lifes of the Roman emperors and no ancient historical text or book about gardens and plants (including rare plants and trees from other countries) shows or mentions anything that could be identified as an orange tree or fruit. Hui (1999) states that he has identified oranges in images at the mausoleum built by Constantine in Rome for his daughter Constantia: *„Sweet oranges are depicted at a mausoleum erected by Constantine (274-337 CE)“*. From the same mausoleum Attlee (2014) mentions images of lemons and bitter oranges. A study of the fruit images at the ceiling of the mausoleum carried out during two visits and an internet search only revealed some images which could represent citron (*Citrus medica*). All other potential “orange-like” fruits clearly are either pomegranates, apples, pears or quinces.

In the light of these observations a recent discussion about the identfication of seeds found in Rome (Grasso & al. 2017) potentially representing *C. aurantium* or *C. reticulatum* needs to be looked at critically.

Oranges: Apples of the Hesperides or the tree of paradise?

When we think about the story of Heracles and his theft of the “apples of the Hesperides”, the “golden apples”, today, we have the picture of oranges in mind. This is caused by Giovanni Battista Ferrari (1646) who rewrote the ancient myth of the Hesperides and connected it to oranges. However, if ancient sources interpre-ted these “apples” as *Citrus* species, they referred to them as citrons (*Citrus medica*). This is, e.g., reflected by Antiphanes in Athen. III 84b (= Kap. 27) where newly introduced fruits of *Citrus medica* are compared with the apples of the Hesperides. The same comparison is found in Athenaios 83b, 85c: *“Juba king of Mauretania and a very learned man, mentions the citron in his History of Libya, asserting that among the Libyans it is called the apple of Hesperia, whence Heracles brought to Greece the apples called, from their colour, golden.”* (Yonge 1854). There are also modern speculations that the ancient myth of the golden apples of the Hesperides could reflect an ancient knowledge about orange trees in spite of the fact that they did not exist in the Mediteranean. Genaust (2005), e.g., writes: *„Nur am Rande kann hier die Frage gestreift werden, ob die antiken Völker über ihre Mythen eine indirekte Kenntnis von kostbaren goldenen Baumfrüchten* *hatten, die im Mittelmeergebiet fehlten"*. This is highly unlikely, taking the clear indication into account that people in ancient times synonymized, if at all, citrons with the apples of the Hesperides. The same holds true for the hypothesis, e.g., suggested by Theroux (1996) that an orange might have been the fruit of the tree of paradise. No support for such a hypothesis can be found in the bible or in ancient Hebrew texts.

Introduction of oranges to the Mediterranean region

Bitter oranges were brought to the Mediterranean not much earlier than the 10th century AD by the Arabs (Schirarend 1996). The probably earliest evidence for sweet oranges in Europe dates to the end of the 15th century AD. In 1498 Vasco da Gama mentions that he got sweet oranges in Mombasa which were sweeter than those he got in Portugal: *„ laranjas … muito boas milhores que has de Potugall"* (Marques 1999). According to other sources, sweet oran-ges were already cultivated at the Terraces of Pona Verde near Lisbon around 1480 (Bonavia 1888). Maybe this refers to a location today called Pena. The first sweet orange tree is said to have bloomed and fruited in the garden of Duke St. Laurent near Lisbon (Hehn 1911). In many languages (including the Turkish) the sweet orange is called „portugalo" or similar, while the bitter orange is named „naranja" or similar. This is a strong indication that the Portuguese and not the Arabs distributed the sweet orange in the Mediterranean region first. Also the name *"Olympiense"* as for instance use by Battista Ferrari (1646) indicates a Portuguese origin of the sweet orange, as it refers to the old name of Lisbon.

No oranges in Roman times!

As a summary it can be stated that no unequivocal evidence for sweet or bitter oranges in ancient literature, wall paintings, mosaics and sculptures could be found.

Citron (*Citrus medica* L.)

Citrons most probably originate from the Central Himalayan foothill regions (see, e.g., Langgut 2017). From that region there have been two most probably independent introduction ways of *Citrus medica* into the Mediterranean region: one through the Near East and one as a result of the Persian campaign of Alexander the Great through Greece. Many relevant sources for and discussions about these introductions have been recently summarized by Kiehn (2017) and Langgut (2017). Therefore, only the most important and controversial ones will be dealt with here.

Citrons in the Near East

Citrus seeds are reported as early as c. 4.000 BC from Nippur south of Babylonia (Langgut 2017). Numerous reliefs at the palace of Nimrud from the 9th century BC show figures during a ceremony connected with the so-called "sacred tree". A King (or mythical "Eaglehead") and winged figures hold cone-like structures in their hands. In the literature, these "cones" are identified as conifer-cones which are used to "pollinate" or sprinkle the sacred trees (Rathgeber 1857, Magueron 1992). Those sacred trees clearly are not conifers. Why should the "cones" then represent conifer structures? Isn´t it more plausible that they are images of the fruits of the sacred trees? The similarity of these fruits with citrons is striking. This could indicate that both the tree and the fruit are showing and representing – the citron (Kiehn 2017).

The Jews presumably came in contact with the sacred tree first during their Babylonian Exile 597-539 BC. Quite probably they synonymised this tree with the "goodly tree", "beautiful tree" or "tree of paradise" in their belief. Plants of citron were brought to Israel, where first archaeological records are documented for the 5th century BC (Langgut & al. 2014, Langgut 2015). The fruits of the "sacred tree" became part of the Sukkot-ceremony as the fruit of the beautiful tree *"etz hadar"*. The fruits used that way by the Jews only got the name "Etrog" in the first century AD (Moskovitz 2015, Langgut 2017), when other citron trees reached the Roman Empire (Moskovitz 2015). The name for this fruit probably was the result of the need to distinguish the „Etrog" from the other fruits and cultivars of *Citrus medica* now appearing all over the Roman empire (Kiehn 2017).

Citrons in Greece

The first information about the citron reached the Greek world in the 4th century BC. During the Persian campaign of Alexander the Great (between 334 and 324 BC) his scientists found citrons in Persia and Media. They described the plants and brought seeds and probably young plants back to Greece. The first documented botanical description of citrons in the Western world was provided by Theophrast around 310 BC. Tree and fruit were called by him the Persian or Median apple. In Roman times, also the name "Kitron" was used for *Citrus medica.*

Shortly after this introduction to Greece, Antiphanes talked about the citron in his comedy play Boeotia, but did not explicitly mention its name. According to the text of his play, citron seeds had only recently been brought to Athens by King Alexander. In the play, the precious fruits are compared to the golden apples of the Hesperides. It should, however, take another 300 years before the tree is proven to be cultivated in the Roman Empire.

Citrons in the Roman Empire

At the beginning of the first century AD, Pliny the Elder still mentions that citrons do not grow well in Italy, and that they do not produce fruits. (Plin. nat. XVI 135). This situation changed after the Jewish war (70 AD). Now Jewish communities emerged all over the Empire. As the Jews had the knowledge how to propagate and cultivate citron trees because they had used them in their Sukkot ceremony for more than 600 years, it is quite probable that this knowledge was spread across the Roman Empire. Many mosaics and paintings of citron fruits now document the presence of the species in Italy, the Near East and Northern Africa; they show a broad variety of fruit forms (see, e.g., Hornig 2015).

The Romans used citron fruits for many purposes, for example in cooking, seeds against bad breath, and fruits against moths or to perfume clothes and rooms. Citron was also said to be a powerful antidote against all kinds of poisoning, especially against snake bites (for more details about the uses see Kiehn 2017).

Name confusion: what is meant by the Roman citrus or citron?

The Romans used the name citrus or citron not only for *Citrus medica*. They also applied this name to the wood of the sandarac tree (*Tetraclinis articulata*). This conifer has an aromatically smelling wood that was partly used for the same purposes as *Citrus medica*: to perfume clothes to protect them against vermin. Besides this, sandarac wood was also used for luxurious and expensive tables. The translation "citrus-wood-tables" for these prestigious pieces of furniture, therefore, is misleading; it would be more correct to speak about "sandarac-wood-tables".

New theories about earlier introductions of Citrus medica into the Mediterranean region

In recent years, especially a team called AGRUMED (consisting of archaeobotanists, archaeologists and palynologists, see Fiorentino & al. 2014) has presented theories of a much earlier introduction of *Citrus* into the Mediterranean region than indicated above. They argue for the presence of *Citrus*-remains in Italy already in Phoenician times (Pagnoux & al. 2013). In order to evaluate this theory, their findings and conclusions are critically looked at. For four cases the results of this evaluation are presented below (an in-depth discussion of the other papers promoting this theory is found in Kiehn 2017):

(a) On Sardinia polymethoxy-flavonoids were detected in a wine-amphora from the 6th century BC and published as a proof for the early presence of *Citrus* in Italy (Pagnoux & al. 2013). But polymethoxy-flavonoids do not only occur in *Citrus*, but in a number of other aromatic plants like members of the genera *Artemisia* or *Sideritis* (Valant-Vetschera & Wollenweber 2005). According to Pliny the Elder (Plin. nat. XXV 42-44) or Dioscurides (Diosc. mat. med. III 165; IV 34-36) aromatic herbs were mixed with wine and used as medicine. Without a clear structural identification of the polymethoxy-flavonoids found in the wine-amphora revealing a structure uniquely found in *Citrus,* it seems much more plausible that the chemical compounds found in the wine-amphora represent the remains of aromatic herbs and not of *Citrus*. (b) Coubray (1996) and Coubray & al. (2010a) reported a carbonized *Citrus* fruit from the 6th century BC from Ischia. However, at closer inspection, the same authors admitted that it could be a Maloideae fruit as well (Coubray & al. 2010b). (c) Citrus pollen are reported in a soil profile from Cumae equally spread from 896 BC to the 17th century AD. This is taken as an indication for a Phoenicians introduction and a continuous culture of *Citrus* in Italy (Pagnoux & al. 2013). But is this really conclusive? In general it can be stated that *Citrus* pollen is rare to be found in soil samples because the plants are pollinated by insects and do not shed pollen in masses like wind-pollinated species. If pollen is found this indicates a high likelihood of the presence of (probably numerous) trees nearby (this argument is also taken forward by Langgut & al. 2014). However, there are a number of facts which create doubts about the report from Cumae. Pagnoux & al. (2013) talk about *"... being continously recorded ..."*. This would, as they say, indicate a continuous culture of *Citrus* in the region. However, there is no other archaeological evidence for the presence of *Citrus* in that area. In addition, neither Varro nor Columella nor C. Oppidus (who wrote a book about trees at the time of Julius Caesar) mention citron. Thus the question must be asked whether such a valuable and beautiful tree could have been common to for such a long time in Cumae, the Roman city of the rich and famous, and could have been overlooked or neglected by all Roman authors for centuries? Pollen grains evenly spread in the soil sample thus could probably indicate a contamination of the soil profile with modern pollen, as, today, *Citrus*-plants are found in the region. (d) The earliest archaeological samples identified as citron seeds are dated by the authors to the 3rd-2nd century B.C. *"in the Samnite levels under the Roman temple of Venus at Pompeii"* (Fiorentino & al. 2014, Celant & Fiorentino 2017). The presence of seeds, however, does not necessarily indicate a cultivation of citron in Italy, especially as ancient writers like Pliny the Elder report that citron did not grow in Italy before the first century AD (Plin. nat. XII 16).

Summary
To summarize the results of the evaluation of the papers on an early Phoenician introduction of citrons: There is no convincing and conclusive indication for the presence of *Citrus* in the Mediterranean before the introductions to the Near East and Greece mentioned above.

Lemon (*Citrus* x *limon*)
Lemons have originated in China as hybrids between citrons (*Citrus medica*) and bitter oranges (*C. x aurantium*) (Mabberley 2004, Luro & al. 2017) and were, according to most authors, brought into the Mediterranean world by the Arabs (see, e.g., Lack 2001, Mabberley 2004).

Lemons in ancient Rome?
In recent years, several authors have expressed the view that lemons were already well known in the Mediterranean world in ancient times. Here some examples of such statements:
Jashemski & Meyer (2002): *„ … but the Romans clearly knew the lemon and painted lemon trees with accurately portrayed fruit.“*; Ciarallo (2001): *„ … consider the lemon, which was probably imported to Campania for its medicinal properties. Until a few decades ago, it was thought to have been introduced by the Arabs, but it is unequivocally depicted in a fresco of the House of the Fruit Orchard“* and *“The lemon was imported from the Middle East. Pliny recounts that to encourage the seedlings to take root they were grown in perforated vases in their countries of origin to then be transported into Italy, where they were transplanted into the ground. The fruits were used for medicinical, especially antiseptic purposes.“*; Ceccarelli & Wachter (2015): *„Aber es muss sie gegeben haben, denn in Pompeji gab es Wandgemälde mit Abbildungen von Zitronenbäumen“*; Hauschild (2017): *„Zu den Pflanzen, die die römischen Gärten zierten, gehörte auch die Zitrone“*. A recent publication about the plant iconography of ancient Rome based on a newly established database attributes *“4-10 images”* to *Citrus* x *limon* (Kumbaric & Caneva 2014).
The above mentioned views seem to be supported by recent archaeobotanical reports of pollen and seed discoveries, e.g., by Mariotti Lippi (2000, 2012); Pagnoux & al. (2013) or Fiorentino & al. (2014).
In order to evaluate all such statements it is necessary to look at the images mentioned by the authors as well as at the archaeobotanical findings more closely.

Images
According to my studies, none of the images from Roman times identified as lemon in the literature undoubtedly shows *Citrus x limon*. Here some examples: (a) A mosaic from Salzburg (Waagplatz) dated to the 3rd century AD shows *Citrus medica* (Thüry 2001). (b) Fruit images at the ceiling of the mausoleum of Constantia in Rome: as already mentioned above, the only potential images of *Citrus,* show citron. (c) Wall paintings in the „House of the Fruit Orchard“ (Insula I. 9) in Pompeji: they are identified as lemons, e.g., by Ciarello (2001), Jashemsky & Meyer (2002) or De Carolis (2017). I seriously question this identifications for several reasons: the main argument for Ciarello´s (2001) identification is based on a wrong understanding of the identity of the *Citrus* described by Pliny: his texts do not refer to lemons, as assumed by Ciarello (2001), but to citrons! In addition, the fruit surface on the painting seems to exhibit wrinkles indicating with much more likelihood the image of a citron. (d) Jashemski & Meyer (2002) identify a second potential lemon tree in the „House of the Fruit Orchard“. Taking the upright position of the fruits, their rounded tops and their size (also in comparison to the bird sitting in the tree) into account, this tree much more likely represents a member of the Rosaceae-family (e.g., apricot, or plum). (e) Wall painting of a garland from the Museo Nationale in Naples (NM Inv. No. 8526): here, Calabrese (2002) as well as Jashemski & Meyer (2002) *„the three fruits to the left of the Eros have the characteristic shape and color of lemons“* identify lemons. However, the statement by Jashemski and Meyer (2002) is not conclusive, as the structures seen here more likely could be leaves or fruits of Rosaceae. (f) Mosaics from Northern Africa: Gozlan (1990) writes *„Il est en effet bien difficile de ne pas reconnaître des citrons sur une certain nombre de nos tapis“*. She provides a list of mosaics she has identified lemons. At closer inspection, all of them turn out to show citrons, which is not surprising, as Gozlan herself, in the same publication, points to the considerable variation in fruit forms of *Citrus medica*. (g) *„Emblema con uccelli e frutta“* (Fig. 1). This xenia mosaic (Inv. No. 58596) from the Museo Nationale Romano is mentioned by a number of authors as convincing proof for the presence of two Citrus species in Roman times: Balmelle (1990) *„des fruits d’espèces diverses (un citron?, des pommes ?, un cédrat, une grenade) posés sur un lit de feuilles…“*. Jashemski & Meyer (2002): *„… the Romans … distinguished the lemon and citron as two distinct fruits, as a mosaic of about AD 100 in the Terme Museum at Rome (inv. No 58596) shows the lemon (second fruit from the left) and the citron (fourth fruit from the left)“*. They call the mosaic: *„Basket of fruit with lemon and citron“*. Calabrese (2002): *“showing two round reddish fruits rather like oranges, near a lemon and a citron fruit.“*. Paris & Di Sarcina

(2012): *„iconoscono pomi (forse mele cotogne e pesche) e agrumi, identificabili con un limone - il secondo, Citrus limon … e un cedro – il quarto Citrus medica.“*. Hornik (2015): *„Korb mit Früchten: zwei verschiedene Zitronen, drei rötliche Früchte (Pfirsich und Äpfel?), eine gelbliche Frucht (Birne?).“* Celant & Fiorentino (2017): *„Roman mosaic from Palazzo Massimo alle Terme with lemon and citron fruits”.*

Figure 1: „Emblema con uccelli e frutta“. Museo Nationale Romano, Inv. No. 58596. Photo M. Kiehn 2016.

Here, I provide a totally different theory about the objects in the basket: they all represent FUNGI! In order to test my hypothesis I showed the mosaic to mycologists at the University of Vienna (Univ.-Prof. Dr. Irmgard Greilhuber and her team). They did not have any background information about the potential identifications, but without any hesitation named different species of fungi depicted on the mosaic: from left to right: a boletus (*Boletus edulis*), a chanterelle (*Cantharellus sp.*), a mushroom (*Agaricus sp.)* or young Caesar's mushroom (*Amanita caesarea*), a morel (*Morchella esculenta*), and a brown mushroom (probably again *Agaricus sp.* or *Amanita caesarea*). Only the last mushroom image is of uncertain identity.

The lemon-like form of one “fruit” could probably have been intensified during a restoration of the mosaic. This corroborates exactly my own considerations; there are no fruits, no citron and no lemon in this basket, just mushrooms.

Archaeobotany

Several recently published papers argue for the presence of lemon (*Citrus x lemon*) in Roman times. Below a critical assessment of the most important publications (for a full discussion see Kiehn 2017):

(1) Pagnoux & al. (2013) and, with more details, Celant & Fiorentino (2017) report the discovery of 13 lemon seeds and a part of a *Citrus*-fruit skin dated to most probably the time of Augustus (43 v-14 n.) *“in the centre of Rome, in a votive deposit sealed under the floor of the Carcer-Tullianum, a Roman building used as a prison … 13 seeds and a fragment of skin belonging to citrus have been found”* (Pagnoux & al. 2013). This would be the first archaeological proof for lemons in Roman times. However, there is a number of questions to be asked about this report: (a) Is the identification of the seeds as *C. x limon* unequivocal? Obviously not, as Grasso & al. 2017) identify them as potentially representing *C. aurantium* or *C. reticulatum*. (b) Does the fruit skin doubtlessly represent *C. x limon*? No, as Celant and Fiorentino (2017) state that the comparision makes “the genus determination of *Citrus* a certainty.” (c) There is no evidence for any ceremonial use of any *Citrus* in Roman temples. (d) If at all, why should someone make a votive deposit of very precious fruits under the floor of a prison while the temples were just outside? (e) *Citrus* medica was known at the time the found is dated. It was believed to be an antidote against any kind of poisoning.

Taking all these arguments into account, the more conclusive interpretation of the findings is, that, in the first century AD, someone imprisoned in the Carcer Tullianum had eaten a citron, perhaps to protect himself against being poisoned. The described circumstances of the deposit in a hole under the prison floor covered by a stone plate could, instead of being part of a sacred ceremony, more probably represent a part of a sanitary deposit.

(2) A recent report of *Citrus medica* and *C. x limon* pollen from a garden of the Villa di Poppea in Oplontis from the 1st century BC (Russo Ermolli & al. 2017) needs to be further studied, as pollen of hybrids is often heterogeneous and a comparison with other *Citrus* pollen would have been of interest as well.

