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Plant collecting: underpinning the work of botanic gardens

BOTANIC GARDENS CONSERVATION INTERNATIONAL

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Cover Photo: The team of explorers from the 2017 North America-China Plant Exploration Consortium on the trail in Northern Sichuan (Michael Dosmann)

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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.

United Nations Decade on Biodiversity

IN THIS ISSUE...

EDITORIAL:
PLANT COLLECTING

It gives me great pleasure to write the editorial for this issue of BGjournal because the theme of plant collecting is an activity that has given me some unforgettable experiences over many years, and taken me to some wonderful places. My botanical career began in Zambia in the early 1990s where I was employed to carry out a botanical and ecological survey of North Luangwa National Park, a botanically unexplored area of 4,500 km^2. Equipped with a Landcruiser and a rifle, and accompanied by an enthusiastic assistant, we spent two years collecting herbarium specimens and laying out transects. The result was a checklist of over 1,000 plant species, with a dozen or so new to science. The thrill of finding a plant that is new to you – and possibly undescribed – is something I suspect that only plant collectors can appreciate!

The herbarium specimens I collected in North Luangwa took me to Kew, where the next big career step was a job as an International Co-ordinator for the Millennium Seed Bank (MSB). My area was southern Africa and Madagascar, and here the task was to collect seeds from rare and threatened plant species. In this edition of *BGjournal,* we have two MSB seed collecting stories. The first, describing the UK National Tree Seed Project (p.16), comes from the Millennium Seed Bank itself and tackles the perennial question of how to make genetically comprehensive collections, sampling as many alleles as possible. As always, there is a trade off between capturing maximum genetic diversity and sampling effort. The second MSB story (p.39) comes from Austria, where the Botanical Garden of the University of Vienna has been working with the Millennium Seed Bank for some years to collect and conserve seed from rare and threatened species, including around 180 species on the Austrian Red List. Both of these articles have some extremely useful tips and advice for seed collectors.

The thrill of finding a rare or threatened plant in the wild is the culmination of a great deal of research and effort, including collating herbarium data on locality, phenology and descriptions, sourcing images wherever possible and, of course, the planning, permits and logistics involved in an expedition to remote areas. The article by Gullele Botanic Garden in Ethiopia on page 48 reminds us of the importance of getting plant collecting permission not just from the authorities but also from the local community. Once in the vicinity of your target species, thorough exploration of the site and surveying of the population is essential to ensure adequate sampling. This process is described in the article on page 28 about the conservation and restoration of *Vatica kanthanensis*, a rare limestone tree species in Malaysia, and is literally taken to a new level in the inspiring article by the National Tropical Botanical Garden in Hawai'i (p.25) where drones are being used to survey populations of extremely rare plants in inaccessible areas.

Of course it isn't just rare and threatened species that we make collections from. Useful species are also the focus of plant collecting efforts. We have some excellent examples of this in the article by Meise Botanical Garden (p.20) working with partners in the DR Congo to collect and conserve wild coffee and the article from Beijing Botanical Garden describing efforts to collect and characterise *Rosa chinensis* – the progenitor of many ornamental rose cultivars. Socio-economically important plants are also an essential element of the collecting policies of the Balkan Botanic Garden of Kroussia (p.42) where an impressive, sustained effort over many years has yielded collections from 1,470 rare, threatened and useful taxa.

International partnerships bring another dimension to plant collecting, including the opportunity to meet like-minded people, build friendships that may last a lifetime and share both plant material and field trip experiences. The North America-China Plant Exploration Consortium (NACPEC) is just such an example of an international collaboration that has endured – in this case for nearly 30 years (p.30). The Arnold Arboretum is a member of NACPEC, and their article on page 35 gives us a wonderful insight into the benefits of international collaboration and progressive collections policies. Our plant hunting story from Atlanta Botanical Garden on page 8 is another example of international collaboration, and illustrates both the challenges of making successful plant collections and the value of long term partnerships to enable repeated attempts where necessary.

