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SEED BANKS FOR BIODIVERSITY: INVESTING IN THE FUTURE

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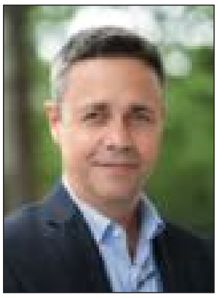

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Cover image: Seed cold storage where inventories are maintained

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BGCI is a worldwide membership organisation established in 1987. Its mission is to mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet. BGCI is an independent organisation registered in the United Kingdom as a charity (Charity Reg No 1098834) and a company limited by guarantee, No 4673175. BGCI is a tax-exempt 501(c)(3) non-profit organisation in the USA and is a registered non-profit organisation in Russia.

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EDITORIAL

SEED BANKS FOR BIODIVERSITY: INVESTING IN THE FUTURE

Welcome to the latest edition of BGJournal, which focuses on seed conservation – a topic very dear to my heart. Before joining BGCI, I worked at Kew's Millennium Seed Bank (MSB) for 14 years, starting out as a seed collector and co-ordinator for Southern Africa and Madagascar (2000-2005), and then leading the MSB from 2005 to 2014. During my time seed collecting in Southern Africa, I met Carly (editor of this magazine) who led the MSB seed collecting team in the Western Cape. Funny how our career paths diverge and then converge again.

The Millennium Seed Bank was the brainchild of Roger Smith (no relation), who led Kew's Seed Conservation Department based at Wakehurst Place in Sussex, 60 miles south of Kew Gardens. Against all odds – including external and internal opposition – Roger, Simon Linington, the Kew Director Sir Ghillean Prance, Giles Coode-Adams, Sir Jeffery Bowman and a few other individuals persuaded the Millennium Commission and the Wellcome Trust to fund the world's first global seed bank for wild species. Built to last 500 years at a cost of £20 million, the Millennium Seed Bank currently contains more than 2.4 billion seeds from 40,000 wild plant species, prioritizing endangered, endemic and economically important species. Our featured garden is indeed the MSB at Wakehurst Place which celebrates its 25th Anniversary this year (page 15).

Seed storage

Seed cleaning

Millennium Seed Bank, Wakehurst, UK

To my mind, the greatest legacy of the MSB is the thousands of people trained, and the hundreds of wild plant seed banks supported by the Millennium Seed Bank Partnership over the past 25 years. These include the South Australian Seed Conservation Centre (page 31), the Forestry Department Seed Bank in Zambia (page 59), and the IIAM Seed Bank in Mozambique (page 49). Thanks to the efforts of MSB staff and like-minded individuals around the world, wild seed banks are no longer the poor cousins of crop genebanks. Amongst the roughly 400 wild seed banks documented by BGCI around the world are some of the largest, most sophisticated facilities in the world, such as the Baekdudaegan Global Seed Vault Center in Korea (page 18), the Genebank of Wild Species in China and PlantBank in Australia.

Seed conservation is not an end in itself. It is most effective when it is part of an integrated *ex situ/in situ* conservation approach to species recovery or restoration, an example of which is provided from Brazil on page 55. Essential to integrated plant conservation is the building of partnerships with *in situ* conservation managers, restoration ecologists and other partners (see page 35 [Atlanta]) and the role of seed banks is not just to provide seed material; it is also to provide information on how to collect, process, store and germinate seeds. This dual role of long-term seed conservation and short-term supply of seeds and information is illustrated by the article from Minnesota Landscape Arboretum on page 45. In short, seed conservation is an essential element to recovery of most threatened plant species. The only question I can't answer is why isn't everyone doing it? Maybe this edition of BG Journal will encourage you to get started!

Dr Paul Smith,
BGCI Secretary General

(Stephanie Miles)

FEATURES

NEWS FROM BGCI

CUTTINGS

Here we present a selection of the most recent news stories from BGCI. Please browse our website to keep up-to-date with the latest news and events from BGCI and the botanic garden community: **www.bgci.org**

New GBGF Seed Conservation Grant

The Global Botanic Garden Fund (GBGF) is made up of several grants which aim to drive plant conservation, sustainability efforts, and global partnerships – with a focus on botanic gardens and arboreta in developing countries and biodiversity hotspots. This year, we were delighted to add a new Global Seed Conservation Grant to the GBGF.

The Global Seed Conservation Grants are made possible through a cooperative agreement between the Korea Arboreta and Gardens Institute and BGCI. The main purpose of the grants is to allow botanic gardens/ arboreta to create new collections of threatened species, increase seed banking capacity and safeguard these collections by duplicating seeds in the Baekdudaegan Global Seed Vault (BGSV).

Baekdudaegan Global Seed Vault

The Marsh Awards 2025

In partnership with the Marsh Charitable Trust, BGCI annually delivers The Marsh Awards to recognise the contribution of dedicated individuals working in different sectors. There are 2 awards available, and awardees are nominated by their peers.

This year, the Marsh Award for International Plant Conservation was presented to Rodrigo De Sousa, the Tropical Forests Program Manager at Osa Conservation, Costa Rica and the Marsh Award for Education in Botanic Gardens was presented to Vesta Vančugovienė, an educator at Vytautas Magnus University Botanical Garden, Lithuania.

The winners received their awards at two separate events. Rodrigo's work was showcased in a webinar and Vesta's work was highlighted at the 11th International Congress on Education in Botanic Gardens, in Seoul, South Korea. Read more about their work and watch Rodrigo's webinar here.

Individual Membership

BGCI are now pleased to offer Individual Membership, for those who cannot access institutional membership. Benefits include access to all our training courses and discounted Congress attendance (including BGCI Global, Education, and Horticulture Congresses). Visit our membership page to find out more.

BGCI accreditation scheme

BGCI's accreditation scheme empowers gardens to enhance their plant conservation efforts and increase their impact through recognition of their unique skills and collections. No matter if your garden is small or big or well established, the mentorship programme helps raise standards by evaluating processes and documentation against international standards.

Since the publication of the last BGjournal the following gardens from 11 different countries have been accredited or re-accredited by BGCI.

BGCI
Accreditation Scheme

Congratulations to all:

- Beal Botanical Garden (US)
- Birmingham Botanical Gardens (UK)
- Botanical Garden at University Hawaii – Hilo (US)
- Botanical Garden of Klaipeda University (Lithuania)
- Botanical Garden of Vilnius University (Lithuania)
- Botanischer Garten der Universität Bern BOGA (Switzerland)
- Fort Worth Botanic Garden (US)
- The Grounds and Gardens University of Exeter (UK)
- H.M. Queen Sirikit Park (Thailand)
- Jardín Botánico de Aguas Antofagasta (Chile)
- Jardín Botánico de Bogotá José Celestino Mutis (Colombia)
- Jardín Botánico Mapulemu (Chile)
- Jardín Botánico Regional de Cadereyta 'Ing. Manuel González de Cosío' (Mexico)
- Lincoln Zoo Park (US)
- Leon Levy Native Plant Preserve (Bahamas)
- The Shuttleworth Botanic Garden (UK)
- North Carolina Zoo (US)
- Rotterdam Zoo and Botanical Garden (Netherlands)
- Royal Botanic Gardens, Kew (UK)
- Royal Park Rajapruek (Thailand)
- Stone Lane Gardens (UK)
- Teplice Botanical Garden (Czech Republic)
- Tohono Chul Park (US)
- WahU Arboretum (US)

Enhancing PlantSearch with New Communication Feature

BGCI Plant Search

Thanks to the support from Cambridge University Botanic Garden, a new communication feature in PlantSearch is now available, enabling garden staff and researchers to more easily request plant information or materials from other gardens.

PlantSearch is a one-of-a-kind global database that links botanic garden collections with conservationists, researchers, educators, and policymakers.

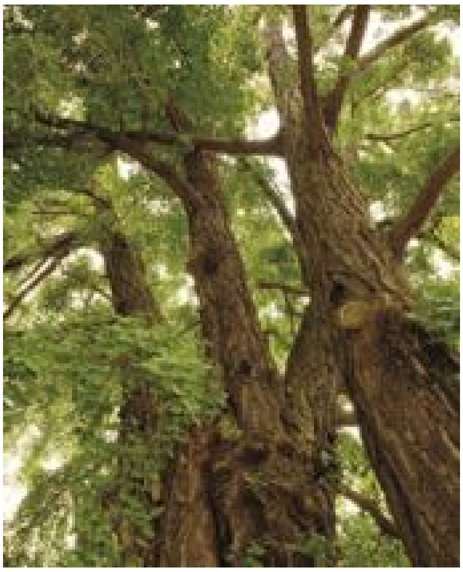
Used alongside GardenSearch, it helps users locate and connect with plant collections worldwide. This upgrade replaces the previous 'blind request' system — garden staff can now see the institutions they're contacting, improving collaboration and targeting plant material exchange. Researchers not affiliated with a garden can still make blind requests.

This improvement builds on data contributed by thousands of gardens globally, further supporting the shared mission of plant conservation.

Submissions for the next issue of BGlournal

BG Journal is now inviting submissions for its upcoming issue, which will explore the theme of living collections and databases in botanic gardens. We welcome articles that highlight innovative approaches to managing and documenting collections, the use of digital tools and platforms, and case studies demonstrating their role in research, conservation, and education. Contributions may include practical experiences, new methodologies, or collaborative projects. Share your insights to inspire and inform the global botanic garden community. Deadline details forthcoming.

Please send submissions to
patricia.malcolm@bgci.org



Royal Botanic Gardens, Kew

Global Conservation Consortium News

GCC Global Conservation Consortia

GCC Erica: an international collaboration coordinated by the GCCE programme has recently published important research supporting conservation of threatened heather species. This collection of 12 research and review papers were published by 42 different authors from 23 partner institutions spread across 14 countries.

Global Conservation Consortium Erica

Use the QR code above to access all the Erica publications on PhytoKeys

GCC Nothofagus: the first ever global Conservation Gap Analysis of the threatened and near threatened species in the genus Nothofagus has set out key conservation priorities for the future preservation of the iconic southern beech. The analysis, led by Wakehurst, Royal Botanic Gardens, Kew, Forestry England and Botanic Gardens Conservation International (BGCI) was a global collaboration, with research carried out in every centre of diversity for the genus.

Global Conservation Consortium Nothofagus

Use the QR code above to download the Nothofagus gap analysis report from BGCI

Erica sp and sunbird (Sam McCarren, University of Cape Town)

Authors: A.R. Hudson, A. Richard-Bollans, N. Mills, A. Pajdo, J.A. Tamura, A. Tucker and P. Gómez Barreiro

Just how small orchid seeds are. (Pablo Gómez Barreiro).

USING MACHINE LEARNING TO ADDRESS *EX SITU* SEED CONSERVATION CHALLENGES

Machine learning (ML) presents an opportunity to address some of the challenges associated with seed conservation in a unique way. We are currently exploring this potential by addressing the challenge of scoring epiphytic orchid tetrazolium chloride (TZ) viability tests. Aiming to develop a ML model to isolate, classify and count seeds within an image of a TZ orchid seed test, ultimately delivering this through a publicly accessible web application.

Introduction

An effective seed conservation programme ensures that seeds held are alive and remain viable, therefore relying on protocols and techniques to monitor this. As time moves forward, re-assessing techniques and looking for new and improved protocols is a natural part of the scientific process, particularly where existing protocols and techniques are challenging. Here we showcase one such project supported by Bloomberg Philanthropies "Exploring machine learning as a tool to improve the accuracy and speed of orchid viability testing".

Orchid seeds present a unique challenge to traditional orthodox seed banking due to the short-lived nature of their seeds (meaning they require quick post-collection processing and seed banking), their microscopic dust-like size (0.05 - 6.0 mm long (Arditti & Ghani, 2000) Fig. 1), sensitivity to the impacts of over drying (Pradham et al., 2022 and references therein), and their dependency on specific mycorrhizal fungal associations to germinate (a process that can take years making it challenging to use traditional viability testing procedures).

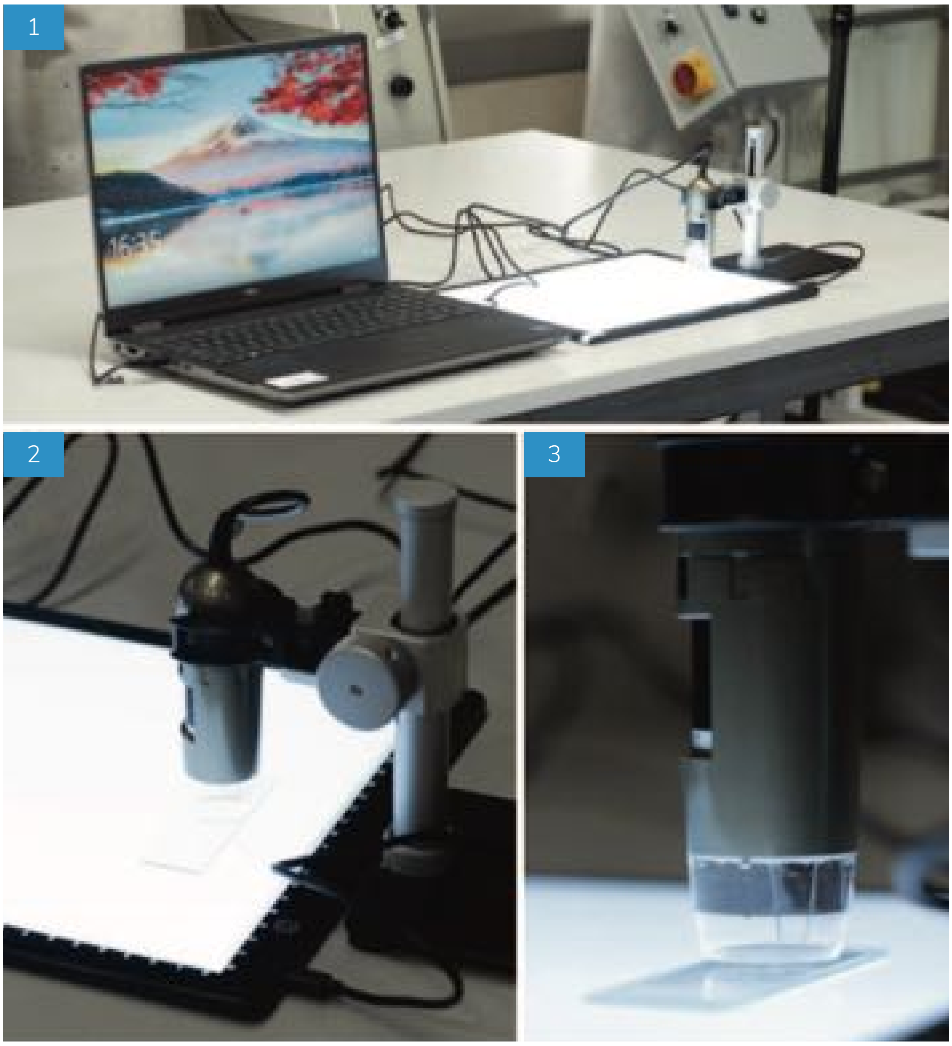
Due to their size and complicated germination behaviour, viability assessments for orchid seeds rely on staining techniques [e.g. Tetrazolium chloride (TZ), fluorescein diacetate (FDA) and Evans blue (EB)], resulting in colour variations reflecting whether the seed tissue is alive or dead (respiring or not). These tests in themselves can be challenging as the scoring (counting the number of seeds that are alive) can be subjective, often having to be done by the same person to ensure consistency (e.g., Gosling, 2003, Pradhan *et al.*, 2022;) and must be done either under a microscope or via a digital image of the sample (Custódio et *al.*, 2016). Assessing the viability of orchids using the Millennium Seed Bank's (MSB) standardised tests (typically involving 200 to 300 stained seeds) can take trained staff around 20 minutes. However, this time estimate is based on counting only the first 50 seeds of each test, whereas ideally all seeds (usually between 200 and 300) should be counted.

Machine learning offers one option for addressing this challenge, as it has already been successfully used in certain areas of seed science including isolating seeds from sand granules in images (Ott & Lautenschlager, 2022) as well as some morphological seed analyses (Dayrell *et al.*, 2023). Supported by Bloomberg Philanthropies, this project is one of the first steps in using machine learning for seed collection conservation at the MSB, working to develop a model capable of isolating each individual seed within an image, and then classifying them as to whether the seeds are dead, alive or empty based on their colour from the TZ staining test. Ultimately aiming to deliver this model via a web application able to be used by seed banks across the world.

Building a protocol and a training dataset

Developing the training dataset comprised of two main steps. Step one was to develop a replicable image taking protocol and step two was to capture and annotate a suite of TZ images.

One of the key aims in developing the imaging protocol, was to keep it as low tech, and therefore as affordable as possible. To this end, our protocol uses a Dino-Lite microscope



Imaging set up as per the protocol. (Gómez Barreiro)

camera and an A4 crafting lightbox as the two main components (Fig. 2). Once completed, the imaging protocol was independently tested by two project partners, Atlanta Botanic Garden, USA, and Badan Riset dan Inovasi Nasional (BRIN), Indonesia, to see if they were able to obtain similar quality images to those achieved at the MSB. This step provided vital feedback to enhance the protocol including factors such as filter paper tearing during TZ testing, and image quality versus the number of seeds in an image. In addition, it helps ensure that once released through the web application we are confident the model will be able to cope with images produced through the protocol.

Using collections made by Silo National des Graines Forestieres (SNGF) Madagascar, Ministry of Agriculture, Lands, Housing and Environment Montserrat, Instituto de Investigação Agrária de Moçambique (IIAM) Mozambique, Departmento de Recursos Naturales y Ambientales Puerto Rico and the British Virgin Islands National Parks Trust stored at the MSB, TZ tests were undertaken and imaged following the imaging protocol, resulting in a dataset of 522 images across 173 TZ tests. Using the CVAT data annotation platform, the 522-image dataset was annotated by a team of 11 individuals (Fig. 3 & 4). Once annotated this gave us a total dataset of 518 images with around 63,000 annotations. Due to the number of different annotators involved and the known subjectivity of the TZ test, every fifth image of the dataset was independently annotated by 3 different annotators. Analysis of these images showed that 58% of the seeds were unanimously given the same classification, 14% were identified by all 3 annotators but given different classifications, while 28% were not segmented by at least 1 annotator.

A human annotated image, with viable seeds outlined in green and non viable seeds outlined in red. (RBG Kew)

This means that annotators were accurate when identifying and segmenting orchid seeds but were less agreeable when classifying said seeds into the categories of viable, non-viable, or empty. This was primarily caused by the TZ test's reliance on an individual's interpretation of colour to identify seed viability. Additionally, qualitative analysis of annotated images showed objective errors in some images that resulted in a lower model performance (e.g. missed seeds, multiple seeds being segmented as one object, segmentation of the seed embryo but not the coat, etc.).

To increase the overall quality of the segmentation and reduce the number of unannotated seeds while preventing the classification of seeds being biased towards one annotator, an additional quality checking process was conducted. This process included one of our annotators correcting true errors by annotating seeds that were missed, splitting up seeds that were labelled as one object, adjusting the annotation to be closer to the outline of the whole seed, but did not include changing any existing individual classifications. These steps were applied to the base 522 images of the dataset, but not to the duplicates of these images.

What's next?

Now the dataset is complete, model training, validation and testing is underway, with user requirement scoping for the web application in progress too. We aim to launch the web application towards the end of September. In addition, we are developing a second dataset focused on micro- and small seeds of species that are difficult and time consuming to count manually. We hope to then expand the existing model to be able to more accurately determine the number of seeds within an entire collection based on a fixed weighed sample.

An orchid and cookies image annotating session at the MSB. (Ania Padjo)

Acknowledgements

We would like to thank Silo National des Graines Forestieres (SNGF) Madagascar, Ministry of Agriculture, Lands, Housing and Environment Montserrat, Instituto de Investigação Agrária de Moçambique (IIAM) Mozambique, Departmento de Recursos Naturales y Ambientales Puerto Rico and the British Virgin Islands National Parks Trust for their permissions to use their seed collections within the project. We would also like to thank Dr Dian Latifah, Dr Puspitakrb Ningtyas, Elizabeth Handini, Lina Arabyat, Dr Jessamine Finch and Jason Ligon for their work in testing and providing feed-back on the imaging protocol.

References

- Arditti, J. & Ghani, A.K.A. (2000) Numerical and physical properties of orchid seeds and their biological implications. New Phytologist (145), 367-421.
- Custódio, C.C., Marks, T.R., Pritchard, H.W., Hosomi, S.T. & Macado-Neto, N.B. (2016) Improved tetrazolium viability testing in orchid seeds with a thick carapace (*Dactylorhiza fuchsia*) or dark seed coat (*Vanda curvifolia*). Seed Science and Technology (44), 177-188.
- Dayrell, R.L.C., Ott, T., Horrocks, T. & Poschlod, P. (2023) Automated extraction of seed morphological traits from images. Methods in Ecology and Evolution (14), 1708-1718.
- Gosling, P.G. (2003) Ch 24. Viability testing, in Smith, R.D., Dickie, J.D., Linnington, S.H., Pritchard, H.W. & Probert, R.J. (eds) *Seed Conservation: turning science into practice.* RBG Kew. London, England.
- Ott., T. & Lautenschlager, U. (2021) GinJinn2: Object detection and segmentation for ecology and evolution. Methods in Ecology and Evolution (13), 603-610.
- Pradham, N., Fan, X., Martini, F., Chen, H., Liu, H., Gao, J. & Manage Goodale, U. (2022) Seed viability testing for research and conservation of epiphytic and terrestrial orchids. Botanical Studies (63), 3.

Author: Primack, Richard B (full authors list at the end of the article)

Figure 1. Researchers monitoring phenology at botanical gardens. Clockwise from left – Robert Rauschkolb (Jena Botanical Garden), Sungwon Son and Han-Gyeol Kim (Korea National Arboretum), and Amanda Gallinat (Arnold Arboretum).

INTERNATIONAL PARTNERSHIP

INFORMAL RESEARCH NETWORKS OF BOTANICAL GARDENS

Botanical garden scientists are increasingly participating in informal research networks that use living collections to address key questions in plant ecology, evolution and climate change. These initiatives share many common features that represent a less formal model for carrying out international research; they are short-term, question-driven, low-cost, cooperative projects focused on results and publications. We showcase three projects that highlight the advantages of this approach: monitoring leaf-out times; an ongoing project recording the phenomenon of leaf marcescence; and a project on the phenology of herbaceous perennial plants. We recommend this model be more widely adopted by the botanical garden community.

Introduction

Botanical gardens have been exchanging plant materials and knowledge for over a thousand years. Indeed, it is hard to imagine a botanical garden surviving long in isolation. In recent decades, formal networks of gardens, established to achieve specific objectives, have become increasingly important. These networks include the Plant Collection Network (APGA, 2024), the International Plant Exchange Network (IPEN), ArbNet, and networks associated with Botanic Gardens Conservation International (BGCI), such as the Global Conservation Consortia (GCC), International Plant Sentinel Network (IPSN), and Ecological Restoration Alliance (ERA) of Botanical Gardens. More recently, researchers have facilitated the creation of networks of botanical gardens to study phenology, the timing of nature's seasonal events including leaf out, flowering, fruiting, and leaf senescence (van Vliet, et al., 2003).

In addition to these formal networks, botanical gardens can establish informal research networks to investigate questions related to ecology, evolution, climate change, and related topics. Informal research networks generally address specific questions and last just one or a few years. They often have minimal funding and administrative structure. Informal networks represent a nimble alternative to formal networks, which tend to be large, highly organized, and run for many years.

Over the past decade, we have established and participated in informal research networks of botanical gardens to address specific questions in plant biology. We believe wider adoption of this approach could speed the pace of research, address questions difficult to address in other ways, and benefit the botanical garden and scientific communities more broadly.

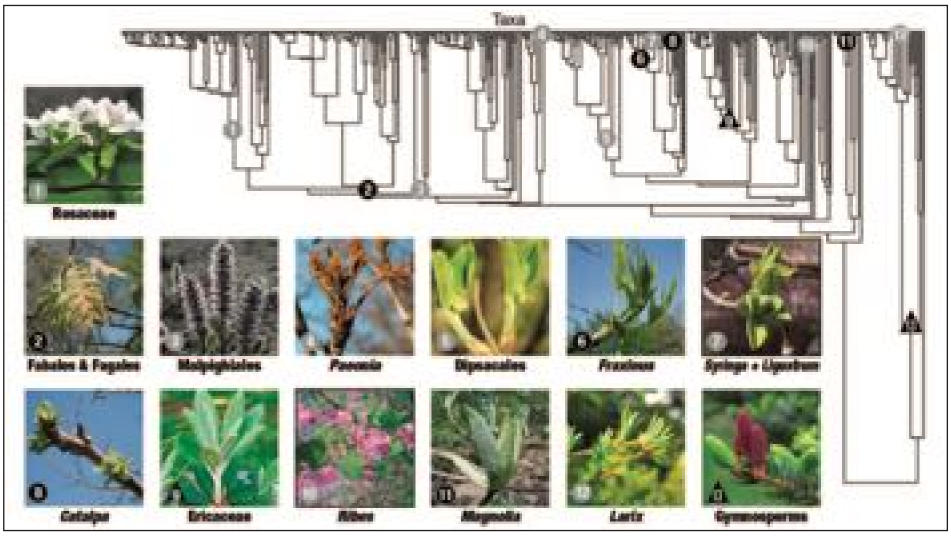


Figure 2. Leaf out times vary among species and have a strong evolutionary pattern with deciduous species leafing out before evergreen species. The phylogeny highlights major clades with significantly early leaf out dates (in grey), significantly late leaf out dates (in black). Numbered circles representing clades with predominantly deciduous species, and numbered triangles representing clades with predominantly evergreen species. Modified from Panchen, et al., (2014).

Recent informal networks of botanical gardens investigated the timing of spring leaf out (Panchen, et al., 2014), autumn senescence (Panchen, et al., 2015), and fruit maturation (Gallinat, et al., 2018) in temperate woody plants. Another informal network is currently investigating the phenomenon of leaf marcescence, the retention of dead leaves over winter. The PhenObs network, established to investigate the phenology of herbaceous perennial plants, represents a hybrid model that includes both formal and informal elements (Nordt, et al., 2021). In each of these projects, researchers, garden staff, and volunteers monitored large numbers of species, often in the hundreds, using standard protocols at multiple gardens (Fig. 1). The taxonomic representation and replication of many species growing in multiple gardens in different parts of the world allowed us to address questions that cannot be answered by typical field studies or studies at a single garden.