Summary

As shown about neither the images nor the archaeobotanical findings provide secure proofs for the presence of *Citrus x limon* in Roman times. But as they seem to support each other they form the basis for circular conclusions like Mariotti Lippi (2012) *“Even if the attribution of the Citrus pollen grains of Pompeii to C. limon is uncertain, this is not the first trace of the presence of lemon in the Vesuvian area. ... Moreover, wall paintings attest that several citrus fruits were known in Pompeii … Lemon and citron were also portrayed* *with their distinctive features in a I-II century mosaic now in the Museo delle Terme di Diocleziano in Rome"*. And because of statements like *„Some recent finds in Italy have raised the question of an earlier introduction, notably for the lemon"* it is not surprising that, in the secondary literature, meanwhile the presence of lemons is considered proven.

CONCLUSIONS

After in-depth studies of all available sources it can be concluded that only citron (*Citrus medica*) was present in the Mediterranean in ancient times. Arguments for a presence of lemon (*C. limon*) in Roman times are not correct and, therefore, the assumptions that "seeds and fruits must be from lemon because lemons are depict on images", and "images show lemons because there is archaeological evidence" obviously are circular. Citron reached Greece during the Alexandrian campaigns. Single seeds from Pompeji dated to the 3rd-2nd century BC (Fiorentino & al. 2014, Celant & Fiorentino 2017) are no proof for a cultivation of *C. medica* at that time; according to the ancient authors citrons got established in the Roman world in the first century AD. A second introduction pathway was through the Near East. All speculations about a Phoenician introduction are improbable.

ACKNOWLEDGMENTS

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REFERENCES

Attlee H. (2014) *´The land where lemons grow: the story of Italy and its citrus fruit.´* Woodstock: Countryman Press.

Balmelle C. (1990) *´8 –Quelques images de mosaïques à xenia hors de Tunisie.´* pp. 51-71 in Balmelle C., Abed-Ben Khader B., Ben Osman W., Darmon J.P., Ennaïfer M., Gozlan S., Hanoune R., Guimier-Sorbets A.-M. *´Recherches Franco-Tunisiennes sur la mosaïque de l`Afrique antique. 1. Xenia´*. Rome: École française de Rome.

Bowe, P. (2004) *´Gardens of the Roman World.´* Los Angeles: J. Paul Getty Museum.

Bonavia E. (1888) *´The cultivated oranges and lemons, etc. of India and Ceylon.´* London: W.H. Allen.

Carcopino J. (1941) *´Daily Life in Ancient Rome. The People and the City at the Height of the Empire.´* London: George Routledge And Sons Ltd.

Calabrese F. (2002) *´Origin and history.´* pp. 1-15 in Dugo G., Di Giacomo A. (eds.) *´Citrus: The Genus Citrus.´*. London & New York: Taylor & Francis.

Ceccarelli L., Wachter G. (2015) *´Tutti Frutti, Bäume und Früchte des Mittelmeerraums in Kultur und Geschichte.´* Berlin: Parthas.

Celant A., Fiorentino G. (2017) *´Macroremains of citrus fruit in Italy.´* In: Zech-Matterne V., Fiorentino G. (eds.) *´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/ pcjb/2194 (accessed August 16, 2018).

Ciarallo A. (2001) *´Gardens of Pompeii.´* Rome: L'Erma di Bretschneider.

Coubray S. (1996) *´Restes végétaux du dépôt votif.´* Atti Mem. Soc. Magna Grecia 3: 105–108.

Coubray S., Fiorentino G., Zech-Matterne V., Bui Thi Mai, Pagnoux C. (2010a) *´New perspectives about the history of Citrus in Western Mediterranean: a multidisciplinary investigation in the Campania region (Italy).´* Terra Nostra: 124.

Coubray S., Zech-Matterne V., Mazurier A. (2010b) *´The earliest remains of a Citrus fruit from a western Mediterranean archaeological context? A microtomographic-based re-assessment.´* Comptes Rendus Palevol. 9: 277–282.

De Carolis E. (2017) *´Painted gardens: Observations on execution technique.´* In: Zech-Matterne V., Fiorentino G. (eds.) *´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/pcjb/2188 (accessed August 16, 2018).

Ferrari G. B. (1646) *´De Hesperides sive de malorum aureorum cultura et uso.´* Rome: Hermann Scheus. Online: http://www.e-rara.ch/doi/10.3931/e-rara-9768 (accessed July 26, 2018).

Fiorentino G., Zech-Matterne V., Boaretto E., Celant A., Coubray S., Garnier N., Luro F., Pagnoux C., Ruas M.-P. (2014) *´AGRUMED: The history of citrus fruits in the*

Mediterranean. Introductions, diversifications, uses.´ Antiquity 088 339 (2014). https://www.researchgate.net/publication/270048187_AGRUMED _the_history_of_citrus_fruits_in_the_Mediterranean_Introductions_diversifications_and_uses (accessed July 19, 2018).

Gams H. (1979) *´Citrus.´* Der Kleine Pauli 1: 1192-1198.

Genaust H. (2005) *´Etymologisches Wörterbuch der botanischen Pflanzennamen.´* 3rd edition. Hamburg: Nikol.

Gozlan S., (1990) *´11 – Xenia: Quelques problèmes d´identification.´* pp. 85-106 in Balmelle C., Abed-Ben Khader B., Ben Osman W., Darmon J.P., Ennaïfer M., Gozlan S., Hanoune R., Guimier-Sorbets A.-M. *´Recherches Franco-Tunisiennes sur la mosaïque de l`Afrique antique. 1. Xenia´*. Rome: École française de Rome.

Grasso A.M., Mavelli F, Fiorentino G. (2017) *´Quantitative evaluation of modern Citrus seed shape and comparison with archaeological remains discovered in Pompeii and Rome.´* In: Zech-Matterne V., Fiorentino G. (eds.) *´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/pcjb/2211. (accessed August 16, 2018).

Hauschild S. (2017) *´Akanthus und Zitronen. Die Welt der römischen Gärten.´* Darmstadt: Wissenschaftliche Buchgesellschaft.

Hehn V. (1911) *´Kulturpflanzen und Haustiere in ihrem Übergang aus Asien nach Griechenland und Italien sowie in das übrige Europa.´* 8th edition: Schrader O. (ed.). Berlin: Gebrüder Bornträger.

Hornik M. (2015) *´Asarota und Xenia. Die antike Ikonografie von Speiseresten und Nahrungsmitteln im Mosaik.´* PhD Thesis. Marburg: University of Marburg..

Hui S. (1999) *´Sweet oranges: The biogeography of Citrus sinensis´*. Online: http://archive.is /RRKBE, retrieved from http://www.aquapulse.net/knowledge/orange (accessed July 19, 2018).

Jashemski, W. F., Meyer, F. G. (ed.) 2002 *´The natural history of Pompeii.´* Cambridge: Cambridge University Press.

Kiehn M. (2017) *´Exemplarische Studien zu Nutz- und Zierpflanzen der römischen Antike. Zitrus- und Kürbisgewächse´.* PhD thesis. Vienna: University of Vienna.

Kumbaric A., Caneva G. (2014) *´Updated outline of floristic richness in Roman iconography.´* Rend. Fis. Acc. Lincei 25: 181- 193.

Lack H. W. (2001) *´Ein Garten Eden. Meisterwerke botanischer Illustration.´* Köln: Taschen.

Langgut D. (2015) *´Prestigious fruit trees in ancient Israel: first palynological evidence for growing Juglans regia and Citrus medica.´* Israel Journal of Plant Sciences 62: 98-110.

Langgut D. (2017) *´The history of Citrus medica (citron) in the Near East: Botanical remains and ancient art and texts.´* In: Zech-Matterne V., Fiorentino G. (eds.) *´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/pcjb/2184. (accessed August 16, 2018).

Langgut D., Gadot Y., Lipschits O. (2014) *´"Fruit of Goodly Trees." The beginning of Citron cultivation in Israel and its penetration into Jewish tradition and culture. ´* Beit Mikra 59: 38–55.

Luro F., Curk F., Froelicher Y., Ollitrault P. (2017): *´Recent insights on Citrus diversity and phylogeny.´ In: Zech-Matterne V., Fiorentino G. (eds.) ´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/pcjb/2169. (accessed August 16, 2018).

Mabberley D. (2004) *´Citrus (Rutaceae): a review of recent advances in etymology, systematics and medicinal applications´*. Blumea 49: 481-498.

Magueron J.-C. (1992) *´Die Gärten im Vorderen Orient.´* pp. 45-80 In Carroll-Spillecke M. (ed.) *´Der Garten von der Antike bis zum Mittelalter. Kulturgeschichte der antiken Welt Bd. 57.´* Mainz: Philipp von Zabern Verlag.

Mariotti Lippi, M. (2000) *´The garden of the "Casa delle Nozze di Ercole ed Ebe" in Pompeji (Italy): palynological investigations.´* Plant Biosystems 134: 205-211.

Mariotti Lippi M. (2012) *´Ancient floras, vegetational reconstructions and man-plant relationships: case studies from archaeological sites.´* Bocconea 24: 105-113.

Marques J. (1999) *´Roteiro da primeira viagem de Vasco da Gama à Índia (Álvaro Velho). Leitura crítica, notas e estudo introductório.´* Porto: Universidade do Porto.

Moskovitz G. (2015) *´The genesis of the Etrog (citron) as part of the four species.´* Jewish Bible Quaterly 43: 109-115.

Pagnoux C., Celant A., Coubray S., Fiorentino G., Zech-Matterne V. (2013) *´The introduction of Citrus to Italy, with reference to the identification problems of seed remains.´* Veg. Hist. Archaeobot. 22: 421-438.

Paris R., Di Sarcina M. T. (Eds.) (2012) *´Palazzo massimo alle terme, I mosaici.´* Milano:Electra..

Rathgeber G. (1857) *´Archäologische Schriften: Nike in hellenischen Vasenbildern; zusammengesetzte und geflügelte Gestalten in den Denkmälern der Kunst der Babylonier, Assyrier, Phoiniker.´* Gotha: Müller.

Russo Ermolli E., Menale B., Barone Lumaga M. R. (2017) *´Pollen morphology reveals the presence of Citrus medica and Citrus x limon in a garden of Villa di Poppea in Oplontis (1st century BC).´* In: Zech-Matterne V.,

Fiorentino G. (eds.) *´AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses.´* Naples: Publications du Centre Jean Bérard. http://books.openedition.org/pcjb/2190. (accessed August 16, 2018).
Schirarend C. (1996) *'Von Apfelsine bis Zitrone'.* pp. 12-41 in Schirarend C., Heilmeyer M. (eds.) *'Die goldenen Äpfel'.* Berlin: G+H Verlag.
Theroux A. (1996) *'The Secondary Colors: Three Essays.'* New York: Holt Publ.
Thüry G. E. (2001) *'Sie "entbehrten nicht der Feste". Das römische "Gastmahlmosaik" vom Salzburger Waagplatz.'* Das kunstwerk des monats: Blatt 163.
Yonge C. D. (ed.) (1854) *´Athenaeus, The Deipnosophists. Or banquet of the learned of Athenaeus.´* London: Henry G. Bohn.
Valant-Vetschera K. M., Wollenweber E. (2005) *´Flavones and Flavonols.´* In: Andersen Ø. M., Markham K. R. (ed.) *´Flavonoids. Chemistry, Biochemistry and Applications.´* (Boca Raton 2005) 617-748.

CONNECTING HERITAGE WITH MODERN SCIENCE: THE NEW SYSTEMATIC DIVISION AT THE BOTANICAL GARDEN OF THE UNIVERSITY OF VIENNA

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ABSTRACT
Botanical research at the University of Vienna has always been famous for its focus on systematic research. Because the directors of the garden always were University professors involved in systematics, new botanical theories were likely to make their way directly into layout of the plantings in the garden. This already dates back to the times of Nikolaus Joseph von Jacquin (1727-1817). During his directorship from 1768-1796, he established a systematic division according to the Linnean classification.
Nowadays, the systematic division covers about one third of the garden area. The size and the historical background of the systematic division are outstanding features of the garden. Plant arrangements in the systematic divisions have a long and well documented history. They reflect changes in views about systematic concepts or groupings of flowering plants. Such historical features are worthwhile to be conserved, but also need explanations to understand the "different time-layers". With the recent raise of molecular phylogenetic approaches in plant systematics, there was a growing need for the University garden to exhibit these latest results in systematic research.
The Endlicher-Fenzl-Kerner-("EFK"-)trail was established in 2015 within the framework of the 650th anniversary of the University of Vienna. It highlights an important period of the garden development (between c. 1840 and 1900) and the perception of botanical systematics and of systematic research influenced by the garden directors Stephan Endlicher, Eduard Fenzl and Anton Kerner von Marilaun. They all were significantly involved in the layout and content of the systematic divisions.
The trail aims to combine the history of botanical science reflected in the garden with the newest classification approaches. The whole project is embedded into the implementation of the APG IV system in the systematic division. The „heart of the trail" are eight boards highlighting selected plant families or genera along the trail and the changing views about the taxonomic placements of taxa planted in their immediate surrounding. Three boards provide information about the biographies of the directors, and some additional boards give citations fitting to the context.
The trail is well perceived by the garden visitors. It is used in university teaching and is the subject of guided garden tours. A folder gives short information about its position in the garden and about its aims. An elaborated text informing about the EFK-trail is available on the homesite of the garden.

KEYWORDS
Historical Heritage, Botanical Systematics, APG IV

INTRODUCTION

The paper gives an insight of how the Botanical Garden of the University of Vienna dealt with the challenge to present the most actual developments in botanical systematics, connected with the specific historical heritage of the garden.

SYSTEMATICS – A LONG TRADITION IN VIENNA

At the University of Vienna, Botanical research always had a strong focus on systematics. And there even was a tradition that the chair of systematics was the director of the garden at the same time. Thus, some of these directors used the garden to show (and grow) their scientific views and concepts, as will be shown. It is documented that the

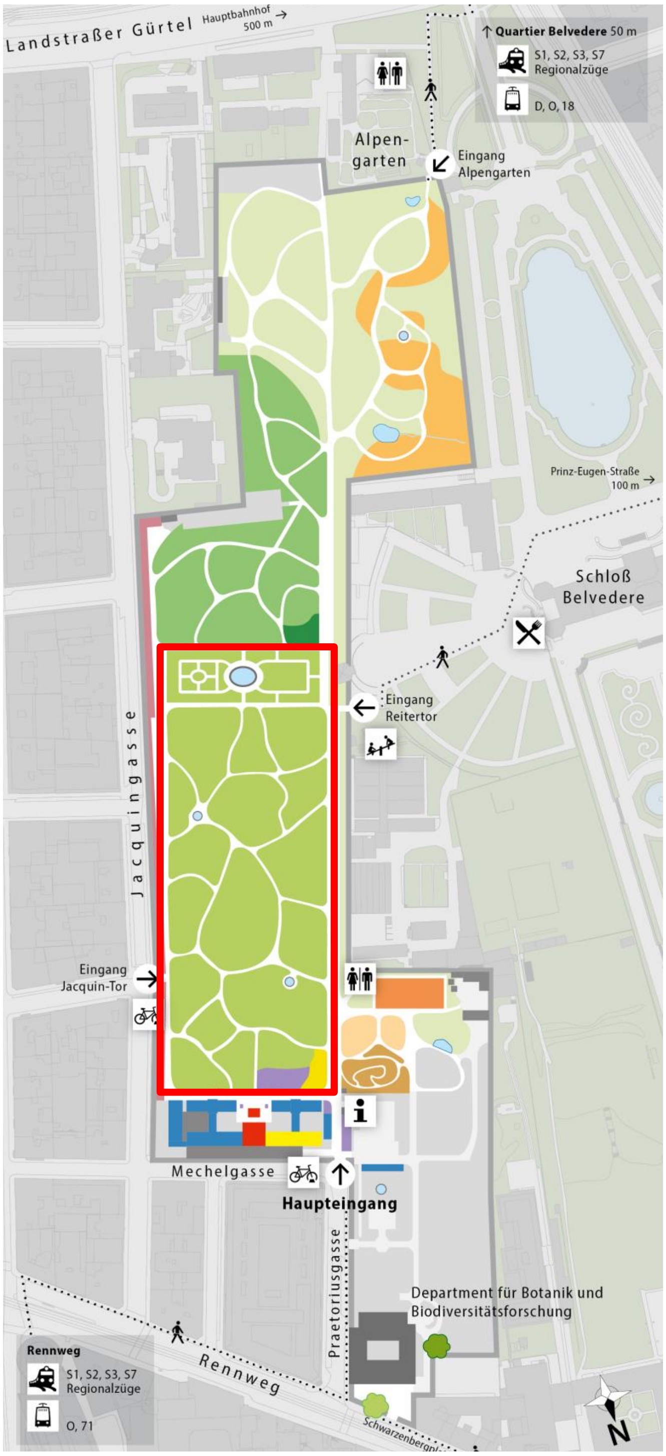

Figure 1: Garden map

garden had a systematic division right from the beginning. Founded 1754 as a medicinal garden, the plants were presented according to the Linnean system.

A unique feature of the systematic division of the garden is the size of the area of the systematic division since the middle of the 19th century. It is extraordinarily large and covers more than half of the outside area of the garden. Since it was laid out in that size, this part of the garden has undergone minor and major changes. Thus structures and contents of different times came to be positioned next to each other and on top of each other. But visitors could not "read" and understand what he or she saw; explanations were lacking. Over the years, the division got systematically unsystematic, the situation got more and more unsatisfying.

Because the systematic division still showed some "old fashioned" ideas of scientific classification concepts, we were well aware about its historical relevance regarding content, design and size.

At the same time there was a strong need for changes, i.a., to show the most actual classification approaches resulting from molecular research.

ESTABLISHING THE ENDLICHER-FENZL-KERNER-TRAIL

The "Viennese solution" on how and what to change was to establish the so-called Endlicher-Fenzl-Kerner-trail, an information trail through the systematic division that provides a look back in time. The trail is named after three former garden directors that made significant contributions to the systematic division (Petz-Grabenbauer 1997, 2015; Petz-Grabenbauer & Kiehn 2004) and whose traces are now preserved. The trail was established in 2015 within the framework of the 650th anniversary of the University of Vienna.

ANALYSIS OF HISTORICAL SOURCES

Before establishing the trail, an important step was to analyse the historical sources. First of all, the important book "Genera plantarum secundum ordines naturales disposita" written by Endlicher (1836-1840) has to be mentioned. In this book, Endlicher wrote down his ideas of a "natural system". It was published in several parts, starting in 1836. Endlicher anticipated some principal ideas of evolution long before Darwin had published his "On the Origin of species" in 1859. With the book, his concept spread throughout Europe and other Botanical Gardens even started to arrange their plants according to this "Endlicher"-system.

Fortunately, there is also an inventory of the plants that existed in the garden in the year 1842. It records 8.186 taxa,

an enormous number, especially considering the fact that these plants were mainly species to be planted outdoors.
Another important historical source is an article of the head gardener Johann Jedlicka, published in a Viennese garden magazine in 1882. Jedlicka gives a detailed description of the systematic divisions, connected with a detailed plan.
The most precious sources are the handwritten plans and lists by Anton Kerner von Marilaun, starting with the year 1894. They were only detected by the last author of this contribution a few years ago in the archives of the University of Vienna.
Anton Kerner von Marilaun´s (1890-1891) book "Pflanzenleben" ("The natural history of plants") is essential to understand Kerner´s approach to plant systematics. There were three editions of the book. In the first edition, he presented his own new ideas of systematic classifications. As they were not widely accepted, these chapters are missing in the second and third edition. But these ideas were "made visible" in the garden where they "survived" in the arrangements and placements of taxa in the systematic divisions, more or less unchanged in some parts until recently.