Our featured garden this issue is Montgomery Botanical Center, a garden BGCI knows well, and an institution at the forefront of palm and cycad conservation efforts worldwide. MBC's plant collecting adventures are legendary, as illustrated by Patrick's article (p.11), and all for an incredibly important cause – to conserve plant diversity for future generations.

I hope that you enjoy this edition of *BGjournal*. If you enjoy reading *BGjournal*, or you have comments you would like to make, I would like to encourage you to email us at info@bgci.org. We would also like to hear from you with suggestions about future editions of *BGjournal*, features you would like to see, and how we can make this publication more relevant to you.

Paul Smith
Secretary General BGCI

FEATURES

NEWS FROM BGCI

Here we present a selection of recent news stories from BGCI. Please explore the 'new-look' BGCI website for more news and events from BGCI and the botanic garden community: **www.bgci.org**

Global Botanic Garden Fund

BGCI is pleased to announce a call for applications for grants through the Global Botanic Garden Fund.

BGCI's Global Botanic Garden Fund aims to drive plant conservation, especially in smaller gardens. The fund will initially disburse 15-20 small grants of USD 1,000-2,500 each per year and is available to BGCI members only.

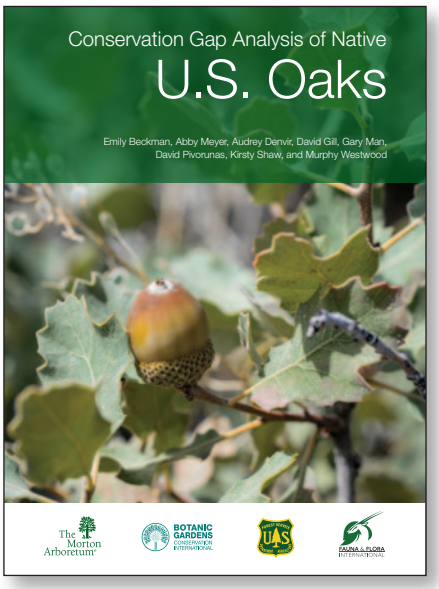
Grants will be framed within the Global Strategy for Plant Conservation, and will support plant conservation practices, plant conservation policy and education, infrastructure development, training for plant conservation, international partnerships, and mentoring botanic gardens in efforts to achieve success through BGCI's Botanic Garden Accreditation Scheme.

BGCI's Global Botanic Garden Fund will also administer restricted grant funding through the BGCI/ArbNet Partnership Programme and the BGCI/Minnesota Landscape Arboretum Grants.

Proposals may be submitted to all of the funding opportunities for which they are eligible, but only one grant will be awarded per successful proposal.

BGCI's Global Botanic Garden Fund will accept grant applications until 17:00 BST on 13 September 2019.

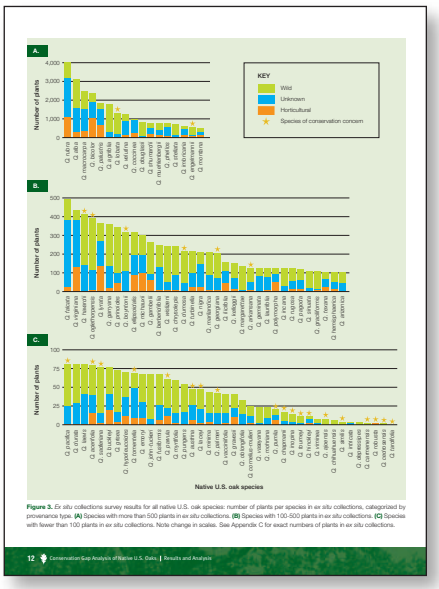
To learn more and to apply for a grant visit: https://www.bgci.org/our-work/services-for-botanic-gardens/global-botanic-garden-fund/bgci-global-botanic-garden-fund-application/