Informal networks of botanical gardens represent a nimble alternative to formal networks, which tend to be large, highly organized, and run for many years.

Examples of informal botanical garden networks

Leaf-out—A network of eight gardens in Germany, United States, Canada, and China participated in a study of the spring leaf out times of woody trees, shrubs and vines (Panchen, et al., 2014). Across the gardens, researchers, garden staff, and volunteers monitored over 1600 species, representing

We believe wider adoption of this approach could speed the pace of research, address questions difficult to address in other ways, and benefit the botanical garden and scientific communities more broadly.

88 angiosperm families and seven gymnosperm families, for two years. A survey of the variation in spring leaf out times had not previously been conducted, despite the importance of leaf phenology for ecosystem processes such as carbon cycling, forest microclimate, water balance, and plant-insect interactions. The research team found that at a single site, the leaf-out season typically spanned more than three months, shrubs leafed out before trees, and there was a strong evolutionary pattern in leaf out times (Panchen, et al., 2014) (Fig. 2). Certain families, such as the Rosaceae, tended to leaf out early, and other families, such as the Fagaceae and Pinaceae, tended to leaf out late (Fig. 3a and b). Deciduous species tended to leaf out before evergreen species and species with diffuse porous wood anatomy tended to leaf out before species with ring porous anatomy.

Figure 3a. In the leaf out study, many species of Rosaceae had early leaf out times. (Richard Primack)

Figure 3b. In the leaf out study, many species of Pinaceae had late leaf out times. (Richard Primack)

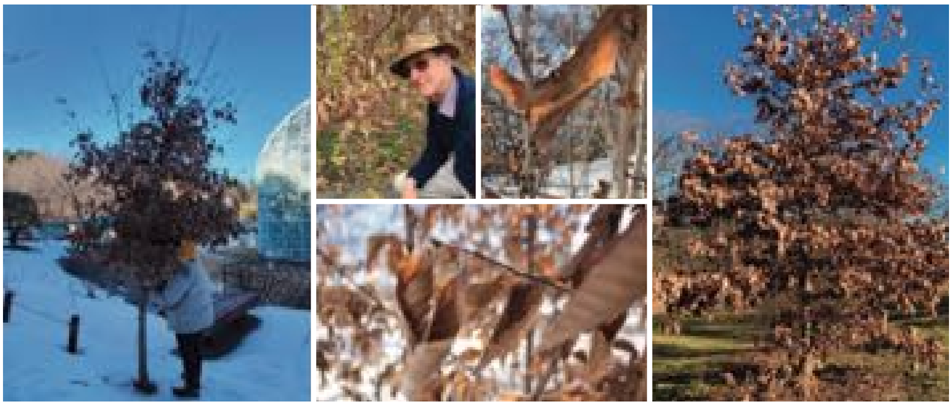


Figure 4. The survey showed that leaf marcescence is widespread among plant families. Clockwise from left – *Acer triflorum, Lindera umbellata, Hamamelis vernalis, Quercus alba, Carpinus caroliniana*. (Sungwon Son, Richard Primack, Matthew Austin)

Leaf marcescence—Researchers and garden staff recently created a new network of 18 botanical gardens to investigate leaf marcescence, the under-studied phenomenon in which plants retain dead leaves on their twigs through the winter (Heberling and Muzika, 2023). A major initial effort involved creating a standardized protocol that could be used across a wide range of plant sizes and growth forms. The team evaluated over a thousand species for marcescence, with many species recorded at five or more gardens. Marcescence was surprisingly widespread across the plant phylogeny: 152 species from 36 families had at least 25% of their leaves being marcescent through midwinter (Fig. 4).

Herbaceous perennial plant phenology—PhenObs is a network of botanical gardens established to investigate the vegetative and reproductive phenology of herbaceous perennial plants, a group that had been understudied in phenology research. PhenObs includes 20 botanical gardens spread across 13 countries (Fig. 5). The network has a hybrid structure in which researchers and gardens are invited to participate informally by monitoring phenology and measuring plant functional traits (Nordt, et al., 2021). The network is administered by a formal organizational team headquartered at Jena University (Germany) and funded by the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig. The initial focus of the network was to develop a standard protocol to monitor leaf out, flowering, fruiting, and leaf senescence times across a wide range of herbaceous perennial plants (Nordt, et al., 2021). The network of gardens has investigated correlations among phenological characters and the relationships among phenology, functional traits, and growth forms (Sporbert, et al., 2022; Rauschkolb, et al., 2024; Deilmann, et al., 2024). As new gardens joined PhenObs, the number of studied species and scale of data collection have increased in tandem (Fig. 6). The PhenObs team plans to extend the network to the tropics to test consistency of phenology and plant traits across biomes.

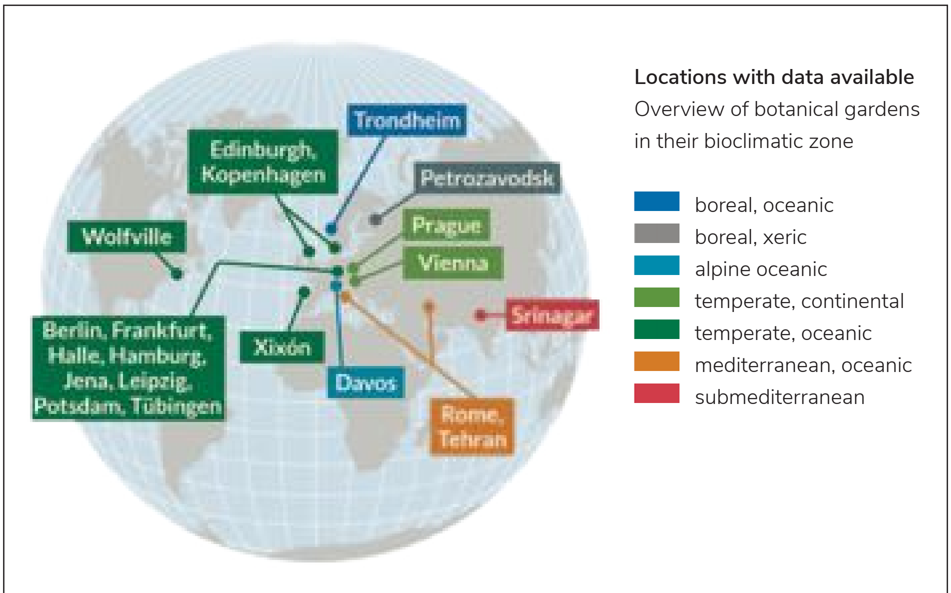


Figure 5. The PhenObs network includes 20 botanical gardens spread across 13 countries. (https://www.idiv.de/phenobs)

Key features of informal botanical garden networks

Question-driven—Informal networks are often driven by a key research question that could best be addressed by studying plants in several botanical gardens. For example, what are the factors that affect the variation in spring leaf out times among species? The projects make use of the diversity of plant species at gardens, replicated species across gardens, and test the effects of environmental differences between gardens.

Low-cost, feasible, and low environmental impact—Each of our informal network projects was established by an individual motivated scientist or a small group of scientists. The projects did not require formal agreements between institutions, and, with the exception of PhenObs, the projects ran without centralised funding.

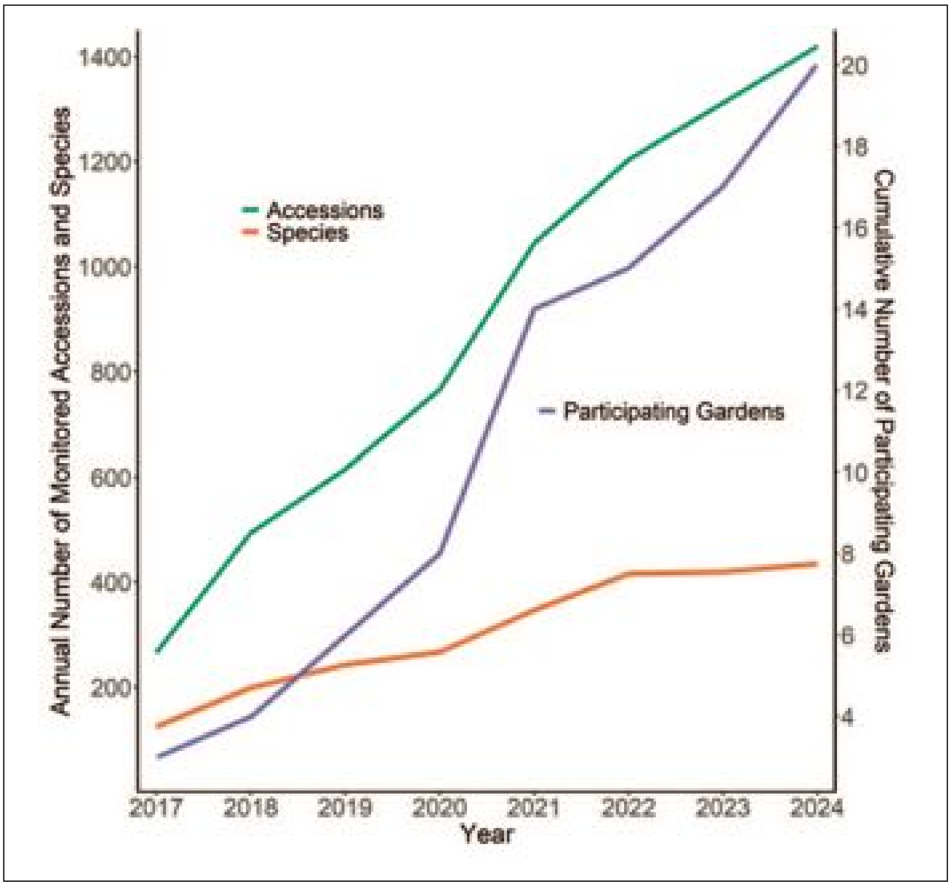


Figure 6. Growth in the PhenObs network facilitated monitoring more species and increased data collection.

Researchers and botanical gardens contributed their time and resources because they were interested in the questions, and wanted to contribute to an international project. Often volunteers gathered much of the data, helping to reduce costs. With no in-person meetings or extra travel, the projects kept carbon emissions and environmental impacts low.

Shared protocols and cooperative decision-making—It can take considerable discussion, via email and video calls, to develop standard research protocols that are easy to understand and use in different countries and with diverse plant species. In our projects, we trialled protocols at a subset of the interested gardens and then refined them through further discussion for use across a broader group of gardens. Project teams made decisions cooperatively, often with a core leadership team. These decisions included schedules and deadlines, plans for research and data collection, analysis, and publication, and communication of results. Researchers communicated frequently during data collection and exchanged photographs with occasional virtual meetings.

In our projects, we trialled standard research protocols at a subset of the interested gardens and then refined them for use across a broader group of gardens.

Productive and enjoyable—Team approaches to data collation, analysis, and writing reduced the burden of work on individual collaborators but collectively achieved more. All participating researchers were invited to be co-authors of resulting articles, which were published in peer-reviewed journals. Researchers were also free to publish separate articles on the results of research in their own gardens, and to further study the publicly available data sets. The projects were designed to be enjoyable, with lots of time in beautiful botanical gardens. Some participants published stories about the projects in their botanical garden newsletters. Given the positive experience of the researchers involved, the networks often continue to conduct collaborative research after the completion of the initial studies.

Conclusion

The success of the projects described here illustrates the value of informal short-lived networks of botanical gardens established with specific research questions in mind. Informal networks can co-exist with more formal and organized research networks, and represent a valuable way to address research questions that would be difficult to address any other way.

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References

- APGA, 2024. *Plant Collections Network* [online]. Available at: https://www.publicgardens.org/program/plant-collections-network/. [Accessed 4 December 2024].
- Deilmann, T.J., Ulrich, J. and Römermann, C., 2024. Habitat conditions filter stronger for functional traits than for phenology in herbaceous species. Ecology and Evolution, 14(6), p.e11505.
- Gallinat, A.S., Primack, R.B., Willis, C.G., Nordt, B., Stevens, A.D., Fahey, R., Whittemore, A.T., Du, Y. and Panchen, Z.A., 2018. Patterns and predictors of fleshy fruit phenology at five international botanical gardens. American Journal of Botany, 105(11), pp.1824-1834.
- Heberling, J.M. and Muzika, R.M., 2023. Not all temperate deciduous trees are leafless in winter: the curious case of marcescence. Ecosphere, 14(3), p.e4410.
- Nordt, B., Hensen, I., Bucher, S.F., Freiberg, M., Primack, R.B., Stevens, A.D., Bonn, A., Wirth, C., Jakubka, D., Plos, C. and Sporbert, M., 2021. The PhenObs initiative: A standardised protocol for monitoring phenological responses to climate change using herbaceous plant species in botanical gardens. Functional Ecology, 35(4), pp.821-834.

The taxonomic representation and replication of many species growing in multiple gardens in different parts of the world allowed us to address questions beyond what is possible of typical field studies or experiments at single gardens.

- Panchen, Z.A., Primack, R.B., Nordt, B., Ellwood, E.R., Stevens, A.D., Renner, S.S., Willis, C.G., Fahey, R., Whittemore, A., Du, Y. and Davis, C.C., 2014. Leaf out times of temperate woody plants are related to phylogeny, deciduousness, growth habit and wood anatomy. New Phytologist, 203(4), pp.1208-1219.
- Panchen, Z.A., Primack, R.B., Gallinat, A.S., Nordt, B., Stevens, A.D., Du, Y. and Fahey, R., 2015. Substantial variation in leaf senescence times among 1360 temperate woody plant species: implications for phenology and ecosystem processes. Annals of Botany, 116(6), pp.865-873.
- Rauschkolb, R., Bucher, S.F., Hensen, I., Ahrends, A., Fernández-Pascual, E., Heubach, K., Jakubka, D., Jiménez-Alfaro, B., König, A., Koubek, T. and Kehl, A., 2024. Spatial variability in herbaceous plant phenology is mostly explained by variability in temperature but also by photoperiod and functional traits. International Journal of Biometeorology, 68(4), pp.761-775.
- Sporbert, M., Jakubka, D., Bucher, S.F., Hensen, I., Freiberg, M., Heubach, K., König, A., Nordt, B., Plos, C., Blinova, I. and Bonn, A., 2022. Functional traits influence patterns in vegetative and reproductive plant phenology–a multi-botanical garden study. New Phytologist, 235(6), pp.2199-2210.
- van Vliet, A.J., de Groot, R.S., Bellens, Y., Braun, P., Bruegger, R., Bruns, E., Clevers, J., Estreguil, C., Flechsig, M., Jeanneret, F. and Maggi, M., 2003. The European phenology network. International Journal of Biometeorology, 47, pp.202-212.

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Millennium Seed Bank staff (Bethan Hobbs)

FEATURED GARDEN

CELEBRATING THE PAST AND SEEDING THE FUTURE: LOOKING BACK AT 25 YEARS OF RBG KEW'S MILLENNIUM SEED BANK AT WAKEHURST, SUSSEX.

This year, we're proudly celebrating 25 years of the Millennium Seed Bank (MSB) at Wakehurst, Kew's wild botanic garden in Sussex. Opening its doors in 2000, this pioneering, purpose-built facility now safeguards nearly 2.5 billion seeds from over 40,000 wild plant species — protecting an extraordinary amount of biodiversity in one place for use both now and into the future.

Over the last quarter-century, the Millennium Seed Bank has grown into the largest and most diverse wild plant seed bank in the world. This remarkable achievement has been made possible through the Millennium Seed Bank Partnership (MSBP) — a collaborative, global effort which has united over 275 partners in 100 countries and territories. Together, we've shared knowledge, built skills, and worked to safeguard wild plant species threatened by land use change, over-exploitation and climate change, across the world.

Here we highlight some of the key milestones from the past 25 years, with a particular focus on UK work and research undertaken at the MSB.

2000: The MSB building was officially opened by HRH The Prince of Wales, who at the time called the initiative a *'gold reserve…a place where this reserve currency, in this case life itself, is stored.'* But planning and preparation began a lot earlier! A Millennium Commission grant was awarded in 1995 for the project and the building work started in 1996. This enabled the seed bank to move from Wakehurst's Mansion chapel into a purpose-built facility.

Left: Mansion chapel seed bank (RBG Kew)

2003: Publication of the book 'Seed Conservation – turning science into practice' which resulted from an International Workshop held at the MSB in 2001. The workshop focused on the application of seed banking to meet global needs for the conservation and sustainable use of plant diversity.

2005: Yellow fatu (*Abutilon pitcairnense*), native to the Pitcairn Islands, went extinct in the wild, after a landslide killed the last known wild plant. Cuttings of the plant had previously been taken and seeds collected from one of the cultivated plants are now stored in the MSB.

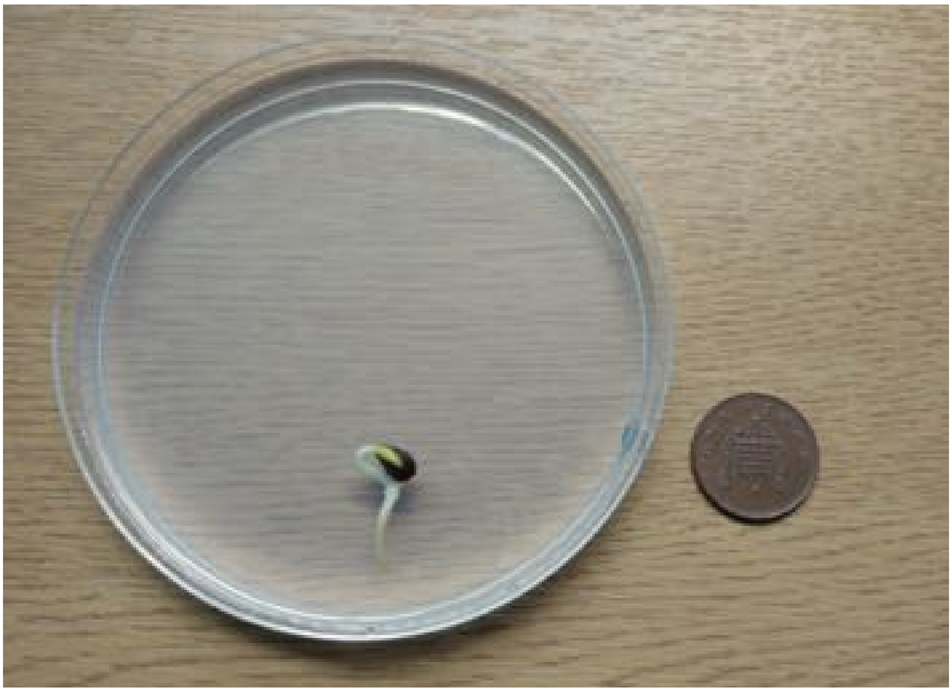
2009: 10% of the world's known flora was successfully banked with the addition of the wild banana *Musa itinerans*, duplicated to the MSB from the Germplasm Bank of Wild Species at the Kunming Institute of Botany, China. This species is a crop wild relative of the domesticated banana.

2011: In collaboration with the Global Crop Diversity Trust, the Crop Wild Relatives (CWR) project launched, involving 25 institutions across 24 countries. The programme collected over 12.8 million seeds, capturing as much genetic diversity as possible from the wild relatives of our domesticated crop species - key to helping with crop resilience to threats such as climate change and plant pathogens.

2013: In 2013 the MSB launched the UK National Tree Seed Project (UKNTSP), an ambitious project to make genetically representative seed collections from trees across their native UK distributions. By 2020, 13 million seeds from over 10,000 native UK trees and shrubs had been stored at the MSB representing more than 70 species, including ash, juniper and yew. This was accomplished with the help of over 400 volunteers and staff. Successor collecting projects continue to build on the success of the UKNTSP, expanding the number and quality of collections and the suite of species conserved at regional level across the UK. Seed and data have also been supplied to support UK restoration efforts, for example through research into dormancy and germination behaviour and the creation of new registered seed stands and orchards for largescale tree production.

"It is the most important ex situ *conservation project in the world and provides a model for global co-operation in tackling our most pressing challenges."*
Richard Deverell, Director of the Royal Botanic Gardens, Kew.

The MSBP has been recognised for its "extraordinary contribution to the preservation of the world's plant biodiversity".
BBVA Award (2021)



A germinated apple seed returned from space. (Anne Visscher)

The Millennium Seed Bank is not just an insurance policy against the ultimate apocalypse, this is of huge value right now, for wherever we discover that a plant is teetering on the brink of extinction, we can now bolster its numbers with seeds from here and so ensure that no plant species on Earth would go extinct.
David Attenborough, Kingdom of Plants (2012):

Collecting the BBVA award. (Aisyah Faruk)

2015: In 2015 the Global Tree Seed Bank (GTSB) launched, supported by the Garfield Weston Foundation. Since its inception the programme has brought together partner organisations in 41 countries and territories across the world to conserve the rarest, most threatened and useful trees. It has also enabled Kew to conduct research to fill vital gaps in our knowledge of tree conservation. The Weston Global Tree Seed Bank is now an unparalleled and globally unique resource for the conservation of threatened trees. This programme now focuses on seed-based restoration for trees, improving outcomes by overcoming barriers to use of native tree species in tree planting and restoration work.

2020: A sapling of the 'Flower of Kent' apple tree was planted by astronaut Tim Peake at Woolsthorpe Manor, Sir Isaac Newton's birthplace and family home. The seed used to grow this sapling was originally collected from Newton's tree at Woolsthorpe Manor, before being processed at the MSB and sent to the International Space Station to coincide with Tim Peake's mission. Once back on earth after six months in space, the seeds were germinated at the MSB and nurtured into seedlings by horticulturalists, before they were distributed to new homes, including back to Woolsthorpe Manor.

2021: The MSBP wins the BBVA Foundation Worldwide Award for Biodiversity Conservation "for its extraordinary contribution to the preservation of the world's plant biodiversity". The citation continues that the MSBP has "contributed significantly to preserving many of the world's most threatened plant species" and that "this exemplary initiative reflects how cooperation without borders can advance nature conservation worldwide and successfully address the central challenge of preserving biodiversity."


Jenny Peach collecting *Potamogeton alpinus* in a Scottish Loch for the threatened flora project. Photo: Stephanie Miles

2024: 85% of UK threatened species are secured in the MSB, with 54 species fully represented by multiple collections from across their distribution in the UK. The UK Threatened Flora project aimed to make genetically-representative, multi-population seed collections of the UK's threatened and declining plant species for conservation in the MSB as well as research and develop germination and propagation protocols for threatened species. The project provided seeds, plants, advice and technical assistance to organisations and projects wishing to grow and use native species aiming to make an effective and genuine contribution to the conservation and restoration of biodiversity in the UK. This project built on the success of the UK Flora project which enhanced the MSB's UK collections, by adding an additional 892 collections and 42 new UK species.

2025: Our work is far from finished. As we mark this milestone, we're looking to the next 25 years — a future where seeds are not only preserved but actively used to restore and return species richness to landscapes, to bring back diversity to strengthen food security, to support local communities, to create nature-based solutions to climate change.

INTERVIEW

KIM HOEJIN

Senior Manager of Seedvault center
Korea Arboreta and Gardens Institute (KOAGI)

Kim Hoe-jin oversees the conservation of wild forest plant seeds, managing over 240,000 specimens representing nearly 5,800 species. With a strong focus on long-term viability testing, seed data management, and international collaboration, Kim plays a key role in global biodiversity preservation. He actively contributes to initiatives such as the AFoCO Seed Management Working Group and regional capacity-building programs like STEP and KEYS. His leadership ensures Korea's seed vault serves as a vital hub for conservation and emergency preparedness in Asia.

Could you elaborate on the origins of the Baekdudaegan Global Seed Vault Center and the motivations that led to its establishment?

The significance of preserving plant genetic resources and ecosystems is increasing in response to the global biodiversity crisis that has been induced by climate change. The habitats of temperate- and cold-climate plants, particularly alpine species, are being reduced by the increasing global temperatures, which is putting forest ecosystems at a significant risk.

The demand for facilities that can securely store seeds has increased to prepare for the climate crisis and ensure global biodiversity. The Baekdudaegan Global Seed Vault (BGSV) was established in Korea by the Korea Forest Service (KFS) as part of the Baekdudaegan National Arboretum construction project. BGSV is situated along the Baekdudaegan mountain range, which is a significant ecological corridor in Northeast Asia. As a result of its ecological significance and stable environment, it provides optimal conditions for the conservation of wild plant seeds from all around the world.

Korea's historical accomplishments are of greater significance. Korea, which was previously an aid recipient, is now the 16th largest donor of Official Development Assistance (ODA) in the globe. Korea built BGSV by utilizing its expertise and superior technologies to benefit global and future generations.

In what year was the Center formally inaugurated, and who were the principal organizations or individuals instrumental in its development?

BGSV officially started operations in 2018. Recognizing the importance of biodiversity conservation, KFS, led by the Korean government, planned and oversaw BGSV's construction. KFS continued to promote BGSV through its cooperation networks and initiated collaborative projects. To ensure the safety and reliability of the deposited seeds, BGSV was designated a national security facility and is subject to regular inspections.

What is the central mission of the Baekdudaegan Global Seed Vault Center, and how does it align with broader national or international conservation efforts?

BGSV's objective is to conserve global biodiversity by duplicating wild plant seeds from various regions worldwide. BGSV functions as a 'Vault of Life,' preserving plant genetic resources permanently from unforeseen global catastrophes, including natural disasters and climate change. BGSV is an ultimate safeguard that is consistent with the national biodiversity conservation objectives in Korea.

The seeds that have been stored at BGSV are essential resources for the restoration and reintroduction of endangered natural plant species. BGSV thereby directly contributes to Korea's policy objectives regarding the restoration of their habitats and the preservation of endangered species. On a global scale, BGSV backs a number of the Kunming-Montreal Global Biodiversity Framework's main objectives. The protection and recovery of endangered species are the primary objectives of Target 4, which is achieved through ex-*situ* conservation. Maintaining transparency in seed storage and distribution, BGSV operates in compliance with Access and Benefit-Sharing (ABS) principles in support of Target 12. Target 22 encourages the development of scientific capacity and the transfer of technology through international collaboration and seed conservation training.