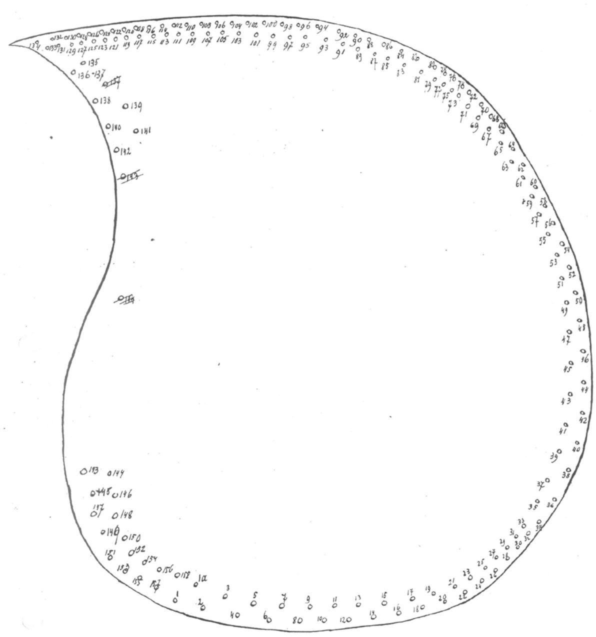

Figure 2: Hand drawn map by Anton Kerner von Marilaun, c. 1894, showing a part of the systematic division

CHANGES OF GARDEN DESIGN

When Endlicher took over the directorship from Jacquin the Younger in 1839, the garden was a baroque style garden with straight alleys and rectangular beds. Endlicher´s idea of a natural system matched perfectly with the ideas of an English landscape garden, so the central garden part was transformed into such a design, with the plants arranged according to their relationship. Endlicher died after ten years, only aged 45, and we do not know how much progress had been made in the rearrangements until his death. His successor as director was Eduard Fenzl. He had been working alongside Endlicher for years. We know for sure that it was mostly thanks to him that Endlicher´s ideas made their way into the systematic plant arrangements in the garden. The results of Fenzl´s effort are documented by the article of the head gardener Jedlicka already mentioned above. In 1878 Anton Kerner von Marilaun took over the directorship of the Botanical Garden. Because we still have his maps and his plant lists we can document that he undertook a complete rearrangement and replanting of the herbaceous plant species in the systematic division. This was a huge challenge. All herbaceous plants were displayed in round beds, arranged in two rows alongside the paths (see figure 3). A garden map of 1890 does not show much change in design, but the legend already clearly showed major changes in the arrangements of the plant families compared to the map of Jedlicka.
Since Kerner´s times, the general layout of the systematic divisions has been conserved. The only significant change was related to the shape of the beds. In the 1920s, the round beds were replaced by rectangular beds due to the degree of mechanisation of maintenance. Also the arrangement of plant families did not change much.

SPIRIT AND PURPOSE OF THE ENDLICHER-FENZL-KERNER-TRAIL

There are numerous rationales behind the creation of the Endlicher-Fenzl-Kerner-trail ("EFK-trail"). First of all, the trail provides the opportunity to present the biographies of three former garden directors of eminent international and national importance for botanical research at their time: Stefan Endlicher, Eduard Fenzl and Anton Kerner von Marilaun.
Secondly, historically important "hot spots" in the systematic groups were filtered out based on the analysis of the historic sources mentioned above. The trail then was created along these hot spots and takes note of them. In one section of the trail the layout was changed

back to Kerner´s idea of round beds in two rows on each side of the path. The new planting follows the latest APG IV classification. Thus we can also show scientific concepts and classification approaches which existed in botanical systematics in the 19th century, and even were developed by the three botanists, and we can answer the questions: Are these concepts discernible in the garden, and if so, how? What can still be perceived in the garden? To allow the visitors to get into these topics, explanations are given along the EFK-trail of HOW and WHY changes are made (or have not been necessary) in comparison to the "historical" systematic arrangements of Kerner.

Figure 3:Rectangular beds (2013) vs. Round beds (2015) (@ B. Knickmann, HBV)

Kerner was said to have been an extraordinary highly skilled teacher. And from a didactic point of view, the round beds containing only one taxon each are much more effective.

Somehow problematic were the woody plants. Of course valuable old specimens were not removed. Only if necessary for safety reasons, they will be replaced in the future by taxa reasonably fitting to the APG IV concept. Consequently, the replanting of the systematic division has been done mostly with herbaceous plants; woody plant species are only added if small enough to be presented in the beds alongside the trail.

Finally, the fact that the important historical traces and old ideas are now conserved and explained alongside the EFK-trail allows the reorganization of the remaining area of the systematic divisions according to the APG IV WITHOUT the need to take historical features into account, which made the changes much easier.

CONTENT OF THE ENDLICHER-FENZL KERNER-TRAIL

A general introduction can be found at the starting and ending point of the trail. The trail is designed to be walked-on in two directions. There are three information boards dedicated to the three former directors and eight information boards dedicated to the systematic planting scheme.

Figure 4: Information board dedicated to Anton Kerner von Marilaun (@ B. Knickmann, HBV)

Five boards give citations fitting to the context, such as *"The thread within Botany is the system; without it, the whole knowledge of plants would be chaos."* (Linné in: Mägdefrau (1992), translated by the authors), or *"Knowing only little is still better than knowing nothing"* (Anton Kerner von Marilaun; translation by the authors).

A very important part of the project is the "transfer of knowledge". The aim was that the visitors should understand the processes of systematic research, they should understand the specific Viennese situation of the systematic group and they should learn something about three directors that have contributed so much to the garden and to botanic research in general. There are different ways for the visitors to get access to that knowledge: a folder, the information boards, an elaborated text on the garden's website and guided tours.

STATUS QUO/ WHAT'S NEXT

Starting in spring 2017, the „monocots"have been incorporated. With the finalization of these plantings in spring 2019 the APG IV-based restructuring of the systematic groups basically is completed.

Comprehensive information boards are planned to be set up within the whole systematic division; furthermore, there is a booklet planned to be published with information on the specific situation and plants shown in the systematic division of the Botanic Garden of the University of Vienna; plants and researchers will tell their stories!

ACKNOWLEDGEMENTS

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REFERENCES

Darwin, Charles (1859): On the origin of species. London

Endlicher, Stephan (1836-40): Genera plantarum secundum ordines naturales disposita. Wien

Endlicher, Stephan (1842): Catalogus Horti Academici Vindobonensis. ERASMUS Wien

Jedlicka, Johann (1882), in: Petz-Grabenbauer, Maria (1997): Der "Hortus Botanicus Vindobonensis" unter der Leitung von Joseph Franz von Jacquin, Stephan Endlicher und Eduard Fenzl; 2 Bde, Wien

Kerner von Marilaun, Anton (1890-1891): Pflanzenleben. Leipzig

Linné, Carl von, in: Mägdefrau, Karl (1992): Geschichte der Botanik; Stuttgart In einer Übersetzung von Helmuth Grössing

Petz-Grabenbauer, Maria (1997): Der "Hortus Botanicus Vindobonensis" unter der Leitung von Joseph Franz von Jacquin, Stephan Endlicher und Eduard Fenzl; 2 Bde, Wien

Petz-Grabenbauer, Maria (2015): Zum Lebenswerk von Eduard Fenzl. Der Botanische Garten der Universität Wien und Fenzls Beitrag an den "Genera plantarum secundum ordines naturales disposita"; in: Mitteilungen der österreichischen Gesellschaft für Wissenschaftsgeschichte Bd. 31, S. 167-194

Petz-Grabenbauer, Maria und Kiehn, Michael (Hrsg.) (2004): Anton Kerner von Marilaun. Verlag der Österreichischen Akademie der Wissenschaften, Wien

Historische Pläne: Archiv Botanischer Garten der Universität Wien.

Figure 5: View of the Endlicher-Fenzl-Kerner-trail, September 2017 (© R. Hromniak, HBV)

LISBON'S HISTORIC GARDENS: *EX-SITU* BIODIVERSITY CONSERVATION OF ENDANGERED SPECIES

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ABSTRACT

The aim of research project LX GARDENS- Lisbon's Historic Gardens and Parks: Study and Landscape Heritage Inventory (financed by FCT: PTDC/EAT-EAT/110826/2009) was study the historic and botanical components of Lisbon's historic gardens (from the 18th century up to the 1960's). This research, from 2011 to 2014, studied the historic and botanical components of 64 Lisbon's historic gardens as part of the city's Cultural Heritage including the four botanical gardens of Lisbon (Botanical Garden of Ajuda, Tropical Botanical Garden, Lisbon Botanical Garden and Botanical park of Tapada da Ajuda). One of the aims of this study was to contribute to the identification and assessment of Lisbon's historic gardens tree diversity. The tree inventory includes plants survey (height > 2 m), of each garden that was identified and placed on a map with GIS localization tools.

The taxonomy study of these plant collections has been carried out 27 610 trees and shrubs were identified (799 species belong to 103 families) published in EBOOK - *Levantamento Arbóreo dos Jardins e Parques Históricos de Lisboa*. However, this paper is only concerned to the species included in the International Union for Conservation of Nature (IUCN) categories: EW- Extinct in the Wild, CR- Critically Endangered; EN- Endangered; Vu-Vulnerable.

Among the taxa studied were found 39 species, in different categories. EW: *Brugmansia arborea* (L.) Steud.; *B. pittieri* (Saff.) Moldenke; CR: *Araucaria angustifolia* (Bertol.) Kuntze, *Pinus torreyana* Parry ex Carrière; EN: *Abies pinsapo* Boiss., *Brahea edulis* H.Wendl. ex S.Watson, *Chamaecyparis formosensis* Matsum., *Chrysophyllum imperiale* (Linden ex K.Koch & Fintelm.) Benth. & Hook.f., *Cunninghamia konishii* Hayata, *Cupressus goveniana* Gordon, *Ginkgo biloba* L., *Juniperus cedrus* Webb & Berthel., *Malus niedzwetzkyana* Dieck ex Koehne, *Metasequoia glyptostroboides* Hu & W.C.Cheng, *Pinus radiata* D.Don, *Sabal bermudana* L.H. Bailey, *Schefflera elegantissima* (Veitch ex Mast.) Lowry & Frodin, *Sequoia sempervirens* (D.Don) Endl.; VU: *Afrocarpus mannii* (Hook.f.) C.N.Page, *Araucaria heterophylla* (Salisb.) Franco, *Butia eriospatha* (Mart. ex Druce) Becc., *Caesalpinia paraguariensis* (Parodi) Burkart, *Cedrela odorata* L., *Cedrus libani* A.Rich., *Ceratozamia mexicana* Brongn., *Colletia paradoxa* (Spreng.) Escal., *Cupressus bakeri* Jeps., *C. macrocarpa* Hartw., *Dracaena draco* (L.) L. subsp. c*aboverdeana* Marrero Rodr. & R.Almeida, *Encephalartos altensteinii* Lehm., *Howea belmoreana* (C.Moore & F.Muell.) Becc., *H. forsteriana* (F.Muell.) Becc., *Jacaranda mimosifolia* D.Don, *Jubaea chilensis* (Molina) Baill., *Macadamia integrifolia* Maiden & Betche, *M. tetraphylla* L.A.S.Johnson, *Sideroxylon mirmulans* R. Br., *Torreya californica* Torr.). The germplam collections of these green areas of Lisbon are a very important heritage to our *ex situ* biodiversity conservation.

This systematic study constitutes a tool to protect and enhance the gardens and their botanical assessment in order to protect and promote this legacy as cultural heritage with high ecological, recreational, artistic, aesthetic, social and tourism value.

KEYWORDS

Portugal, Heritage, Biodiversity Conservation

INTRODUCTION

The main aim of this article is to identify the 27 610 trees inventoried during the research project known as LX GARDENS- Lisbon's Historic Gardens and Parks: Study and Landscape Heritage Inventory (financed by FCT: PTDC/EAT-EAT/110826/2009), the major results, highlighting the specimens and species whose conservation status

in nature is threatened according to the categories defined in the *International Union for Conservation of Nature* (IUCN) *Red List of Threatened Species* (Version 2017-1. <WWW.IUCNREDLIST.ORG>. Downloaded on 01 September 2017). These trees can be found in the gardens studied and thus contribute in an "*ex-situ*" manner to the biodiversity conservation of endangered species.
The materials and methods section set out the methodology used to conduct a survey and inventory of the tree composition of the 64 gardens and parks studied in Lisbon. The tree inventory includes a plants survey (height > 2 m) of each garden that was identified and placed on a map with GIS localization tools.
The main conclusions can be found at the end of the article together with the location and distribution of the species and respective specimens, highlighting the gardens and parks that house the largest number of the species whose conservation status in nature is threatened, which can be summarised as follows: 37 threatened species are in "botanical gardens" vs. 9 species in "other gardens". It should be mentioned that Lisbon has four botanical gardens, included in this study, Ajuda Botanical Garden (3.5 ha), Lisbon Botanical Garden (5.6 ha), the Tropical Botanical Garden (6.4 ha) and Tapada da Ajuda Botanical Park (100 ha).

MATERIAL AND METHODS

The area studied, which amounts to around 3% of the Lisbon's total area (100 Km^2), includes 64 historic gardens and parks (figure 1 – map of Lisbon showing location of gardens), of which 59 possess an inventory identifying all existing specimens and their respective locations, while for 1 garden there is only a list of the tree species present and for 4 gardens there is a mixture since there is a list of all tree species which identifies and gives the location of each specimen in the garden while there is only a species list for the wooded area. Of these inventories 62 had been undertaken by the LXGardens Project team (coordinated by Teresa Vasconcelos), while the other two relating to the Tropical Botanical Garden and the Calouste Gulbenkian Foundation Garden were supplied by the managing bodies
The methodology consisted of the following tasks: inventory of tree specimens including botanical identification, uploading into geographical information systems and processing and interpreting of data.
The data entered into the SIG from 2011 to 2014, included the following items: (1) Specimen ID number; (2) Garden code; (3) Type of green space (Garden, Park, Botanical Garden, Enclosure and Hunting Ground or Recreation Ground); (4) Species code; (5) Family; (6) Genus; (7) Species; (8) Species classifier; (9) Geographic origin of the taxa; (10) Status of the region's plants life: native to mainland Portugal, non-native and/or invasive); (11) Growth form – Plant physiognomy; (12) ETRS 1989 coordinates; (13) Classified as being of public interest; (14) Legislation classifying the tree; (15) Classified as having a conservation status in nature of threatened as per the *International Union for Conservation of Nature* (IUCN) *Red List of Threatened Species* (Version 2017-1. <WWW.IUCNREDLIST.ORG>. Downloaded on 01 September 2017),

In terms of specimen identification, the study was conducted on the basis of external morphological features, using works of reference specific to the field – Bailey (1975), Bailey & Bailey (1976), Eggli (2003), Franco (1971, 1984); Franco & Afonso (1994, 1998, 1993), Huxley et al. (1992) and Walters et al. (1986, 1984, 1989, 1995, 1997) – and by comparison to specimens to be found in the João Carvalho e Vasconcellos herbarium (LISI) at Lisbon University's School of Agronomy.
Works of reference were used to check the names of families [Kubitzki, (1990, 1993, 1998a, b)], the names of species [The Plant List – version 1.1.] and the respective names of the authors of species [Brummitt & Powell, (1992)].
The geographic origin (Brummit, 2001) of each of the taxa was studied, as well as its conservation status under the IUCN categories of Walter & Gillett (1998).
As for classifying a species as having a conservation status in nature of threatened, the categories defined in the *International Union for Conservation of Nature* (IUCN) *Red List of Threatened Species* was used, namely:

- EW-Extinct in the Wild
- CR- Critically Endangered
- EN-Endangered
- VU-Vulnerable

The data collected was introduced into a relational database built in a SQL server 2014 and processed using statistical analysis (software such as Excel and R) which made it possible to identify the more abundant species, group them by geographical origin, and other information relevant to an understanding of the tree diversity in Lisbon. Of particular note in this article is the identification and quantification of the species deemed threatened in nature and which can be found in Lisbon's gardens and parks.

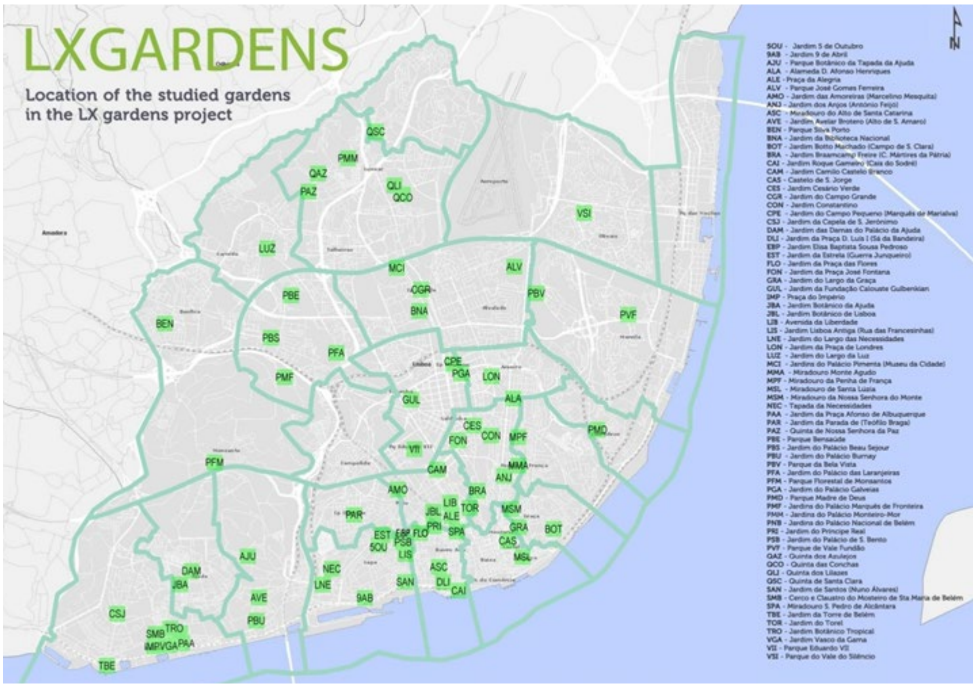

Figure 1: Green areas inventoried by the "LX GARDENS - Lisbon's Historic Gardens and Parks" team project

RESULTS AND DISCUSSION

In the 64 gardens studied it was possible to collect data on plant diversity and identify and locate 27 610 trees. Some of the results have been summarized below. A total of 103 families, 317 genera and 799 species.

Regarding the geographical origin of the specimens and species inventoried, the results were as follows:

- Of the 27 610 trees inventoried 62% are non-native, 35% native (from mainland Portugal) and 3% invasive.
- Of the 799 species identified 90% are non-native, 8% native (from mainland Portugal) and 2% invasive.

After that the species to be found on the Red list of threatened species were identified using the International Union for Conservation of Nature (IUCN) categories. The list defines the following categories: CR-Critically Endangered; EN-Endangered; VU-Vulnerable or EW-Extinct in the Wild.

Of the 27 610 specimens surveyed 928 (3.4%) fall into the endangered category and of the 799 species 39 (4.9%) are in this category. The number of specimens and respective species to be found in the gardens studied are distributed across the IUCN categories as shown in table 1, which also shows the breakdown between botanical gardens and other gardens.