Conservation gap analysis for native US oaks published

Many native US oaks are threatened with extinction in the wild. These trees are critical to the health and function of forest and shrubland ecosystems and provide essential habitat and food for many species. Conservation efforts exist, but more can be done by coordinating efforts and setting priorities. With this in mind, The Morton Arboretum, in partnership with BGCI-US and with funding from the USDA Forest Service, conducted a comprehensive analysis of the achievements and most urgent needs for *in situ* and *ex situ* conservation of oak species in the United States. The final report presents a summary of the analysis, including patterns in threats and conservation efforts for the most at-risk species and recommendations for the most urgently needed conservation activities. Of the 91 native U.S. oak species, the study identified 28 species of conservation concern.

To find out more and download a copy of the report, visit: https://www.bgci.org/news-events/the-conservation-gap-analysis-of-native-u-s-oaks-published/



GTA
GLOBAL TREE ASSESSMENT

Major milestone reached for the Global Tree Assessment

Over 5,000 conservation assessments for trees from 180 countries have been added so far this year to the IUCN Red List of Threatened Species (July 2019). These assessments are all part of the Global Tree Assessment and bring the total number of tree assessments on the IUCN Red List to over 16,000. This new total, in combination with global conservation assessments for trees recorded in BGCI's ThreatSearch Database, means that over half of the world's 60,000 tree species now have a conservation assessment. We have therefore crossed the halfway mark towards reaching our 2020 goal, to have conservation assessments for all the world's trees.

Find out more about the Global Tree Assessment here: https://www.bgci.org/our-work/projects-and-case-studies/global-tree-assessment/

New video launched for the International Plant Sentinel Network

BGCI has recently launched a new video promoting the International Plant Sentinel Network (IPSN). Alien pests and pathogens are posing an increasing threat to global plant health; monitoring and surveillance of plants in collections can play a key role in addressing this threat. The IPSN is a global network of botanic gardens and arboreta that work together and, in partnership with national plant protection agencies, share tools, resources and information on new and emerging pest issues. By joining the IPSN, botanic gardens can become part of a global plant protection network and build their skills in pest and disease monitoring.

To find out more and view the video, visit: www.plantsentinel.org

New guidance on threatened species recovery

BGCI supports conservation practitioners to develop the skills and techniques required to recover threatened species. Building on the Species Recovery Manual that was published in 2018, and with support from the Rufford Foundation, BGCI has produced a series of six concise guidance briefs based on the chapters of the manual. They cover the following topics:

- Carrying out eco-geographical surveys
- Designing a species recovery plan
- Collecting material for species recovery
- Engaging with local communities
- Carrying out population reinforcement
- Monitoring species recovery projects.

The guidance briefs are designed to be easy to follow and downloadable so they can be taken into the field by practitioners. They are freely available to download in English and Chinese.

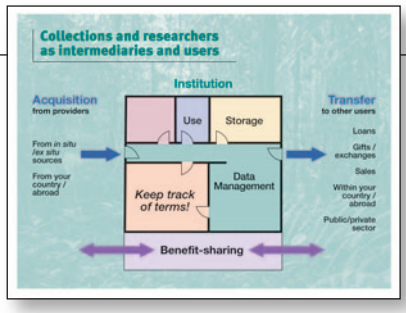
To find out more, visit: https://www.bgci.org/news-events/new-guidance-on-threatened-species-recovery-launched/

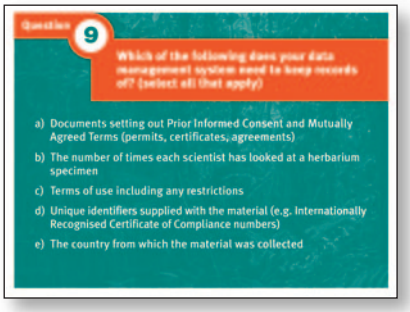
Access and Benefit-Sharing: a Learning Package

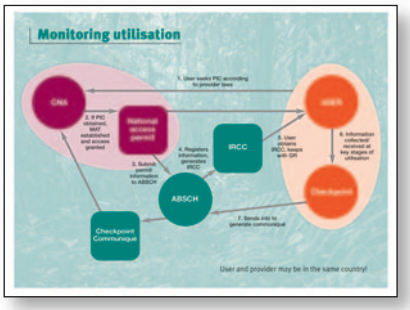
With the support of the Darwin Initiative, BGCI has produced a Learning Package on Access and Benefit-Sharing (ABS) to support researchers and collection holders to understand, and teach others about the international ABS framework and how this impacts on the work of collection-based institutions.