Exterior of seed vault

Additionally, BGSV is consistent with the ecosystem-based adaptation strategies delineated in the UNFCCC Adaptation Framework. The seed vault directly supports the Sustainable Development Goals (SDGs), with a particular emphasis on SDG 13 on climate action, SDG 15 on the preservation of terrestrial ecosystems, and SDG 17 on the promotion of global partnerships.

BGSV serves as a Nature-based Solution (NbS) that offers a crucial alternative system for seed resources that are required for ecological restoration and climate response. The vault promotes long-term ecosystem recovery and resilience in the presence of escalating environmental threats by preserving the fundamental components of biodiversity.

What role does the Seed Vault play in addressing global challenges such as climate change, food insecurity, and the loss of biodiversity?

BGSV is storing wild plant seeds. BGSV saves species that may become endangered due to climate change, as well as those whose potential value has yet to be discovered — all for the benefit of future generations.

BGSV also stores Crop Wild Relatives (CWRs), which are genetically related to domesticated crops and serve as critical resources for developing climate-resilient and adaptive crop varieties. Many wild plants remain understudied, with their ecological functions and potential uses largely unknown. For this reason, BGSV aims to collect and preserve as many wild species as possible, contributing to the prevention of biodiversity loss and the collapse of ecosystems.

Could you provide an overview of the types of seeds currently housed within the Vault, and the criteria used for their selection?

BGSV stores any seeds that are sent by depositors from around the world. Among them, BGSV prioritizes storing seeds of endangered species and other plants currently at risk, as well as rare plants and regional specialties. Next in priority are CWRs related to food security and useful plants from various countries. In addition, when storing wild plant seeds, BGSV also prioritizes them on a regional basis. According to the climate crisis, BGSV prioritizes selecting vulnerable areas, focusing first on plants in SIDS regions at risk of submersion or in high-altitude areas.

Does the Center maintain collaborative relationships with botanical institutions, gene banks, or agricultural research bodies—either domestically or internationally?

Domestically, BGSV operates the K-seed Network, a consortium that brings together national agencies and both public and private arboreta involved in biological resource management. Through this network, collaborative efforts are underway to safeguard native seeds across Korea. BGSV also works closely with the National Agrobiodiversity Center

Deposits in seed vault

under the Rural Development Administration to duplicate and store agricultural crop seeds. Additional partnerships include the National Institute of Biological Resources under the Ministry of Environment and the Korea National Arboretum under the Korea Forest Service, which contribute native plant seeds for backup storage at the Seed Vault.

Internationally, BGSV has built a growing network of partnerships with botanical research institutes and arboreta across Central, Southeast, and West Asia. Through joint projects, key regional plant species are being duplicated and preserved at the vault. These collaborations typically involve sharing seed collection and management techniques, setting conservation priorities, and implementing *ex-situ* conservation strategies that include depositing wild plant seeds at BGSV.

Beginning in 2025, BGSV is expanding its efforts through partnerships with international organizations. It is actively sharing seed conservation technologies with more countries and scaling up its seed duplication activities. Such work includes administering the BGCI and GSC Grants to support global *ex-situ* conservation efforts. A pilot project with the UNDP Seoul Policy Centre is also underway to support seed conservation in two regions of Africa, offering technical consulting and capacity-building training. Furthermore, BGSV has submitted a proposal to the International Union for Conservation of Nature (IUCN) to initiate seed conservation projects for Small Island Developing States (SIDS) and is currently implementing pilot activities aligned with this initiative.

Depositors Wall Baekdudaegan Global Seed Vault

Have there been any instances in which seed samples from the Vault have been utilized to restore or revitalize endangered species or critical crop varieties?

As of right now, there have been no reports of seeds being taken out and put back into the Baekdu-daegan Global Seed Vault. The seeds are withdrawn and restored in the event that a wild plant species goes extinct or the seeds preserved by the depositing institution are lost. Fortunately, such incidents have not yet occurred. We are saving seeds for the future, but it would be best if we never had to remove them.

What key lessons have emerged since the Vault's inception that could inform similar initiatives elsewhere?

I would want to point out that there is no future without seeds, and because there is little known about wild plant seeds, study must always be undertaken. Furthermore, study is required on seeds that cannot be stored since certain traits of seeds allow them to be kept in seed vaults. If the importance of seed conservation grows widely and the entire world joins, that would be just fantastic.

Is there a particular story, milestone, or specimen that you believe encapsulates the essence and aspiration of the Baekdudaegan Seed Vault?

The Korean fir (*Abies koreana*) is an indigenous species in Korea and a very rare conifer worldwide. It is currently listed as "Endangered (EN)" on the International Union for Conservation of Nature (IUCN) Red List. This tree grows mostly in high-altitude places above 1,000 meters, such as Hallasan, Jirisan, Deogyusan, and Sobaeksan, and it is considered a species of high biodiversity and scenic significance due to its ecological beauty and unique cone shape.

The Korean fir is vulnerable to climate change due to its restricted natural habitat, which is characterized by specific climatic conditions in a very restricted area (alpine zone) within the Korean Peninsula. The Korean fir's growth environment has been rapidly deteriorating in recent decades as a result of the increase in high-altitude temperatures on the Korean Peninsula. The death rate is increasing, and the incidence and growth of young individuals/seedlings are almost nonexistent, particularly in the Hallasan area.

Baekdudaegan Global Seed Vault interior corridor

The Korean fir is becoming increasingly exposed to parasites and diseases, particularly the pine needle gall midge, as a result of climate change. Additionally, the reduction in soil moisture is a significant factor contributing to its decline. In addition, the growth of the plant is affected by root injury and stress caused by human disturbances, such as the expansion of trails and the increase in hikers.

In this manner, the Korean fir is disappearing at the forefront of the climate crisis, acting as a warning signal for the forest ecosystem that requires protection.

The Korea Arboreta and Gardens Institute (KoAGI) is systematically developing strategies for collecting and preserving the seeds of the Abies koreana, which is rapidly declining. This strategy includes the duplicate storage of 1,188 seed accessions in BGSV. It is not only conducting local monitoring initiatives to determine the status and causes of population decline, but it is also making efforts to establish off-site conservation stands. In particular, they are working on conservation initiatives for endangered coniferous species through partnerships between academia, industry, and government. They are collaborating with the National Institute of Forest Science, KoAGI, and Yuhan Kimberly to duplicate seeds in BGSV and establish *ex-situ* conservation sites under the supervision of the Korea Forest Service. They are making every effort to achieve this goal.

What message would you wish to convey to the international community regarding the importance of seed conservation?

I think that seeds are living things that can turn into full plants in the future. I want to say that we should try to stop plants from going extinct before we even know what they are. This way, future generations can enjoy the same variety of plants and seeds that we do, thanks to the work of people who handle them.

(Derrick Banda)

ARTICLES

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SEED CONSERVATION IN COLOMBIA'S DRY TROPICAL FOREST: A CASE STUDY FROM THE CARTAGENA BOTANICAL GARDEN SEED BANK PROJECT

Libidibia punctata (ébano) seeds (Mariana Sánchez)

Seed conservation has emerged as a vital *ex-situ* strategy for plant conservation, encompassing not only species of agricultural importance but also native plants that contribute to mitigating biodiversity loss. This approach is particularly crucial when seed banking efforts focus on threatened and endemic species. Established in 2016, the seed bank of the Cartagena Botanical Garden is one of the first initiatives in Colombia dedicated to conserving seeds of native plants. To-date, the Garden has collected and stored more than 1,000 accessions from the Tropical Dry Forest, one of the most endangered ecosystems globally. What began as a medium-term storage effort has evolved into a long-term conservation program, supported by international collaborations that enabled the acquisition of specialized equipment and the implementation of international standards. Moreover, the Garden's leadership in seed conservation has catalyzed the formation of a national seed conservation network, strengthening collaboration and knowledge exchange across Colombia.

Introduction

For centuries, communities around the world have preserved seeds as acts of memory, food security, and cultural lineage. This traditional knowledge has been essential to maintaining the genetic diversity of plants that feed and sustain humanity.

The Colombian Caribbean is home to the Tropical Dry Forest, an ecosystem historically degraded and now considered one of the most poorly conserved globally, with only 8% of its original coverage remaining (Ocón et al., 2021). Its unique biogeography harbors a great diversity of plant species, many of which provide food, ecological services, and shape biocultural relations to local communities. Deforestation, the primary local threat, has led to a range of environmental and social problems, including the erosion of global biodiversity (Ocón et al., 2021), increased carbon emissions, the spread of zoonotic diseases, and the marginalization of millions of people who rely on these forests for their livelihoods (Buchadas et al., 2022).

1,668 georeferenced GBIF records that are part of the Cartagena Botanical Garden Seed Bank collection, from 1992 to 2021 (GBIF)

In response to these threats, local initiatives have taken action. In the department of Bolívar, the Cartagena Botanical Garden Seed Bank project has emerged as the largest plant and seed collection in the Colombian Caribbean region. It serves as a vital *ex-situ* conservation strategy, currently hosting more than 1,000 accessions native to the Tropical Dry Forest. The Garden is committed to the collection, storage, and quality control of plant genetic diversity as a means to safeguard the future of this endangered ecosystem.

Libidibia punctata (ébano) seeds vacuum-packed and stored in the freezer (Ana María Oliva)

Libidibia punctata (ébano) seeds and fruits being processed for storage and sowing in the research nursery (Ana María Oliva)

Seed banking, as an *ex-situ* conservation strategy, is both a national and international collaborative effort

Under the Global Strategy for Plant Conservation (GSPC), adopted by the Convention on Biological Diversity, Colombia was a pioneer in formulating a National Strategy for Plant Conservation (ENCP) in 2001. This strategy serves as a guiding framework for integrating and coordinating key stakeholders around plant conservation (Castellanos et al., 2017). To help achieve the ENCP's targets, the Colombian Network for Seed Conservation was established.

The network includes partner institutions across Colombia, such as the Agrosavia germplasm bank, the Humboldt Institution of Biological Research, Bogotá Botanical Garden, The International Centre of Tropical Agriculture (CIAT) and the Cartagena Botanical Garden. As of 2019, the Network conserves seeds of more than 700 native species and 30 species of economic importance. The best represented ecosystems include the páramo and the Tropical Dry Forest, both of which are threatened and strategically important for Colombia (Diaz et al., 2020).

The conservation of native plant seeds at the Cartagena Botanical Garden represents not only a local initiative but also a global commitment to safeguarding one of the planet's most endangered ecosystems.

International financial support is crucial for the implementation and sustainability of these efforts, particularly because non-profit institutions like the Cartagena Botanical Garden often face significant budgetary constraints. The high cost of infrastructure and specialized equipment required for seed banking, as seen in projects like the "Caquetá Native Seed Bank," which has an estimated budget exceeding one million dollars according to the Inter-American Development Bank (2024),underscores this challenge.

The long-term success of Latin America's seed conservation projects depends on robust national and international partnerships that provide both funding and technical support.

These collaborations are essential to reinforce local capacities in research, seed collection, drying protocols, and storage techniques. The lack of equipment and trained personnel often leads to the loss of large and sometimes irreplaceable quantities of seed material, as seeds cannot be properly processed and prevailing climate conditions hinder preservation. The loss of genetic material is particularly detrimental to conservation and restoration initiatives. Once seeds are collected, they must be processed promptly in the seed bank or vivarium to maintain viability, an operation that requires specialized infrastructure. In severely degraded ecosystems, the loss of even a single seed might represent the last opportunity to restore ecological balance.

Cartagena Botanical Garden's Seed Bank Project: A Case Study

The Seed Bank Project at the Cartagena Botanical Garden aims to conserve a representative sample of populations of native and endemic species from the seasonal Tropical Dry Forest of the Colombian Caribbean. The research guidelines for the collection focus on compiling extensive biological and ethnobotanical information on the specimens, in accordance with standardized protocols for seed collection, processing, and storage.

As of 2024, and since its inception in 2016, the Botanical Garden has registered a total of 1,672 accessions. Of these, 569 correspond

Libidibia punctata (ébano) seedlings, 50 days after planting in the research nursery, each from a different accession (Ana Maria Olíva)

to live seeds currently stored in the seed bank. The updating and publication of accession data are supported by BID-GBIF funding initiatives.

The seed bank holds specimens primarily collected in the Caribbean region of Colombia, including the departments of Bolívar, Atlántico, Magdalena, La Guajira, Cesar, Córdoba, and Sucre. It also includes contributions from botanical gardens in countries such as the United Kingdom, the United States, Australia, and Brazil. The most represented families in the collection are Fabaceae, Malvaceae, Bignoniaceae, and Meliaceae (Contreras & Madriñán, 2023).

Thanks to new alliances established in 2025, particularly through two projects supported by the BGCI's Global Botanic Garden Fund, the Cartagena Botanical Garden is currently expanding its conservation efforts. The first project, being developed in partnership with the Missouri Botanical Garden through an ArbNet Grant, focuses on strengthening conservation horticulture for threatened species of the Colombian Caribbean Tropical Dry Forest, with a particular emphasis on *Libidibia punctata*. This initiative involves staff training, improvements to seed storage infrastructure, and the ongoing development of propagation and seed banking protocols. The second project, funded by the Leon Levy Native Plant Preserve Grant, is enhancing the Cartagena Botanical Garden Seed Bank, by acquiring new equipment and archival-quality materials to improve storage conditions for native orthodox seeds. These collaborations represent a significant step forward in actively safeguarding regional biodiversity through ex-*situ* conservation.

Due to these types of international alliances, the Garden is currently transitioning from a medium-term to a long-term seed conservation

Libidibia punctata (ébano) seeds vacuum-packed and stored in the freezer (Ana Maria Olíva)

strategy, enabling us to transfer the entire seed bank to freezer storage at –20°C and 20% relative humidity. This shift allows for ex-*situ* conservation for at least ten years, an essential measure given the ecological degradation of the Dry Tropical Forest as the most threatened ecosystems in the world, particularly in a context of climate change and ongoing ecological degradation.

The seed collection and storage process follows a curated methodology based on international protocols. It begins with preliminary research prior to collection (including conservation status of the species, field collection planning, and sampling strategies), followed by seed collecting and processing. Each accession is recorded in a dedicated logbook, and a species storage behavior is reviewed using the seed databases. Seeds are then stored according to their desiccation tolerance: orthodox seeds are kept in freezers at –20°C with 20% relative humidity, while recalcitrant seeds are sown directly in the research nursery. There, we monitor growth rates and document key variables such as substrate type, transplant dates, and survival rates. Although more data is being collected than can currently be analyzed, this expanding dataset is an invaluable resource for developing more effective conservation and propagation strategies.

Vacuum-sealed seeds in hermetic containers stored in the freezer—an example of successful storage from this year (Ana María Oliva)

To date, all orthodox seeds collected this year have been transferred to freezer storage. The next step is to analyze the viability of collections from previous years to determine their eligibility for transfer, based on the specific conditions and storage behavior of each accession.

In the coming years, the Garden aims to continue and strengthen seed collection efforts in the Tropical Dry Forest in the Colombian Caribbean, contributing to ecosystem conservation, mitigating biodiversity loss, and promoting stability within the region's socio-ecological system. However, the availability of financial resources remains a challenge for the seed bank project; continued collaboration with local communities and international institutions is therefore essential. This continuous support facilitates improvement of infrastructure, access to new protocols, and the integration of up-to-date information, crucial not only for equipment and facilities, but also for enhancing the entire seed sampling and collection process.

Silica gel drying of seed material from different accessions, with a hygrometer included (Ana María Oliva)

Seed Banks as Agents of plant diversity Conservation and Resilience

Historically, seed collection and storage have been practiced by indigenous and farming communities as a means of preserving germplasm for food security. Today, this practice has evolved into a strategic conservation tool, with institutions increasingly storing seeds not only for their agricultural value but also for their ecological significance. In Colombia, where biodiverse ecosystems such as the Tropical Dry Forest face growing threats, seed banks have become essential pillars of both food sovereignty and ex-*situ* plant diversity conservation. Their relevance is particularly pronounced in ecologically and socially vulnerable regions, where climate change and environmental degradation continue to accelerate biodiversity loss.

Seed banking now represents more than an ecological intervention, it serves as a framework for building national and international collaborations that expand access to knowledge, strengthen technical capacity, and ensure the proper storage of native and endemic species. Within this context, the Cartagena Botanical Garden's commitment to ex-*situ* conservation of threatened seeds from the Tropical Dry Forest is especially significant. Our ongoing efforts to adopt international protocols, invest in specialized equipment, and cultivate cooperative networks underscore our central role in mitigating the loss of Colombia's biocultural diversity. Strengthening partnerships with local communities and global institutions enhances the long-term sustainability of seed conservation, ensuring that both natural ecosystems and human societies are better equipped to face future challenges.

In doing so, the Garden is not only safeguarding plant genetic diversity, it is also preserving the resilience of territories, ecosystems, and the communities that guard them.

Bibliography

- Buchadas, A., Baumann, M., Meyfroidt, P., Rueda, X. & Kuemmerle, T., 2022. Uncovering major types of deforestation frontiers across the world's tropical dry woodlands. Nature Sustainability, 5, pp.619–627. https://doi.org/10.1038/s41893-022-00886-9
- Castellanos, C., Sofrony, C., Higuera, D., Peña, N. and Valderrama, N., 2017. Estrategia nacional para la conservación de plantas. Reporte de estado y tendencias de la biodiversidad continental de Colombia.
- Contreras, M.P. and Madriñán, S., 2023. Banco de Semillas Jardín Botánico de Cartagena "Guillermo Piñeres". Version 1.4. Jardín Botánico de Cartagena "Guillermo Piñeres". Occurrence dataset. https://doi.org/10.15472/8uehrf accessed via GBIF.org on 2025-05-07.
- Inter-American Development Bank. (s.f.). CO-T1736: Banco de semillas nativas del Caquetá. https://www.iadb.org/es/proyecto/CO-T1736
- Ocón, J.P., Ibanez, T., Franklin, J., Pau, S. & Keppel, G., 2021. Global tropical dry forest extent and cover: A comparative study of bioclimatic definitions using two climatic data sets. PLOS ONE, 16(5), e0252063. https://doi.org/10.1371/journal.pone.0252063

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The Qur'anic Botanic Garden, Doha, Qatar

SEED CONSERVATION IN THE QUR'ANIC BOTANIC GARDEN, DOHA, QATAR

The Qur'anic Botanic Garden (QBG), a member of Hamad Bin Khalifa University, Doha, Qatar, introduces a new concept for botanical gardens. It is the first garden that works to collect, conserve, and display plant species mentioned in the Qur'an and the Hadiths (reports attributed to the Prophet Muhammad peace be upon him). Its efforts also seek to preserve the genetic resources of Qatar's flora.

The QBG believes that seed conservation is a fundamental pillar of biodiversity conservation. It contributes to achieving food security, preserving culture through perpetuating traditional uses, restoring ecosystems, and ensuring sustainability for future generations.

1. Principles of Seed Conservation in QBG: Conserving Cultural Heritage: Between Authenticity and Modernity

The importance of seed conservation in the Qur'anic Botanic Garden is highlighted through a cultural dimension inspired by the story of the Prophet Joseph, peace be upon him, dating back centuries BC. Joseph's wisdom represents one of the oldest examples of sustainable agricultural resource management and closely resembles the principles of modern plant conservation. These principles include following a sustainable agricultural plan, maintaining seed quality and viability by preserving the seeds in their spikes and storing them for long periods, and managing agricultural stock in the face of climate challenges.

[Joseph] said, "*You will plant for seven years consecutively; and what you harvest leave in its spikes, except a little from which you will eat*" [Surah Yusuf, Verse 47], this advice is consistent with modern best practices for seed preservation, which is storing grains in their husks to maintain maximum viability and prevent spoilage.

Genetic Diversity

The QBG contains a diverse collection of plants across three different climate zones, including Qatar's climate, Arid, Mediterranean, and Tropical. Genetic diversity of plant species is maintained at QBG though having a herbarium specimen for each accession, preserving seed in a seedbank, and a living plant collection in the nursery. By conducting germination and propagation protocol trails and recording results future work on plant species is ensured.

2. Seed Conservation Mechanism

Habitat Assessment and Vegetation Mapping in Qatar:

The first step in the QBG conservation workflow is conducting comprehensive ecological surveys. These surveys involve assessing natural habitats and mapping Qatar's vegetation cover. The QBG conservation team, in collaboration with the Ministry of Environment and Climate Change, is conducting systematic surveys of more than ten "Rawdat" (a desert depression that is usually rich in vegetation). These surveys serve several purposes:

- Identifying wild plant populations
- Evaluating plant communities
- Documenting habits and habitats
- Monitoring seasons, including flowering and fruit ripening periods

Seed collection during habitat assessment

This data is vital for selecting the best seed harvesting periods and targeting rare, endangered, or high-value species for restoration projects.

Seed Collection:

Collecting seeds is one of the most important stages of seed conservation. The Qur'anic Botanic Garden maintains the following principle when harvesting seed; harvesting only healthy and mature plants and avoiding overharvesting, to avoid threatening wild species. Each seed is then documented with detailed information, including:

- Scientific and local name
- Geographic location (GPS Coordinates)
- Habit, habitat description
- Date of collection
- Name of seed collector

Cleaning and Drying:

After returning to the QBG's Conservation Center located in Doha, the seeds undergo a cleaning and drying process. This step is essential for preparing the seeds for storage and preventing them from insect and fungal infestation.

Habitat assessment in North Qatar

Seeds are dried in shaded, well-ventilated rooms on newspaper-lined trays. Under drying conditions (temperature: 15-23°C and relative humidity: 15%-20%). The seeds are spread out in a single layer and turned periodically to ensure even drying. The humidity levels are continuously monitored using specialized moisture meters, until the required storage percentages are reached.

The cleaning process depends on the type of plant. For example:

- Leguminous plants (e.g. *Vachellia tortilis*): The dried pods are gently crushed using a mortar and pestle to release the seeds without damaging them.
- Fleshy fruits (e.g. buckthorn fruits - *Zisphus nummularia*): The seeds are separated manually after the outer layer has completely dried.
- Delicate seed pods (e.g. *Nigella sativa*): The seeds are filtered using fine sieves and mechanical shakers.

Furthermore, in order to improve seed purity, the seeds are passed through a seed blower, which separates them from chaff and debris using carefully controlled airflow based on weight differences.

> *"QBG seeds are preserved in conditions that ensure their long-term survival even under arid conditions."*

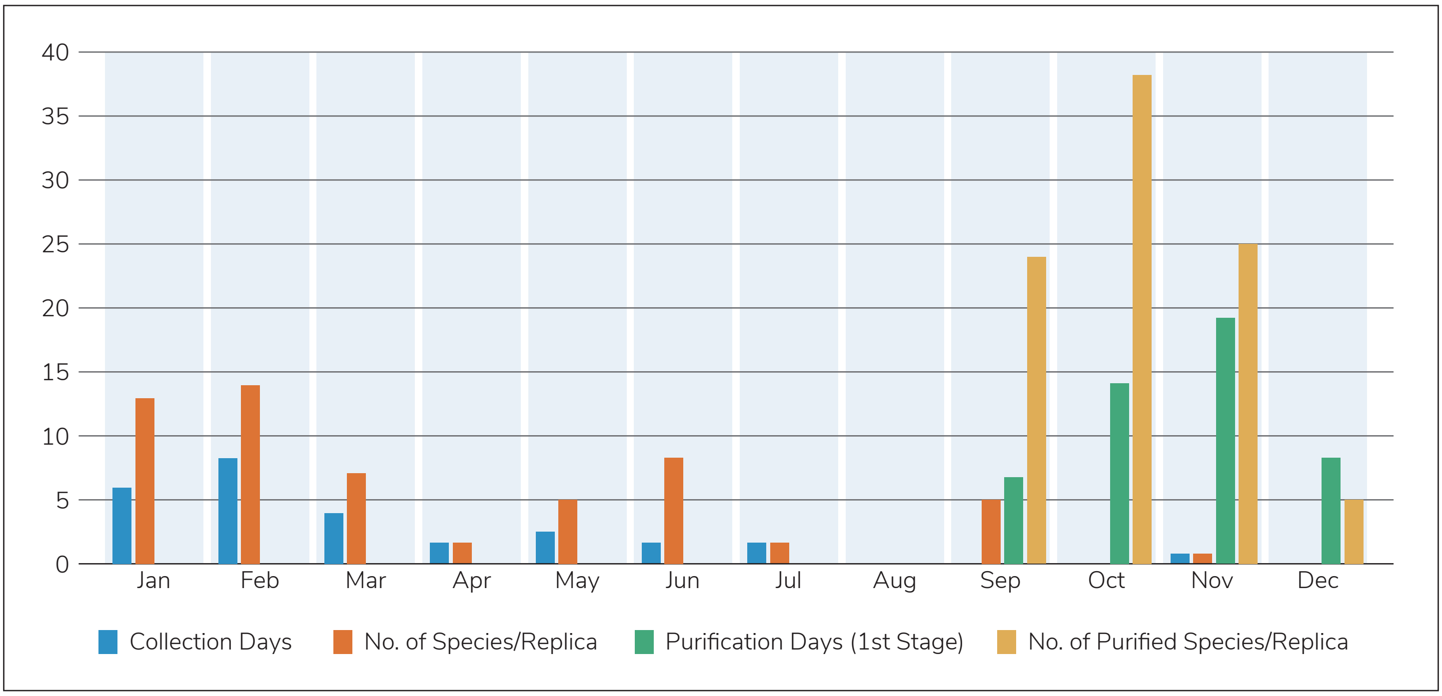
Sterilization:

Prior to long-term storage, sterilization is one of the most important steps in QBG seed conservation, as a precaution seeds are stored in refrigerated units at subzero temperatures -10°C to -20°C for a full seven days to eliminate insects and their eggs that may have been transferred during the plant sample collection process or during initial drying.

The QBG Seed Bank Database:

After collecting, and during the drying and sterilization processes, all seeds are documented in the QBG's seed bank database, data fields that are recorded include:

- Scientific name, local name, and plant family
- Location (GPS coordinates, habitat)



QBG seed collection 2021

- Weight before and after drying
- Moisture content
- Storage date
- Accession number and serial number
- Number of containers holding pure seeds for each species, whether renewed, due to loss of viability, or duplicates.