			EW - Extinct in the Wild		CR - Critically Endangered		EN - Endangered		VU - Vulnerable	
	Number trees	Number species	Number trees	Number species	Number trees	Number species	Number trees	Number species	Number trees	Number species
LX Gardens IUCN	928	39	2	2	6	2	153	15	767	21
Botanical Gardens IUCN	278	37	2	2	4	2	75	15	197	18
Other gardens IUCN	650	15	0	0	2	1	78	5	570	9

Table 1: 39 species in different categories

Among the taxa studied were found 39 species, in different categories. EW: *Brugmansia arborea* (L.) Steud.; *B. pittieri* (Saff.) Moldenke; CR: *Araucaria angustifolia* (Bertol.) Kuntze, *Pinus torreyana* Parry ex Carrière; EN: *Abies pinsapo* Boiss., *Brahea edulis* H.Wendl. ex S.Watson, *Chamaecyparis formosensis* Matsum., *Chrysophyllum imperiale* (Linden ex K.Koch & Fintelm.) Benth. & Hook.f., *Cunninghamia konishii* Hayata, *Cupressus goveniana* Gordon, *Ginkgo biloba* L., *Juniperus cedrus* Webb & Berthel., *Malus niedzwetzkyana* Dieck ex Koehne, *Metasequoia glyptostroboides* Hu & W.C.Cheng, *Pinus radiata* D.Don, *Sabal bermudana* L.H. Bailey, *Schefflera elegantissima* (Veitch ex Mast.) Lowry & Frodin, *Sequoia sempervirens* (D.Don) Endl.; VU: *Afrocarpus mannii* (Hook.f.) C.N.Page, *Araucaria heterophylla* (Salisb.) Franco, *Butia eriospatha* (Mart. ex Druce) Becc., *Caesalpinia paraguariensis* (Parodi) Burkart, *Cedrela odorata* L., *Cedrus libani* A.Rich., *Ceratozamia mexicana* Brongn., *Colletia paradoxa* (Spreng.) Escal., *Cupressus bakeri* Jeps., *C. macrocarpa* Hartw., *Dracaena draco* (L.) L. subsp. *caboverdeana* Marrero Rodr. & R.Almeida, *Encephalartos altensteinii* Lehm., *Howea belmoreana* (C.Moore & F.Muell.) Becc., *H. forsteriana* (F.Muell.) Becc., *Jacaranda mimosifolia* D.Don, *Jubaea chilensis* (Molina) Baill., *Macadamia integrifolia* Maiden & Betche, *M. tetraphylla* L.A.S.Johnson, *Sideroxylon mirmulans* R. Br., *Torreya californica* Torr.).

Table 2 summarises the specimens inventoried broken down by IUCN category and indicating the plant species, the total number of specimens, as well as the name of the Lisbon garden. Attention is drawn here to the species in each category of which there are the most specimens and the abbreviation for the garden in which they can be found:

EW - *Brugmansia arborea* (L.) Steud., 1 specimen located in Lisbon Botanical Garden (11 JBL)

CR - *Araucaria angustifolia* (Bertol.) Kuntze, 5 specimens located in 11 JBL, 50 VII, 68 AJU

EN- *Ginkgo biloba* L., 90 specimens located in 05AMO, 10JBA, 11JBL, 12TRO, 14BRA, 17CGR, 25EST, 28LNE, 30LUZ, 37PBU, 40PMF, 47PMM, 50VII, 61PRI, 68AJU

VU - *Jacaranda mimosifolia* D. Don, 460 specimens located in: 015OU, 029AB, 04ASC, 07AVE, 09PBNA, 10JBA, 11JBL, 12TRO, 13BOT, 14BRA, 15CAI, 17 CGR, 18CPE, 20CAS, 22CON, 25EST, 36PBS, 37PBU, 39PSB, 40PMF, 42PNB, 43PAR, 47PMM, 50VII, 55DU, 57FLO, 58LON.

Project Threatened Species List	IUCN	Trees number	Gardens/Parks*
Abies pinsapo Boiss.	EN	1	11JBL, 68AJU
Afrocarpus mannii (Hook.f.) C.N.Page	VU	22	10JBA, 11JBL, 12TRO, 68AJU
Araucaria angustifolia (Bertol.) Kuntze	CR	5	11JBL, 50VII, 68AJU
Araucaria heterophylla (Salisb.) Franco	VU	20	015OU, 10JBA, 11JBL, 12TRO, 14BRA, 29LIS, 47PMM, 50VII, 58LON, 68AJU, 69NEC
Brahea edulis H.Wendl. ex S.Watson	EN	7	11JBL, 12TRO
Brugmansia arborea (L.) Steud.	EW	1	11JBL
Brugmansia pittieri (Saff.) Moldenke	VU	1	11JBL
Butia eriospatha (Mart. ex Druce) Becc.	VU	1	11JBL
Caesalpinia paraguariensis (Parodi) Burkart	VU	2	10JBA, 68AJU
Cedrela odorata L.	VU	3	10JBA, 12TRO
Cedrus libani A.Rich.	VU	14	25EST, 50VII, 62QCO, 68AJU, 69NEC
Chamaecyparis formosensis Matsum.	EN	1	68AJU
Chrysophyllum imperiale (Linden ex K.Koch & Fintelm.) Benth. & Hook.f.	EN	3	11JBL, 12TRO, 37PBU
Colletia paradoxa (Spreng.) Escal.	VU	1	11JBL, 68AJU
Cunninghamia konishii Hayata	EN	5	68AJU
Cupressus bakeri Jeps.	VU	4	68AJU
Cupressus goveniana Gordon	EN	2	68AJU
Cupressus macrocarpa Hartw.	VU	23	10JBA, 11JBL, 12TRO, 26GUL, 40PMF, 60FON, 62QCO, 63QSC, 68AJU
Dracaena draco (L.) L. subsp. caboverdeana Marrero Rodr. & R.Almeida	VU	52	10JBA, 11JBL, 12TRO, 25EST, 37PBU, 39PSB, 47PMM, 61PRI, 63QSC, 68AJU, 69NEC
Encephalartos altensteinii Lehm.	VU	2	37PBU
Ginkgo biloba L.	EN	90	05AMO, 10JBA, 11JBL, 12TRO, 14BRA, 17CGR, 25EST, 28LNE, 30LUZ, 37PBU, 39PSB, 43PAR, 47PMM, 50VII, 61PRI, 68AJU
Howea belmoreana (C.Moore & F.Muell.) Becc.	VU	3	25EST
Howea forsteriana (F.Muell.) Becc.	VU	145	05AMO, 08LIB, 10JBA, 11JBL, 12TRO, 14BRA, 17CGR, 25EST, 26GUL, 37PBU, 40PMF, 47PMM, 50VII, 61PRI, 66SAN, 68AJU, 69NEC
Jacaranda mimosifolia D.Don	VU	460	015OU, 029AB, 04ASC, 07AVE, 09BNA, 10JBA, 11JBL, 12TRO, 13BOT, 14BRA, 15CAI, 17CGR, 18CPE, 20CAS, 22CON, 25EST, 36PBS, 37PBU, 39PSB, 40PMF, 42PNB, 43PAR, 47PMM, 50VII, 55DLI, 57FLO, 58LON
Jubaea chilensis (Molina) Baill.	VU	4	12TRO, 36PBS, 40PMF, 68AJU
Juniperus cedrus Webb & Berthel.	EN	2	12TRO
Macadamia integrifolia Maiden & Betche	VU	5	11JBL, 12TRO
Macadamia tetraphylla L.A.S.Johnson	VU	1	68AJU
Malus niedzwetzkyana Dieck ex Koehne	EN	2	12TRO
Metasequoia glyptostroboides Hu & W.C.Cheng	EN	3	11JBL, 68AJU
Picconia azorica (Tutin) Knobl.	EN	5	10JBA, 11JBL, 68AJU
Picconia excelsa (Aiton) DC.	VU	3	11JBL, 68AJU
Pinus radiata D.Don	EN	2	26GUL, 47PMM, 52ALV, 68AJU
Pinus torreyana Parry ex Carrière	CR	1	11JBL
Sabal bermudana L.H. Bailey	EN	3	11JBL, 12TRO, 14BRA, 68AJU

Schefflera elegantissima (Veitch ex Mast.) Lowry & Frodin	EN	3	10JBA, 11JBL, 68AJU
Sequoia sempervirens (D.Don) Endl.	EN	24	11JBL, 12TRO, 25EST, 26GUL, 36PBS, 39PSB, 43PAR, 47PMM, 68AJU
Sideroxylon mirmulans R. Br.	VU	1	11JBL
Torreya californica Torr.	VU	1	11JBL

*01SOU - Jardim 5 de Outubro; 029AB - Jardim 9 de Abril (Rocha Conde de Óbidos); 03ALA - Alameda D. Afonso Henriques; 04ASC - Miradouro Alto de Santa Catarina; 05AMO - Jardim das Amoreiras (Marcelino Mesquita); 06ANJ - Jardim dos Anjos (António Feijó); 07AVE - Jardim Avelar Brotero (Alto Santo Amaro); 08LIB - Avenida da Liberdade (Passeio Público); 09BNA - Jardim da Biblioteca Nacional; 10JBA - Jardim Botânico da Ajuda; 11JBL - Jardim Botânico de Lisboa; 12TRO - Jardim Botânico Tropical; 13BOT - Jardim Botto Machado (Campo Santa Clara); 14BRA - Campo Mártires da Pátria (Braamcamp Freire); 15CAI - Jardim Roque Gameiro (Cais do Sodré); 16CAM - Jardim Camilo Castelo Branco; 19CGR - Jardim do Campo Grande; 18CPE - Jardim do Campo Pequeno (Marquês de Marialva); 19CSJ - Jardim da Capela de São Jerónimo (Ducla Soares); 20CAS - Jardim do Castelo de São Jorge; 21CES - Jardim Cesário Verde; 22CON - Jardim Constantino; 23DAM - Jardim das Damas do Palácio da Ajuda; 24EBP - Jardim Elisa Baptista de Sousa Pedroso ; 26EST - Jardim da Estrela (Guerra Junqueiro); 30GUL - Jardim da Fundação Calouste Gulbenkian; 27GRA - Jardim do Largo da Graça (Augusto Gil); 28LNE - Jardim do Largo das Necessidades/ Olavo Bilac; 29LIS - Jardim Lisboa Antiga (Rua das Francesinhas); 30LUZ - Jardim do Largo da Luz (Teixeira Rebelo); 31MSM - Miradouro da Nossa Senhora do Monte; 32MPF - Miradouro da Penha França; 33MSL - Miradouro de Santa Luzia; 34MMA - Miradouro do Monte Agudo; 35MCI - Jardins do Palácio Pimenta (Museu da Cidade); 36PBS - Jardim do Palácio Beau Séjour; 37PBU - Jardim do Palácio Burnay; 39PSB - Palacete de São Bento; 40PMF - Jardins do Palácio dos Marqueses de Fronteira; 41PGA - Jardim do Palácio Galveias (Biblioteca Municipal Central); 42PNB - Jardins do Palácio Nacional de Belém; 43PAR - Jardim da Parada de Campo de Ourique (Teófilo de Braga); 47PMM - Parque do Monteiro-Mor; 49VSI - Parque do Vale do Silêncio; 50VII - Parque Eduardo VII e Estufa Fria; 52ALV - Parque José Gomes Ferreira (Mata de Alvalade); 54PAA - Jardim da Praça Afonso de Albuquerque; 55DLI - Jardim da Praça D. Luís I (Sá da Bandeira); 56ALE - Jardim da Praça da Alegria (Alfredo Keil); 57FLO - Jardim da Praça das Flores (Fialho de Almeida); 58LON - Jardim da Praça de Londres; 59IMP - Jardim da Praça do Império; 60FON - Jardim da Praça José Fontana (Henrique Lopes de Mendonça); 61PRI - Jardim do Príncipe Real (França Borges); 62QCO - Quinta das Conchas; 63QSC - Quinta de Santa Clara; 65QLI - Quinta dos Lilases; 66SAN - Jardim de Santos (Nuno Álvares); 67SPA - Miradouro São Pedro de Alcântara (António Nobre); 68AJU - Parque Botânico da Tapada da Ajuda (Tapada Real de Alcântara); 69NEC - Tapada das Necessidades; 70TOR - Jardim do Torel; 71TBE - Jardim da Torre de Belém; 72VGA - Jardim Vasco da Gama,

Table 2: Specimens inventoried broken down by IUCN category and indicating the plant species, the total number of specimens, as well as the name of the Lisbon garden

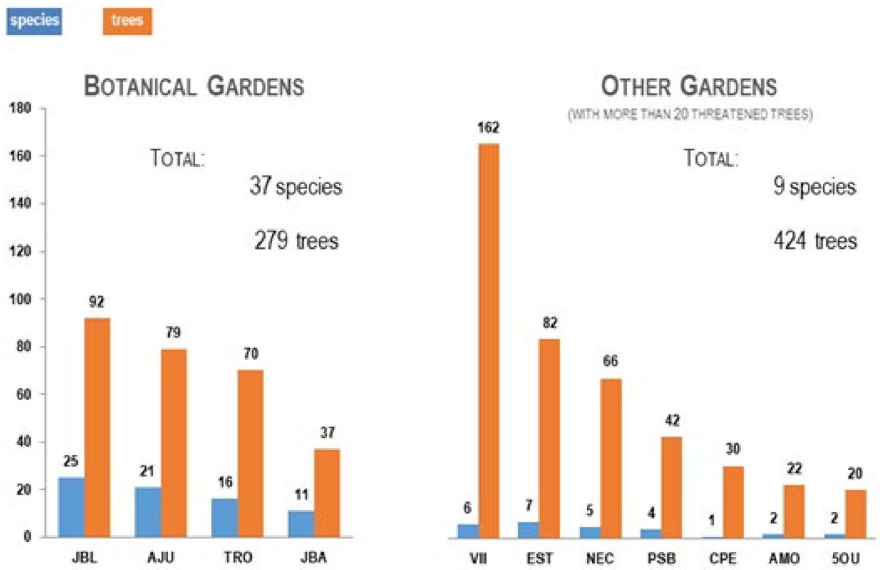

Figure 2: The 64 gardens and parks studied, the "botanical gardens" house the larger diversity of species covered by the IUCN categories compared to the "other gardens"

Looking at figure 2 we find that of the 64 gardens and parks studied, the "botanical gardens" house the larger diversity of species covered by the IUCN categories (37 species) compared to the "other gardens" (15 species). Furthermore, all the 37 species existing in the "botanical gardens" can be found in the "other gardens" except for two species, *Encephalartos altensteinii* (Burnay Palace Garden) and *Howea belmoreana* (Estrela Garden).

The botanical gardens' importance as biodiversity hotspots and their significant role in "*ex-situ*" conservation of species must be underlined.

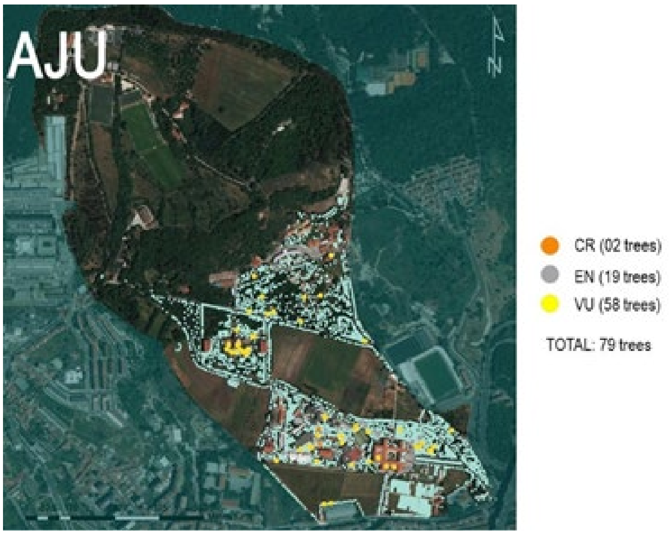

Figure 3: Map of Tapada da Ajuda Botanical Park identifying the trees and respective key, which includes the tree species' IUCN category.

In Tapada da Ajuda Botanical Park (Figure 3) there are 79 specimens distributed in the following manner: 2 CR, 19 EN, 58 VU.

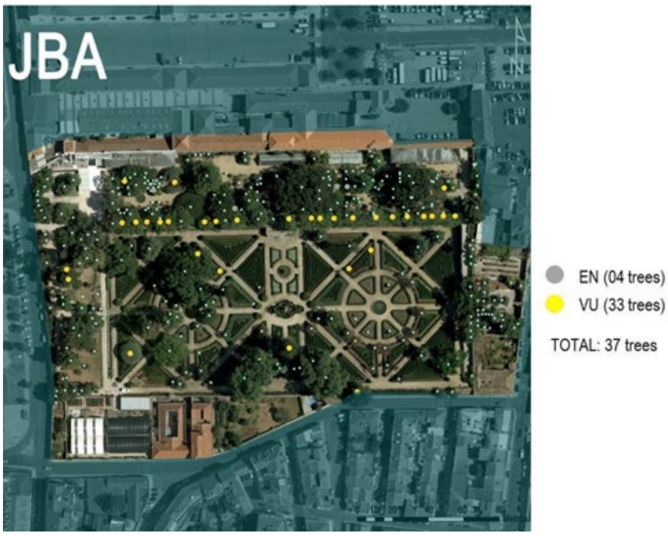

Figure 4: Map of Ajuda Botanical Garden identifying the trees and respective key, which includes the tree species' IUCN category.

In Ajuda Botanical Garden (Figure 4) there are 37 specimens distributed in the following manner: 4 EN, 33 VU.

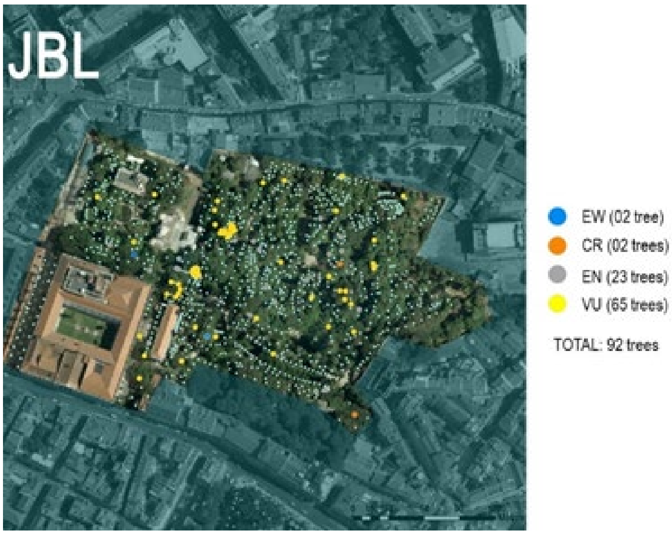

Figure 5: Map of Lisbon Botanical Garden identifying the trees and respective key, which includes the tree species' IUCN category.

In Lisbon Botanical Garden (Figure 5) there are 92 specimens distributed in the following manner: 2 EW, 2 CR, 23 EN, 65 VU.

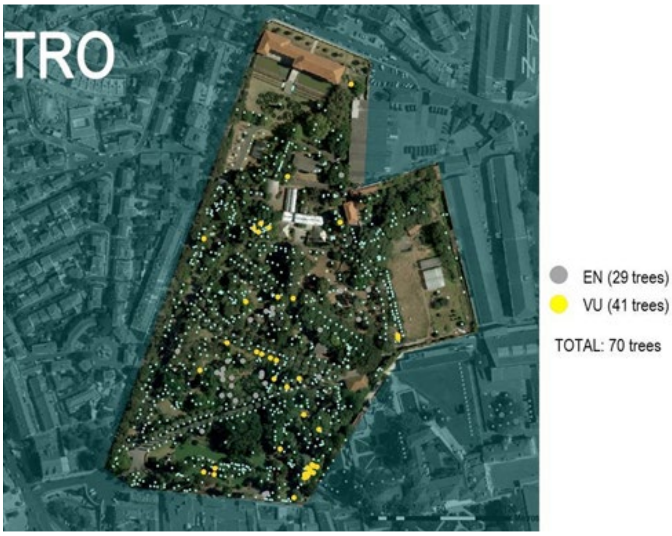

Figure 6: Map of the Tropical Botanical Garden identifying the trees and respective key, which includes the tree species' IUCN category.

In the Tropical Botanical Garden (Figure 6) there are 70 specimens distributed in the following manner: 29 EN, 41 VU.

CONCLUSION

Over the centuries Lisbon's climate has allowed the coexistence of plant species with diverse biogeographical origins, from Northern Europe to the tropics, which has given its gardens a greatly diversified tree composition and contribute to a biodiversity hotspot.