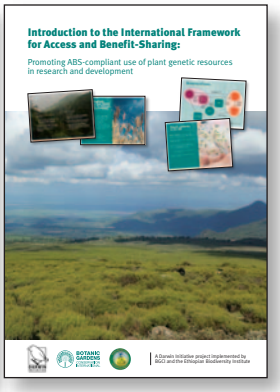
As well as the suite of training materials, BGCI has also collected a number of examples and case studies of how ABS is being implemented by botanic gardens and related institutions around the world and these examples can be viewed on the BGCI website.

To find out more and download the learning resources, visit: https://www.bgci.org/news-events/bgcis-access-and-benefit-sharing-learning-package/









BGCI's 3rd Technical Review: Urban Greening

BGCI's latest Technical Review focuses on the role of botanic gardens in urban greening and conserving urban biodiversity. It includes 35 case studies encompassing urban forestry, urban agriculture, food production, ecological restoration and activities that support urban biodiversity. With a growing urban population, these activities are increasingly important, and this review demonstrates that botanic gardens are rising to the challenge.

To find out more and download a copy of the review, visit: https://www.bgci.org/news-events/bgci-publishes-new-technical-review-on-urban-greening/

BGCNews archive now available on-line

The complete set of BGjournal and its predecessor, BGCNews, is now freely available on-line at JSTOR. This is part of a limited preview of the upcoming JSTOR Plants & Society Collection which will be a diverse collection focusing on the historical, cultural, aesthetic, and environmental implications and uses of plants by people.

Find out more at: www.jstor.org/journal/bgj

BGCI ACCREDITATION SCHEME

BGCI's Accreditation Scheme distinguishes botanic gardens from non-botanic gardens and recognises achievements in plant conservation.

BGCI Botanic Garden Accreditation is aimed at botanical institutions wishing to establish their credentials as botanic gardens. Organisations applying for accreditation will be assessed on criteria encompassing leadership, collections management, horticulture, public education, community/cultural activities, conservation actions, scientific research, staff, networking and sustainability.

BGCI Conservation Practitioner Accreditation recognises botanic gardens with a conservation-oriented approach. **BGCI Advanced Conservation Practitioner Accreditation** recognises botanic gardens with a focus on conservation actions that support local, national or global conservation goals.

Institutions may apply for more than one accreditation. BGCI Botanic Garden accreditation is open to BGCI members and non-members. For BGCI members there is no charge. For non-members a fee of US$65 is required to cover administration costs. BGCI's Conservation Practitioner accreditation is only open to BGCI members, and there is no fee. Advanced Conservation Practitioner Accreditation is only open to BGCI members and $500 will be charged for a BGCI Conservation Assessment on a cost recovery basis.

Botanic gardens that achieve any of the three accreditations will be recognised by BGCI in later issues of BGjournal. Find out more at: www.bgci.org/accreditation

The following botanic gardens achieved BGCI Botanic Garden Accreditation since the last issue of BGjournal:

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Barnes Arboretum at Saint Joseph's University, USA
Botanic Garden of the Natural History Museum of the University of Oslo, Norway
Botanical Garden of the University of Bern, Switzerland
Fossil Plants, United Kingdom
Gothenburg Botanical Garden, Sweden
Jardín Botánico Regional de Cadereyta, Mexico
Leon Levy Native Plant Preserve, Bahamas
Pruhonice Botanic Garden, Czech Republic
San Diego Zoo Global, USA
United States Botanic Garden, USA