Quality Assessment:

At the QBG conservation Center, seed quality is assessed using a range of indicators and is then captured in the QBG's seed bank database:

- Species matching with the variety is the process of accurately identifying and recording seed collections according to their precise scientific names, to avoid any misidentification that could affect their future use (restoration, etc.), and to maintain the same distinguishing characteristics when reproduced.
- Seed biometrics: weight using a high-precision balance (weight of one hundred seeds in grams); number of seeds per gram using a high-precision seed counter; seed moisture measurement using a moisture meter.
- Microscopic examination: measuring seed size (length and width), and assessing its physical characteristics (ex, the presence of a hole, on the Senna Italica seed)
- Seed germination test : since germination capacity of stored seeds tends to decline over time, and to ensure that stored QBG's seeds retain their ability to germinate and produce healthy plants, we employ a precise and reliable method which is germination tests. These tests are performed before the seeds are stored and at regular intervals throughout the storage period. This process enables us to identify the onset of loss of seed viability and take timely measures to renew the seed sample and maintain its quality.

Barcoding system and Storage:

QBG Conservation Center is equipped with modern seed storage facilities that provide short and long-term storage conditions.

Seed biometrics in QBG

Seed packed in airtight glass containers at QBG Conservation Center

Once the seeds reach the desired moisture content (between 3% and 8%), they are packed in airtight glass containers suitable for storage at low temperatures (4°C for short-term storage and -15°C for long-term storage) and controlling humidity, maintaining seed moisture and preventing it from absorbing moisture from the external environment. Each container carries a serial number linked to a barcode which enables the tracking of the accession in the QBG seed bank's database, internal monitoring, scientific reporting, recording of legal transactions for seed exchanges with local and international institutions and biodiversity monitoring and reintroduction planning to take place.

QBG's seed storage room

QBG's seed barcoding

Seed Germination Testing:

Seed viability testing is regularly carried out at the QBG's Conservation Center, to ensure the vitality and quality of both newly collected seeds and those stored in the seed bank. These tests are performed in germination chambers under controlled temperature and humidity conditions. Certain wild species require specific conditions, such as a temperature between 28°C and 30°C and humidity levels as high as 90% for growth. Germination rates vary by species and by seed viability: some seeds show rates below 25%, while others can reach up to 75%, though rarely higher. Approximately 125,000 seedlings are produced annually by germination techniques in the germination rooms at the QBG's Conservation Center. Each seed germination process is documented with detailed information, including:

- Name of species
- Source of seeds: Location and date of collection
- Treatment: If the seeds are dormant
- Date of planting
- Germination room
- Date of the delivery
- Germination rate and total number of seedlings

Vitality testing Senna Italica Seed, Date of planting: Oct 05, 2022, at QBG germination room #3

Seedlings of *Ziziphus spina-christi* ,Date of planting: Nov 22, 2022, Germination rate: 66.5%, Total number of seedlings: 751 seedlings, Date of the delivery: Dec26, 2022, at QBG propagation house #5

3. Challenges and Solutions in *In-Situ* and *Ex-Situ* Conservation

In-Situ Conservation:

Qatar's natural habitats, particularly its vegetation ecosystems, are facing increasing threats due to, climate change (decreased rainfall and increased temperatures), soil degradation, overgrazing, and the introduction of invasive species. To address these risks, the Qur'anic Botanic Garden implements several Restoration programs, to revive the degraded sites such as the Rawdat Al Faras and the Showcase Rawdat in Education City in Doha. The QBG restoration process focuses on reintroducing wild plants to their natural habitats (planting is performed in the QBG Conservation Center), monitoring the health and the adaptation of reintroduced plants, and distributing native seedlings (more than 4,000 are distributed annually) to government agencies and environmental projects.

Plant seedlings (germination, propagation)

Plant seedlings (germination, propagation) in the growth room at QBG Conservation Center

Habitat assessment at Rawdat Al Faras after restoration

Wild animals at Rawdat Al Faras after restoration

> *"The production of seedlings and their reintroduction into natural habitats, along with the creation of dedicated germination rooms in arid areas, represents a beacon of hope."*

Ex-Situ Conservation:

- The Qur'anic Botanic Garden seed bank was established in a desertic environment (where temperatures can exceed 50°C associated with high humidity levels). The bank is specially designed to isolate heat and humidity, and it is equipped with cooling and humidity control systems. These installations require regular maintenance of the infrastructure and equipment to maintain seed quality.

Additionally, most of the wild species are dormant and require special treatment for germination to take place. QBG employs dormancy-breaking techniques such as:

- Scarification: scratching seed coats lightly to allow water to ingress
- Soaking: soaking seeds in the water for 24 to 48 hours to facilitate germination

4. Community Participation in QBG Seed Conservation

The Qur'anic Botanic Garden has developed a variety of educational and outreach initiatives to raise public awareness of plant conservation and its importance. To-date QBG has conducted educational programs with school students where children learn about the basics of agriculture, starting from seed, and achieving food security. Community tree planting activities, with 800 wild trees and shrubs planted in Rawdat Al Faras during 2021-2022, with the participation of community members. Seed exchange initiatives where members of the public are encouraged to exchange and plant native plants. Collaborative research with academic partners including students and researchers (Qatar University) who participate in joint projects in the fields of plant propagation, climate tolerance, and botanical research.

References

Books:

- FAO, 2010. The Second Report on The State of the World's Plant Genetic Resources for Food and Agriculture. Viale delle Terme di Caracalla, 00153 Rome, Italy.

- N. Kameswara Rao, Jean Hanson, M. Ehsan Dulloo, Kakoli Ghosh, David Nowell and Michael Larinde, 2006. Manual of Seed Handling in Genebanks. Bioversity International. Via del Tre Denari 472a, 00057 Maccarese, Rome, Italy

Files:

- The Qur'anic Botanic Garden

Links:

https://quran.ksu.edu.sa/index.php?l=en#aya=12_47&m=hafs&qaree=husary&trans=en_sh

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Community tree planting activities (QBG restoration program)

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SOUTH AUSTRALIAN SEED CONSERVATION CENTRE: COMMUNITY ENGAGEMENT IN PLANT CONSERVATION

Volunteers helping with the first plantings at the opening of the Kangaroo Island Rare Plant Garden (Dan Duval)

Plant conservation in South Australia has the greatest impact within the regions, where most of the plant biodiversity still exists. The main conservation activities include seed collection for long-term storage and establishing living insurance collections in sites within the species natural range. Working with community volunteers has raised awareness about regional threatened flora, created strong relationships, and harnessed their passion and commitment to conservation for the protection of species in the long-term.

Introduction

The South Australian Seed Conservation Centre (SASCC) is dedicated to the long-term conservation of South Australia's native flora. Over the past 20 years, the Centre has successfully secured seeds from approximately 85% of the state's most threatened plant species. The seed collections stored in the South Australian seed bank form an invaluable insurance policy against extinction.

SASCC targets seed collections from a wide range of environments across the state, including parks and reserves, roadside verges, and remnant vegetation on private properties. The top priority flora species for conservation are regional endemics, especially those with few, or very small populations within limited areas. The accumulation of data collected during field work across the state is important to gain an accurate picture of species range, population numbers, habitat types and threats. These data are important for tailoring conservation actions required for each threatened species. Current information is crucial as historically recorded populations often no longer exist, and persisting populations may remain undocumented. Creating accurate distribution maps helps to assess the conservation status, guide seed collection efforts, and inform conservation strategies.

Map of South Australia divided into Herbarium Regions showing Kangaroo Island, South East and Yorke Peninsula Regions.

Collecting from disjunct or morphologically distinct populations is especially important for seed banking programs to capture the genetic diversity across the species range for long-term preservation.

There is a sense of urgency to bank remaining populations of threatened species. Some species may soon disappear entirely if conservation measures are not taken now.

We already know of extinct plant populations, and even entire species, which would not have been lost if ex *situ* conservation efforts had been implemented in time.

While *ex situ* conservation, such as seed banking, is a fundamental conservation strategy for threatened flora, it is even more important to maintain healthy wild populations that contribute to functional biodiversity and ecosystem resilience. Integrating both approaches leads to more robust conservation outcomes.

Working with Communities

Community engagement is central to our mission. Through partnerships with National Parks and Wildlife Service, regional Landscape Boards, and local volunteers, SASCC runs numerous projects that empower communities to protect their local flora. These projects foster a connection to the region's botanical heritage and highlight the importance of conservation.

Volunteers are vital to this work, supporting field work and seed collections since the inception of the program. More than a dozen regular volunteers assist with field surveys, seed collecting, data collection, seed cleaning, propagation, and nursery work. Their passion and commitment to conservation makes a significant and lasting contribution to the program.

The following showcase how the SASCC interacts with community members in regional South Australia to put conservation strategies into effect.

Kangaroo Island

Kangaroo Island has been a key focus for seed conservation due to its high level of species endemism and significant populations of threatened plants. The island is an ark for threatened species growing in well preserved habitats that are now poorly conserved on mainland Australia. For example, the Kangaroo Island Scale-rush *Lepyrodia valliculae* and Lemon Star-bush *Asterolasia muricata* are only known from single populations on mainland Australia. Sweetheart Leaves *Olax obcordata*, once found in similar mainland habitats, is now presumed extinct there, but persists on Kangaroo Island's western tip in sandy soils over sheet calcrete. There are also spectacular pristine peat-bog swamps, lagoons and creeks that boast a diversity of plants that can no longer be found on the mainland.

Following the catastrophic 2019–20 bushfires, which burnt over 211,000 hectares (about 40% of the island), the Kangaroo Island Rare Plant Garden (KIRPG) was established as an *ex situ* conservation initiative. Designed to replicate the island's diverse habitats, including ironstone gravels, coastal calcareous sands, limestone rubble, and ephemeral wetlands, the KIRPG aims to conserve threatened plant species outside their natural environment.

The overall aim was to establish *ex situ* plant populations of threatened species in the KIRPG that would provide propagules for recovery projects on the island and create awareness of these unique plants and their ecology. The community can't value and contribute to the conservation of threatened species if they're not aware these species exist nor undertake conservation actions such as propagation and translocation if genetically diverse propagules aren't readily available. A large proportion of the seeds used in the project were population collections extracted from low temperature storage in the SA seedbank collected by the SASCC over the past twenty years. For example the endangered Kangaroo Island endemic Beyeria Bush-pea *Pultenaea insularis* was propagated from a collection stored in 2004. Over the last couple of decades this pea has declined in number with only three populations remaining with a total of less than 500 plants.

Most of the remaining plants are growing on roadsides and are severely threatened by weed invasion and clearance.

Today volunteers help manage the 5000m^2 KIRPG, collecting seeds and propagating plants for expansion of the garden and recovery projects. In 2025 thousands of plants of nationally endangered plant species, including *P. insularis* are being translocated into protective enclosures in remnant habitat with the help of landholders and volunteers. Seeds harvested from the KIRPG were utilised for this recovery project and collections will also be restored to the seed bank.

A view of the Kangaroo Island Rare Plant Garden (Dan Duval)

South East Region

The Lower South East region of South Australia contains unique wetland complexes, including nationally listed threatened ecological communities (TECs) such as Karst Springs and Seasonal Herbaceous Wetlands communities. Over the years the SASCC has targeted threatened species within the region that are only known from a few extant plants or populations. For example, the Clustered Daisy-bush *Olearia suffruticosa* growing in seasonal wetland systems and the Spade-leaf Bitter-cress *Cardamine gunnii* growing in red gum swamps only known from one population. Recently, through the Grassroots Grants scheme, the SASCC has been working with ecologists, forestry planners, volunteer groups and landowners to undertake conservation actions for these species. Activities such as plant surveys, population assessments, seed collections, constructing herbivore exclosures and introducing new populations into protected sites. Establishing new populations decreases the risk of extinction and provides source material for future conservation and recovery efforts. One of the major successes of these projects has been the discovery and protection of new wild populations, which has also included new species recorded for the region or new species subsequently described.

One example, the Limestone *Phebalium Phebalium* calcicola, is one of Australia's most endangered plants. Only four wild individuals were found growing on Karst limestone on private land. In 2007 the SASCC fenced the small population and propagated plants to establish an insurance population on the property with help of the landowner. At that time these few wild plants were a disjunct population of a Phebalium species also growing in Victoria and New South Wales. A taxonomic revision (Dema et al 2021) named *Phebalium clacicola* as a new species and proposed the national conservation status as Critically Endangered. Despite extensive surveys of areas with similar habitat in subsequent years no new plants have been discovered. The private property is surrounded by farming land which has been rock mulched and the karst limestone habitat is only conserved as small, fragmented remnants within the region.

Phebalium calcicola and *Gentianella gunniana* plants both grow on karst limestone sheets in the Lower South East of South Australia (Dan Duval)

The outlook for the *P. calcicola* has improved since 2007 with small insurance populations established in remnant habitat proximal to the small wild population. In 2025 seed collections from both wild and translocated plants were germinated to produce 400 plants. These will be used to further augment the wild population and establish four new insurance populations in remnant Karst limestone within conservation reserves and protected sites on private land. Landholders, ecologists and volunteers were involved in transplanting into protected enclosures an initial trial in 2024 with the remaining plants to be added in 2025. The involvement in building enclosures, planting and monitoring by volunteers from the community fosters a connection with threatened regional flora. This enables community members to understand the biology and ecology of the plant and increases the chances of discovering new populations of wild plants.

The herbivore exclosures will be utilised to protect other threatened plant species from limestone habitats. The Mountain Gentian Gentialella gunniana grows in Tasmania but is now only known on mainland Australia from a small disjunct population in nearby Piccaninnie Ponds Conservation Park in South Australia. In 2024/25 this endangered Gentian was also propagated from stored seeds so that hundreds of plants can be translocated into suitable habitat with volunteer groups as part of this project.

Workshop participants in a remnant scrub block on Yorke peninsula learning about rare plants (Dan Duval)

Yorke Peninsula

In recent years the SASCC has developed community partnerships in Yorke Peninsula by working with many farmers in the region. Since European settlement the Peninsula has been extensively cleared for agriculture and copper mining, however some private properties have retained remnant vegetation, preserving threatened plants including several orchid species. In spring 2021 the SASCC team met with farmers during threatened orchid surveys which included the Critically Endangered Large-club Spider-orchid *Caladenia macroclavia*. It was during dinner one night when a conversation about the orchids on the Peninsula prompted her memory of seeing a very similar orchid several years prior on a roadside reserve. Although skeptical, we searched the approximate locality the next morning and were delighted to discover a healthy population of *C. macroclavia* that had never been recorded. This new discovery doubled the total plant count known for this critically endangered orchid

The farming community organised and hosted a workshop in a shearing shed with the SASCC team to emphasise the importance of conserving the remaining fragments of natural heritage on the Peninsula. Participants enjoyed walking through nearby scrub blocks, learning about the native flora including rare orchids. Workshop participants soon began their own searches and discovered two new populations of *C. macroclavia* on remnant scrub blocks, increasing the existing numbers to hundreds of plants. Landowners were engaged in hand pollinating orchids to produce pods which facilitated seed collections for banking and propagation from a significantly wider genetic pool than would have been previously possible.

In 2024 seeds and fungal isolates were used for the symbiotic propagation of more than 200 *C. macroclavia* plants and an endangered leek-orchid species *Prasophyllum goldsackii*. These orchids will be translocated into protected areas within remnant scrub on farm properties over the next few years. Seeds and fungal isolates required for the propagation of these orchids were banked in low temperature storage. Partnering landowners have provided access to valuable remnant scrub blocks and has fostered protection of the rare flora on the peninsula. The SASCC is developing programs that continue to restore and protect threatened plants, using a model that establishes self-sustaining insurance plant populations within enclosures on managed private properties. These populations will be a living in situ resource for seed collections required in future conservation work.

Conclusions

Working with volunteers in regional communities has a multitude of benefits to the projects that the centre delivers. Our seed banking program conserves seeds to be put back into the region from where they were collected, this is better managed along-side of people who share concern about the fate of these plants. Connecting people to the threatened plants in their own backyard is empowering, leading to communities that are actively invested in safeguarding South Australia's botanical heritage.

In conclusion:

- Making the right people aware of the threatened flora in their region increases the likelihood of effective conservation actions for those species.
- Spending time with volunteers on ground has been the most successful way to engage and promote learning for both parties.
- Regional contacts are invaluable for local knowledge, species searches, seed collection and monitoring of translocations and wild populations.

References

- Dema, S., Telford, I.R.H., Andrew,R.L., Duval, D.J., Bruhl, J.J. (2021). Phebalium Calcicola (Rutaceae: Boronieae): A Species Described as New, Restricted to South-Eastern South Australia, Is Proposed as Critically Endangered. Swainsona 35 (3), 43--53. https://www.biodiversitylibrary.org/part/364320.

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Caladenia macroclavia flower (Dan Duval)

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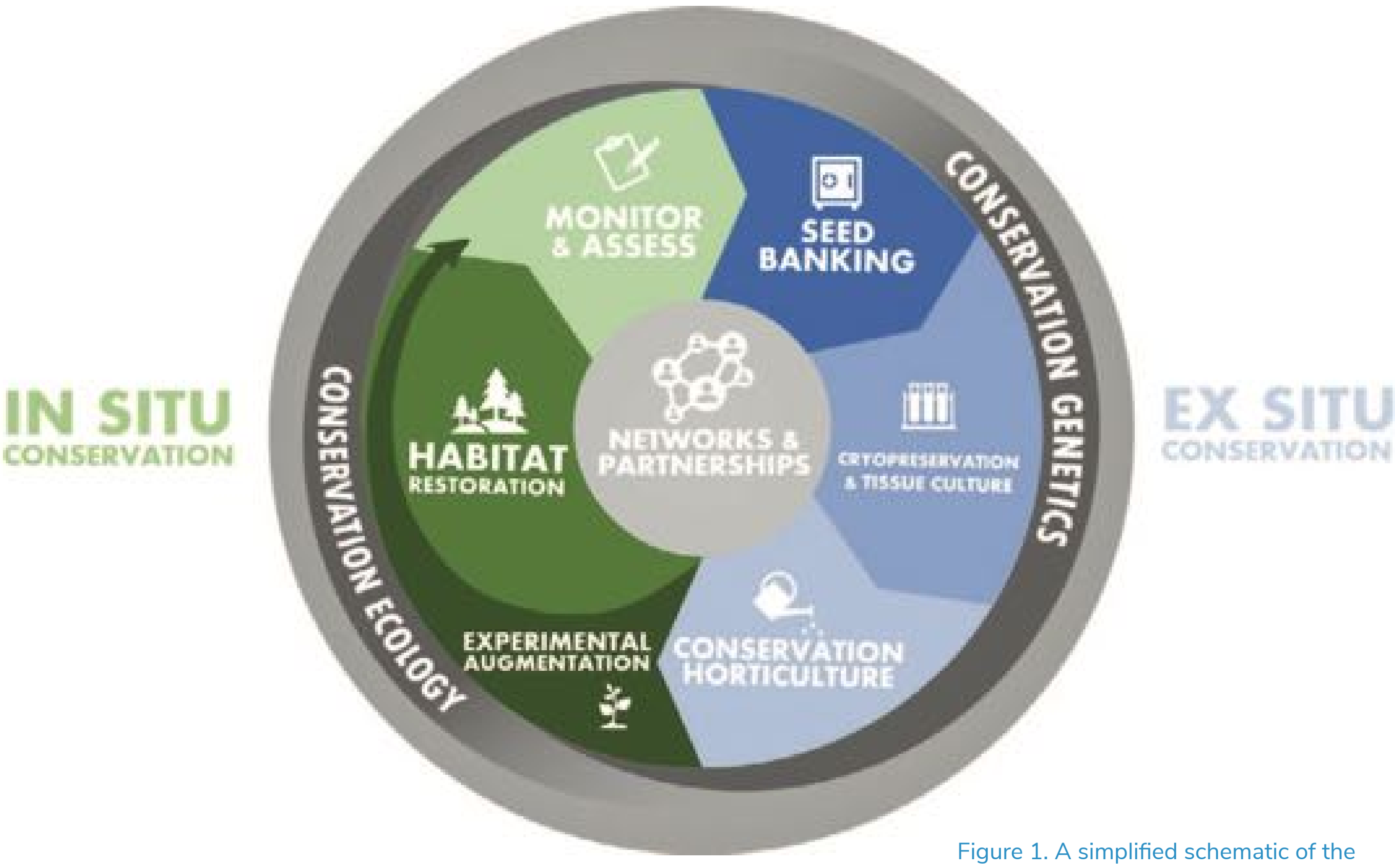

Figure 1. A simplified schematic of the species conservation workflow at the Southeastern Center for Conservation. (Loy Xingwen and Emily Coffey)

ADVANCING SEED CONSERVATION: ATLANTA BOTANICAL GARDEN'S GROWING IMPACT IN THE SOUTHEAST U.S.

The Conservation Seed Bank at the Atlanta Botanical Garden has emerged in the last five years as a regional leader in seed conservation. A component of the Southeastern Center for Conservation, the Seed Bank holds almost 7,000 accessions of >600 taxa collected from the southeastern U.S., Caribbean, Ecuador, and the Garden's living collection to further the mission of conserving imperiled plants and natural communities. We have found that collaboration and knowledge sharing are fundamental to successful seed conservation programs, and enable growth in emerging areas, such as the integration of conservation seed banking with native plant materials development.

Nestled in the heart of Atlanta's bustling Midtown neighborhood is the Southeastern Center for Conservation (SECC). Set within the lush grounds of the Atlanta Botanical Garden amid a dramatic backdrop of skyscrapers, the SECC pursues its mission "to lead innovative strategies and partnerships to conserve imperiled plants and natural communities" of the southeastern United States, Caribbean, and Ecuador. The dynamic work of the SECC fully embodies integrated plant conservation (Guerrant et al. 2004), whereby *in situ* and *ex situ* conservation approaches are tightly linked in a feedback loop incorporating research, horticulture, and education (Fig. 1). The workflow is centered in partnerships and encircled by best practices and novel research in conservation ecology and conservation genetics. Led by Dr. Emily Coffey, the Vice President of Conservation and Research, this integrated approach is realized by a team of less than 40, full and part-time, staff with strategic outposts in northern Georgia and the Florida Panhandle (Coffey et al. 2024).

Building Capacity at the Atlanta Botanical Garden's Conservation Seed Bank

A vital aspect of the SECC's *ex situ* infrastructure is the Conservation Seed Bank. While seed banking at the Atlanta Botanical Garden began as early as 2002, under the oversight of Dr. Coffey the program was re-launched in 2019 with a commitment to the Center for Plant Conservation's Best Plant Conservation Practices to Support Species Survival in the Wild (CPC 2019). This effort was led by Jason Ligon, former Micropropagation and Seed Bank Coordinator, and current Conservation Specialist in the department. Since then, the Seed Bank has grown from around 1,000 accessions to almost 7,000, representing over 600 unique plant taxa. Fueling the Center's growth rate can be attributed in part to its attention to forging strategic partnerships, growing community, and integrating seed banking with other disciplines. Five years on, we are well positioned to embark on new initiatives, such as contributing to the native seed supply in the southeastern U.S.

Within the Conservation Seed Bank, two highly represented groups are orchids and carnivorous plants. The orchid collection in the Seed Bank includes wild collected accessions from the southeast U.S. and Caribbean, as well as seeds from the Atlanta Botanical Garden's Fuqua Orchid Center, a living collection of more than 2,000 species of tropical orchids from around the world. The carnivorous plant seed collection features North American pitcher plants (genus *Sarracenia*), which have a center of diversity in the southeastern United States. The Atlanta Botanical Garden maintains a nationally accredited plant collection of Sarracenia as recognized by the Plant Collection Network, a program of the American Public Gardens Association. The Conservation Seed Bank safeguards the seeds of over 30 unique *Sarracenia* taxa, including all three pitcher plants listed as federally endangered: *Sarracenia oreophila*, *Sarracenia rubra* ssp. *alabamensis*, and *Sarracenia rubra* ssp. *jonesii* (Fig. 2). The collection also includes sundews (*Drosera*), butterworts (*Pinguicula*), and tropical pitcher plants (*Nepenthes*).

Figure 3. The staff of the Conservation Seed Bank at the Atlanta Botanical Garden. From left to right: Lina Arabyat (Lab Manager), Jessamine Finch (Research Scientist), Oliver Hutchens (Seed Bank and Micropropagation Technician), and Jason Ligon (Conservation Specialist). (Brad Harten)

In 2024, to keep up with its rapidly growing collection, the Seed Bank staff expanded to include two new full time staff, Lina Arabyat (Seed Bank Laboratory Manager) and Dr. Jessamine Finch (Research Scientist). Seed Bank operations continue to be supported by Jason Ligon, as well as a part-time technician and small, dedicated group of volunteers (Fig. 3).

Maternal line tracking is foundational to the imperiled plant work carried out by the Conservation Seed Bank, for which each seed accession originates from an individual maternal plant with detailed field data, including precise location information. By maintaining seed separately by maternal line we are better able to manage and utilize the genetic diversity held within the collection. Often, seed collections are paired with leaf tissue collection, which are deposited in our DNA Biorepository and available for molecular genetic research through the Conservation Genetics Lab. Upon reception by the Seed Lab, seed collections are cleaned, counted, and photographed (Fig. 4).

Figure 2. The first true leaves of North American pitcher plants (Sarracenia) are miniature pitchers, seen here in a germination trial of *Sarracenia rubra* ssp. *jonesii. (Oliver Hutchens)*

Figure 4. Left: Lina Arabyat (foreground) and Oliver Hutchens (background) photograph seeds and seedlings using dissecting microscopes. Photo by: Jessamine Finch. Right: Seed reception image for yellow pitcher plant (*Sarracenia flava*). (Lina Arabyat)

Figure 5. Dr. Emily Coffey (VP of Conservation & Research) & Dr. Laura Fidalgo DeSouza (U.S. Forest Service Biologist) collect seed of endemic Lepanthes woodburyana orchid in El Yunque National Forest, Puerto Rico (left) and in vitro germination at Atlanta Botanical Garden (right), supported by the BGCI Forest Service Rare Plant Partnerships. (Jason Ligon (left) and Oliver Hutchens (right)).