These green areas of Lisbon are a very important heritage for our "*ex situ*" biodiversity conservation. Of special note is the important role the botanical gardens have played in biodiversity conservation and enhancement, as well as for species which are part of the Red list of threatened species, as per the *International Union for Conservation of Nature* (IUCN) categories, namely: CR-Critically Endangered; EN-Endangered; VU-Vulnerable or EW-Extinct in the Wild.

This systematic study constitutes a tool to protect and enhance the gardens and their botanical assessment in order to protect and promote this legacy as cultural heritage with high ecological, recreational, artistic, aesthetic, social and tourism value.

ACKNOWLEDGEMENTS

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REFERENCES

Andresen, Teresa (coord.) (2003) — Do Estádio Nacional ao Jardim Gulbenkian - Francisco Caldeira Cabral e a primeira geração de Arquitectos Paisagistas (1940-1970). Lisboa, Fundação Calouste Gulbenkian.

Araújo, Ilídio Alves de (1962) — Arte Paisagista e Arte dos Jardins em Portugal. Lisboa: Direcção Geral dos Serviços de Urbanização.

Azambuja, Sónia Talhé (2001) – "Real Quinta das Necessidades: um fio condutor na arte dos jardins em Portugal". In CASTEL-BRANCO, Cristina (Coord.) - Necessidades: Jardins e Cerca. Lisboa: Livros Horizonte, 2001, pp. 129-151.

Bailey, L.H. & Bailey, E.Z. (1976). Hortus-Third. A. Concise Dicionary of Plants Cultivate in The Unites States and Canada. 1290 pp. Macmillan Publishing Company, New York.

Bailey, L.H. (1975). Manual of Cultivated Plants. The Macmillan Publishing Company, New York.

Brummitt, R.K. & Powell, C.E. (1992). Authors of plans names. 732pp. Royal Botanic Gardens, Kew.

Castel-Branco, C. [coord.) (2001) — Necessidades. Jardins e Cerca. Lisboa: Livros Horizonte, Lisboa.

Castel-Branco, C.; Soares, A. L. (2007) – "As árvores da cidade de Lisboa". In SILVA, José Sande (coord.) – Florestas e Sociedade. Uma história em comum. Colecção Árvores e Florestas de Portugal, n.º 7. Lisboa: Público, pp. 289-334.

Costa, J.C. et. al. (1998) - Biogeografia de Portugal Continental. Quercetea. Vol 0: Lisboa: ALFA, pp. 5-56.

Eggli, U. (ed.). 2003. Illustrated Handbook of succulent plants: monocotyledons. Springer-Verlag. Berlin.

Erhardt, W. Götz, E. & Bödeker, N. (2000). Zander Dictionary of plant names 16. Auflage. Eugen Ulmer Gmb H & Co., Stuttgart. 999 pp.

Franco, J.A. & Afonso, M.L.R. (1994, 1998, 1993). Nova Flora de Portugal (Continente e Açores), 3 (1, 2 & 3), Alismataceae–Iridaceae, Gramineae, & Juncaceae-Orchidaceae. Escolar Editora, Lisboa.

Franco, J.A. (1971, 1984). Nova Flora de Portugal (Continente e Açores), 1 & 2, Franco, J.A. (ed.), Lisboa.

Huxley, A., Griffiths, M. & Levy, M. (eds.) (1992). The New Royal Horticultural Society Dictionary of Gardening, 1-4. The Macmillan Press Limited, London.

Kubitzki, K. (ed.) (1990.1993. 1998a,b) The Families and Genera of Vascular Plants. 1-4. Berlin, Heidelbberg. Springer Verlag.

Tattar, T.A. 1989. Diseases of Shade Trees. Rev. ed., Academic Press, Inc. San Diego, California, USA, 391 pp.

The Plant List (version 1.1.). Retrieved (2015) from http://www.theplantlist.org/

Walter, K.S. & Gillett, H.J. (eds). (1998). 1997 IUCN Red List of Threatened Plants. 862pp. IUCN Gland, Switzerland & Cambridge.

Walters, S.M., Brady, A. et al. (1986, 1984, 1989, 1995, 1997). The European witze Flora, 1–6. Cambridge University Press, Cambridge.

HISTORICAL EXPOSITION "BIOLOGICAL AND MORPHOLOGICAL GROUPS OF PLANTS" IN THE BOTANICAL GARDEN OF THE UNIVERSITY OF LATVIA

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ABSTRACT
The Botanical Garden of the University of Latvia was developed as a place for studies of botany both for students and the general public. Therefore the first exposition was "Biological and Morphological Groups of Plants" created during the late twenties of the 20-th century. Up to these days the arrangement of the exposition has not been changed – it keeps a consistent botanical structure and planting beds. There are more than 500 different taxa in this exposition, including woody plants, herbaceous perennials, annual and biennial plants.
The exposition is divided in four sections. The section for Plant adaptation (A) demonstrates specific exterior features of plants that have been formed as a result of different external conditions. The section for Plant propagation and spreading (B) exhibits a variety of seeds, fruits, examples of vegetative propagation, and adaptations for seed dispersal by wind, animals and humans. The section for Leaves and flowers (C) displays morphology of leaves and the wide diversity of flowers and their morphology. Plants in the section for Pollination (D) demonstrate the dichogamy, heterostyly, the difference between cross-pollination and self-pollination, adaptation to wind or insect pollination.

KEYWORDS
Garden History, 20th Century, Plant Morphology

The Botanical Garden of the University of Latvia is the first botanical garden in Latvia established in 1922. It was developed as a place for studies of botany both for students and the general public. Therefore the first two created expositions were a botanical garden's standard for that time – "Biological and Morphological Groups of Plants" (BMGP) and "Family beds" arranged according to the classification by German botanists A. H. G. Engler and C. A. E. Prantl at the turn of the 19th-20th century.
BMGP was created during the late twenties of the 20-th century (Figure 1) and up to these days the arrangement has not been changed (Figure 2) – it keeps a consistent botanical structure and planting beds, the same coarse sand paths and borders. It has been preserved despite the fact the teaching methods have changed and serves as a memorial to founders of the garden and the garden culture of that period. The creators of the exposition were professors of the University of Latvia - Nikolajs Malta (1890-1944) and Pauls Galenieks (1891-1962).
BMGP exposition is divided in four sections: A – Plant adaptation, B – Plant propagation and spreading, C – Leaves and flowers, D – Pollination (Figure 3). Plants with characteristic features are grown according to this layout to demonstrate morphology on the spot.
The section for Plant adaptations (A) demonstrates specific exterior features of plants that have been formed as a result of different external conditions (Figure 4). Mainly there are three types of the influence: environmental, animal and other plants. The plants have adapted to protect themselves against animal attacks by thorns (*Berberis vulgaris* L.) or sticky substances (*Viscaria vulgaris* Bernh.), they have a thick layer of hairs on the leaves (*Hieracium villosum* Jacq.) to survive excessive drought or humidity, etc. This section includes 38 wild poisonous plants also.
The section for Plant propagation and spreading (B) exhibits a morphological variety of seeds and fruits, examples of vegetative propagation, and adaptations for seed dispersal by wind, animals and humans (Figure 5) .
The section for Leaves and flowers (C) displays morphology of leaves (lamina, leaf margin, shape, venation, divergence, movements) and the wide diversity of flowers and their morphology (structure, raceme, colour, symmetry) (Figure 6).
Plants in the section for Pollination (D) demonstrate the dichogamy, heterostyly, the difference between cross-pollination and self-pollination, adaptation to wind or insect pollination, etc. (Figure 7)
Today BMGP hosts 700 different taxa – mainly species from 85 families: including 49 woody plants, 454 herbaceous perennials, 167 annual and 30 biennial plants. Each year the seedlings are grown for 81 taxa of annual

plants, but for 86 species, the seeds are sown directly in the plant beds of the exposition. Altogether there are 189 species from the wild flora of Latvia. Nowadays, a special attention is paid to the *ex situ* conservation of threatened species. Therefore, this exposition owns endangered species who at the same time demonstrate the specific morphological features as well. In the BMGP there are 33 threatened taxa protected by the Regulations of the Cabinet of Ministers of the Republic of Latvia No. 396 adopted on November 14, 2000 "List of Specially Protected Species and Species with Exploitation Limits" (Noteikumi, 2000). The exposition contains 188 red-listed Baltic Region species as well (Red Data Book of the Baltic Region, 1993). But *Pulsatilla patens* L. (Mill.) represents the plant life span of herbaceous perennials (section A) and it is being protected under Annex II of the EU Habitats Directive (1992).

Despite the fact that new methods in education and different kinds of printed and electronic media are developing, we still believe that the experience that only a live plant can give must be cherished. Expositions like BMGP are of great importance in the future both for botany students and the general public to demonstrate the fascinating peculiarities and wide diversity of plants and to share the interest about flora.

REFERENCES

EU Habitats Directive, 1992, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043

Noteikumi,2000 https://likumi.lv/doc.php?id=12821

'Red Data Book of the Baltic Region, Part 1, List of threatened vascular plants and vertebrate' (1993), ed. by T. Ingelög, R., Andersson, Swedisg Threatened Species Unit, Uppsala, Institute of Biology, Riga, 95 pp.

FIGURES AND TABLES

Figure 1: Exposition "Biological and Morphological Groups of Plants" at the thirties of 20-th century.

Figure 2: The plan of the exposition "Biological and Morphological Groups of Plants".

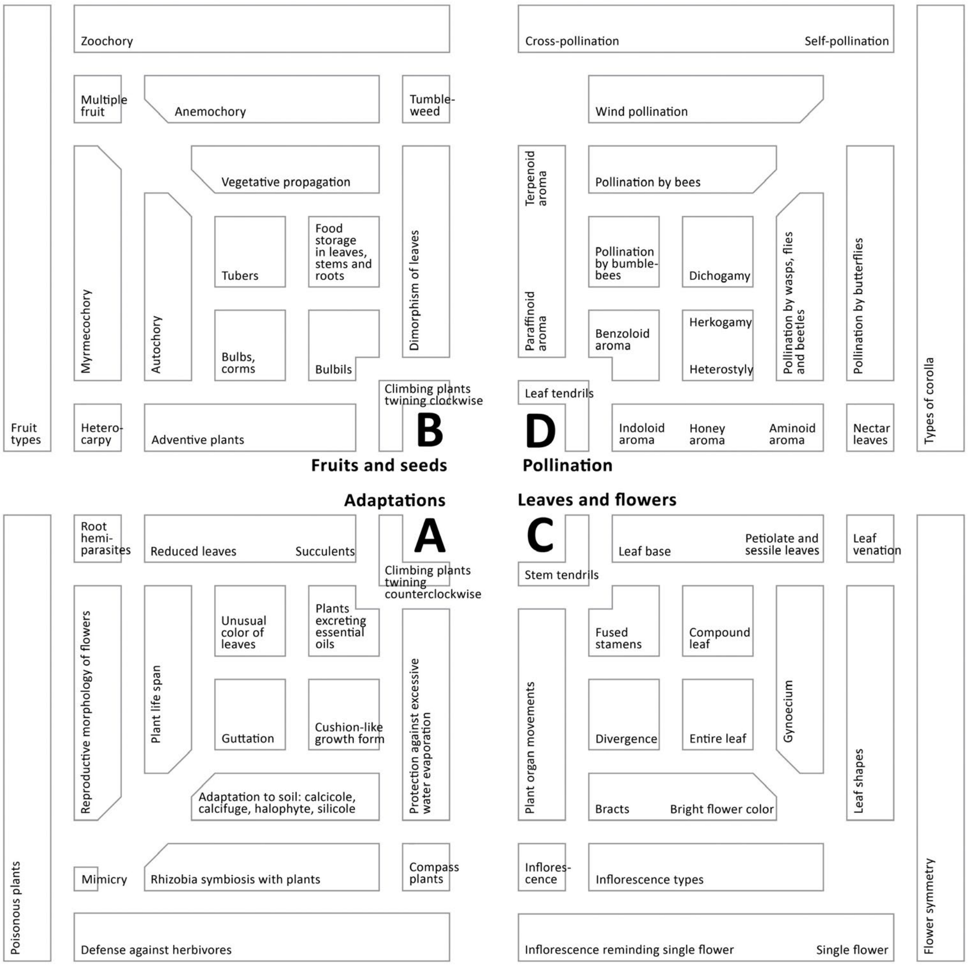


Figure 3: The plan of the exposition "Biological and Morphological Groups of Plants".

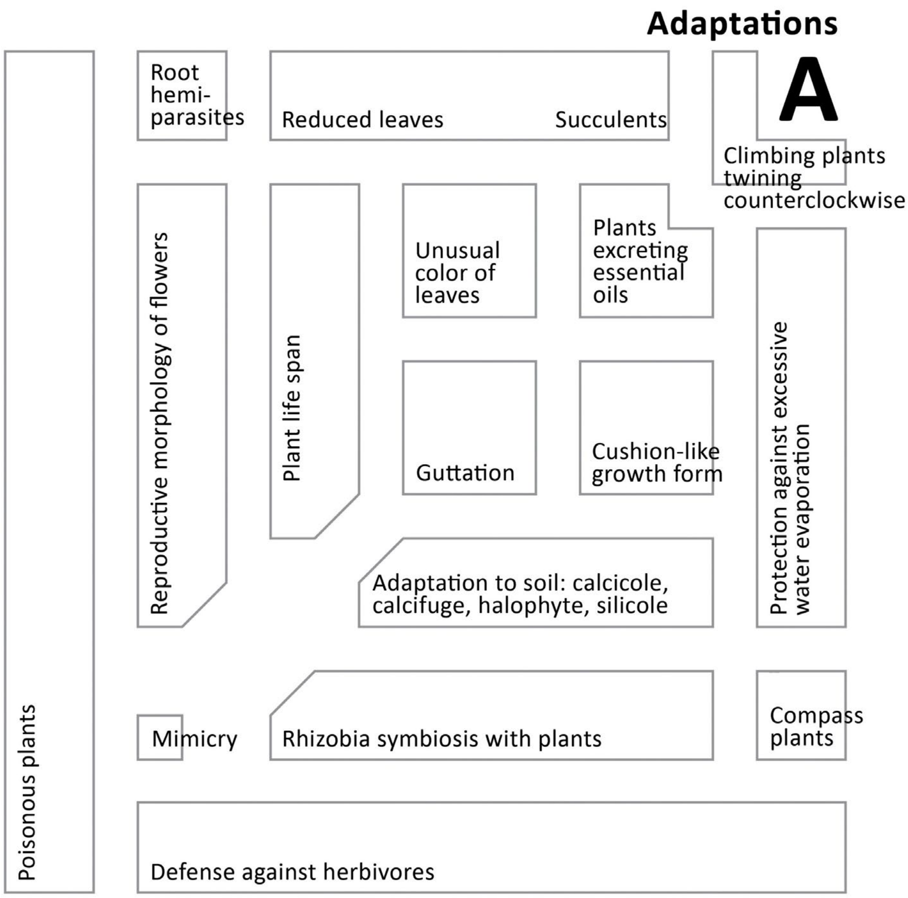


Figure 4: The plan of the section A – "Plant adaptation" in the exposition "Biological and Morphological Groups of Plants".

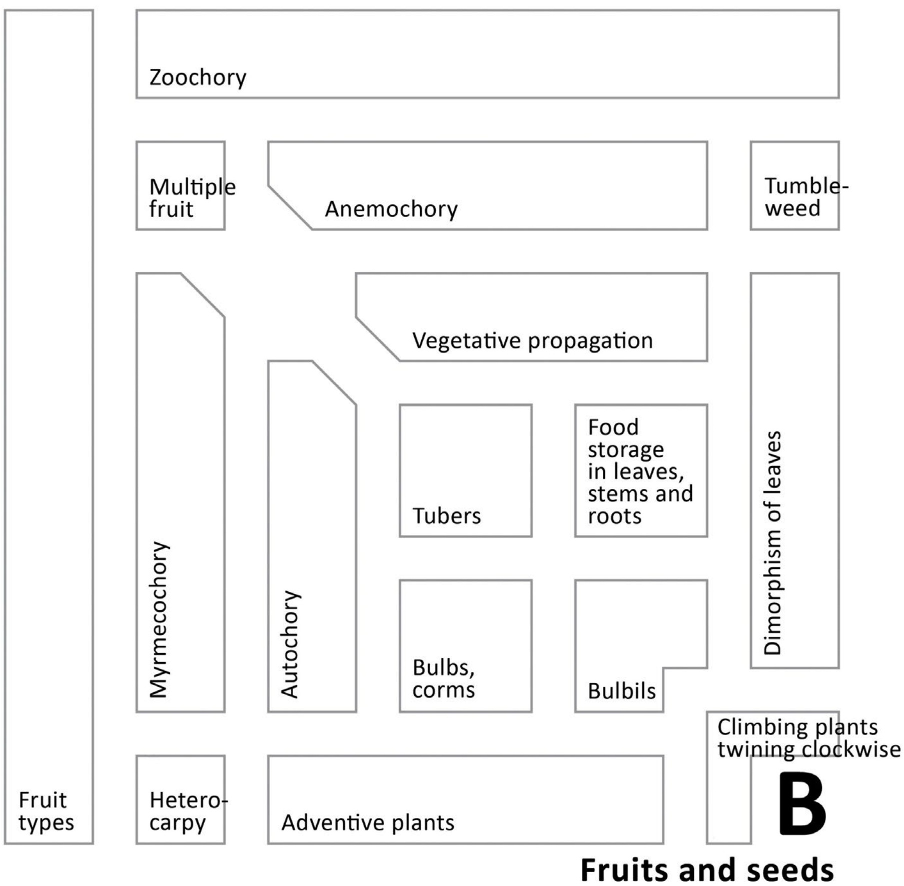


Figure 5: The plan of the section B – "Plant propagation and spreading" in the exposition "Biological and Morphological Groups of Plants".

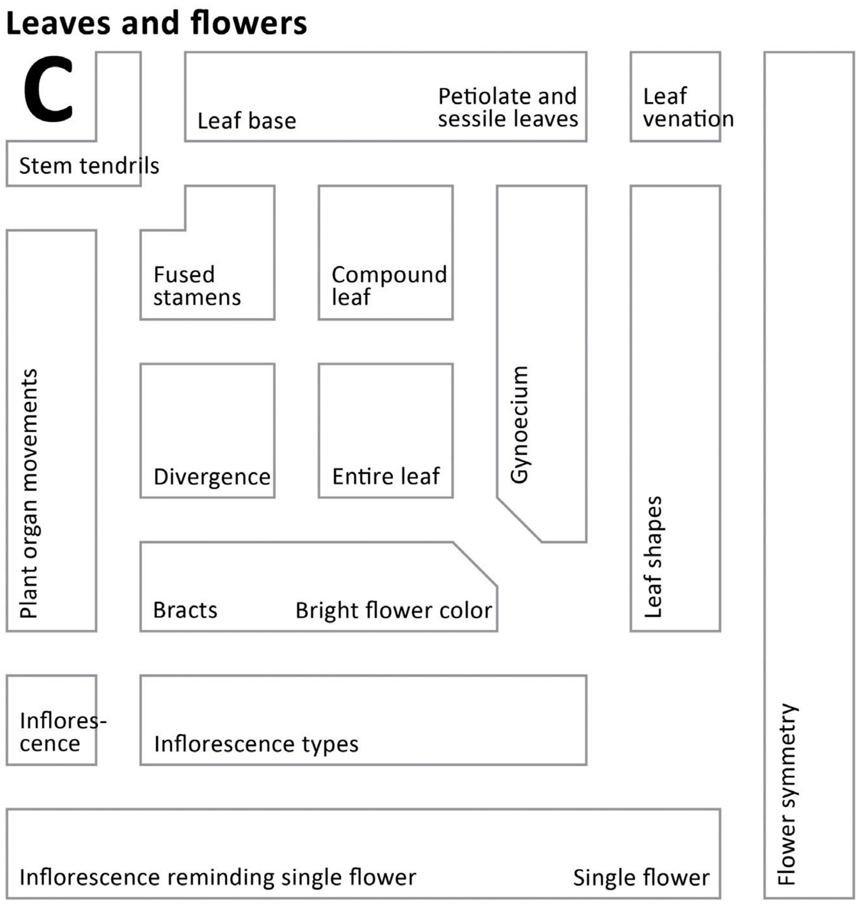


Figure 6: The plan of the section C – "Leaves and flowers" in the exposition "Biological and Morphological Groups of Plants".