The following botanic gardens achieved BGCI Advanced Conservation Practitioner Accreditation since the last issue of *BGjournal*:

Atlanta Botanical Garden, USA
Chicago Botanic Garden, USA
Denver Botanic Garden, USA
Native Plant Trust – Garden in the Woods, USA
Meise Botanic Garden, Belgium
Missouri Botanical Garden, USA
Montgomery Botanical Center, USA
National Botanic Garden of Wales, UK
North Carolina Botanical Garden, USA
Royal Botanic Gardens and Domain Trust, Sydney
Royal Botanic Garden Edinburgh, UK
State Botanical Garden of Georgia, USA

Author: Scott McMahan

PLANT HUNTING TALES
PINUS KREMPFII: THE WORLD'S MOST UNUSUAL PINE

Introduction

In late June of 2018, I was contacted by my colleague Dr. Dzu Van Nguyen from the Institute of Ecology and Biological Resources (IEBR) branch of the Vietnam Academy of Science and Technology (VAST) concerning a return trip to the Central Highlands area of Dalat, Vietnam. We had traveled together to this area in March 2018 because I wanted to see the rich biodiversity for myself and try to gain a better understanding of some of the rare conifers that occur in Bidoup – Nui Ba National Park. In particular, the only known flat needled pine in the world, *Pinus krempfii*. With support from the American Conifer Society, our goal was to try and collect seed from these trees to share with the VAST biodiversity station in northern Vietnam as well as evaluate its ability to grow in temperate climates in the United States. We also began to discuss the idea of building seed beds in areas with more light inside the park to try to increase germination and the ability to distribute seedlings. Since we already had a well-established relationship with VAST, the rangers were very amenable to working with us to collect seed and attempt to establish it in a few botanical gardens outside of Vietnam. It was decided that early December was the best time and the tickets were booked.

Not wanting to fly all that way just for a few days in the field, I began to set up meetings with our colleagues at Fauna and Flora International (FFI) so we could continue to work out a plan for collaborative efforts in Vietnam. I invited Dr. Peter Zale (Associate Director of Conservation, Plant Breeding and Collections) from Longwood Gardens along for these meetings as well since he had expressed an interest in working in Vietnam and I already knew he was a very keen plantsmen. With Peter on the team, I felt like we were ready to have serious discussions about conservation and collaboration in the field with FFI and IEBR.

Dr. Nam with Magnolia blaoensis

Populations of *Pinus Krempfii*

Currently, the IUCN conservation status for *Pinus krempfii* is vulnerable. While it is only known from two locations, the provinces of Khanh Hoa and Lam Dong, there are populations of these trees reported with more than 200 individuals. While our team was hiking through the area, we made note of no more than 10 mature trees with some natural regeneration. However, the immature seedlings coming up in the forest hardly resemble their unique parents. Instead, to me, they looked much more like a vigorous *Podocarpus* seedling. I finally began to understand that our guide was saying "baby, baby" as he pointed to each seedling we passed and it dawned on me what the seedlings were. They look so different in fact, that the taxon *Pinus krempfii* var. *poilane*i was described in 1924 based on the foliage of the younger plants, but it was later deemed invalid. While the morphology of this species has been the topic of discussion amongst conifer researchers for many years, chloroplast DNA analysis has proven that *P. krempfii* falls clearly in the subgenus *Strobus*.

Working in partnership

It was a fast and furious trip, but Peter and I arrived at nearly the same time into Hanoi so we were able to easily gather our gear and head into town to meet Dzu. That very afternoon, Dzu was picking up our signed permits from the forestry department in Hanoi which allowed us to work in Dalat and collect seed of *P. krempfii*. We first needed to meet with our friends at FFI and then the director of IEBR to ensure we were all on the same page with regards to collecting and sharing material and information with all parties involved. The next morning, we had a remarkably productive meeting with the country director of the Vietnam program of FFI (Josh Kempinski), the country manager of the Vietnam program of FFI (Lam Van Hoang), as well as two of their field researchers. As it turns out, the three locations we have identified in the north as being remarkably rich and well preserved are very near areas where FFI is already working to protect the Tonkin snub-nose monkey (*Rhinopithecus avunculus*) and its habitat. In this meeting, it was decided that we were all in agreement as to what areas should be focused on and that a memorandum of understanding would be created.