Means of initial viability assessment are selected based on the size of the collection and the goals of the project, if applicable. Given the dearth of germination and seed dormancy information available for many rare species, most often lab germination trials are carried out to grow our knowledge base in support of future propagations and outplantings. Asymbiotic orchid germination is carried out under sterile conditions in the Micropropagation Lab (Fig. 5). After drying, orthodox seed accessions are stored under medium (5°C) or long-term (-20°C) conditions. The Conservation CryoBank is also available for storage of seeds and other germplasm (-180°C).

Forging Strategic Partnerships to Drive Regional Progress

The work of the Conservation Seed Bank is grounded in the rich tapestry of partnerships and networks at the center of the SECC. Here we spotlight two with substantial impacts on seed conservation regionally.

Founded in 2020, the Southeastern Plant Conservation Alliance (SE PCA, se-pca.org) is a public-private partnership that plays a leading role in setting conservation priorities and coordinating conservation action across the Southeastern U.S., a 15 state and two territory region. Through this partnership the SE PCA aims to secure 60–75% of Southeastern rare plants in seed banks and cultivated (ex situ) living collections, such as those maintained by the Atlanta Botanical Garden. In 2023, the SE PCA completed an assessment called the Regional Species of Greatest Conservation Need, prioritizing ~20% of the flora (~1,800 plant species) based on distribution, status, threats, and conservation needs. This assessment has been critical in guiding project development and securing funding for seed collection, research, and banking of some of those imperiled plants in the Southeast.

Florida Plant Rescue (saveplants.org/florida-plant-rescue), led by the Center for Plant Conservation (CPC), has a more narrow focus as a "statewide seed collections initiative that aims to secure and safeguard Florida's rare plant species." Atlanta Botanical Garden, along with others in the CPC network of Participating Institutions, proposes annual seed collection targets and receives funding to support collecting and safeguarding of plants in ex *situ* collections. As duplicate off-site storage is a best practice in genebanking, orthodox seed collections of sufficient size are split between the Conservation Seed Bank and the USDA-ARS National Laboratory for Genetic Resources (Fort Collins, CO, USA). Cuttings or recalcitrant seeds are established *in vitro* in collaboration with Dr. Qiansheng Li (Research Scientist, In vitro) for the development of tissue culture or conservation horticulture collections (Fig. 6).

Growing the Seed Conservation Community

Seed conservation is a relatively low-cost means of preserving high volumes of genetic diversity ex situ. Despite this, there are many plant conservation groups that do not yet utilize the practice. To this end, the Conservation Seed Bank is committed to expanding training opportunities for conservation professionals and early career individuals in the basic science and practice of seed conservation. By sharing knowledge through hands-on learning and supporting newcomers through a community of practice, we hope to expand seed conservation work in the focal region of the SECC, and beyond. Training opportunities in the past have included a one-day workshop as part of the Southeastern Partners in Plant Conservation Conference, paid internships, and student research (Fig. 7). In addition to in-person training, the Conservation Seed Bank has advised organizations interested in starting or growing a seed bank on workflows, recommended equipment, and budgets.

Integrating Native Seed Farming and Conservation Seed banking

The SECC is committed not just to conserving imperiled plants, but also their natural communities. One challenge in managing and restoring natural communities is a limited native seed supply. In the southeastern United States, genetically-appropriate native seeds are unavailable for many vulnerable habitats, such as climatically sensitive wetlands. To meet this need and further the National Seed Strategy (U.S. BLM & PCA 2015), Atlanta Botanical Garden is developing a new native plant materials development program focused on wetland restoration.

Figure 6. Dr. Qiansheng Li (Research Scientist, In vitro; left) germinated recalcitrant seed of *Hymenocallis henryae* var. *henryae* (right) as part of the Center for Plant Conservation's Florida Plant Rescue program. (Qiansheng Li)

Figure 7. Lina Arabyat (Seed Bank Lab Manager) instructs workshop attendees in scoring germination trials at the 2024 Southeastern Partners in Plant Conservation Conference. (Loy Xingwen)

The program will work directly with public lands to collect, bank, increase, and return plot-produced seed to current and future regional restoration projects. Seed collections are targeting common habitat matrix species integral to wetland ecosystem dynamics that also support rare and endangered wildlife. To maximize outcomes from field-work, protocols also integrate maternal line collection of co-occurring rare plants for deposit in the Conservation Seed Bank. Most of the collected common species' seed will be used to establish production beds at the Conservation Safeguarding Nursery (Gainesville, GA), with a small portion stored as reference samples under medium and long-term storage conditions with the Conservation Seed Bank (Fig. 8). Throughout production, seed lots and their associated data will be managed in adherence to explicit seed distribution zones within each collection region, as defined by the future end-users of increased seed. This project represents an exciting shift towards holistic consideration of plant communities in seed banking and native plant materials development, supporting ecological restorations that will provide high-quality habitat for associated rare plants and wildlife.

Figure 8. Andre Ledet (Conservation Seed Plot Horticulturist) sows seeds in the greenhouse (above) for the seed increase program. Resulting plugs will be planted out into newly created production beds at the Conservation Safeguarding Nursery (below). (Tanner Biggers)

Now over five years into its next chapter, the Conservation Seed Bank at Atlanta Botanical Garden is one of the largest wild seed banks in the southeastern U.S., and its rapid growth is not expected to wane anytime soon. Looking forward, the Seed Bank is interested in further embracing existing and emerging technologies to increase efficiency and improve collections management standards, with a focus on seed imaging and the application of artificial intelligence. The SECC also hopes to grow collaborative research projects utilizing seed accessions, in tandem with other Center resources, to answer basic and applied questions in support of plant conservation. While the scale of the biodiversity crisis is immense, seed conservation continues to offer an accessible, effective strategy that can rapidly fill gaps in our *ex situ* collections and deepen our understanding of species biology. Through the development of our seed increase program, we hope to hone a model for banking seeds of imperiled plant species as well as co-occurring habitat matrix species, simultaneously safeguarding and supporting the restoration of vulnerable plant communities.

"The Conservation Seed Bank at Atlanta Botanical Garden is one of the largest wild seed banks in the southeastern U.S."

References

- Center for Plant Conservation (2019). CPC Best Plant Conservation Practices to Support Species Survival in the Wild. Escondido, California, USA: Center for Plant Conservation.
- Coffey, E. E. D., Evans, J., Ligon, J. J., Smith, A., Eserman, L., Radcliffe, C., Linsky, J., Blackmore, L., Pullaiah, T., & Galbraith, D. A. (2024). The Role of the Atlanta Botanical Garden in Plant Conservation. In Botanical Gardens and Their Role in Plant Conservation (1st ed., Vol. 3, pp. 157–176). CRC Press. https://doi.org/10.1201/9781003282556-8
- Guerrant, E.O., Havens-Young, K. and Maunder, M. (2004). Ex situ plant conservation : supporting species survival in the wild. Washington: Island Press.
- United States Bureau of Land Management and Plant Conservation Alliance (2015). National seed strategy for rehabilitation and restoration, 2015-2020. U.S. Department of the Interior, Bureau of Land Management. https://doi.org/10.5962/bhl.title.155828

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COMMUNITY ENGAGEMENT IN NATIVE SEED CONSERVATION: LESSONS FROM THE CENTRE FOR ECOSYSTEM RESTORATION KENYA

The CER-K team in Kakamega training community members on environmental stewadship. (Brenda Imali)

The Centre for Ecosystem Restoration Kenya (CERK) has developed an innovative community-based seed banking initiative that integrates traditional ecological knowledge with scientific protocols to conserve native forest species. Since August 2022, this program has trained 210 community members, collected 2.1 tons of seeds from 55 species, and generated significant socioeconomic benefits while advancing conservation goals. This article demonstrates how community seed collector networks can effectively support native biodiversity conservation while providing sustainable livelihoods for local communities. The integration of The Global Biodiversity Standard (TGBS) principles enhances the program's ecological integrity, equity, and monitoring rigour, positioning CERK as a model for community-led restoration in East Africa.

Introduction

Globally, biodiversity faces unprecedented threats from habitat loss, degradation, climate change, invasive species, overexploitation, and unsustainable land use practices. Ecosystem restoration has become a central nature-based strategy for mitigating the aforementioned environmental challenges. The use of locally appropriate, native species is critical for enhancing biodiversity in ecological restoration, as it promotes the recovery of self-sustaining, resilient ecosystems that reflect local environmental conditions and species assemblages (Palma et al., 2020; Di Sacco et al 2021). The Global Biodiversity Standard (TGBS) reinforces this principle by highlighting the role of local seed collection in preserving genetic diversity and supporting the reestablishment of site-specific plant communities. Collecting seeds from multiple localities ensures ecological compatibility, maintains adaptive traits, and increases the success of restoration efforts under varying environmental conditions (Bartholomew et al., 2024). This approach also safeguards rare and endemic species, strengthens ecosystem resilience, and aligns with best practices for biodiversity-positive restoration.

Local communities possess traditional ecological knowledge (TEK) that can significantly support native seed conservation through community seed collector networks. In alignment with emerging global standards such TGBS, the Centre for Ecosystem Restoration Kenya (CERK) recognizes the importance of restoring ecosystems in ways that enhance biodiversity, secure community benefits, and ensure long-term ecological monitoring.

Kenya's diverse landscape, ranging from coastal mangroves to high-altitude forests, supports an estimated 6,881 plant species, comprising 6,293 indigenous and 588 exotic species (Zhou et al., 2017). However, this rich diversity is under threat, with an estimated 13% of Kenya's tree species facing extinction (BGCI, 2025). While community crop seed banks exist in several counties in Kenya, limited focus has been given to community-based native forest seed conservation. Community engagement has been largely restricted to user rights for seed collection under the Community Forest Association framework of the Forest Act 2016, with no clear pathways for meaningful participation in native forest seed conservation.

The CERK Seed Banking Initiative

Program Development and Structure

CERK established its seed banking initiative in August 2022, modeled on biodiversity, culture, ecology, and economics (BCEE) principles, with support from the Franklinia Foundation and Terraformation. This initiative leverages the geographical distribution of species (biodiversity), traditional knowledge (culture), functional importance (ecology), and financial incentives from natural resources (economics) to produce, conserve, and sustainably use native forest seeds.

The strategic objectives include establishing community seed collector networks through comprehensive training, enhancing seed production and conservation through source mapping and optimal storage, and developing robust seed propagation and storage protocols.

Community training on best practices of native seed production. (Herbert Migiro)

Community Selection and Training

CERK conducted participatory rural appraisals to select and train community members, prioritize species, and establish fair pricing mechanisms while ensuring gender equity and social inclusion. The program successfully fused traditional ecological knowledge, policy instruments, and scientific information to create an effective conservation framework.

To date, 210 community members, comprising primarily women and youth, have received training in species identification, phenology monitoring, seed production, and nursery management. Our Franklinia Foundation project component has located, collected, and propagated 23 threatened species while banking 10 threatened tree species.

Quality Assurance and Control

CERK implements a comprehensive two-tier quality control system to ensure seed standards comply with Kenya Plant Health Inspectorate Service regulations under the Seeds and Plant Varieties Act (Tree Seed Regulation). The system includes:

1. **Local Level Coordination:** Experienced coordinators allocate seed production targets, ensure genetic diversity by preventing over-collection from individual mother plants, and maintain medium to high purity levels.

2. **Central Seed Bank Management:** Professional assessment of quality control parameters including purity, moisture content, thousand seed weight, germination capacity, and comprehensive data management.

Results and Impact

Production and Economic Outcomes

Since inception, the program has achieved remarkable results. Community collectors have delivered approximately 2.1 tons of clean seeds from 55 species to the seed bank, earning collectors KES 2.1 million. Additionally, 1.2 tons of seeds have been distributed to restoration organizations and individuals, generating KES 2.3 million for the organization.

Community partnering with CER-K in planting programs/seedling maintenance (Quinter Peres)

Socioeconomic Benefits

The additional income has significantly improved household socioeconomic status, enabling families to meet basic needs including food security, education expenses, and investment in small enterprises. This economic incentive has proven crucial for maintaining community engagement and ensuring program sustainability.

Environmental Stewardship

The program has enhanced environmental awareness among landowners regarding biodiversity conservation benefits and sustainable natural resource use.

Community seed collector gathering seeds to be brought to CER-K seedbank (Jackson Mwangi)

Community seed collectors partially dry their seeds before bringing them to the CER-K seed bank. (Jackson Mwangi)

Community seed collector storage room (Jackson Mwangi)

Financial incentives from seed and seedling sales have motivated seed source owners to actively protect mother plants, creating a positive feedback loop for conservation.

Integration with The Global Biodiversity Standard (TGBS)

TGBS Alignment Framework

To align with TGBS principles, CERK employs a comprehensive framework integrating ecological value, community equity, and sustainable practices throughout seed sourcing and banking processes.

Biodiversity: Species prioritization includes threatened and endemic native trees, with focus on the 23 threatened species aligning with TGBS biodiversity indicators.

Equity: Community participation emphasizing women and youth involvement, fair pricing models, and inclusive participatory rural appraisal processes address TGBS social safeguards and Free, Prior and Informed Consent principles.

Sustainability: Integration of traditional ecological knowledge with scientific protocols, long-term seed viability monitoring, and incentives for source protection contribute to sustainable conservation practices.

Monitoring and Evaluation Using TGBS Framework

CERK is developing comprehensive monitoring systems aligned with TGBS indicators:

- **Biodiversity indicators:** Tracking seed contributions by IUCN Red List status and endemism levels
- **Equity indicators:** Documenting participation disaggregated by gender, age, and community groups
- **Sustainability indicators:** Recording source protection actions, traditional ecological knowledge usage, and training follow-up activities
- **Spatial mapping:** GPS-tagged seed source mapping to support long-term monitoring requirements

The organization is developing a comprehensive seed source mapping database with spatial and phenological data to support long-term monitoring in line with TGBS indicator frameworks.

Challenges and Solutions

Post-Harvest Handling

Initial challenges with seed quality arose from inadequate post-harvest handling skills, particularly susceptibility to Bruchid beetle attacks during sun-drying processes. The solution involved implementing controlled drying conditions typical of professional seed banks (15% relative humidity and 15°C) to prevent pest buildup in legume seeds.

Recalcitrant/exceptional Species Management

Many community collectors lacked knowledge about recalcitrant species that cannot be dried to low moisture content or stored at freezing temperatures. Comprehensive education on seed biology of native species has helped address the delivery of non-viable seeds.

Institutional and Policy Gaps

Despite advances in Kenya's crop seed sector, tree seed regulation remains underdeveloped. The Seeds and Plant Varieties Act (Tree Seed Regulation) awaits full operationalization, resulting in informal sector dominance, distorted market prices, and low-quality seed circulation. Strengthening institutional capacity and streamlining sector operations are critical for improving seed quality and conservation efforts.

Discussion

By integrating the principles of TGBS into its seed banking model, CERK advances ecological restoration, strengthens accountability, and contributes to the emerging global community of practice in restoration standardization. This positions CERK as a leader in community-led, biodiversity-focused restoration in East Africa. The success of CERK's community seed banking initiative demonstrates that local community participation in native seed conservation provides an effective approach to conserving and sustainably using plant germplasm while benefiting both environmental conservation and local livelihoods. The program's integration of traditional ecological knowledge with scientific protocols, coupled with fair economic incentives and comprehensive training, creates a replicable model for community-based conservation initiatives.

Inside the CER-K seedbank (Nicola Heath)

The application of TGBS principles ensures that restoration interventions meet high environmental and social standards while promoting community ownership and long-term sustainability. This approach addresses the critical gap in native forest seed conservation in Kenya and provides a framework for scaling similar initiatives across the region.

Conclusions

The Centre for Ecosystem Restoration Kenya's community seed banking initiative exemplifies a successful model for integrating local community knowledge, scientific protocols, and global conservation standards. The program's achievements in species conservation, community empowerment, and sustainable livelihoods highlight the effectiveness of community-based approaches in addressing biodiversity conservation challenges.

Sustaining this success will require addressing existing institutional and policy gaps, continuing capacity-building efforts, and maintaining the delicate balance between conservation objectives and community benefits. The integration of TGBS principles provides a robust framework for ensuring long-term program effectiveness and contribution to global restoration goals.

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References

- Alice Di Sacco, Kate A. Hardwick, David Blakesley et al., (2021). Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits. Glob. Change Biol., 27: 1328-1348. https://doi.org/10.1111/gcb.15498
- Bartholomew and Mosyaftiani et al. (2024). The Global Biodiversity Standard: Manual for assessment and best practices. BGCI, Richmond, UK & SER, Washington, D.C. USA
- BGCI (2025). Global Tree Portal - Country Search: Kenya. Available at: https://www.bgci.org/resources/bgci-databases/globaltree-portal/country-search/?c=KE
- Margaret A. Palmer and Graham A. Stewart (2020). Ecosystem restoration is risky... but we can change that. One Earth, Volume 3, Issue 6, 661 - 664. https://doi.org/10.1016/j.oneear.2020.11.019
- Schmidt, I. B., de Urzedo, D. I., Piña-Rodrigues, F. C., Vieira, D. L., de Rezende, G. M., Sampaio, A. B., & Junqueira, R. G. (2019). Community-based native seed production for restoration in Brazil–the role of science and policy. Plant Biology, 21(3), 389-397.
- Vernooy, R., Shrestha, P., & Sthapit, B. (2015). Community seed banks: Origins, evolutions and prospects. Bioversity International.
- Zhou, Y., Liu, B., Mbuni, Y., Yan, X., Mwachala, G., Hu, G., & Wang, Q. (2017). Vascular flora of Kenya, based on the Flora of Tropical East Africa. PhytoKeys, 90, 113.

Seed drying racks used at CER-K seedbank. Orthodox seeds are dried under controlled conditions of low temperature and humidity. (Post-harvest handing)(Nicola Heath)

CER-K Nursery, where most propagation protocols and seed quality parameters are conducted (Mercy Sigei)

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EXPERIENCIA DE THINK TANK EN MESOAMÉRICA PARA SALVAR ÁRBOLES AMENAZADOS A TRAVÉS DE LA COLABORACIÓN

Mesoamérica es un punto caliente de diversidad de plantas vasculares (Brummit et *al*., 2021) que alberga cerca de 4,046 especies de árboles únicas de la región. A través de la iniciativa *Global Tree Assessment (GTA)*, ahora existe una evaluación integral para los árboles meso-americanos en la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza (UICN). 46% de las especies endémicas de la región se encuentran clasificadas bajo alguna categoría de amenaza (Beech et al., 2025; BGCI, 2025).

La organización sin fines de lucro Conservación Osa, el Morton Arboretum y BGCI, con el apoyo de Fondation Franklinia, han tomado la misión de impulsar las iniciativas de conservación de árboles en Mesoamérica. Para ello, han reunido a un grupo de trabajo compuesto por expertos de la región involucrados en actividades de conservación de árboles. Este grupo, en formato Think Tank, se reunió para identificar los vacíos, analizar las oportunidades y fomentar la colaboración entre las organizaciones participantes, con el objetivo de crear un grupo de trabajo técnico que impulse la conservación de árboles en la región.

Jardines botánicos e instituciones afines en Mesoamérica

En los ocho países mesoamericanos existen al menos 113 jardines botánicos y arboretos, y un número mucho mayor de iniciativas de conservación de plantas lideradas desde organizaciones gubernamentales y no-gubernamentales. A pesar del relevante trabajo llevado a cabo por estas organizaciones, con frecuencia la falta de recursos, información o impulso dificulta una colaboración más estrecha entre actores. Esta desconexión conduce, en muchos casos, a la duplicación de esfuerzos y a una limitada posibilidad de fortalecer capacidades de forma conjunta. La articulación entre quienes trabajan en la conservación de árboles en Mesoamérica representa un reto importante, pero también una gran oportunidad para generar sinergias a través del intercambio de experiencias, datos y esfuerzos colaborativos.

Cantidad de especies de árboles endémicas de cada país y porcentaje de especies de árboles endémicos amenazados para cada país de Mesoamérica.

Compartiendo las lecciones de conservar y reconectar el bosque tropical lluvioso del sur de Costa Rica

En el último parche de bosque tropical lluvioso de tierras bajas del pacífico de Mesoamérica, en Costa Rica, se ubica la Península Osa, un área de 2,739 kilómetros cuadrados que sostiene 1,159 especies de árboles, 4.8% de ellos endémicos. En la Península, y en el corredor biológico que la conecta con uno de los cinco grandes bosques de Mesoamérica, el Parque Internacional La Amistad, Conservación Osa ha liderado esfuerzos de conservación para más de 40 especies de árboles en peligro de extinción desde el 2019, a través de exploración, propagación, restauración, capacitación técnica y educación ambiental. De la mano de dueños de fincas, guías de turismo, y grupos comunitarios, se ha logrado mejorar el estado del conocimiento sobre esas especies clave, evaluar o reevaluar el estado de conservación en la Lista Roja de la UICN, y mitigar amenazas a las poblaciones.

Con la intención de compartir la experiencia y crear nuevas alianzas en la región, en julio del 2024 tuvo lugar el Think Tank *Catalizando Acciones para la Conservación de Árboles en Mesoamérica* que se llevó a cabo en el campus de Conservación Osa, situado en Piro, en la Península de Osa. Este simposio reunió a 23 líderes de la conservación y restauración de 8 países de la región, que compartieron presentaciones de expertos, sesiones de trabajo y salidas a campo.

Al identificar y analizar los retos y las oportunidades, se evidenciaron puntos en común y discrepancias en las capacidades y los vacíos de conocimiento de la región. Por ejemplo, los proyectos de conservación de árboles en la región cuentan con equipos multidisciplinarios y capacitados, y con facilidades de infraestructura. Estas características fueron identificadas como fortalezas y como oportunidades, pero a la vez se identificó la falta de capacitación en temas como administración de proyectos y la falta de infraestructura y personal, como debilidades que necesitan solventarse. Allí quedó demostrada la necesidad de desarrollar un intercambio de conocimientos y experiencias, a través de una *Red Técnica de Conservación de Árboles de Mesoamérica* enmarcada dentro de la Red de Jardines Botánicos del Caribe y Centroamérica.

El grupo de 23 especialistas y estudiantes recorrió los senderos del Arboreto Osa y participó de una siembra de árboles amenazados dentro de su colección ex-situ.

El Think Tank 'Catalizando Acciones para la Conservación de Árboles en Mesoamérica' incluyó presentaciones de expertos, sesiones de trabajo y salidas a campo durante 4 días en el Campus de Conservación Osa. Foto por Conservación Osa.

Los siguientes pasos

Es fundamental facilitar espacios de encuentro y fomentar alianzas entre personas y organizaciones comprometidas con la conservación de árboles amenazados. El intercambio de habilidades, conocimientos y experiencias puede marcar la diferencia para lograr un impacto duradero, especialmente cuando las colaboraciones se enfocan en fortalecer capacidades o en crear condiciones habilitadoras para acciones de conservación sostenibles.

La formación de la Red Técnica de Conservación de Árboles de Mesoamérica representa un llamado a la acción. Mediante el trabajo colaborativo, es posible aprovechar y amplificar el conocimiento existente en la región. Esta labor se ve reforzada por el uso estratégico de redes, herramientas y bases de datos desarrolladas por BGCI —como *Garden Search*, *Plant Search* y el *Conservation Action Tracker*— que permiten identificar vacíos de información clave y guiar esfuerzos más eficaces de conservación, evitando la duplicación de esfuerzos.

Proteger las especies arbóreas del mundo es un desafío de escala global, pero nuestro objetivo es demostrar que, a través de acciones colaborativas, podemos enfrentar las amenazas que las afectan, evitar su desaparición y contribuir activamente a la preservación de ecosistemas más resilientes.

Referencias

- Brummitt, N., Araújo, A. C., & Harris, T. (2021). Areas of plant diversity — What do we know?. *Plants, People, Planet*, 3(1), 33-44.
- Beech, E., Alvarez Clare, S., Brewer, S., Coronado, I., Linares, J. L., MacVean, A. L., Martínez Salas, E., Machuca Machuca, K., Redonda-Martínez, R., Rodríguez Delcid, D., Samain, M.-S., Zacarías Correa, A. G., & Zamora Villalobos, N. (2025). Comprehensive tree assessments for prioritising conservation action in Mesoamerica. Plants, People, Planet, 1–11. https://doi.org/10.1002/ppp3.70045
- BGCI (2025) Global Tree Portal online database. Richmond, UK: Botanic Gardens Conservation International. Available at: https://www.bgci.org/resources/bgci-databases/globaltree-portal/country-search/?c=BZ [Accessed 15/01/2025]

ARTICLE

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CREATING A NATIVE SEED BANK FOR SHORT-TERM AND LONG-TERM FUTURES

Planting team members planting Escobaria seedlings in a granite outcrop in a protected site on a fine November day in Minnesota (air temperature about 4 C) (University of Minnesota Landscape Arboretum)

Seed banks focused on long-term conservation of native species have only been a widely spread phenomenon for the past few decades, although seed exchanges and banks for crops have been around for much longer. As native seeds begin to die in storage, conservation organizations and practitioners are exploring ways to find use out of the seed before they expire in storage. A strategy employed by the University of Minnesota Landscape Arboretum and other conservation banks is to make some seed from each accession available for approved, targeted production or research while also setting aside seed for long-term preservation. Valuable data can be obtained from early use of seed that can pay dividends for that species later. Multi-strategy seed banks, while requiring more work, should be the standard for more effective seed banking.

Humans have recognized the value of plants and saved seeds for millennia as crop domestication developed. Large-scale seed banking for conservation of plant genetic material has been practiced for over 100 years, for a more in-depth history of modern seed banking efforts (Curry, 2022). While most of the over 1700 extant seed banks have focused on the early banks' mission of preserving domesticated crop genetics, more and more banks are including, or are exclusively holding, wild species genetics (Hay and Probert, 2013). Many native species banks would be regarded as short-term holding spaces for seed or libraries, with the focus being processing and distribution of seed used for natural area restoration or similar projects, but long-term native seed banking has gained importance. It has really been in about the last half century, though, that the practice has really spread with large seed banks, covering rare plants and crop species, being the National Center for Genetic Resource Preservation (NCGRP) in Fort Collins, the Svalbard Global Seed Vault in Norway, or the Kew Millennium Seed Bank in England which all have large collections of both crop species/varieties and crop wild relative species (CWR) in addition to growing collections of wild native species. Smaller, regional seed banks dedicated to native/wild plant genetic preservation have established around North America in particular, with groups such as the Center for Plant Conservation and the North American Orchid Conservation Center working to coordinate and support seed banking on that continent.