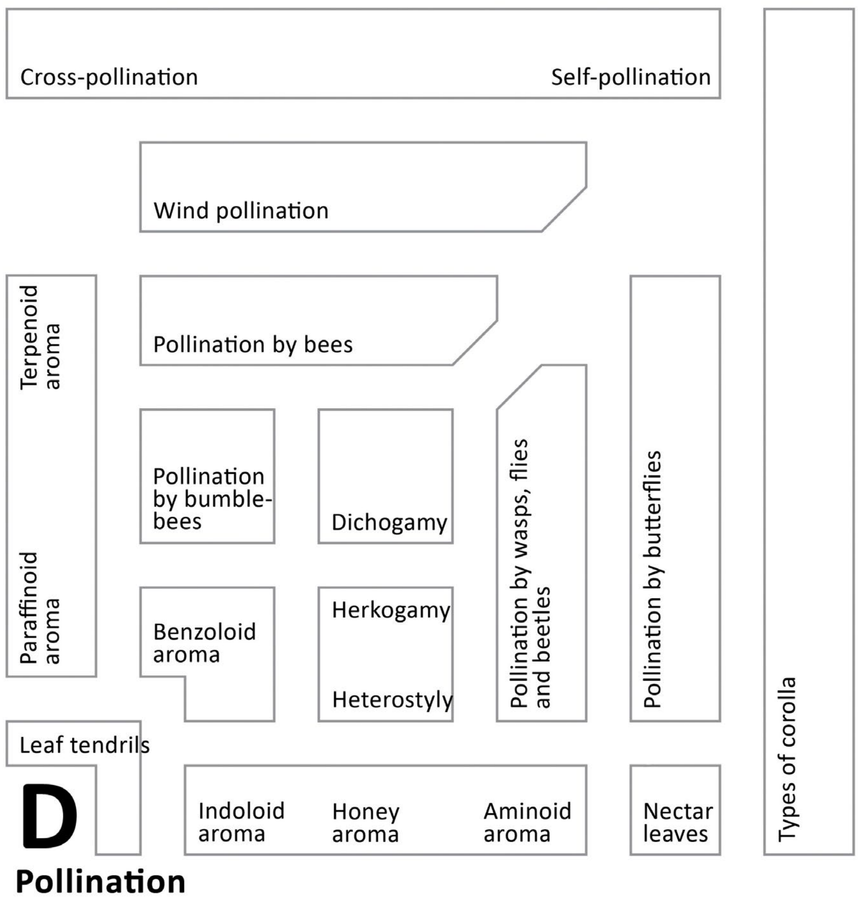
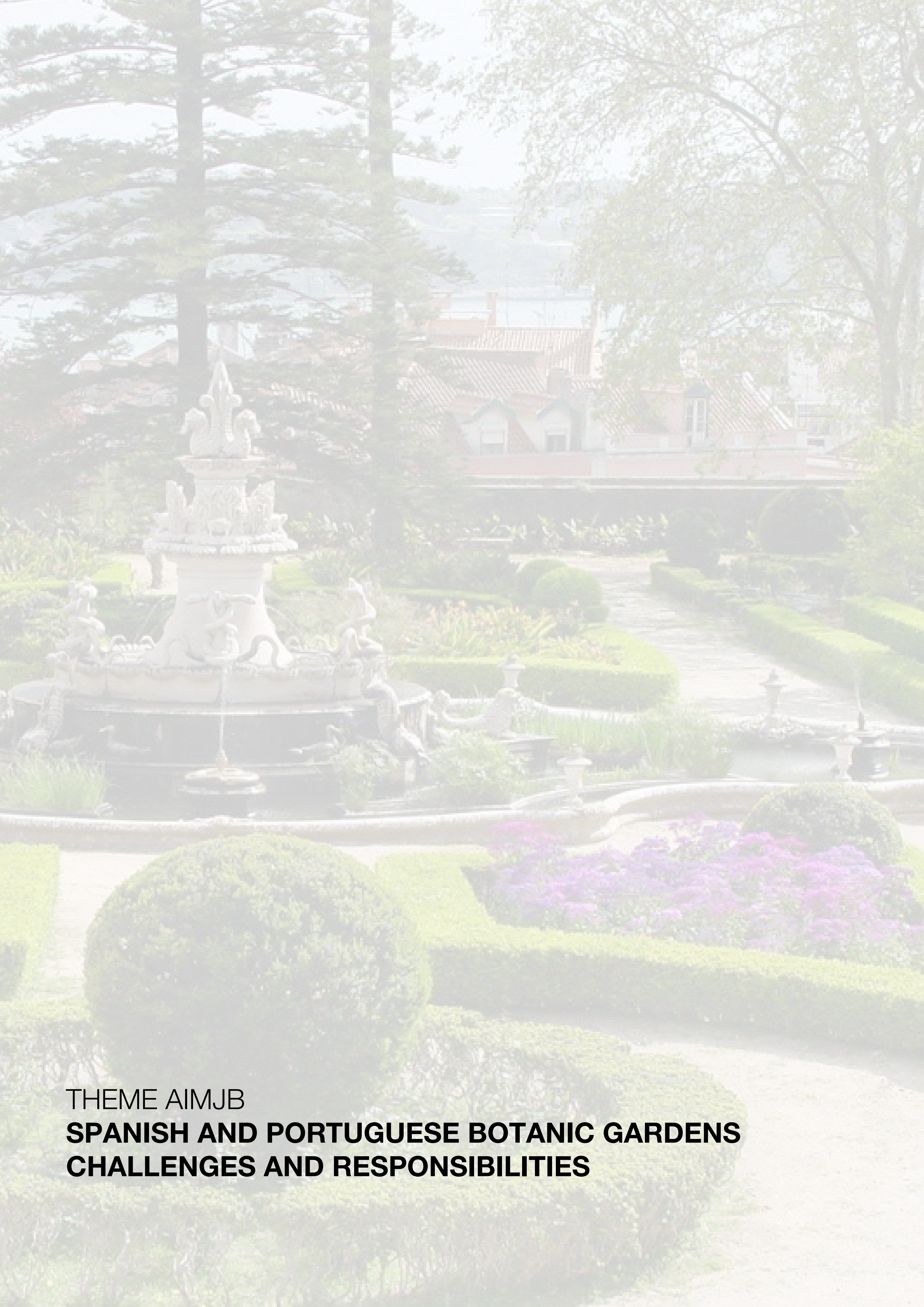


Figure 7: The plan of the section D – "Pollination" in the exposition "Biological and Morphological Groups of Plants".



THEME AIMJB

SPANISH AND PORTUGUESE BOTANIC GARDENS CHALLENGES AND RESPONSIBILITIES

PLANTS AND HERITAGE: THE TROPICAL GREENHOUSE OF THE BOTANIC GARDEN OF THE UNIVERSITY OF COIMBRA

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ABSTRACT

Almost from the time of its creation, the directors of the Botanic Garden of the University of Coimbra (BGUC) considered the need and importance of building a hot greenhouse for tropical species, but its construction started only in 1855, being populated with the first plants ten years later. Materials were exclusively sourced from Portuguese factories and the glasshouse is also one of the first and most complex structures of iron and glass architecture in Portugal.

Throughout its 150 years, the greenhouse received several interventions to guarantee the best climatic conditions to house temperate and tropical plant collections, but in 2013, the BGUC initiated the most ambitious requalification intervention ever made to this structure.

This profound intervention involved the restoration and recovery of the existing structures while maintaining the original architectural features, privileging the historical and patrimonial rehabilitation and reappraisal. Technical solutions were implemented to provide energetically efficient, environment-friendly and ecologically sustainable conditions adequate to plant development, namely concerning the heating, humidification, ventilation and shading.

Due to the demands of the intervention, the existing plants inside the greenhouse were transferred to other areas of the BGUC, to assure their preservation, always respecting the most favourable edaphoclimatic conditions for the acclimatisation process.

The greenhouse internal layout was subjected to changes in the organisation of its areas to increase the diversity of species in the botanical collections. The three wings that compose the greenhouse were granted with conditions to host species of tropical distribution, particularly aquatic plants, carnivorous plants, useful plants for societies such as food, medicinal and ornamental plant species.

This profound rehabilitation of the structure allowed for the development of a different use program of the greenhouse, with the creation of new botanical, taxonomical, ecological and science communication contents, to provide the visitors with a richer experience in this space of unique architectural and historical value.

In this article, we describe how this requalification project allowed for the modernisation of the greenhouse while simultaneously preserving its architectural and historical value and enriching BGUC's botanical collections, and create new attractions for our visitors, reinforcing its importance in the organic composition of the garden.

This rehabilitation project was a significant contribution to the Botanic Garden and to the University of Coimbra, classified as a World Heritage Site by UNESCO, since 2013.

KEYWORDS

Historic Greenhouse, Heritage Garden, Tropical Plants, Architecture Rehabilitation

INTRODUCTION

1772 is a pivotal moment to understand the evolution and relevance of the University of Coimbra, as this was the year the Pombaline reformation was outlined and the transition from a canonical university to an enlightened institution ensued. Higher education was no longer a solitary, bookish practice but started to rely on scientific observation and experimentation. For this purpose, and in order to advance the studies in the medical and natural sciences, the newly issued statutes prescribed the creation of a natural history gallery, a chemistry laboratory or an observatory but, to allow for the advancement of medical studies and other disciplines, a Botanical Garden was created, inside which various living plants were sown and displayed (Martins, 2013).

The Botanic Garden of the University of Coimbra (BGUC) was thus built within the close of St. Benedict's College, close to university. The first plants arrived in 1774, brought from Lisbon by Júlio Mattiazi, the royal gardener, who accompanied the first plantations and training of the head-gardener (Lopes de Almeida, 1937).

Throughout its almost 250 years, the BGUC expanded and saw its plant collections and plant beds redefined. Currently with a total area of more than 13 hectares, of which 3.5 hectares correspond to the Classic Garden and 9.5 hectares to the Woods, BGUC takes on several missions: education, research and conservation, but also acting as a privileged setting for scientific outreach, leisure and tourism.

Since its onset, all BGUC directors stressed the need for a greenhouse that would allow for the growth of plants that could not withstand the climatic conditions of the Portuguese territory. A very small greenhouse was thus built to receive "the most delicate plants" in 1776, shortly after the foundation of the garden (Henriques, 1876).

Some years later, in April 1791, a new project for the greenhouses of the Botanic Garden was designed and may have been partially executed, according to a map of the Garden, where it is possible to verify its incomplete delimitation (Brites, 2006). The establishment of an appropriate tropical greenhouse continued for many years to be requested and desired by all the directors. Finally, in 1854, the authorisation for the construction of a larger greenhouse materialises, and preparatory works ensued. The iron and glass building was designed by Pedro José Pezerat, engineer and architect, not many years after the completion of Kew's Palm House, that was to become the template for many such structures. The BGUC greenhouse began construction in 1855, but it wasn't until 1865 that the building was ready to receive a plant collection (Figure 1). In the meantime, Edmund Goeze became head-gardener and, through a network of congener institutions, but also with private plant collectors, assembled diverse and exuberant collections of exotic and rare plants, mostly from Brazil and the Azores (Goeze, 1871).

Figure 1: The newly built glasshouse in 1868

The building has come to be regarded as a unique and iconic structure that represents one of the first examples of the iron architecture in Portugal, and an important engineering endeavour.

Throughout its existence, the main greenhouse of the BGUC has been subjected to several interventions, but it was in 2013 that began the most ambitious and large-scale intervention of requalification this structure has seen.

PLANNING AND EXECUTION

Over the course of 150 years, the greenhouse was the object of several interventions, mostly maintenance and conservation-related, to ensure the best conditions of acclimation for the plant collections housed within its premises.

Coordinated by the architect João Mendes Ribeiro, this 21st century requalification involved the restoration and recovery of the existing structures while maintaining the original architectural features, privileging the historical and patrimonial rehabilitation and reappraisal (Figure 2).

Technical solutions were implemented to provide energetically efficient, environment-friendly and ecologically sustainable conditions adequate to plant development, namely concerning the heating, humidification, ventilation and shading.

Figure 2: Restoration and rehabilitation

Due to the demands of the intervention, the existing plants inside the greenhouse were transferred to other areas of the BGUC, to assure their preservation, always respecting the most favourable edaphoclimatic conditions for the acclimatisation process.
In order to allow for the implementation of a new program and increase the diversity of species in the botanical collections, the interior planting areas layout was reshaped and reorganised (Figure 3).

Figure 3: Reorganisation of planting areas shapes and distribution (west wing)

The greenhouse boasts a 70 meters façade and occupies ca. 700 m², divided into three wings, eight to twelve meters high.
The three wings that compose the greenhouse were thus granted with conditions to satisfy plants of tropical distribution, (including the creation of a heated lake, with 19500 litres of capacity), from aquatic to epiphytic plants (Figure 4).
In terms of infrastructure, main walls and the iron structure remained and actions were taken to restore and stabilise both features, which in some cases, included the replacement of small iron elements.
Restoration works included the application of translucent, laminated, tempered glass, and the installation of automated vertical screens and ceiling coverage in order to guarantee adequate shading, and to replace the whitewashing process that was practiced in recent years (a passive solution), and thus recover the original appearance of the greenhouse (Figure 5).
To ensure adequate humidity levels inside the greenhouse, a humidifying system was installed and, in addition, the windows were automated to allow for the aeration and ventilation of rooms (Figure 6).

Figure 4: Indoor heated lake for tropical aquatic plants (12.5(L) x 3.9(W) x 0.4(H) m)

Figure 5: Automated ceiling screens

Figure 6: Automated windows

Heating-wise, floor radiators were installed and a lake water-heating system was created in the central room. The existing gas boiler was adapted to natural gas and was complemented with a pellet heating system.
Management and control of these equipment is done

remotely through a centralised technical management system, and according to set-points defined for each criterion, taking into account the environmental conditions inside and outside the greenhouse, and that best suit the conditions of development of the installed botanical collections.

Water drainage systems inside and outside the greenhouse were also recuperated and repaired.

The intervention also improved the condition of accessibility without obstacles to and inside the greenhouse, allowing for more inclusive visitation paths.

The physical layout of the three wings was designed anew. In all the rooms there are now benches that run along the north and south walls and allow for the placement of potted plants.

In the west wing, the earthen beds remain with a new shape. This room was designed to simulate a humid tropical climate, with an average temperature of 23ºC and relative humidity greater than 75%.

The main focus in this room is a collection of native and endemic plants of São Tomé and Príncipe that resulted from a scientific protocol and collaboration with this Gulf of Guinea island nation. On the other half of the west wing, a collection of useful tropical plants was installed, comprising species that are part of the daily life of millions of people, either for their nutritional, medicinal or ornamental value (Figure 7).

With this rehabilitation project, it was also possible to reintroduce botanical species which were part of the BGUC historical collections and which had a great impact on society, such as the Cinchona species. In the late XIX century, quinine bark was cultivated at BGUC for research purposes, testing its acclimation potential to the former Portuguese African colonies to combat malaria (Costa, 1944).

The central room now boasts a heated lake prepared to house tropical aquatic plants, among them the iconic giant water lily, *Victoria cruziana*. Seeded for the first time in the renovated glasshouse in the spring of 2018, adult plants developed and two of them produced flowers. *Victoria cruziana* flowered for the first time on September 13, and flowered about other 10 times through to late November. In some of the flowering events, we have performed manual self- and cross-pollination, and we have collected and stored the resulting seeds (Figure 8).

Soil mixture used for the development and growth of plants consisted of topsoil with added clay, horse manure and sand in a 2:2:1 ratio. After the development of the first adult leaves fertilisation began, and repeated fortnightly. Fertilisation was done by inserting in the soil water-soluble pellets with controlled release of nitrogen and other essential substances for nutrition in an NPK 10: 14: 8 ratio (PONDTABBS®).

Figure 7: Useful plants bed, west wing

Figure 8: *Victoria cruziana* first-night flower

Figure 9: *Victoria cruziana* in non-heated water

In 2019, we tested the same growing method and have successfully grown *Victoria cruziana* inside the greenhouse but in non-heated water; although leaves were smaller, it even flowered (Figure 9).

The collection in the central room also includes carnivorous plants, and orchids, including epiphytic species that are suspended in the iron mezzanine that allows the visitation of the upper floor of the room, through stairs that stem from inside the lake (Figure 10).

The ambient room temperature is to be kept between 22ºC and 26ºC and water temperature was set to 23ºC.

After renovation, the east room did not contemplate any beds, which were eliminated in favour of the creation of a large, versatile and flexible space that allows temporary exhibitions of potted plants or other type of support structures, and which can easily be transferred or arranged in different ways, allowing for other cultural events (Figure 11).

It is in this room that many of the plants that lived in the greenhouse before the re-qualification intervention are now housed, in a mostly non-heated, temperate environment.

Figure 10: Central room: *V. cruziana* night-time flowering visitation activity

Figure 11: East room: setup for a concert

FINAL REMARKS

The intervention lasted close to 5 years and it involved the restoration and rehabilitation of existing structures and the implementation of technical solutions that allowed for the creation of suitable climatic conditions for the development of plants, while ensuring a more energetically efficient and sustainable maintenance, and a safer and more inclusive space for visitation.

This ambitious rehabilitation process included the creation of a renovated program for the use of the greenhouse, creating new botanical, taxonomic, ecological, ornamental and scientific communication contents that enrich visits and simultaneously allow visitors to discover and enjoy this valuable space architectural and historical heritage (Figure 12).

The greenhouse was inaugurated on March 20, 2018 and received the National Urban Rehabilitation Award (2017) in the category of Best Intervention with Social Impact, an Honorable Mention in the Nuno Teotónio Pereira Award in the Rehabilitation of Equipment Building category (2018), and the Diogo Castilho Municipal Architecture Award (2017).

This rehabilitation project was a significant contribution to the Botanic Garden and to the University of Coimbra, classified as a World Heritage Site by UNESCO, since 2013.

Figure 12: The surrounding area of the greenhouse was also rehabilitated

REFERENCES

Brites, J. (2006) *"Jardim Botânico de Coimbra: contraponto entre a arte e a ciência"*, In Paulo Bernaschina, Transnatural, Porto: Artez, pp. 30-69.

Costa, A. F. (1944) O problema das quinas, Lisboa: Cosmos, 140 pp.

Goeze, E. (1871) A Ilha de S. Miguel e o Jardim Botanico de Coimbra. "O Instituto - Jornal Scientifico e Litterario XIV", Coimbra: Imprensa da Universidade, pp. 73-87

Henriques, J. (1876) O Jardim Botânico da Universidade de Coimbra. Coimbra: Imprensa da Universidade, 54 pp.

Knotts, Kit&Ben (2004) "Victoria cultivation guide", Water Gardeners International. Available on http://www.victoria-adventure.org/victoria/victoria_cultivation1.html

Lopes de Almeida, M. (1937) Documentos da Reforma Pombalina, Universidade de Coimbra, Coimbra: Universidade de Coimbra, 353 pp.