Following our meeting with FFI we went straight over to IEBR to meet the director of the department, Dr. Sinh Van Nguyen. By the end of the meeting, we had all agreed on some basic collaborative guidelines and since then, we have had subsequent meetings to further discuss how we should proceed with regard to both *in situ* and *ex situ* conservation work. While there is a basic nursery infrastructure in place within the Academy of Science just north of Hanoi, we have discussed the need to make some changes and upgrades that our group will help facilitate (installation of a small tissue culture lab, soilless growing media, sufficient shade structures) before we can begin to bring seed or plants down from the northern border areas. Much of this will be discussed and worked through in the months ahead. Now that the business side of our trip was successfully behind us it was time to fly down to Dalat to try and fulfill the second goal of the trip…to collect seed of *Pinus krempfii*. The next morning Peter and I were picked up and shuttled off to the airport by Dzu and a new friend that I had asked to join us, Dr. Vu Quang Nam who is an expert in Asian Magnoliaceae from the Vietnam National University of Forestry. The hunt was on.

The field work

The Bidoup - Nui Ba Nature Preserve was established in 2004 and is one of the largest in Vietnam. While much of the surrounding area has been cut over and farmed to complete degradation, the forest in this park has been well-preserved and is remarkably diverse. In 2009 (last IUCN update in this area), the park had 62 vascular plant species on the IUCN Red List and was found to be home to 15 of the 33 known conifer species in Vietnam.

Collecting cones of P. krempfii

P. krempfii *seedling (*in situ*)*

P. krempfii *(cone)*

The park is located in southern Vietnam and quite near the coast, but mountainous surroundings protect the area from temperature extremes. It is named after the two highest peaks around: Bidoup (2,287m) and Nui Ba (2,167m). The typical elevation range of *P. krempfii* is between 1,500-2,000m and the grove of trees we found suitable for climbing were right in the middle of that range at 1,710m. While I knew the area was rich based on my first visit a few months ago, on this trip I was able to pay more attention to the amazing diversity growing in association with this ancient Pine. The edge of the forest was full of flowering *Impatiens* species as well as terrestrial and epiphytic orchids, but the woody plant diversity was equally amazing. We were surrounded by large *Rhodoleia championii*, *Magnolia blaoensis*, *Fokienia hodginsii* and *Dacridium elatum* to name just a few.

After a short hike, we began to see the enormous trunks of the trees that we had come to collect. The *Pinus krempfii* in this park have been around for nearly 2,000 years and some have reached a height of over 200 feet tall. Once these mammoth trees reach their mature height, their picturesque flat tops make them easy to spot towering over the canopy. As with most pines, the cones are not produced close to the ground or even close to the trunk. Someone was going to have to climb up these trees (whose lowest limbs were 100 ft. off the ground) and crawl out on to the branches so a smaller limb with cones could be cut with a machete and dropped down. This is why we brought our local guys with us, but even they were scratching their heads as to how they should get started.