For many species, seed banks at their base create an "ark", meant to build a biodiverse bulwark against catastrophic loss of genetic variability for a species, or even catastrophic loss of the entire species. This species extinction event is not a far-fetched prospect for species with population numbers in the single-digits in a world where direct human landscape modification (development and water use) and indirect modification (climate change) appear to be accelerating. In North America alone, there are 215 species of One Known Occurrence (OKO), which include species of One Remaining Occurrence (ORO) and Single Site Endemics (SSE) (Knapp, 2024). There are many more species that have fewer than 10 known occurrences. Most, if not all, of these species could be wiped out completely due to single weather-, geologic-, or human-

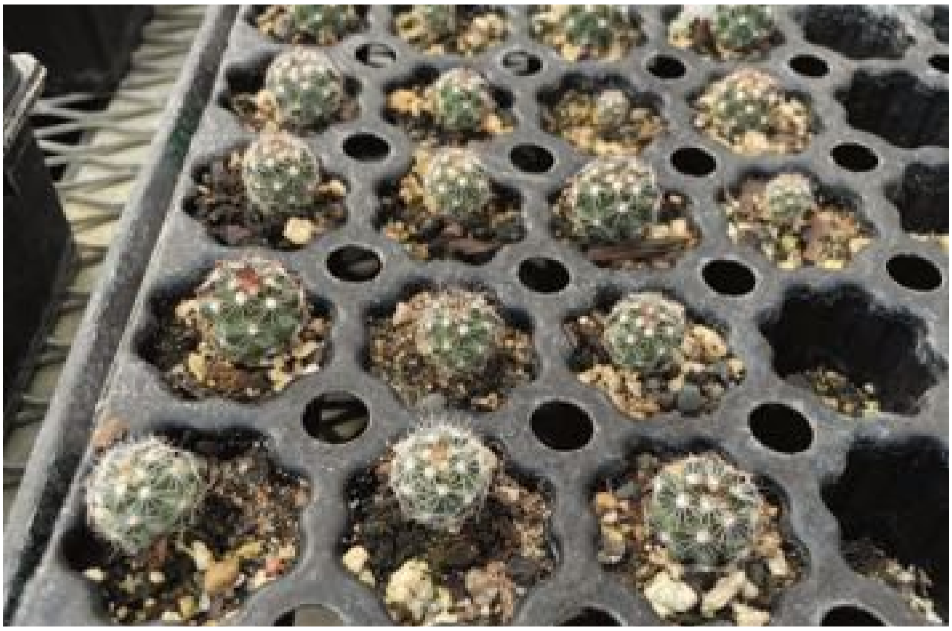
If seed dies in our seedbanks without being grown, did we miss an opportunity to benefit the species either through research, education or through direct reintroduction of that material to the wild?

related causes. To protect these, and really any rare plant species, the general standard practice is to collect as much of the biodiversity of each species as is reasonable, prepare and store the seed under appropriate conditions, test the seed regularly and then replace as needed as it ages in storage. Orthodox seed, when stored properly, will remain viable in cold storage for decades, or even potentially centuries depending on the species. The push to bank native seed is recent enough that many seed banks are only now dealing with the loss of first waves of seed that are expiring in storage, and this loss has sparked a minor crisis of conscience . If seed dies in our seed banks without being grown, did we miss an opportunity to benefit the species either through research, education or through direct reintroduction of that material to the wild? Viewing seed banks solely as an "ark" may be an important missed opportunity.

The University of Minnesota Landscape Arboretum (UMLA) has a rare plant conservation program that has been working since 2013

Escobaria vivipara in flower (University of Minnesota Landscape Arboretum)

to conserve native orchids and rare native plants in the upper Midwest of the United States. The heart of the Plant Conservation Program is its seed bank, where, like many conservation seed banks at botanic gardens and research institutions around the world, seeds are collected, verified to identity, tested for initial viability, and stored under orthodox conditions (when appropriate for the species).



Escobaria seedlings propagated from local genetics for population augmentation and introductions (University of Minnesota Landscape Arboretum)

When seed is curated properly as recommended by best practices (Center for Plant Conservation, 2019), maternal sources are stored individually within a bank, meaning that all seed produced and collected from one plant is kept physically separated from seeds from other conspecific sources in that population. This is done so that when propagules are being produced for a new population, the founding population can be populated with offspring representing the maximum genetic variability available from the represented maternal seed parents in the banked collection. Even with thoughtful collection and curation, there are a myriad of considerations that must be acknowledged as complicating factors when managing seeds long-term in a bank, including mutations, inbreeding, genetic drift, and adaptation to domestic conditions. Many seed banks offer their seed bank as a kind of library; approved-use requests can see seed being used for reintroduction, scientific research, or seed amplification but these kinds of uses take staff and facilities to manage and track moving seed in and out of storage, and not all seed banks are able to manage that.

Escobaria vivipara seeds, showing fine detail for identification for seedbank quality control (University of Minnesota Landscape Arboretum)

Additionally, pulling subsets of these seed from each individual maternal bank when seed is stored in a seed bank takes time. And unless the seed bank has the facilities to do this sublot division while maintaining storage conditions during the division process, the process can compromise the longevity of the remaining seed in the seed bank. So, when possible, developing purposes for seed at the time of collection is ideal, that way subsets of seed can be divided up initially so subsets wouldn't need to be created later after seeds have been acclimated to storage conditions, saving both storage integrity and staff time and resources. An added benefit, especially for rare species with complex or largely undescribed propagation and outplanting protocols, is that the work done and data produced with these research or propagation subsets can contribute to better reestablishment of that species or population if there is a catastrophic loss of wild populations.

In our program as in many others at botanic gardens, we endeavor to use seed banking as a method for ex situ conservation that we pair with as many other activities we take part in as possible, whether those are rare plant surveys or rescues where we are moving adult plants. Specifically, our garden typically participates in multiple rare plant rescues each year, and as part of our standard planning process we try to collect seed in addition to any translocation work a rescue or salvage may entail. Translocation success, when reviewed in meta-analytical literature, is generally regarded as an only moderately successful conservation technique (Guerrant, 2013; Dalyrmple, 2012), but often the data for these meta-analyses represent short-term (<3 years) monitoring of translocation event survival and recruitment. When the true measure of success for translocations or reintroductions is seedling recruitment, much longer-term monitoring data must be used to truly evaluate these techniques as recruitment may take nearly two decades to be evidenced (Albrecht et al., 2019). Because the failure rate for translocation of adult plants is moderately high, concurrently or proactively banking seed is a redundancy that can be leveraged when adult translocation fails, or other problems occur. While using adult plants is generally recommended over seedlings for introduction or reintroduction projects (Guerrant et al., 2004; Albrecht and Maschinski, 2012), when transplanting adults, the physical act of extracting adults from a location often severely reduces root mass and events that place extracted plants immediately into their final location often result in plants that need both immediate and subsequent watering throughout a growing season. Seedlings (or adults propagated from seed), on the other hand won't have that same root-stress when planting as their roots are undamaged and can often be planted when is most advantageous. With plants in temperate areas, such as where our garden is in the center of North America, translocations or introductions can be done after vegetation on the landscape has gone dormant in the fall, eliminating the need for follow-up watering. A recent example of an early success story is a population augmentation we have been doing with *Escobaria vivipara* (ball cactus) that has a range covering much of western North America but reaches into Minnesota in a single population on the west edge of the state. This single population is threatened by land-use on its granite outcrop habitat and we took up a project to move adult plants from these threatened locations to protected ones. Funding for this project was provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative-Citizen Commission on Minnesota Resources (LCCMR). In preparation for this project we banked thousands of seeds from hundreds of individuals on the threatened locations. We grew several hundred seedlings, split among roughly 200 maternal sources. The local permitting process for the development land-use slowed down and in the meantime, we have created two new populations and augmented current subpopulations with seedlings. Planting started in 2022 and no recruitment has been noted yet, but fruiting individuals were found in 2024.

Part of the UMLA long-term conservation seedbank, showing storage containers for the native orchid seed collection (University of Minnesota Landscape Arboretum)

Overall survivorship from year to year has been around 85% regardless of microsite planting locations, which is very encouraging. We now know that when we finally move adult plants, if those fail, seedling introductions may be a viable replacement. If we had not banked seed as part of our conservation strategy for this population, we would not have realized a complementary, and perhaps superior, option to moving adults through this production and research project. This proactive complementary banking has created both an immediate beneficial use of the stored genetic material as well as a deeper long-term bank.

Volunteers digging up adult Arnoglossum plants to be moved to a new site, or brought back to UMLA to clean weed species prior to outplanting to protected sites (University of Minnesota Landscape Arboretum)

Bringing seed in with a plan can both contribute to future research or reintroductions as well as protect a core set of seed under continuous storage conditions for an "ark" subset of seed. Especially for rare plant species that do not have an established record of reintroduction, research and propagation protocols haven't been firmly established, these planned projects can also have the benefit of providing an early test case to document best-practices for each species for future attempts to establish or reestablish the species if something catastrophic has gone wrong to remaining natural populations. Seed banks should be active seed libraries as well as the more traditional arks to maximize the benefit from the genetic storage material. Fortunately, many botanic gardens and seed banks are already on this journey.

References

- Albrecht, M.A., and Maschinski, J. 2012. Influence of founder population size, propagule stages, and life history on the survival of reintroduced plant populations. In J. Maschinski and K. E. Haskins, eds. *Plant reintroduction in a changing climate: promises and perils*. Island Press, Washington DC.

- Albrecht, M.A., Osazuwa-Peters, O.L., Maschinski, J., Bell, T.J., Bowles, M.L., Brumback, W.E., Duquesnel, J., Kunz, M., Lange, J., McCue, K.A., McEachern, A.K., Murray, S., Olwell, P., Pavlovic, N.B., Peterson, C. L., Possley, J., Randall, J.L., and Wright, S.J., 2019. Effects of life history and reproduction on recruitment time lags in reintroductions of rare plants. *Conservation biology: the journal of the Society for Conservation Biology*, 33(3), 601–611. https://doi.org/10.1111/cobi.13255

- Bellis, J., Osazuwa-Peters, O., Maschinski, J., Keir, M.J., Parsons, E. W., Kaye, T.N., Kunz, M., Possley, J., Menges, E., Smith, S. A., Roth, D., Brewer, D., Brumback, W., Lange, J.J., Niederer, C., Turner-Skoff, J.B., Bontrager, M., Braham, R., Coppoletta, M., Holl, K.D., ... Albrecht, M.A., 2024. Identifying predictors of translocation success in rare plant species. *Conservation biology : the journal of the Society for Conservation Biology*, 38(2), e14190. https://doi.org/10.1111/cobi.14190

- Curry H.A., 2022. The history of seed banking and the hazards of backup. *Social studies of science*, 52(5), 3063127221106728.
Advance online publication. https://doi.org/10.1177/03063127221106728

- Guerrant, E.O., Jr., Fiedler, P.L., Havens, K., and Maunder, M., 2004. Revised genetic sampling guidelines for conservation collections of rare and endangered plants. In E. O. Guerrant, E.O., Jr., Havens, K., and Maunder, M., eds. *Ex situ plant conservation: supporting species survival in the wild.* Washington, D.C.: Island Press. pp.419-438.

- Hay, F.R., and Probert, R.J., 2013. Advances in seed conservation of wild plant species: a review of recent research. Conservation physiology, 1(1), cot030. https://doi.org/10.1093/conphys/cot030

- Knapp, W., 2024. The Importance Of Taxonomy, Species Discovery, And Prioritization In Preventing Plant Extinctions. PhD. University of North Carolina at Chapel Hill. Available at <https://doi.org/10.17615/6c69-ty78> [Accessed 12/05/2025]

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Seeds are tracked and stored carefully in a seedbank so they can be used effectively for future research and propagation (University of Minnesota Landscape Arboretum)

Authors: Petrus Joaquim Dique, Cacilda Manhiça and Jo Osborne

CHALLENGES AND SOLUTIONS FOR *EX SITU* AND *IN SITU* CONSERVATION – THE CASE OF MOUNT NAMULI IMPORTANT PLANT AREA IN MOZAMBIQUE

Part of the Muretxa Forest above 1600 m altitude, completely destroyed by fire for agricultural purposes (Petrus Dique)

Mount Namuli, Mozambique's second highest peak, is a critically important site for plant conservation, supporting 22 globally threatened and 19 locally endemic plant taxa. Despite international recognition as a Key Biodiversity Area, Important Plant Area, and Important Bird Area, it lacks formal protection and faces severe threats from agricultural expansion, with 40% forest loss between 2000-2020. Conservation solutions include ex *situ* seed banking through Mozambique's National Seed Conservation Programme, habitat restoration with community involvement, and cultivation of threatened taxa in botanical gardens to raise awareness of Mount Namuli's botanical significance.

Introduction

Mount Namuli is one of the most biodiverse sites in Mozambique. It is located in the Gurué district of Zambézia province in northern Mozambique, approximately 250 km from the Indian Ocean coast, incorporating a complex of granite inselbergs linked by the Muretxa Plateau. With one of its three main peaks rising to 2,419 m a.s.l., Mount Namuli is the second highest point in Mozambique after Mount Binga in the Chimanimani Mountains. It is a significant component of the threatened South East Africa Montane Archipelago (SEAMA) region (Bayliss et al., 2024) and is part of the Eastern Afromontane Biodiversity Hotspot (BirdLife International, 2012). Mount Namuli is designated as a Key Biodiversity Area (KBA), Important Plant Area (IPA) and Important Bird Area, although it does not yet have formal conservation protection.

Mount Namuli is a major part of the proposed Mulanje-Namuli-Ribáuè Centre of Plant Endemism (CoE) in southern Malawi and northern Mozambique. The Mount Namuli IPA covers an area of 146 km^2, supporting 22 globally threatened plant taxa and 19 taxa that are endemic to this site (Darbyshire et al., 2023). Nationally important areas of montane grassland and montane moist forest are supported within the IPA. It is one of the most important botanical sites in Mozambique and, in fact, in the mountainous region of southern tropical Africa.

Because of the high number of threatened and endemic taxa found at Mount Namuli, the mountain is a target site for Mozambique's National Seed Conservation Programme, through which seeds of Mozambique's diverse flora are banked to ensure long-term survival and to contribute to seed biology research, *in situ* species recovery and habitat restoration.

Production of *Faurea racemosa* (tchetchere) seedlings (Petrus Dique)

Through this programme, four expeditions were carried out in the Mount Namuli IPA, between 2023 and 2024. This work has led us to consider the challenges and propose solutions for ex situ and in situ conservation of Mount Namuli's valuable flora.

Challenges

Subsistence agriculture is one of the major conservation challenges in the Mount Namuli IPA. Continued population growth has increased production in recent decades, achieved through expanding the cultivated area, also associated with the extraction of wood for the production of charcoal, which is the main source of fuel for most people. As a consequence, Mount Namuli continually suffers extensive habitat loss, which in turn represents a major threat to the Mozambican flora. The loss of forest cover was estimated at 40% (568 ha) between 2000 and 2020 (Legado Namuli, 2021) while the total forest cover of the Mount Namuli IPA is now less than 10 km^2 with an estimated a total of about 7 km^2 of remaining forest above 1,400 m (Darbyshire et al., 2023).

Despite being internationally recognised as a site of great importance for a range of biodiversity, the entire IPA is currently unprotected and is one of the most threatened mountain regions in Mozambique. In recent decades the expansion of agricultural practices have resulted in mid-altitude and lowland forests being cleared for subsistence farming and small-scale commercial crops, including an increase in potato cultivation. Potato crops significantly reduce soil fertility, leading to a reduced yield in subsequent years. After five years, newly cleared areas of forest soil are needed for cultivation.

In addition to forest clearing, Darbyshire et al. (2023) highlighted an issue of selective and unsustainable logging of the threatened tree species *Faurea racemosa* or 'tchetchere' for construction and carpentry locally. Mount Namuli should be considered one of the highest conservation priorities in Mozambique (Timberlake, 2021).

Solutions

In order to contribute to the conservation of the Mount Namuli IPA, the following actions are proposed:

1. We have prioritised Mount Namuli's threatened and endemic plant taxa for seed collection and seed banking at IIAM's Genebank in Maputo, to be duplicated at the Millennium Seed Bank in the UK, to ensure their long-term conservation ex *situ*. Through Mozambique's National Seed Conservation Programme we will build up knowledge of their seed biology and germination requirements in readiness for species recovery should any of Mount Namuli's threatened and endemic plants become extinct in the wild.

2. Collecting seeds of framework species, producing seedlings and restoring vegetation that is continually being lost, is critical to ensure *in situ* conservation, working closely with local communities. The organization Nitidae that operates on the Mount Namuli plateau has already been identified as a potential partner, and there is also a Community Management of Natural Resources Committee, which we believe will positively contribute to implementing conservation ideas.

3. We propose to use seeds from our seed collections to propagate Mount Namuli's threatened and endemic plant taxa for display in cultivated horticultural collections at IIAM's botanical garden in Maputo. These horticultural displays will raise awareness of Mozambique's endemic and threatened plants and the botanical importance of Mount Namuli.

References

- Bayliss, J., Bittencourt-Silva, G.B., Branch, W.R. et al. A biogeographical appraisal of the threatened South East Africa Montane Archipelago ecoregion. Sci Rep 14, 5971 (2024). https://doi.org/10.1038/s41598-024-54671-z

- BirdLife International. (2012) Ecosystem Profile. Eastern Afromontane Biodiversity Hotspot

- Darbyshire, I., Richards, S., Osborne, J., Matimele, H., Langa, C., Datizua, C., Massingue, A., Rokni, S., Williams, J., Alves, T. & Sousa, C. de., 2023. The Important Plant Areas of Mozambique: Royal Botanic Gardens, Kew.

- Legado Namuli, 2021. O Monte Namuli Área De Conservação Comunitária Na República De Moçambique. Available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.legadoinitiative.org/wp-content/uploads/Namuli_community_conservation_letter_2021.pdf. [Accessed 15 Abril 2025].

- Timberlake, J., (2021). A first plant checklist for Mt. Namuli, northern Mozambique. Kirkia 19(2), 191-225.

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Harvesting *Aloe mawii* seeds for conservation (Petrus Dique)

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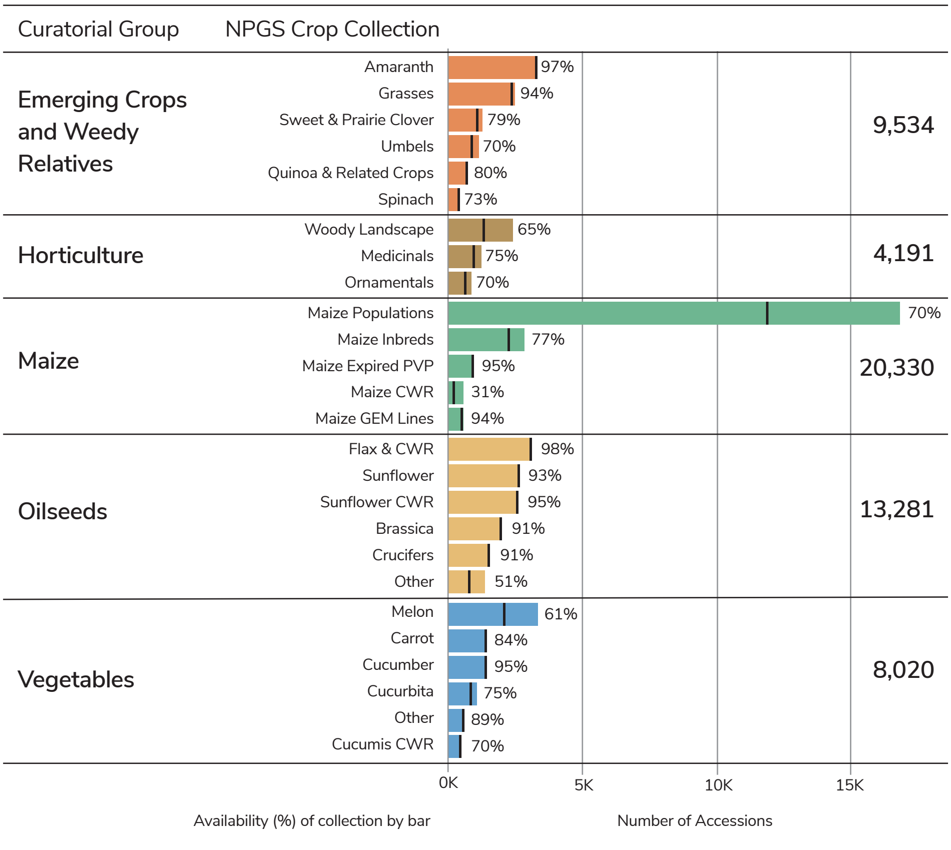
1. An aerial image of the North Central Plant Introduction Station in Ames, Iowa.

INTRODUCTION TO SEED CONSERVATION ACTIVITIES AT THE NORTH CENTRAL REGIONAL PLANT INTRODUCTION STATION

The North Central Regional Plant Introduction Station (NCRPIS) is one of four regional plant introduction stations in the United States and is one of 20 active sites that make up the National Plant Germplasm System. The NCRPIS curates over 1800 plant taxa across five curation teams: maize, emerging crops and weedy relatives, horticulture, vegetables, and oilseeds. Curation of a wide array of taxa presents challenges especially for maintenance and regeneration. These challenges are met by many processes including insects for controlled pollination, seed storage, germination testing of seed viability, pathology testing, and many other seed preservation best practices.

The North Central Regional Plant Introduction Station (NCRPIS) (Image 1) is a collaborative effort between the United States Department of Agriculture, Agriculture Research Service (USDA-ARS), State Agricultural Experiment Stations of the North Central Region, and Iowa State University. NCRPIS is part of the US National Plant Germplasm System (NPGS) administered by the USDA. The NPGS is one of the largest, most comprehensive collections of plant genetic resources in the world. A network of 20+ genebanks safeguard plant genetic resources. To achieve the mission, the genebanks acquire germplasm, conserve genetically diverse germplasm, curate associated information, conduct germplasm-related research, distributions, and encourage the use of germplasm and related information for research, crop improvement, and product development. The NCRPIS was established in 1948 (authorized by the Congressional Hatch Act in 1946) as one of four plant introduction hubs. The station operates on Iowa State University land and is staffed by USDA-ARS and ISU employees who have expertise in plant genetic resource conservation, molecular biology, plant pathology, plant physiology, entomology, horticulture, genetics and plant breeding.



2. Graph of NCRPIS collections by curation teams. Percentages indicate the number of available accessions.

Plant germplasm expertise at NCRPIS is organized into five curatorial teams that maintain 55,000+ accessions (distinct seed or plant tissue inventory) representing over 1800 plant taxa (Image 2). The five curatorial teams are emerging crops and weedy relatives, horticulture, maize, oilseeds, and vegetables. Personnel with expertise in farm and facilities management, germination, pathology, entomology, seed storage, distribution, and information technology provide support to the curation teams. Each curatorial team works towards achieving the major mission areas at NCRPIS.

Acquisition. Acquisition goals for NCRPIS are to obtain populations of crop wild and relatives, useful modern germplasm, species that are of interest to stakeholders, unique traits, and under-represented geographic and genetic backgrounds. One of the biggest challenges after identifying gaps in a collection is the timing, quality, quantity, handling, and physical collection of new germplasm. Gaps are generally identified via a combination of stakeholder input, geographic range and current representation in the collection, among others. The next frontier in identifying gaps within a collection at NCRPIS is incorporating genetic markers and whole genome sequencing. This is underway in several genera across the NPGS and requires public and industry support to accomplish.

Documentation. The Germplasm Resource Information Network (GRIN) has a publicly accessible website from which germplasm can be requested (link at the end of the article), as well as a database utilized by collection staff. This database documents collection information, regenerations, inventory, storage/field location, observation/evaluation data, and images of seeds and/or plant parts.

Characterization and Evaluation. During regeneration, phenotypical/morphological characteristics are observed and noted. Data is captured via field notes and by taking images. Morphological descriptors are defined by curators, and crop germplasm committees and are often taxa specific. Commonly collected descriptors include plant height, flower color, flower arrangement, etc. Images are acquired using a flatbed scanner, camera, or microscope, depending on the seed size, flowering parts, and plant. All the information gathered through characterization and evaluation are made available on the public GRIN website. This data also includes information shared back to our collections from seed requestors.

Maintenance. Regenerations are determined by several factors including the quantity of seed, viability, and distribution frequency. The goal of regeneration is to maintain the original genetic composition of germplasm as it was received and to increase the number of seeds available for distribution. Depending on the genus and species, accessions may be grown in cages, field plot, or greenhouse environments. To ensure identity preservation of seed and plant samples of cross-pollinated species, regeneration occurs using controlled pollinations. Controlled pollinations are achieved by using insect cages (keep pollinators in and exclude other insects and prevent cross-pollination between accessions), hand pollinations (labor-intensive), removal of flower parts, and isolation by geography or time.

After regeneration, seeds are processed and stored. Cleaning, viability testing, and identity preservation of harvested seeds can be a labor-intensive endeavor but is crucial to a germplasm collections success. With most of our germplasm being cross-pollinated, much genetic variation exists within a given accession. Curators rely on previous field notes and photos when comparing a new seed lot to the parent lot. Accessions of crop wild relatives, and non-cultivated species make up a smaller portion of the holdings at NCRPIS but require the most care during processing. There can be a tremendous difference between an accession, with the most noticeable differences being in seed size, shape, texture, and color (Image 3). An optical color sorter works well for cultivated species (maize), and incorporation of this technology into other genus (carrots, spinach, brassica etc) are under development.

3. Seed scan of different spinach species. Wild relatives are at the bottom, and more cultivated accessions are at the top.

4. Diversity of fruit from an accession of *Cucurbita pepo.*

If mechanized cleaning, blowing, and an automated color-sorter can't be used efficiently, as is the case with many crop wild and weedy relatives, the alternative is hand-picking seed. Hand-picking seed is tedious and time consuming. Some accessions require special handling post-harvest such as the wet processing of pumpkins, melons and cucumbers which require an extensive drying process (Image 4). Other innovative techniques have been developed at NCRPIS to streamline seed cleaning process. For example, seeds of Salix species are difficult to handle due to being extremely fluffy and desiccate easily. The technique utilized by the horticulture team to process Salix involves using a handheld vacuum cleaner with a fine mesh to catch dispersing seeds; agitation using pressurized air to separate seeds from pappus; and finally separation of inert matter and aborted seeds (light weight materials) with a column blower. Salix seeds after being harvested must be processed and immediately placed in -20 °C seed storage because the seeds desiccate quickly.