Martins, D. (2013) "A Faculdade de Filosofia Natural (1772-1911)". In Carlos Fiolhais, C. Simões, D. Martins (eds.) História da Ciência da Universidade de Coimbra (1772-1933), Coimbra: Imprensa da Universidade, pp. 65-116

Reis, S. C., Gonçalves L., Azevedo C., Trincão P. (2014) No Jardim há histórias sem fim. Jardim Botânico da Universidade de Coimbra, Coimbra: Imprensa da Universidade, ISBN: 978-989-26-0923-2

A SUSTAINABLE GARDEN IN THE BOTANIC GARDEN OF PYRAMIDS OF GÜÍMAR, TENERIFE, CANARY ISLANDS

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ABSTRACT
The Ethnographic Park Pyramids of Güímar with a total area of 64,000 m², was founded in 1998 by the famous Norwegian researcher Thor Heyerdahl. In addition to the legacy of Heyerdahl, the first three decades of the new century have marked a time of growth and maturation. Since 2016, the ethnographic park has been managed as a Botanical Garden and integrated into the Ibero-Macaronesian Association of Botanical Gardens. Six large outdoor routes allow visitors to enjoy more than 20,000 m² of landscaped areas. Also, three independent areascomplement the visit, one on "Easter Island", another called "Poisonous Garden" and the "Sustainable Garden". Cultural events, temporary exhibitions, and other activities always give rise to something to be seen by everyone in the Ethnographic Park. The Sustainable Garden of Pyramids of Güímar reproduces, in its 1000 m², the atmosphere of a watercourse in the Canary Islands and a traditional ravine with native flora, with the aim of raising awareness among the visiting population about this new model of landscaping and to value the use of a scarce resource in the islands, water. A channel of a ravine has been reconstructed and autochthonous species typical of these Canarian ecosystems have been incorporated, a hydrophytic flora represented by plants dependent on the level of the surrounding water and riparian plants on the edge of a ravine. For the selection of the suitable species of the Sustainable Garden, a previous geobotanical study of the territory has been carried out.

KEYWORDS
Canary Islands, Native Flora, Sustainable Garden, Horizon 2030

INTRODUCTION

The existence of the step pyramids in Güímar (Fig. 1) began to manifest itself strongly in the early nineties. The information came into the hands of the prestigious anthropologist Thor Heyerdahl. This researcher, who devoted much of his life to studying the cultural origins of ancient civilizations worldwide, carefully examined the structures of Güímar and proposed the hypothesis that they had been built in accordance with the same architectural principles used in the Old and New World. The similarity of these constructions with those of Sicily, Mexico, Mesopotamia, Polynesia and Peru encouraged the researcher to settle in Tenerife to study them in the field. On the origin and the antiquity of the pyramids several theories exist. Some researchers propose that they are mounds of stones, called "majanos", placed in the 19th century by farmers to clean the land to cultivate it; a common practice in Canarian agriculture. On the other hand, Heyerdahl related the existence of the pyramids to ancient civilizations that had passed through the island. A more recent theory suggests that the pyramids were built by a freemason who bought these lands in the 19th century, after living many years in South America. In 1991, a team of archaeologists from the University of La Laguna and the Foundation for Exploration and Research of Cultural Origins (FERCO) carried out the first excavations. In parallel, researchers from the Institute of Astrophysics of the Canary Islands carried out a study of the archaeoastronomic characteristics of these constructions. These investigations showed that the pyramids are astronomically oriented to the summer and winter solstices. The space on which the pyramids now stand was intended to accommodate an urban expansion plan in the upper part of the city, which endangered its conservation. The interest of Thor Heyerdahl for the enclave became a personal commitment when the land that houses the pyramids were acquired by Fred. Olsen S.A. with the purpose of protecting them, and creating what is now the Ethnographic Park Pyramids of Güímar.

The Canarian Archipelago has a high proportion of endemic species and plant communities that live only on the islands or are shared with the other Atlantic archipelagos that make up the Macaronesian biogeographic region. The volcanic nature, together with the relief, the great heights of the islands and the climatic variety, give rise to the formation of different landscapes or units of vegetation. Among the best known canary endemic species are the Canary Palmtree (*Phoenix canariensis*), Cardón (*Euphorbia canariensis*), Dragon tree (*Dracaena draco*) or the Canary Pinetree (*Pinus canariensis*). The botanical route proposes a tour of the gardens to see these and other plant endemism. All the plants are identified with their scientific and common name, and specific information panels complement the most representative species

Figure 1: Aerial view of the Ethnographic Park and Botanical Garden of Pyramids of Güímar.

OBJECTIVES

The Sustainable Garden of Pyramids of Güímar reproduces in its 1000 m², the atmosphere of a watercourse in the Canary Islands, a traditional ravine with native flora, with the aim of raising awareness among the visiting population about this new model of landscaping and to value the use of a scarce resource in the islands, water.

The design and replication of this natural habitat has the objective of encouraging this model of sustainability for gardened areas in the Canary Islands through the application and respect of the three principles of the concept of Sustainability: environmental, economic and social.

- Environmental because it uses autochthonous species of the Canary Islands.
- Economical because it suppresses the need for irrigation, fertilization, pesticides, etc.
- Social because it acts as a way for the awareness and environmental education of the population in regard the conservation of the Canarian natural environment.

MATERIAL AND METHODS

A channel through a ravine has been reconstructed and autochthonous species typical of these Canarian ecosystems have been incorporated, a hydrophytic flora represented by plants dependent on the level of the surrounding water and on the edge of the ravine riparian plants. The selection of the suitable speciesfor the Sustainable Garden, a previous geobotanical study of the territory has been carried out (Martín Osorio 2009, Wildpret & Martín Osorio 1997).

The circuit is regulated by a hydroefficient system, aquaponics. The use of aquaponics for the small-scale treatment of wastewater of animal origin is a mixture of integrated polyculture and hydroponics. It is based on the use, by existing plants, of organic waste generated by fish. Through a closed circuit of recirculation of water it passes from the pond that houses the fish to the biofilter with its solids settler, from there to the ponds, where the selected plants are found, and returns, clean and oxygenated to the watercourse of the gully and to the pond that contains the fish.

RESULTS

According to the geobotanical study carried out in the area, The Botanical Garden is located on the slope formed by a gravitational mega-landslide of 830,000 years ago with a volume of 47 km^3 of lava slides on a surface of 130 Km^2. It originated submarine deposits of 120 Km^3 in an area of 1600 Km^2.The mega-landslide caused a tsunami with a wave of 20-30 m which occurred in Agaete (GC) leaving a deposit of marine fauna at 60-120 m high (Carracedo et al. 2009).The Botanical Garden is located on basaltic lava "aa" with olivines formed by the historical eruption of the Arafo volcano of 1705.

The maximum altitude of the Botanical Garden: 340 m. The maximum altitude at the Pico Cho Marcial is 2022 m).The meteorological station that has been used is Arafo-Añavingo, with an altitude of 565 m, average temperature of 17.8ºC and annual precipitation of 342.9 mm.

The Bioclimatic Belts (Rivas Martínez 2009) and the Potential Vegetation Series found in the territory are:Infra-Thermomediterranean semiarid upper-dry low.

Aeonio-Euphorbion canariensis

- *Periploco laevigatae-Euphorbio canariensis Sigmetum (Cardonales)*

Mayteno canariensis-Juniperion canariensis

- *Junipero canariensis-Oleo cerasiformis Sigmetum (Sabinares)*

The botanical collections that can be found in the complex of Pyramids of Güímar are grouped into two types of environments, one representing the potential vegetation of the Canarian territory and the other, a mixed "Arboretum" where indigenous, exotic and fruit trees are represented.

Figure 2: *Euphorbia canariensis* on the route of Flora Canaria.

Canary flora collections according to the following vegetation units

Tabaibal: *Ceropegio-Euphorbieto balsamifera*
Cardonal: *Periploco-Euphorbieto canariensis* (Fig. 2).
Sabinar, junipers, Canarian wild olive trees and dragon trees: *Junipero canariensis-Oleo cerasiformis*
Monte Verde of Canarian strawberry trees and mocanes: *Visneo mocanerae-Arbuteto canariensis*
Canarian pine forest: *Sideritido-Pineto canariensis*
Canary palm palm grove: *Periploco-Phoeniceto canariensis*
Tarajales of canary tarajal: *Atriplici ifniensis-Tamaricetum canariensis*
Sauces of canary willow: *Rubo-Salicetum canariensis*
Aquatic and riparian plants
Rupicolous flora of Canary Bejeques, Bryo-Lichenic communities and Ferns.

Currently, 266 botanical species are catalogued between native and exotic plants (Acebes et al. 2010). Of the total catalogued flora there are 141 species of Canarian wild vascular plants (101 native and 40 introduced) (Annex I), of which there are 33 canary endemics and 5 from Tenerife. The exotic flora, including fruit trees, is represented by 125 species.

Arboretum

It is represented by arboreal specimens of the autochthonous flora mainly *Phoenix canariensis, Pinus canariensis, Juniperus cedrus, Dracaena draco, Pistacia atlantica* and *Juniperus turbinata* subsp. *canariensis*.
Also for specimens of exotic species such as *Corymbia citriodora, Eucalyptus calmadulensis* and *E. robusta*, *Greevilla robusta, Ficus benjamina, Ficus microcarpa, Schinus terebenthifolius, Brassaia actinophylla, Delonix regia, Bouganvillea glabra* and B. *spectabilis*, *Arecastrum romanzoffianum*, *Cycas revoluta, Euphorbia tirucalis*.
Among the fruit trees we can find fig trees *Ficus carica, Persea americana, Musa sp., Punica granatum, Prunus dulci, Mangifera indica* and *Vitis vinífera*.

Research for *"ex situ"* conservation

In the current 20,000 m² grounds of the Pyramids of Güímar gardens there are numerous Canarian endemism and some specimens of protected species. It is an ideal place to implement "*ex situ*" conservation projects for some endangered species in the environment.
The main objective of the Botanical Garden of Pyramids of Güímar is to have, in addition to the already existing collections of Canarian flora, an exhibition of endemic species from Tenerife and especially the region of Güímar and its surroundings, in order to spread the ethnobotanical values of local plants.
There will be facilities to locate the herbarium of the Botanical Garden of Pyramids of Güímar and the seed bank for the preparation of the *Index Seminum*.

Figure 3: Exemplar in flower and fruit of Neochamaelea pulverulenta.

The lines of research that have already begun with the signing of the Collaboration Agreement with the Universidade de La Laguna (ULL) are among others:

- Control and eradication of invasive alien species and especially "cat's tail" *Pennisetum setaceum*. The aggressiveness of the species makes it necessary a systematic control of the continuous invasion in the Park. For that purpose it is important carrying out formative and divulging experiences that can be implemented in other places.
- Beekeeping: Conservation of native bees.
- Ornithology and Entomology.

In order to fulfil the research aims it is important, in addition to the agreement with ULLestablish a collaboration with students of the Degrees of Environmental Sciences and Biology of the ULL and other universities (Fig. 4). Development of Final Degree Project, Master's Thesis and External Practices. Internship in the subject "Environmental Education and Sustainable Development" of the Degree in Environmental Sciences. Offer the facilities to the Erasmus students of the University and to the national and international environmental volunteers for the realization of curricular practices.

Education, Training and Leisure

Educating in the environment and for the environment is the basis of a multidisciplinary, transversal and globalizing teaching. In this sense, the transverse axis of the Botanical Garden is Education for Sustainability, understanding that it represents a basic objective for the training of future citizens, with respect to the natural environment.
Pyramids of Güímar aims to be a great learning classroom in Nature. The main purpose is that the visitor knows a unique space of great ethnographic and botanical value. Pyramids of Güímar have a consolidated trajectory in the visit of groups of schoolchildren (Fig. 5, 6) from all over the island. Guided tours, thematic workshops and bilingual camps are held in the summer.
Work is also being done on the development of Digital Teaching Materials from the curriculum of Primary, Secondary and High School Education that are useful for teachers who visit the facilities with their students.
Another line to be developed will be the installation of plots where crops can be carried out through permaculture, which can be used for agricultural training of groups of young people in Vocational Training. As well as, introducing gardening and botanical workshops to contribute to the promotion of green employment.

Figure 4: Sustainable Garden Pond with native flora and eels.

Figure 5: Group of schoolchildren in the viewpoint of the Botanical Garden.

Figure 6: Didactic mobile puzzle for the identification of the Canary Island palm.

DISCUSSION

Based on the information we can define that the Botanical Garden of Pyramids of Güímar is a center whose objectives wish to comply with the objectives of Horizon 2030:

- Conservation of the Natural and Cultural Heritage of the environment.
- Environmental Education and Training for Sustainability. Demonstrating sustainability in all aspects of the gardens' operations.
- Botanical research to combat climate change and its impacts.
- Scientific Disclosure to Society ot the Natural and Cultural Heritage, as well as promoting knowledge and respect for Nature.

CONCLUSIONS

The Botanical Garden of Pyramids of Güímar currently has the following resources and potential:

1. Various plant collections duly organized for consultation, visit and recognition.
2. Plant collections organized following the scientific conservation and cultural-educational objectives.
3. To guarantee the principles of connectivity between national and international institutions, the JBPG is committed to maintaining an exchange of plant material and information for scientific purposes, with a special relationship with the Canarian Botanical Gardens and scientific institutions.
4. It has a Collaboration Framework Agreement and advice signed with the University of La Laguna.

REFERENCES

Acebes-Ginovés JR., León Arencibia MC., Rodríguez-Navarro ML. Del Arco- Aguilar MJ., García-Gallo A., Pérez-De Paz PL., Rodríguez-Delgado O., Martín- Osorio VE., Wildpret de La Torre W. (2010) *'Pteridophyta, Spermatophyta'.* In: Arechavaleta, M., Rodríguez, S., Zurita, N. & García, A. (Eds.), Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). (2009) Gobierno de Canarias: 119-172.

Carracedo JC., Pérez Torrado FJ., Paris R., Rodríguez Badiola E. (2009) *'Megadeslizamientos en las islas Canarias'.* Enseñanzas de las Ciencias de la Tierra (17.1): 44-56.

Martín Osorio, VE. (2009) *'Jardines Sostenibles'.* In Beltrán Tejera E., Afonso-Carrillo J., García Gallo A., Rodríguez Delgado O., (Eds.): Homenaje al Profesor Dr. Wolfredo Wildpret de la Torre. Instituto de Estudios Canarios. La Laguna (Tenerife. Islas Canarias). Monografía LXXVIII. pp. 345-369.

Rivas-Martínez S. (2009) *'Ensayo geobotánico global sobre la Macaronesia'.* In Beltrán Tejera E., Afonso-Carrillo J., García Gallo A., Rodríguez Delgado O., (Eds.): Homenaje al Profesor Dr. Wolfredo Wildpret de la Torre. Instituto de Estudios Canarios. La Laguna (Tenerife. Islas Canarias). Monografía LXXVIII. pp. 255-296.

Wildpret de La Torre W., Martín Osorio, VE. (1997) *'Application de la méthode phy- tosociologique dans la création d'environnements de végétation autochtones dans le parc urbain du Drago de Icod de los Vinos. Tenerife'*. Colloques Phytosociologiques XXVII: 999-1005. Bailleul.

FIGURES AND TABLES

Table 1: Floristic catalog

Native and exotic wild flora in the Canary Islands present in the Botanical Garden.

Acacia cyclops A.Cunn- ex Don
Acacia cyanophylla Lindl.
Achyranthes aspera L.
Aeonium arboreum (L.) Webb& Berthel. ssp holochrysum (H.Y.Liu) Bañares
Aeonium urbicum (C. Sm. ex Buch)Webb & Berthel.
Aizoon canariense (L.)
Aloe vera (L.) Burm F.
Amaranthus hybridus L.
Anagallis arvensis var. coerulea (L.) Gouan
Annograma leptophylla (L.) Link
Apium nodiflorum (L.) Lag.
Arbutus canariensis Veill.
Argemone mexicana L.
Argyranthemum frutescens (L.) Sch. Bip.
Aristida adscensionis L. ssp. coerulescens
Artemisia thuscula Cav.
Arundo donax L.
Asparagus umbellatus Link subsp. umbellatus
Asteriscus sericeus (L.f.)DC.
Atalanthus pinnatus (L. f.) D. Don
Avena sterilis L.
Bencomia caudata (Aiton) Webb & Berthel.
Bituminaria bituminosa (L.) C.H. Stirt
Bougainvillea glabra Choisy
Bryonia verrucosa Dryand.
Calendula arvensis L.
Canarina canariensis (L.) Vatke
Carduus pycnocephalus L.
Cenchrus ciliaris L.
Centaurea melitensis L.
Convolvulus floridus L.f.
Conyza bonaeriensis (L.) Cronquist
Conyza canadensis (L.) Cronquist
Cosentinia vellea (Aiton) Tod. (=Cheilanthes catanensis)
Cynodon dactylon (L.) Pers.
Cyperus laevigatus L.
Cyperus laevigatus L. subsp. distachyos (All.) Maire & Weiller
Datura innoxia Mill.
Datura stramonium L.
Dracaena draco L.
Drusa glandulosa (Poir.) Bornm.

Echium decaisnei Webb	*Melia azedarach L.*
Echium simplex DC.	*Melilotus indicus (L.) All.*
Echium simplex x decaisnei	*Mentha longifolia (L.) Huds.*
Equisetum ramosissimum Desf.	*Mesembryanthemum crystallinum L.*
Euphorbia aphylla Brouss. ex Willd	*Mesembryanthemum nodiflorum L.*
Euphorbia atropurpurea (Brouss.) Webb & Berthel.	*Micromeria hyssopifolia Webb & Berthel.*
Euphorbia balsamífera Ait.	*Neochamaelea pulverulenta(Vent.) Erdtman*
Euphorbia canariensis L.	*Nicotiana glauca R.C. Graham*
Euphorbia lamarckii Sweet	*Nicotiana tabacum L.*
Euphorbia segetalis L.	*Notholaena marantae (L.) Desv ssp. subcordata (Cav.) G. Kunkel*
Ficus carica L.	*Olea cerasiformis Rivas-Mart. & del Arco*
Forsskaolea angustifolia Retz.	*Opuntia máxima Mill*
Geranium robertianum L.	*Opuntia tomentosa Salm. Dyck*
Hedera canariensis Willd.	*Pallenis spinosa (L.) Cass.*
Hedera helix L.	*Pancratium canariense Ker-Gawl.*
Heliotropium ramosissimum (Lehm.) D.C.	*Papaver dubium L.*
Heliotropium europaeum L.	*Papaver sommiferum L. subsp. setigerum DC. Arcang.*
Hyparrhenia sinaica (Delile) Llauradó ex G. López	*Papaverum rhoeas L.*
Hypericum canariense L.	*Parietaria debilis G. Forst.*
Hypericum glandulosum Aiton	*Patellifolia patellaris (Moq.) A. Scott, Ford Lloyd & J.T. Williams*
Juncus bufonius L.	*Pennisetum setaceum (Forsk.) Chiov.*
Juniperus cedrus Webb & Berthel.	*Periploca laevigata Aiton*
Juniperus turbinata Guss. ssp. canariensis (A. P. Guyot in Mathou & A.P.Guyot) Rivas-Mart., Wildpret & P. Pérez	*Phagnalon saxatile (L.) Cass.*
Kickxia elatine (L.) Dumort.	*Phoenix canariensis H. Wildpret*
Kleinia neriifolia Haw.	*Pinus canariensis Sweet ex Spreng.*
Lactuca serriola L.	*Pistacia atlantica Desf.*
Lamarckia aurea (L.) Moench.	*Plocama pendula Aiton*
Lantana camara L.	*Potamogeton fluitans Roth*
Lavandula canariensis Mill.	*Prunus dulcis (Mill.) D.A. Webb*
Limoniun sinuatum (L.) Mill.	*Punica granatum L.*
Lotus maculatus Breitf.	*Retama rhodorhizoides Webb & Berthel.*
Lotus sessilifolius DC	*Ricinus communis L.*
Lythrum hyssopifolia L.	*Robinia pseudoacacia L.*
Malephora crocea (Jacq.) Schwantes	*Rorippa nasturtium-aquaticum (L.) Hayek*
Malva parviflora L.	*Rorippa nasturtium-aquaticum (L.) Hayek (=Nasturtium officinale)*
Medicago italica (Mill) Fiori in Fiori & Paol.	