Extreme tree-climbing

After seeing the trees, they told me it would be 500,000 Vietnamese Dong (~$20USD) per tree climbed. I agreed, they were ecstatic and the climbing ropes came out. First, they tried to climb up a tree with a bare trunk using a rope in hopes they could get to the lowest limb and tie off, but the tree was too large and the distance too great to go very far. Then they tried to climb a smaller tree growing next to the pine thinking that they could then somehow transfer from one to the other at some point, but that proved too dangerous. Finally, they decided on a tree that had a very old vine growing up the side. One of the climbers had the rope tied to his waist and then used the vine to get footholds as he worked his way up the trunk of the tree. Within minutes, he was in the canopy. I could not believe his agility while up there. Once he had tied himself off, he began walking out on the biggest branches and cutting off small branches with cones. We were a little late and could tell that many of the cones had already dehisced. However, between this tree and one other, our climber was able to get us about 18 green cones before the afternoon rain started. After Peter and I manually pried open each cone and extracted any seed there was, we had close to 80 that looked good. Once we did a float test, we determined that only 3 of those sank and subsequently one did germinate. We are unsure if the low viability had to do with the age of the trees or our timing. Further studies and more expeditions are needed to determine this. However, putting all of our hopes in that one seedling proved too much and it ultimately damped-off shortly after germination. Too much time has passed to expect the other 2 sinkers to germinate, but the harder job of creating the relationship is done. We are now planning a return visit this fall.

Scott McMahan
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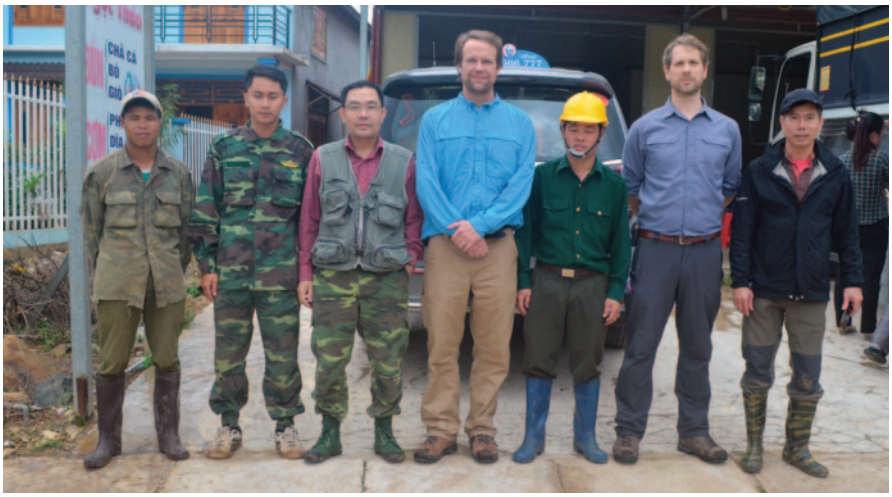
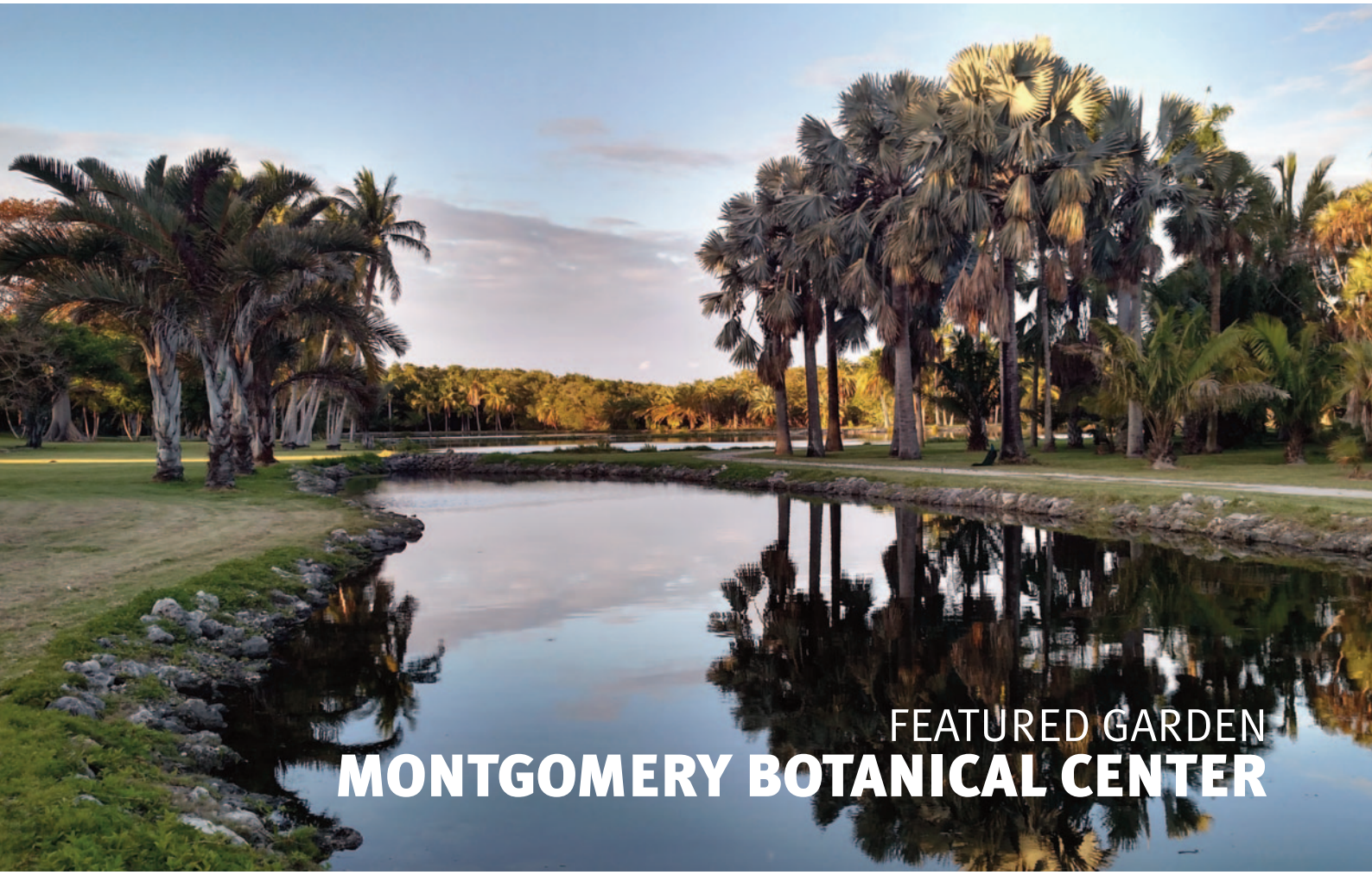
Polytunnels outside of Dalat