Once the seeds are cleaned, germination tests are performed. The germination support team, following Association of Official Seed Analysts (AOSA) seed testing methods, provides viability information on increased seeds and newly received material. Seeds that have been stored are tested on a regular maintenance schedule. It is important to not only know the quality of newly harvested material to establish a baseline for storage, but also to monitor viability over time. Wild species often require in-house trial and error resulting in the development of repeatable germination protocols that are freely shared.

Storage and Distribution. Plant genetic resources (PGR) are distributed to researchers and educators in the United States and internationally, free of charge, in accordance with the USDA policy. Each year, more than 40,000 seed packets are distributed in more than 1,000 orders. The seed storage team manages these seeds in jars and packets in cold storage (Image 5). Temperature is controlled at 4 °C (38 °F) and relative humidity is maintained at 25%. Controlling temperature and humidity are critical to the seed's viability. Glass jars are used to prevent static electricity in small, seeded accessions (amaranth, panicum); while plastic jars are used for large seeds (corn, cultivated sunflowers). Jars are stored on library stacks with movable shelves to conserve space. Library stacks and shelves increase storage space as well as being able to easily gain access to inventories. Original seed sources and some accessions more difficult to regenerate or maintain viability are stored in a minus 20 °C (0 °F) freezer. Storing seeds in minus 20 °C (0 °F) increases the longevity of the seeds. Increasing the amount of freezer storage at NCRPIS is critical for maintaining the long-term viability of many of our accessions including tree species such as Ash and oilseed brassica accessions of sunflower, canola, flax, and others. Safety backups are at Fort Collins, Colorado and Svalbard Global Seed Vault in Norway.

5. Seed cold storage where inventories are maintained.

6. Willow (*Salix*) accession cuttings increase for distribution.

Unique curation team challenges

Emerging crops and weedy relatives curation team consists of amaranth, quinoa, spinach, proso and foxtail millet, miscellaneous umbels, and sweet and prairie clover. Spinach is wind pollinated and must be grown in isolates. Cultivated spinach is regenerated in Salinas, California through collaborations; while one accession per greenhouse is grown in Ames, Iowa. Some Chenopodium need to be scratched on a sharpening stone or have the embryo pierced before germination can occur. Dormancy in Setaria has been found to be broken with medical oxygen gas concentrators.

Horticulture team has the fastest growing collection due to many collaborators across the U.S. actively sampling from natural sites and manages the most taxonomic diverse taxa. These accessions range from *Salix* (willow; Image 6) to Gymnocladus dioicus (Kentucky coffeetree) to *Monarda* (beebalm) to *Calendula* (pot-marigold) to *Aronia* (chokeberry) and *Echinacea* (coneflower; Image 7). This collection is resource-intensive with long growth cycles (trees); plants that may attain substantial size prior to flowering; and largely self-incompatible. Accessions that cannot be maintained as seeds in storage (recalcitrant) are maintained as plants in the field and may be cryopreserved as dormant budwood.

The NC7 Regional Ornamental Plant Trials administered by the NCRPIS horticulture team aims to identify high performing plants with desirable ornamental characters resulting in the expansion in the diversity of woody plants in the nursery industry. Each year selected woody plant accessions are offered to approximately 30 trial site cooperators across 18 states. Evaluations of planted accessions are performed in year 1, 5, 10. This broad range of environments and climatic extremes helps to gauge the range of performance, provides an assessment of plant performance before potential marketing, increases awareness of plant diversity and adaptability, and provides information to breeders on ornamental characteristics along with insight on adaptability to defined conditions.

Maize collection consists of diverse, heterogenous populations, inbred lines, expired plant variety protection material, and crop wild relatives (teosinte, coix-lacryma, trispicum). The goal is to support continued cultivar development, basic foundational genetic research, and to safeguard and provide access to culturally important varieties. This collection is a large, mature collection with a growing list of accessions that need to be regenerated in the near future. Due to being cross-pollinated, maize must be hand pollinated. Approximately 75% of the collection is open-pollinated populations which have the added complexity of not self-pollinating the plants by hand, but by sibling pollination, to best mimic open-pollinated genetic variability. Additionally, many of these populations require elevation and short-day length which we cannot provide in the central United States. Thus, costly off-site nurseries must be utilized. Regeneration of maize crop wild relatives requires use of open pollination in a greenhouse and physical isolation from other accessions, since hand pollination for these accessions is very challenging. The chronic predicament for the maize collection is balancing the regeneration of elite material with protecting traditional, more genetically diverse accessions.

North Central Plant Introduction Station maintains over 55,000 accessions ranging from maize to Fraxinus (Ash) to sunflowers (wild and cultivated) to quinoa to carrots. The accessions add significant value to agriculture. Prioritizing gaps within the collection and filling in those gaps remains a challenge. There is an increasing backlog within the collections to regenerate material before seed viability becomes too low. The NCPRIS and NPGS collections hold undiscovered potential for disease, pest, and abiotic resistance.

To learn more, visit: https://grin-u.org/ for information on curating germplasm; https://www.ars.usda.gov/midwest-area/ames/plant-introduction-research/ for information specific to the NCRPIS; https://npgsweb.ars-grin.gov/gringlobal/search to order germplasm of the entire NPGS and explore associated data.

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7. Coneflower (*Echinacea*) seed regeneration inside a pollinator exclusion cage.

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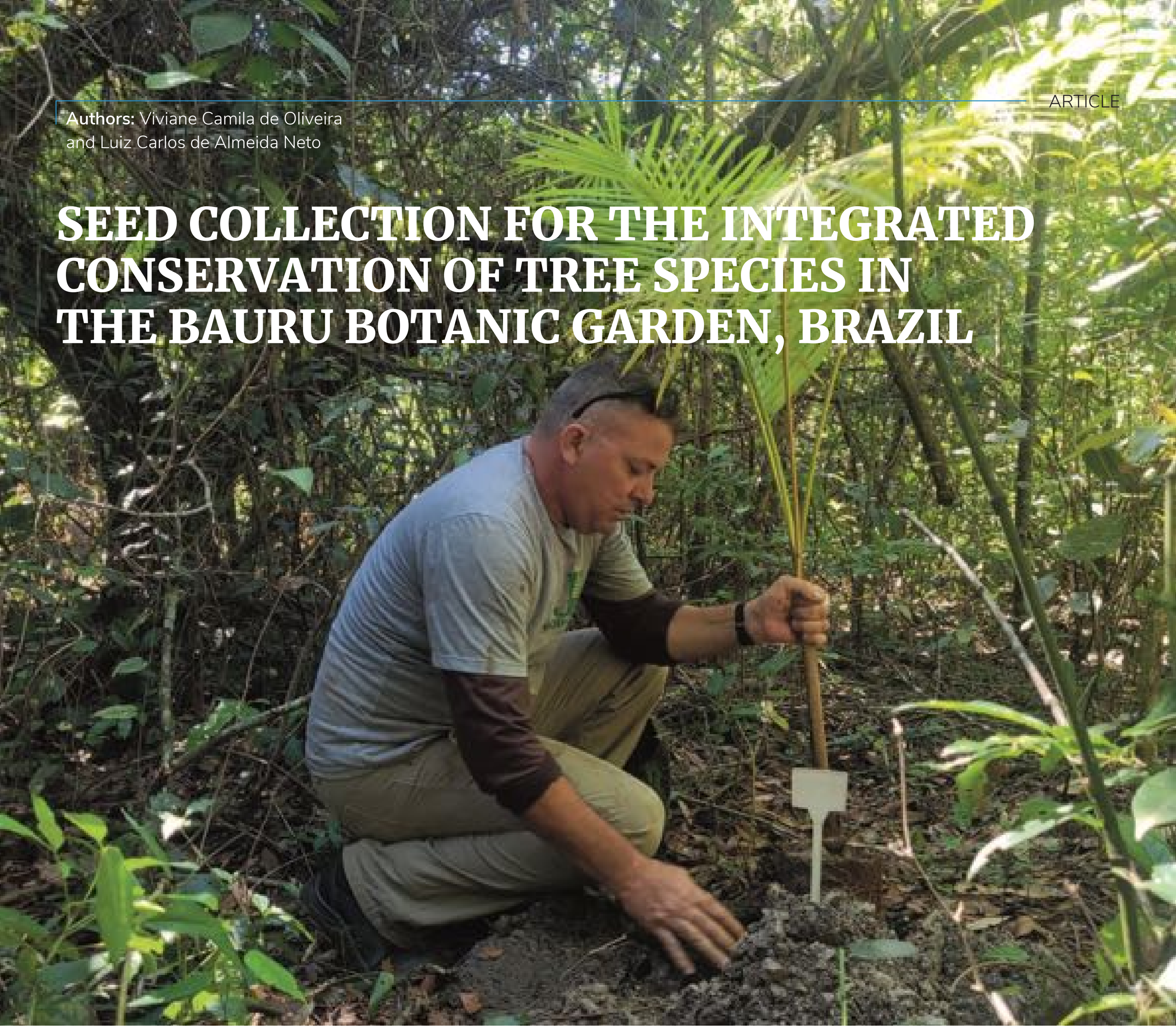
SEED COLLECTION FOR THE INTEGRATED CONSERVATION OF TREE SPECIES IN THE BAURU BOTANIC GARDEN, BRAZIL



Planting of *Euterpe edulis* for species enrichment in the environmental reserve of the Bauru Botanic Garden. (Archives of the Bauru Botanic Garden)

Since 2017, the Bauru Botanic Garden (JBMB) has been implementing projects to collect and conserve seeds of regional tree species, marking seed matrices, training its staff to collect seeds including from the forest canopy, storing seeds in a seed bank owned by JBMB, and establishing partnerships for seed exchanges and donations. This work has addressed different integrated conservation strategies that begin with seed collection and unfold into *in situ* and *ex situ* conservation actions, ecological restoration, and species reintroduction, supporting research, horticulture, and environmental education, seeking to support the survival of species in nature.

Fruit of *Zeyheria tuberculosa*, collected by the team at the Bauru Botanic Garden (Archives of the Bauru Botanic Garden)

Introduction

The Bauru Botanic Garden (JBMB) is located on the edge of the urban area of the municipality of Bauru, state of São Paulo, Brazil. More than a space for socializing, leisure, and a tourist attraction for the city, the JBMB is a place for the conservation of regional flora, integrating environmental education and research. It has several collections of plants for ex *situ* conservation in different nurseries and open beds, in addition to managing an environmental reserve of 321 hectares, one of the last large cerrado reserves in the state of São Paulo maintained for *in situ* conservation. The JBMB's mission is to promote the maintenance of Brazil's genetic heritage with an emphasis on regional flora, through comprehensive conservation between its natural reserve, plant collections, education, research, and seedling production. In its 31 years of existence, it has sought to fulfil its institutional mission, as well as the goals of the Global Strategy for Plant Conservation, seeking to increasingly improve itself in the collection, storage, and conservation of seeds, as well as in the production of seedlings.

Integrated Conservation Projects

Over the last decade, JBMB has been investing in integrated species conservation practices. One of these, "Solidarity Forest: Seeds of the Future," aims to establish partnerships with individuals and companies that own private properties with forest remnants and are sensitive to JBMB's conservation mission, allowing access to and collection of genetic resources present in these areas. Another project, "Back Home: Restoration and Conservation of Our Flora," has several lines of action, including enrichment of forest fragments with flora species and ongoing restoration projects, development and execution of forest restoration projects, and maintenance of a seed bank. In 2025, the project "Conservation of threatened tree species in the Brazilian Atlantic Forest, a biodiversity hotspot," funded by BGCI's Global Botanic Garden Fund, will also be put into practice, focusing on the integrated conservation of threatened species of local flora.

These studies have addressed different integrated conservation strategies that begin with seed collection and unfold into *in situ* and *ex situ* conservation actions, ecological restoration and reintroduction of species, supporting research, horticulture and environmental education, seeking to support the survival of species in nature.

Training and qualification of the Bauru Botanic Garden team in arboriculture techniques that allowed the collection of seeds in the forest canopy (Archives of the Bauru Botanic Garden)

In our projects at JBMB, even before the actual seed collection, the first step was species selection. Due to its mission, JBMB collects a wide variety of seeds from species that occur regionally, and through this project it has dedicated special attention to tree species threatened and at risk of extinction globally or regionally including species that are difficult to collect, native individuals with genetic quality. Some examples include *Zeyheria tuberculosa* (Bignoniaceae), *Balfourodendron riedelianum* (Rutaceae), *Cedrela fissilis* (Meliaceae), *Aspidosperma polyneuron* (Apocynaceae), *Cariniana estrellensis* (Lecythidaceae), *Astronium urundeuva* (Anacardiaceae), *Myroxylon peruiferum* (Fabaceae), *Handroanthus heptaphyllum* (Bignoniaceae) and *Euterpe edulis* (Arecaceae). Although they are endangered species, due to their large size, almost all of these species are often left out of seed collection and forest restoration programs due to the difficulty in locating parent trees and especially due to the difficulty in collecting seeds.

Preparation of seedlings of endangered species within the scope of the integrated species conservation project "Back Home" (Archives of the Bauru Botanic Garden)

Some species, even though they are threatened, are often left out of seed collection and forest restoration programs because they are tall trees.

Planting of seedlings for species enrichment in a restoration project led by the Bauru Botanic Garden (Archives of the Bauru Botanic Garden)

After selecting the species, habitat fragments were also located and selected within a 62 miles radius of the JBMB approximately, in public and private conservation areas. Collecting native forest seeds involves a set of difficulties, including the selection of quality populations, locating parent trees, monitoring phenophases in the face of climate change, and logistical factors for accessing seeds in the demarcated parent trees.

Big challenges

Through numerous field expeditions and many hours of hard work, 441 matrices of species of interest were located and demarcated, which were then monitored until fruit production and seed collection. Fruit and seed collection was one of the most challenging phases of the project because, in addition to the difficulties already highlighted, it involved almost exclusively large species, often with winged seeds that disperse easily and therefore must be collected when dispersal begins, by climbing into the canopy. The JBMB team has undergone frequent training that allows them to climb into the canopy, combining tree climbing and rock-climbing techniques.

For this stage of seed collection involving ascent to the canopy, the team brings together the efforts of numerous people who participate on the ground and/or at height: biologists and assistants from the JBMB's horticulture and plant collections sections, experienced climbers and tree climbers, and interns. To this end, the JBMB invested in equipment appropriate for working at heights, and the team had to undergo guidance from experienced firefighters in this area and were taught by arborists certified by the International Society of Arboriculture (ISA). Ascending to the canopy allowed for maximum efficiency in seed collection, greatly improving the quantity and quality of the seeds collected because it extends the reach of the collection tools and allows not only access to the fruits themselves, but also more careful selection regarding seed maturation.

Another major challenge was the change in phenological patterns of flower and fruit production in response to climate change. As highlighted in other studies (Havens *et al.* 2015), some species have changed their seed production periods due to the increasingly frequent extreme weather conditions resulting from climate change and global warming. This has made monitoring phenophases more delicate and necessary so that seeds can be collected at the time they are produced, in addition to guiding future studies.

Seed destination

The collected seeds have several destinations: some are kept in a JBMB seed bank, while others are available for donation to other botanical gardens and similar public and private institutions interested in the production and conservation of the species. The objective of the JBMB was to offer other botanical gardens and similar public and private institutions, such as seedling nurseries, seeds of good genetic quality from these difficult-to-collect species to increase conservation collections.

Finally, a third batch of seeds will be cultivated and propagated in the JBMB nursery. Some of the seedlings produced are kept in the JBMB collection of living plants, while the vast majority are used in forest restoration and reintroduction projects for endangered species carried out by the JBMB itself.

Community participation

The local community has participated in various ways through the establishment of partnerships with public institutions, private companies and landowners where several forest fragments are located and which allow the collection of seeds and the planting of seedlings for ecological restoration and species enrichment. Such participation also frequently occurs in the monitoring of phenophases for seed collection, in plantings and subsequent maintenance of the same.

Seeds of endangered species prepared for shipment to other Botanical Gardens and seedling production nurseries.
(Archives of the Bauru Botanic Garden)

Seed collections in private conservation areas must be authorized by the owners of these reserves, who become partners of the JBMB and often also allow the planting of seedlings for the reintroduction of species or even ecological restoration when necessary. Currently, the JBMB is the Seed Bank of the Brazilian Alliance of Botanical Gardens and is therefore responsible for storing seeds from other botanical gardens and sending them when requested. Plant exchange is a vital mechanism for effective conservation, whether by making seeds available for reintroduction and restoration programs, reinforcing wild populations, or exchanging plant material between gardens (Kitching *et al.* 2023).

Over the past year, seeds stored at the JBMB Seed Bank have been donated to five other botanical gardens and six private nurseries through the GBGF project which provided support for the purchase of seed collection equipment and inputs for seedling production.

Conclusion

All this work feeds a database that may in the future provide information on the occurrence and location of matrices, phenophases in the face of climate change, horticultural techniques adopted for the selected species, in addition to indicating the success of the project. With this, the JBMB has sought to fulfil its mission and aligning its objectives with the Global Strategy for Plant Conservation.

Effective conservation of tree species may require a combination of different strategies of *ex situ* and *in situ* conservation actions, ecological restoration and species reintroduction. These actions should complement each other, supported by research, horticulture and environmental education. In this sense, botanic gardens can act as valuable leaders in supporting conservation and make important contributions, as they can bring together skills and techniques to identify, cultivate and propagate a wide variety of species, in addition to maintaining important collections of living plants, seed banks and other germplasm (Mounce *et al.* 2017, Oldfield & Newton 2012).

Integrated conservation projects such as the one presented here can achieve even more encouraging results as they join forces with other public and private institutions and the local community. These projects are long-term, involve professionals from different areas and involve considerable costs, but they can achieve effective conservation of tree species.

Cariniana estrellensis seedlings being prepared for planting as part of the integrated species conservation project "Back Home" (Archives of the Bauru Botanic Garden)

Collection of seeds of tree species by the Bauru Botanic Garden team using Arboriculture techniques (Archives of the Bauru Botanic Garden)

References

- Havens, K.; Vitt, P.; Still, S.; Kramer, A.; Fant, J.B. & Schatz, K. (2015) Seed Sourcing for Restoration in an Era of Climate Change. Natural Areas Journal. 35 (1), 122-133.
- Kitching, M.; Sharrock, S. & Smith, P. (2023). Purpose and trends in exchange of plant material between botanic gardens. Botanic Gardens Conservation International, Richmond, United Kingdom.
- Mounce, R.; Smith, P. & Brockington, S. (2017) *Ex situ* conservation of plant diversity in the world's botanic gardens. Nature Plants 3: 795-802.
- Oldfield, S. & Newton, A.C. (2012) Integrated conservation of tree species by botanic gardens: a reference manual. Botanic Gardens Conservation International, Richmond, United Kingdom.

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ACHIEVEMENTS AND CHALLENGES OF SEED CONSERVATION PROGRAM IN ZAMBIA

The collaboration to preserve Zambia's native plant species through seed banking by the Millennium Seed Bank Partnership (MSBP), Kew Gardens, and the Forestry Department of Zambia has successfully banked millions of seeds. For successful seed collection on customary land, obtaining prior consent from traditional leaders is important. Engaging with local communities near forests brings valuable indigenous knowledge about the forests. There is also a need for the integration of modern technology in seed processing, germination testing, data analysis, GIS and in-depth training in the BRAHMS. The Zambian Forestry Department maintains a seed bank at the National Forestry Seed Centre in Kitwe, supplying quality native seeds for research and ecological restoration projects.

The collaborative seed conservation initiative between the MSBP, Kew, UK, and the Forestry Department - Research Branch within the Ministry of Green Economy and Environment (formerly known as the Ministry of Lands and Natural Resources), Zambia, has achieved remarkable success in *ex situ* conservation efforts through the banking of millions of seeds from different native plants collected across the country. The program has faced various obstacles at different stages, but many of these challenges have led to creative solutions being developed.

Figure 1: *Sopubia lanata* seeds mixed with chaff (Derrick Banda)

Zambia is endowed with vast and diverse forest systems that cover approximately 66% of the country's land area. However, approximately 51 to 54 percent of the land is customary land (Sitko 2016), controlled by traditional authorities who must give permission before anyone can carry out activities in the area. So, before the seed collection team can start its work, it has to meet with the traditional leaders, explain the purpose of the mission, and obtain their approval. Once the authorities are satisfied, a permit will be issued, and appropriate community members will be designated to accompany the collection team into the field. This process follows rules that ensure the seeds, herbarium vouchers, and data are legally collected and conserved (Millennium Seed Bank Partnership Data Warehouse: Standards - BRAHMS Online (kew.org)). Advantageously, designated community resident members provide valuable information, such as local plant names, plant uses, population dynamics, distribution, and influencing factors.

The other challenge relates to inadequate capacity to accurately identify different types of plants listed for collection, which include native plants, endemic species, rare varieties, CITES-listed species, IUCN-listed species, commercially important trees and useful plants of Zambia. The main problem is a lack of specialized botanists and taxonomists in Zambia, compounded by a lack of advanced training in this field both in the country and abroad, creating a significant gap in flora identification and classification. In order to mitigate this challenge, for uncertain plant names on the target list, the collection team captures color photographs of the specific plants and uses them as tools for identification.

Figure 2: Seeds of *Eragrostis sclerantha* mixed with chaff (David Mwale)

Once in the field, these images are presented to local communities, who, in most cases, provide the local name for that particular plant. This is because people who live near forests are familiar with the plants in their environment and have learned to identify them based on their appearance. This is supported by the study conducted by Padmanaba M *et al* (2013) which revealed that local people play a critical role in identifying where species of conservation concern occur. This clearly signifies the importance of integrating local communities, the stewards of indigenous knowledge, into the conservation and sustainable utilization of plants and environmental resources.

The processing of seeds belonging to certain families and genera, such as Poaceae (grass family), Orobanchaceae (broomrapes), Aloes and thorny fruit species, poses a challenge; long-term seed storage programs require thorough seed cleaning to eliminate empty, underdeveloped and insect-infested seeds. However, there are other species, such as Eragrostis, seeds can be difficult to distinguish from chaff, needing carefulness to detail (Fig 2). Similarly, most species belonging to Orobancheaceae are difficult to thoroughly clean the seeds (Fig 1).

Apart from that, Aloe species (Fig 4) seeds demand careful removal of their delicate individual coverings. Thus, to effectively separate the seeds from their coverings or chaff, one must diligently inspect each seed and manually extract any surrounding seed coverings or chaff. This labor-intensive process can be exceedingly time-consuming and requires considerable patience to ensure that only the seeds remain.

Further, extracting seeds from the thorny or spiny fruits, such as *Harpagophytum procumbens*, commonly known as Devil's Claw (Fig 3), proves to be a formidable challenge. Tools like secateurs and industrial gloves had to be used, as one needed to be careful and cautious to avoid injury to oneself or to a delicate seed. Similarly, seed processing of *Pterocarpus angolensis* (Mukwa) and *P. tinctorius* (Mukula) requires careful attention to avoid damage of seed and injury to oneself (Fig 5)

These challenges provides an opportunity to explore modern technology and specialized equipment for complete seed purification, especially for challenging plant groups. In addition, it is crucial to emphasize the importance of proper training for processors involved in seed conservation activities, especially for difficult to process plants.

Currently, only the cut test is used for seed viability due to a k of X-ray equipment. Enhancing testing with X-ray technology is thus needed. Combining the cut test with X-ray analysis can make the viability test more accurate and efficient. Although the cut test has proven invaluable in conducting viability assessments of various seeds collected, it is not without its limitations, particularly when addressing hard-coated seeds such as *Schinziophyton rautanenii*, locally referred to as Mungongo. In such cases, X-ray analysis can provide valuable insights by allowing us to visualize the internal composition of seeds without causing any damage. Moreover, integrating X-ray technology into our viability testing protocol would enable us to identify potential issues such as undeveloped embryos or fungal infections that may not be easily detectable through the traditional cut test alone. In all, by combining these two techniques, the quality of testing protocols can be raised and ensure more precise and reliable results for our research and forest afforestation practices.

Low seed numbers for target plants, especially rare and endangered ones is a constraint tha requires the establishment of specialized nurseries in order to increase the overall quantity of seeds that are conserved for long-term storage. For instance, in the case of endangered plant species, such as *Hypoxis goetzei* (Fig 5), specialized nurseries become essential hubs for conservation efforts.

Specialized nurseries are crucial for conserving rare and endangered plant species through seed propagation, genetic preservation, and public education (Swapnaja et al, 2017; Aribi, M.M., 2024). Further, inadequate knowledge of statistical analysis, Geographic Information Systems (GIS) and mapping of banked seeds presents another challenge.

On data management and analysis, the seed conservation team depends on the use of analytical packages such as BRAHMS. However, the staff needs more training in statistical analysis, GIS and BRAHMS to efficiently analyze data.

Figure 3: The fruits and processed seeds of *Harpagophytum procumbens* (Davies Simposya)

Figure 4: Aloe seed & germination test (Davies Simposya)

To address this gap, providing comprehensive in-country training sessions on packages such as BRAHMS could significantly benefit the staff. There is also a valuable opportunity to equip our staff in statistical analysis, GIS and drone operations. In this case, hands-on sessions on statistical analysis could empower our team to extract meaningful insights from data, leading to more informed decision-making processes. Additionally, mastering GIS techniques would enable our staff to create detailed maps that can greatly help in decision-making regarding conservation initiatives. Furthermore, providing training in drone operations could revolutionize how we collect data in the field. These specialized trainings could be conducted at either the national, regional, or international level, depending on the availability of resources and expertise. Expanding our staff's skills in these areas would not only enhance their professional development but also contribute to the overall effectiveness of our conservation efforts.