Rubia fruticosa Aiton
Rumex lunaria L.
Rumex vesicarius L. var. rhodophisea Ball.
Ruta graveolens L.
Ruta pinnata L.f.
Salix canariensis C. Sm. ex Link
Salvia canariensis L.
Sansevieria trifasciata Prain
Schizogyne sericea (L. f.) DC.
Schinus molle L.
Scirpus holoschoenus L. subsp. globiferus (L.f.) Husn.
Sedum rubens L.
Silene gallica L.
Solanum nigrum L.
Stipa capensis Thunb.
Tamarix canariensis Willd.
Teucrium heterophyllum L'Hér.
Torilis leptophylla (L.) Rch. f.
Trachynia distachya (L.) Link
Tricholaena teneriffae (L. f.) Link
Typha domingensis (Pers.) Steud.
Umbilicus gaditanus Boiss.
Veronica anagallis-aquatica L.
Vitis vinífera L.
Visnea mocanera L. f.
Vulpia myuros (L.) C.C. Gmel.
Wahlenbergia lobelioides (L. f.) Link
Xanthium spinosum L.

WILD PYRUS IN PORTUGAL: DISTRIBUTION AND DIVERSITY ASSESSMENT

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ABSTRACT
Three wild pear species (*Pyrus cordata, P. pyraster* and *P. bourgaeana*) that occur naturally in Portugal, were studied to characterize their genetic diversity and to assess the status of native populations for genetic conservation. Three different analytical systems were used: fruits and leaves morphological characteristics, genetic analysis by microsatellite markers (Simple Sequence Repeats or SSR) and flow cytometry. The fruits and the leaves expressed differences of shape and allowed the discrimination of the three species. The set of the SSR markers employed revealed a marked tendency for vegetative multiplication in *P. cordata* and *P. bourgaeana*, since neighboring plants shared the same genotype. The flow cytometry allowed to confirm the presence of mixoploids in *P. bourgaeana*.

KEYWORDS
Genetic Resources, Ssr Genotyping, Nuclear Dna Content, *In Situ* Conservation

INTRODUCTION
Wild pear species are widespread in Europe. Interest in these species has been revived by the prospect of breeding resistant varieties in common pear. Taxonomic identification is fraught with difficulties, as these species frequently hybridize, and many intermediate forms are frequently observed (Zheng et al. 2014). Both morphological markers (Aldasoro et al. 1996) and molecular markers (Korotkova et al.2018) have been used to establish a phylogeny of the species in this *Genus*. In Portugal, three species have been identified and their distribution mapped: *Pyrus cordata* and *P. pyraster* in the north and *P. bourgaeana* in the centre and south (Franco and Rocha-Afonso, 1965). Germplasm of the native material has not been collected and therefore it is not represented in germplasm collections (Maggioni et al. 2004). While common pear varieties have been the subject of genetic studies, genetic diversity in wild pears has not been extensively studied, and the status of native populations for genetic conservation is largely unknown. Identification of existing genetic diversity is essential and the process should start with morphological studies, such as the leaves and fruits characteristics. Methodologies involving molecular markers should complement the morphological characterization. For instance, SSRs have been shown to be very useful in the characterization of pear germplasm (Evans et al. 2010; Queiroz et al. 2015). Flow cytometry has been used for DNA ploidy analysis in plants (Loureiro et al. 2007) and helps to deepen the knowledge on plant diversity.
The aim of this study was to: i) assess the distribution of the wild pears in Portugal; ii) analyze their genetic diversity using morphological characteristics, microsatellite markers (SSR) and flow cytometry.

MATERIALS AND METHODS
Three populations of *P. cordata* (North of Portugal – Minho region), three populations of *P. bourgaeana* (one in south of Portugal, one in Santarém region and one in Lisbon region) and single individual trees of *P. pyraster* (North of Portugal – Minho region) were studied (Fig. 1) in a total of 105 trees.
Fruit and leaf morphology: fruits and leaves were collected for two years (2010-2011). Four leaf characters were evaluated: length, width, perimeter and area. The diameter of the fruits was registered. The Kruskal-Wallis test was applied to the data analysis.
Microsatellite (SSR) study: DNA was isolated from 100mg

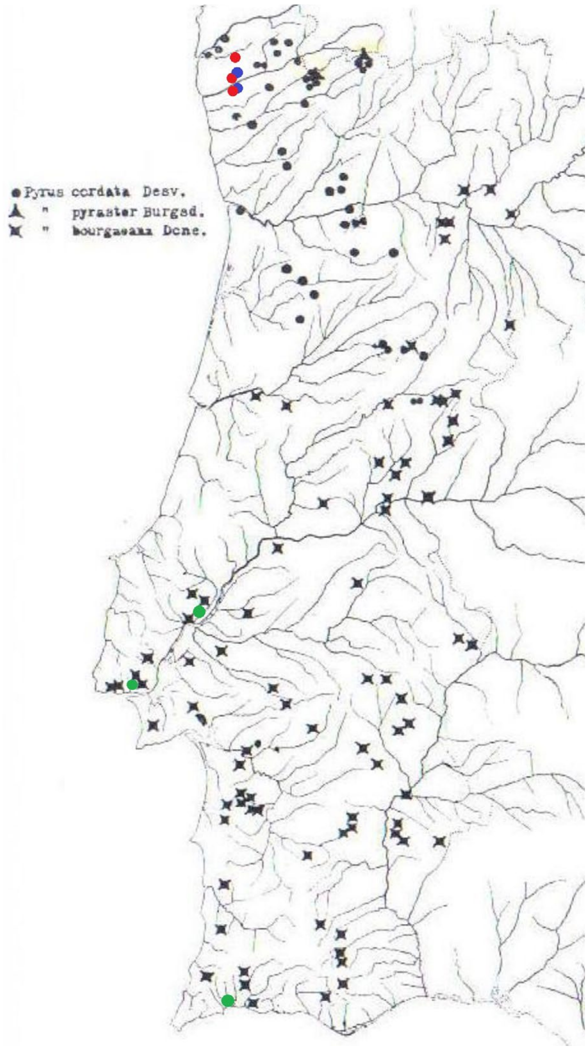

Figure 1: *Wild Pyrus* distribution in Portugal according to Franco (1965) and location of the sites of the populations studied. *P. bourgaeana* (green spots); *P. cordata* (red spots); *P. pyraster* (blue spots)

of fresh young leaves ground in liquid nitrogen using the DNeasy Plant Mini Kit (QIAGEN GmbH, Hilden, Germany) according to the manufacturer's protocol. DNA quality was checked on 0.8% agarose gel. For the tree genotyping six nuclear SSRs loci (Evans et al. 2008) were used: CH01d08, CH03g07, CH01f07a, CH05c06, EMPc11 and EMPc117. PCR was conducted in a final volume of 25 µl, containing 25 ng of DNA, 10mM Tris-HCl pH 8.0, 1.5 mM MgCl2, 0.2 mM dNTPs, 0.25 µM forward primer fluorescently labeled with WELLRED dyes at the 5´-end and unlabeled reverse primers, and 0.05 units of Taq DNA polymerase (Invitrogen, Carlsbad, CA, USA). Capillary electrophoresis was performed to separate the PCR products using CEQ 8000 Genetic Analysis System (Beckman Coulter Inc., Brea, CA, USA). The sizes of the amplified products were determined based on an internal standard included with each sample. Data Analysis was performed using the CEQ 8000 Fragment Analysis software, version 9.0, according to the manufacturer's recommendations. Sizes of SSR fragments were automatically calculated using the CEQ 8000 Genetic Analysis System. The information obtained was used to study the genetic diversity.

Flow cytometry study: genome size and DNA ploidy levels were assessed using flow cytometry that was performed by Plant Cytometry Services (www.PlantCytometry.nl).

RESULTS AND DISCUSSION

Fruit and leaf morphology

The fruit and leaf morphology are shown in Figure 2.

We found that fruit diameter was highest in *P. pyraster* and lowest in *P. cordata*, among the wild *Pyrus* (Table 1).

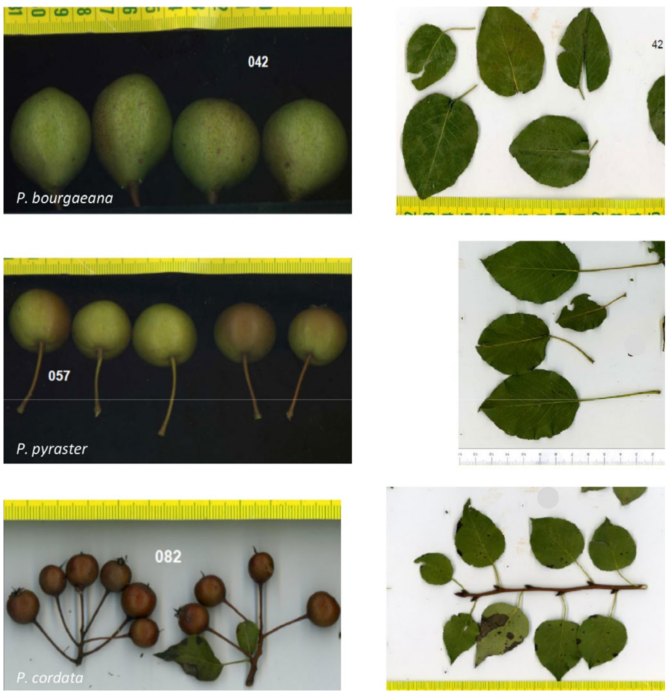

Figure 2: Fruit and leaf morphology of the different *Pyrus* species.

Species	Nº fruits	Mean diameter	sd*
P. bourgaeana	134	2,356	0,3693
P. cordata	292	1,276	0,1919
P. pyraster	42	2,678	0,3693
P. communis	2	3,225	0,3606

sd* - standard deviation

Table 1: *Pyrus spp.* number of fruits and mean

diameter

	Area	Perimeter	Length	Width	
Kruskal-Wallis chi squared	47,557	45,731	44,611	47,109	
df*	2	2	2	2	
p-value	0,000	0,000	0,000	0,000	**A**
	Fruit diameter				
Kruskal-Wallis chi squared	286,38				
df	3				
p-value	$2.2e^{-16}$				**B**

*degrees of freedom

Table 2: Kruskal-Wallis rank sum test. A – leaves characters; B – fruits diameter.

P. bourgaeana has the greatest variation concerning the fruit diameter (Figure 3).
Each species has distinct leaves and fruits shapes that allow the discrimination of the three species, using the Kruskal-Wallis statistics test (Table 2).

Microsatellite (SSR) study

The characterization of the trees was further performed by SSR analysis. Twenty-four different alleles were scored (11 alleles for P. cordata, 5 alleles for *P. pyraster* and 8 alleles for *P. bourgaeana*). The low number of alleles for *P. pyraster* can result from the small sample size of this species. The distinct species have similar effective numbers of alleles.

Species	N	Na	Ne	Ho	He
P. bourgaeana	31	8	6,05	0,85	0,83
P. cordata	37	11	6,08	0,65	0,75
P. pyraster	6	5	5,51	0,65	0,81

Table 3: Genetic diversity of wild *Pyrus* as assessed using SSRs loci. N- number of accessions; Na- medium number of alleles; Ne - medium effective number of alleles; Ho - medium observed heterozygosity; He- medium expected heterozygosity.

When evaluating the genetic diversity, it was found that the expected heterozygosity (He) was similar to the observed heterozygosity (Ho) for *P. bourgaeana*. Regarding observed heterozygosity (Ho) the values were lower than those of He for *P. cordata* and *P. pyraster*.
Unlike *P. pyraster*, *P. cordata* and *P. bourgaeana* showed a marked tendency for vegetative multiplication since neighboring plants shared the same genotype in several *P. cordata* populations. Both Lisbon and Santarém *P. bourgaeana* populations (respectively with seven and nine adults plants sampled) turned to be clonal stands with different genotypes while plants from the Algarve population (fifteen plants) showed six distinct SSR profiles. Differences observed in some of the Algarve trees referred to only one locus therefore seeming to result from a clonal mutation.

Flow cytometry study

The determination of the nuclear DNA content of *Pyrus* was performed with the simultaneous analysis of nuclei isolated from *Pachysandra communis* (Figure 4). *P. communis* commercial variety "Conference" was used as a control reference. This variety is diploid (2X) and has a relative DNA ratio with *Pachysandra* of 0.37.

In *P. bourgaeana* mixed ploidy was detected, mixoploids having 20% diploid nuclei and 80% tetraploid nuclei in the leaves analyzed.

CONCLUSIONS

Microsatellites have provided useful information about the identity and genetic characteristics of wild *Pyrus* germplasm in Portugal. Our study simultaneously revealed a large clonal multiplication in *P. bourgaeana* and *P. cordata*. However, to delineate future conservation strategies, we consider that a larger set of SSRs should be applied. This will be valuable for the preservation of wild *Pyrus* that may be threatened by forest fires which are reducing the area of suitable habitats for wild pears (mainly for *P. cordata* and *P. pyraster*).

Mixoploidy was detected by flow cytometry in P. bourgaeana. Whether it is a common trait in plants of this species is not known. Polyploids were already found in P. communis which are, usually, associated with bigger fruit sizes. In addition to changes in morphology, polyploids can eventually exhibit novel physiological characteristics important for the adaptation to a broader ecological amplitude.

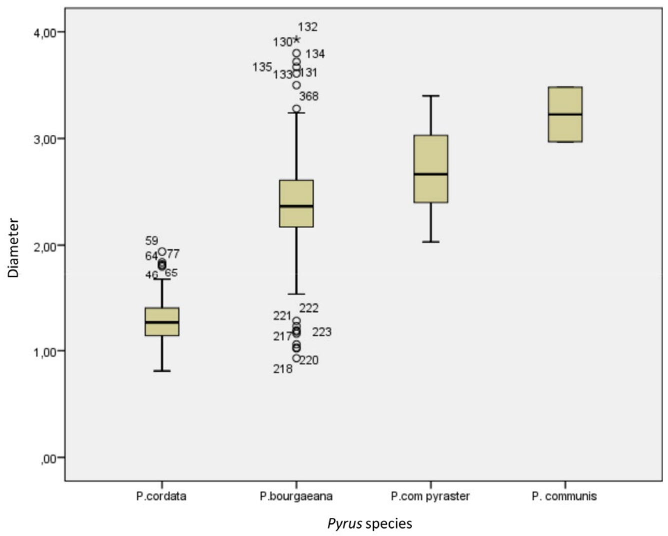

Figure 3: Fruit diameters of the different *Pyrus* species.

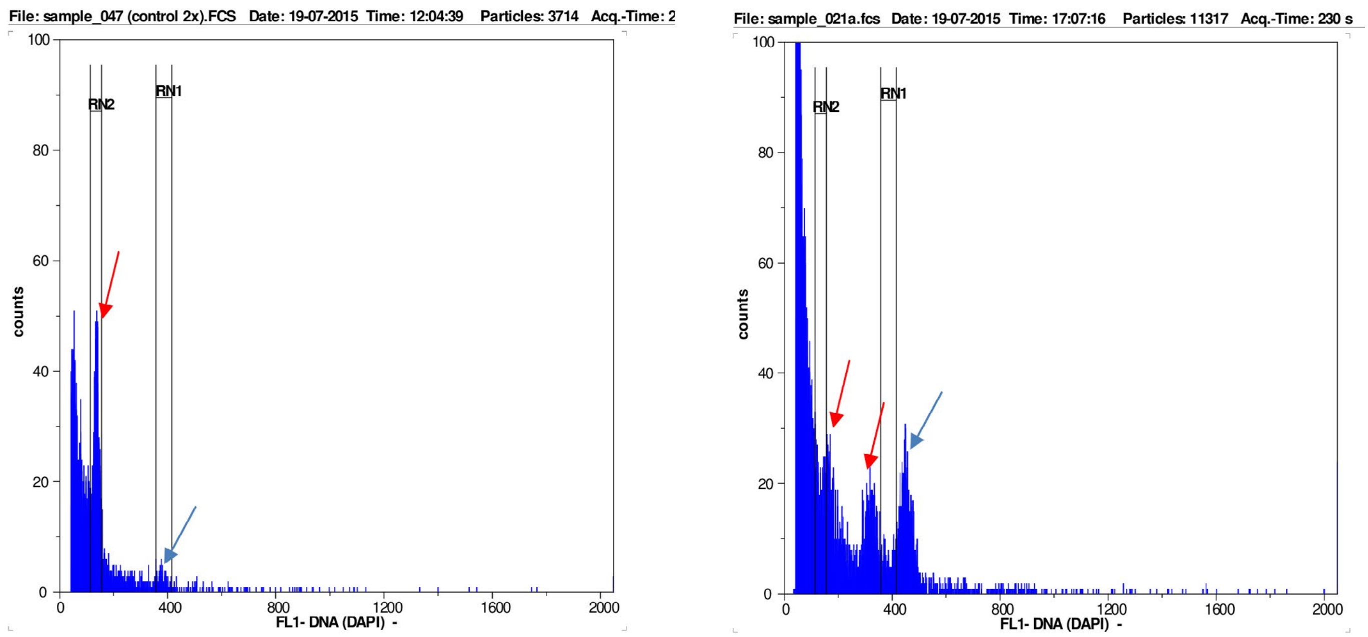

Figure 4: Histograms of relative fluorescent intensity obtained after analysis of nuclei isolated from: A – *P. communis* (commercial variety "Conference" diploid-2x); B- *P. bourgaeana* (mixoploid: 20% diploid – 2x and 40% tetraploid – 4x). The control 2x sample has a relative DNA ratio with *Pachysandr*a of 0.37. Blue arrow *Pachysandra* peak (RN1). Red arrow sample peak (RN2).

REFERENCES

Aldasoro J. J., Aedo C., Gaemendia F. M. (1996) *"The genus Pyrus L. (Rosaceae) in south-west Europe and North Africa".* Botanical Journal of the Linnean Society 121: 143 – 158.

Evans K.M., Fernández-Fernández F., Govan C. (2009) *"Harmonising fingerprinting protocols to allow comparisons between germplasm collections–Pyrus".* Proc. XIIth Eucarpia Symp. on Fruit Breeding and Genetics, 2007. Acta Hort. 814: 103–106.

Loureiro J. , Rodriguez E. , Costa A. , Santos C. (2007) *"Nuclear DNA content estimations in wild olive (Olea europaea L. europaea var. sylvestris Brot.) and Portuguese cultivars of O. europaea using flow cytometry".* Genetic Resources and Crop Evolution 54: 21-25.

Franco and Rocha Afonso (1965) Revista Faculdade de Ciências, Universidade de Lisboa 13: 175 – 213.

Korotkova N., Parolly G., Khachatryan A., Ghulikyan L., Sargsyan H., Akopian J., Borsch T., Gruenstaeudl M. (2018) *"Towards resolving the evolutionary history of Caucasian pears (Pyrus, Rosaceae)—Phylogenetic relationships, divergence times and leaf trait evolution"*. Journal of Systematics and Evolution 6: 35-47.

Maggioni et al. (2004). Report of a Working Group on Malus/Pyrus, Second Meeting. IPGRI, Rome, Italy.

Queiroz A., Assunção A., Ramadas I., Viegas W., Manuela Veloso M.M. (2015). *"Molecular characterization of Portuguese pear landraces (Pyrus communis L.) using SSR markers".* Scientia Horticulturae 183: 72–76.

Zheng X., Cai D., Potter D., Postman J., Liu J., Teng Y. (2014). *"Phylogeny and evolutionary histories of Pyrus L. revealed by phylogenetic trees and networks based on data from multiple DNA sequences"*. Molecular Phylogenetics and Evolution 80: 4-65.

INDEX

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