The lack of modern seed conservation facilities and herbarium services in Zambia poses a challenge in preserving plant species *ex situ*. Without proper infrastructure, safeguarding plants becomes difficult. Outdated seed storage facilities can compromise seed viability and lead to biodiversity loss. Investing in Zambia's seed storage facilities and herbarium infrastructure could greatly enhance plant diversity and yield significant benefits for humanity. State-of-the-art seed banks can enhance seed longevity and support research. Addressing the lack of modern seed conservation facilities and herbarium services in Zambia can strengthen *ex situ* conservation through seed banking and contribute significantly to national and global conservation efforts. Increased demand for forest restoration has led to a surge in seed distribution from our storage facilities. This heightened demand has presented challenges as we struggle to keep up with the need for seeds, indicating a pressing need to expand our collection efforts beyond the current 10% of national native plant seeds collected and banked. Ever since the inception of our collaborative seed conservation program in 2018, the Forestry Department - Research Branch has emerged as the primary source of seeds for the national forest restoration program aiming at restoring deforestated and degraded land areas across the country. Currently, Zambia has committed to restoring a minimum of 2 to 4 million hectares of deforested and degraded land. Currently, Zambia is committed to restoring a minimum of 2 million hectares by 2030. The African Forest Landscape Restoration Initiative (AFR100) is a country-led effort to bring 100 million hectares of these deforested and degraded landscapes across Africa into restoration by 2030. The forestry seed bank will serve as the major distribution center for different native plant species stored at the National Forestry Seed Centre, Kitwe, Zambia.

Figure 5: *Pterocarpus tinctorius* - mukula fruit & seed (David Mwale)

In light of this escalating demand, it is imperative that we intensify our seed collection activities to meet the growing needs of organizations engaged in forest restoration projects. By expanding our collection efforts and enhancing the efficiency of seed distribution, we can further bolster the impact of our program on the broader conservation landscape.

REFERENCES

- Aribi, M.M. (2024) Plant Gene Banks: Conservation of Genetic Resources. Sustainable Development and Biodiversity, Vol. 35. Springer, Singapore.
- Padmanaba M. et al. (2013) Accessing local knowledge to identify where species of conservation concern occur in a tropical forest landscape. Environ Manage.
- Sitko, N. (2016) The Geography of Zambia's Customary Land: Assessing the Prospects of Smallholder Development
- Swapnaja. et al. (2017) Role of botanical gardens in conservation of rare plants: a case study of lead Botanic Garden of Shivaji University. Indian forester, 143. 471-482.

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RESUMEN DEL GÉNERO *JATROPHA L.* (EUPHORBIACEAE) PARA EL SALVADOR Y DOS NUEVAS ADICIONES DE ESPECIES EN PELIGRO DENTRO DE LAS COLECCIONES VIVAS DEL JARDÍN BOTÁNICO LA LAGUNA (JBLL)

Se provee una sinopsis de 7 especies de Jatropha (Euphorbiaceae) presentes en El Salvador, incluyendo *J. costaricensis*, *J. stevensii* y *J. gossypiifolia* como nuevos registros en su distribución natural, y el descubrimiento del hábitat natural de J. podagrica, registrada únicamente en forma cultivada. Además, se incluye una clave taxonómica, fotografías de las especies, datos sobre el material depositado en el herbario LAGU y un mapa de distribución de las especies. Las 2 primeras se incluirán en la colección viva del JBLL debido a su estatus en la UICN y para fortalecer la educación ambiental y serán propuestas para la lista de especies en peligro de extinción del Ministerio de Medio Ambiente y Recursos Naturales (MARN).

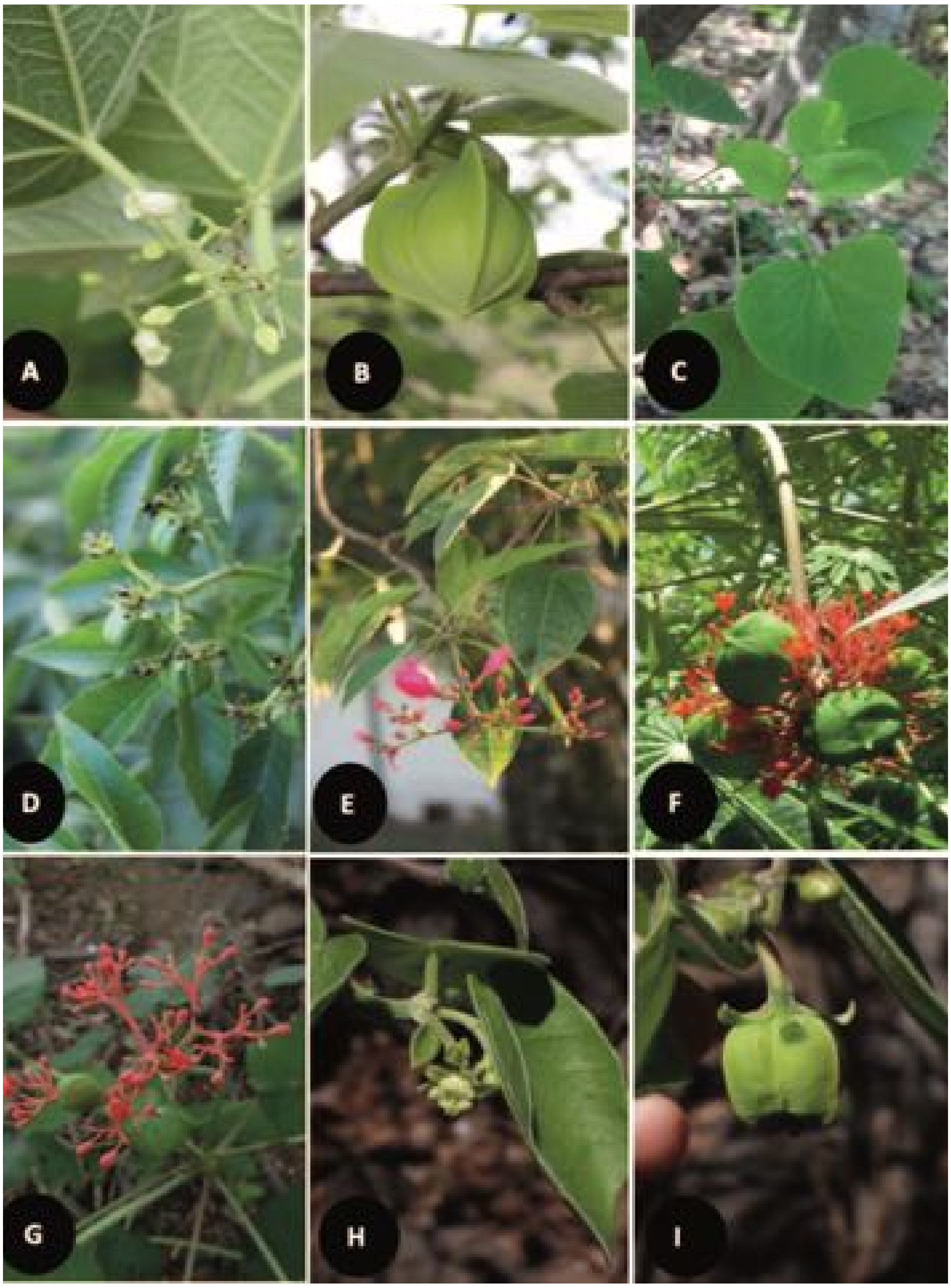
Palabras clave: Colecciones vivas, Jatropha, Educación ambiental. Euphorbiaceae, El Salvador, Mesoamérica, UICN, Sistemática

El género *Jatropha L.* cuenta con casi 155 especies que habitan desde el Sur de EUA (Texas) a Chile y Venezuela, Trinidad & Tobago, Guayanas, Brasil, Paraguay, Argentina, Antillas, Bahamas, trópicos y sub-trópicos del Viejo Mundo (González, 2010). La investigación presentada en este articulo, conllevó una revisión exhaustiva de literatura con importantes documentos históricos, los cuales contienen registros de las especies del género *Jatropha* en El Salvador. Entre ellos: Guzmán (1950) en su libro "Especies Útiles de la Flora Salvadoreña" menciona a *J. curcas* y *J. multifida*, las que cataloga como especies de medicina tradicional útiles para el país. Standley y Calderón (1927) reportan 5 especies de Jatropha en su obra "Lista Preliminar de Plantas de El Salvador", *J. aconitifolia*, *J. curcas*, *J. gossypiifolia*, *J. podagrica*, *J. urens*, y proporcionan breves descripciones, nombres comunes, y algunos usos medicinales de estas especies. En la obra inédita de Allen (1959) Silva Cuscatlanica "Native and exotic trees of El Salvador", solamente registra a 2 especies, *J. aconitifolia* y *J. curcas*; mientras que Choussy (1975) en su primer "Tomo de la Flora Salvadoreña", menciona a Jatropha curcas y el mismo autor en su tercer Tomo (1975) incorpora a *J. podagrica* y *J. aconitifolia* var. *papaya* de las cuales, en ambos aportes, incluyen nombres comunes con sus utilidades a causa de propiedades de medicina tradicional que les atribuyen. En otros aportes, Barrance et al. (2003), Linares (2003) y Berendsohn et al. (2009) enlistan a *J. curcas* en sus obras, proporcionando usos tradicionales atribuidos y su distribución geográfica.

La colección de plantas vivas del Jardín Botánico La Laguna (JBLL) ejerce un rol clave en la Educación Ambiental para que sus visitantes, ya sean de instituciones educativas u otros, comprendan la importancia de nuestros recursos (Escobar, 1997). A través de la Sección Técnica Científica del JBLL, se continúan con las giras de campo que permiten profundizar el conocimiento sobre la flora salvadoreña; así, las especies clasificadas en estado crítico según la UICN serán incorporadas a la zona alusiva al Bosque Seco, y con ello aumentar la temática de especies amenazadas o en peligro de extinción que se exhibe en el Jardín (Bosse, 2007).

Materiales y Metodos

El trabajo consistió en la verificación de especímenes del género *Jatropha*, resguardados en las colecciones del herbario LAGU, con el objetivo de corroborar la clasificación taxonómica, localidades, coordenadas, fenología y nombres comunes, todas información útil para la elaboración de un mapa de distribución del material revisado. Además, para la verificación taxonómica se utilizó literatura regional como: Arboles de Costa Rica, Arboles de Guatemala, Flora de Guatemala, Flora de Nicaragua, Manual de Plantas de Costa Rica, entre otros, así como sitios web concernientes al trabajo taxonómico. Las especies reportadas se verificaron en el sitio web de la Unión Internacional para la Conservación de la Naturaleza (UICN) para conocer su estatus de conservación según la Lista Roja.



Especies de Jatropha para El Salvador: A y B) *J. costaricensis;* C) *J. curcas,* D) *J. gossypiifolia,* E) *J. integerrima,* F) *J. multifida,* G) *J. podagrica,* H é I) *J. stevensii*

Resultados y Discusion

Por el momento, solo 7 especies del género *Jatropha*, entre cultivadas y nativas, se encuentran en El Salvador, en forma de arbustos o árboles, desde pequeños hasta grandes, alcanzando alturas de hasta 8 metros. Como anexo se incluye la clave taxonómica, un cuadro comparativo, fotografías y el mapa de distribución de las especies.

Las descripciones taxonómicas completas del género y de sus especies, asi como su rango de distribución, pueden ser revisadas en la literatura previamente publicada de las floras regionales.

Conclusion

La ocurrencia de *J. costaricensis, J. stevensii, J. gossypiifolia* y *J. podagrica*, contribuyen a aumentar el conocimiento sobre la biodiversidad florística de El Salvador, y a la vez, resaltan la importancia ecológica que proveen los espacios de Bosque Seco del país. Pese a utilizarse en el ámbito medicinal y ornamental, las especies *J. curcas, J. integerrima, J. multifida,* se registran principalmente en viviendas, plazas, viveros o sirviendo de cercos vivos para delimitar espacios físicos en áreas rurales. Las poblaciones nativas de *Jatropha*, principalmente las descritas con estado En Peligro de Extinción, se espera a que se tomen como alternativas para futuros trabajos de extensionistas enfocados en la restauraciones ecológicas del país y que las nueveas adiciones en el JBLL puedan servir para fortalecer el tema de las especies amenazadas a través de la educación ambiental.

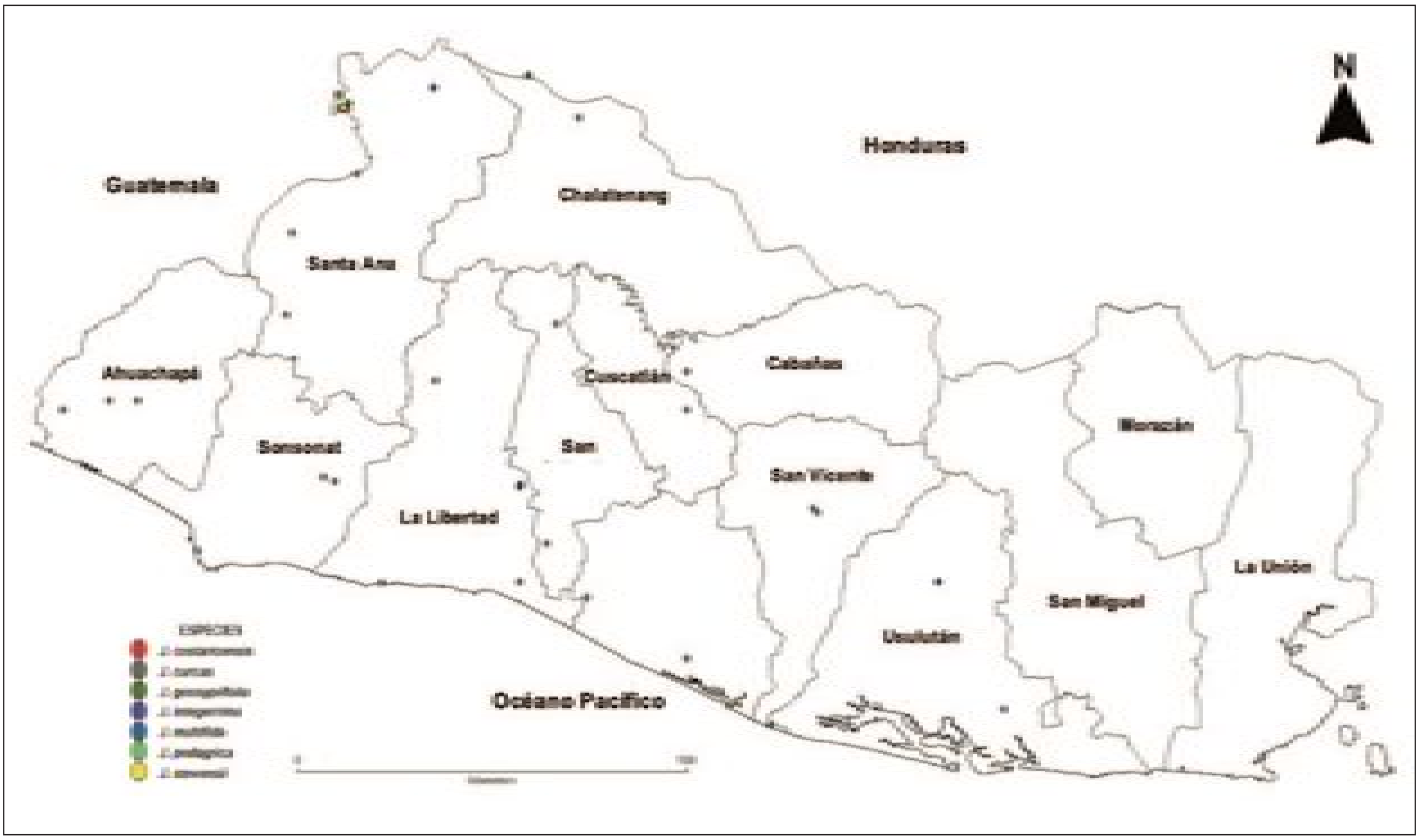
Agradecimientos

Muchas gracias a las personas conservacionistas y Guardaparques de los diferentes espacios naturales protegidos nacionales y privados visitados, por el compromiso con la protección y conservación.

Revision de Material

1. *Jatropha costaricensis* G.L. Webster & Poveda, Brittonia 30: 265. 1978.
Material examinado. Santa Ana. Rodríguez, Ruíz & Díaz 09559 (B, LAGU, MICH, MO); Rodríguez, Ruíz, Calles & Díaz 09604 (LAGU); Rodríguez, Ruíz & Calles 09612 (LAGU).
Hábitat local: Bosque seco, matorrales espinosos y sabana de Crecentia alata (morro)

2. *Jatropha curcas* L., Sp. Pl. 1006. 1753.
Material examinado. Ahuachapán. Guerrero s.n. [ISF00255] (B, LAGU); Rosales 00617 (B, BM, F, LAGU, MO); Rosales 00734 (B, BM, F, LAGU, MO); Rosales 02330 (B, BM, F, LAGU, MO); Rosales 02503 (B, LAGU, MO). Santa Ana. Padilla, Granados & Molina 6 [JBL07694] (LAGU, MHES); Rodríguez & Rodas 01666 (LAGU); Rodríguez, Ruíz & Rivas 09590 (LAGU). Sonsonate. Galán & Franco 1065 [JBL06830] (LAGU); Rodríguez, Ruíz & Pineda 09154 (LAGU). Chalatenango. La Palma, Sloot & Reina 574 [MAG00547] (LAGU). La Libertad. Cruz 00220 (B, F, HBG, LAGU, MO); Flores 00232 (B, LAGU, M); Flores s.n. [JBL00498] "tempate" (LAGU, MO); Cruz 00056 "tempate" (B, LAGU, MO); Fry s.n. [JBL04319] (B, BM, INB, F, LAGU, MO); Monro, Carballo, Castaneda & de López 03671 (B, BM, ITIC, LAGU, MO); Galán, Borja & Castillo 309 [JBL06411] (LAGU); Galán & Rodríguez 02993 (B, LAGU, MO). San Salvador. González & Hernández 00226 (B, ITIC, LAGU, MO); Renderos 00190 (LAGU). La Paz. Merino s.n. [JBL03890] (B, LAGU, MO). Cuscatlán. Vicente, Iraheta, R., Iraheta, C. & Vicente, A. 22 [JBL06199] (LAGU). Cabañas. Carballo 00374 (LAGU). San Vicente. Galán, Espinoza, Manueles & Vásquez 02302



Mapa de ubicación de las especies de *Jatropha* colectadas en El Salvador

(B, LAGU, MEXU, MHES); Rodríguez, Galán, Manueles, Vásquez, D. & Vásquez, J.C. 04103 (LAGU). San Miguel. Girón 27 [JBL08327] (LAGU, FMO).
Hábitat local: Utilizado principalmente para cercos y poco visto de forma silvestre.

3. *Jatropha gossypiifolia* L., Sp. Pl. 1006. 1753.
Material examinado. Santa Ana. Rodríguez & Portillo 07868 (LAGU, MO); Rodríguez & Galán 08658 (LAGU). Chalatenango. Villacorta & Lara 02528 (B, LAGU, M, MO). La Libertad. Flores 00231 (B, HBG, LAGU); Villacorta 00033 (LAGU, MO); Moreno s.n [JBL08141] (LAGU). San Vicente. Sidwel, Davidse, Monro, Quezada Díaz & Fundación CORDES 00635 (B, BM, ITIC, LAGU, MO). San Miguel. Villacorta 02387 (B, F, LAGU, MO).
Hábitat local: Bosque seco, orillas de cuerpos de agua en zonas bajas y potreros a pleno sol.

4. *Jatropha integerrima* Jacq., Select. Stirp. Amer. Hist. 256. 1763.
Material examinado. Santa. Ana. Galán 05682 (LAGU, MO); Ruíz & Rodríguez 00287 (LAGU). La Libertad, Berendsohn 00238 (LAGU, MO); Galán 05392 (LAGU, MO).
Hábitat local: cultivada, ornamental

5. *Jatropha multifida* L., Sp. Pl. 1006. 1753.
Material examinado. La Libertad. Galán 05415 (LAGU, MO). Usulután. Rodríguez, Monterrosa & Hernández 01662 (B, LAGU, MO).
Hábitat local: cultivada, ornamental

6. *Jatropha podagrica* Hook., Bot. Mag. 74: t. 4376. 1848.
Material examinado. Santa Ana. Rodríguez, Galán & Portillo 08547 (B, LAGU). La Libertad. Montalvo 06292 (B, F, LAGU, MO).
Hábitat local: cultivada, medicinal y ornamental en ciudades y en forma silvestre se encuentra en Bosque seco.

7. *Jatropha stevensii* GL Webster, Ann. Missouri Bot. Gard. 74: 117. 1987.
Material examinado. Santa Ana. Rodríguez, Ruíz & Díaz 09743 (B, LAGU, MO); Rodríguez, Ruíz, Calles & Díaz 09763 (LAGU)
Hábitat local: Bosque seco, matorrales espinosos y sabana de Crecentia alata (morro)

Referencias

- Barrance, A., J. Beer, D. Boshier, J. Chamberlain, J. Cordero, G. Detlefsen, B. Finegan, G. Galloway, M. Gómez, J. Gordon, M. Hands, J. Hellin, C. Hughes, M. Ibrahim, D.L. Kass, R.R.B. Leakey, F. Mesén, M. Montero, C. Rivas, E. Somarriba, J.L. Stewart, J. L. and T. Pennington. 2003. Árboles de Centroamérica, un manual para extensionistas. Turrialba, Costa Rica: Centro Agronómico Tropical de Investigación y Enseñanza, CATIE.

- Berendsohn, W., A.K. Gruber, and Monterrosa Salomón, J. 2009. Nova Silva Cuscatlanica. Árboles nativos e introducidos de El Salvador. Parte 1: Angiospermae – Familias A a L. Englera 29 (1)

- Bosse, 2007. J. Plantas en peligro de extinción y amenazadas en El Salvador. Pankia 26 (1):8-9.

- Choussy, H.J. 1975. Flora Salvadoreña. Colección Temachtiani. Vol. No. 2. Tomos I y III. 2ª ed. Editorial Universitaria, San Salvador, El Salvador.

- González, J. 2010. Euphorbiaceae. En: B.E. Hammel, M.H. Grayum, C. herrera, N. Zamora eds. Manual de Plantas de Costa Rica, Dicotiledóneas (Clusiaceae-Gunneraceae). Volumen V.

- Guzmán, D.J. 1950. Especies Útiles de la Flora Salvadoreña. 2ª. ed. Dirección de Publicaciones, Ministerio de Educación San Salvador, El Salvador, Centro América. 2: 1–684.

- Linares, J.L. 2003. Listado comentado de los árboles nativos y cultivados en la república de El Salvador. Ceiba 44 (2), Honduras.

- Parker, T. 2008: Trees of Guatemala. – Austin.

- Plants of the World online (POWO). 2024. https://powo.science.kew.org/ Accessed Ago 2024.

- Portal de Biodiversidad de Guatemala. 2024. https://biodiversidad.gt/portal/ Accessed Ago 2024.

- Rodríguez-Acosta, M., K. Vega-Flores, V.H. De Gante-Cabrera, and J. Jiménez-Ramírez. 2009. Distribución del genero Jatropha L. (Euphorbiaceae) en el estado de Puebla, México. Polibotánica, (28), 37-48. Recuperado en 02 de septiembre de 2024, de http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-27682009000200003&lng=es&tlng=es.

- Standley, P.C. and J.A. Steyermark. 1949. Euphorbiaceae. 24(6): 25–170. In P.C. Standley and J.A. Steyermark (eds.). Fl. Guatemala, Part VI, Fieldiana, Bot. Field Museum of Natural History, Chicago.

- Tropicos.org. Missouri Botanical Garden. 2024. https://www.tropicos.org/name/40033218 Accessed Ago 2024

- Webster, G.L. 2001. Euphorbiaceae. En: Stevens, W.D., C. Ulloa Ulloa, A. Pool & O.M. Montiel Jarquín. Flora de Nicaragua. Monogr. Syst. Bot. Missouri Bot. Gard. 85: I

CLAVE DE ESPECIES PARA EL SALVADOR

1.Plantas con pétalos de color rojo o similar a este	**2**
2. Plantas estrictamente cultivadas o si silvestres sin hojas y estípulas prominentemente glandulares	**3**
3. Plantas medicinales con hojas peltadas, habitando como cultivada o raramente vista de forma silvestre........	***J. podagrica***
3. Plantas ornamentales cultivadas con hojas no peltadas........	**4**
4. Hojas profundamente 9–11-lobadas........	***J. multifida***
4. Hojas no lobadas a levemente 3–7-lobadas........	***J. integerrima***
2. Plantas habitando de forma silvestre con hojas y estípulas prominentemente Glandulares	***J. gossypiifolia***
1. Plantas con pétalos de color verde claro o algo así	***5***
5. Hojas evidentemente hirsutas en el envés, plantas dioicas	***J. costaricensis***
5. Hojas glabras (poco puberulentas en las axilas y nervios principales), plantas monoicas	***6***
6. Hojas maduras de tamaño grande 25 cm de largo y 21 cm ancho (en ocasiones lobuladas), peciolo de hasta 15 cm de largo	***J. curcas***
6. Hojas maduras nunca lobuladas, tamaño menor al literal anterior y el peciolo no superando los 8 cm de largo	***J. stevensii***

Comparación entre forma de vida, altura y la distribución regional de cada una de las especies

ESPECIE	FORMA DE VIDA	DISTRIBUCIÓN U ORIGEN
*J. COSTARICENCIS**	árboles hasta 8 m	Guatemala, El Salvador, Nicaragua y Costa Rica.
J. CURCAS	árboles hasta 5 m	Posiblemente nativa de México y distribuida en los trópicos.
J. GOSSYPIIFOLIA	arbustos hasta 2 m	Posiblemente nativa de Sudamérica y distribuida en los trópicos.
J. INTEGERRIMA	arbustos hasta 4 m	Nativa de Cuba, ampliamente y distribuida en los trópicos.
J. MULTIFIDA	arbustos hasta 3 m	supuestamente americana, aunque solo vista cultivada en zonas tropicales.
J. PODAGRICA	arbustos hasta 2 m (de forma cultivada)	Guatemala y El Salvador hasta Nicaragua y cultivada como medicinal en las ciudades
*J. STEVENSII**	árboles de hasta 7 m	Guatemala, El Salvador, Nicaragua y Costa Rica.

* ESTAS ESPECIES SE ENCUENTRAN ENLISTADAS DENTRO DE LA UICN CON CATEGORÍA EN PELIGRO (EN) DEBIDO A SUS ESCASOS INDIVIDUOS SILVESTRES.

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