The collecting team

Author: M. Patrick Griffith



FEATURED GARDEN

MONTGOMERY BOTANICAL CENTER

Living collections are central to Montgomery's work; examples here include Raphia *from South Africa,* Bismarkia *from Madagascar,* Elaeis *from Costa Rica, and* Acoelorrhaphe *from Belize – and in the distance* Phoenix *from the Canaries and* Roystonea *from Jamaica. Currently, 78% of the collection is of known wild provenance, up from 70% ten years ago.*

A garden built on exploration

In 1932, Colonel Robert Montgomery established his estate south of Miami, Florida – a perfect climate for his horticultural passion, palms and cycads. Robert and his wife Nell explored worldwide in search of interesting plants for their Coconut Grove Palmetum, which quickly joined the most important collections of its era! Botanical luminaries, plant explorers and curiosity seekers journeyed from afar to see the Colonel's palms, novel for the USA by being grown outdoors in a natural climate.

Robert and Nell Montgomery at Cienfuegos Botanical Garden (Cuba) in 1935. Seeds exchanged on this trip survive today as palms and trees at Montgomery and Cienfuegos – showing the lasting legacy of international collaborations. This tradition of sharing continues today at Montgomery.

The Collections Genetics Project studies how best to conserve genetic diversity in garden collections – which plants to grow, and how many. This native Florida species, Leucothrinax morrisii, *provides a model by comparing the native genetic diversity (Big Pine Key, left) with the cultivated collections (Montgomery, right). These studies involve many collaborators, especially BGCI-US. Results and recommendations are presented at www.montgomerybotanical.org.*

After Col. Montgomery died, Nell thoughtfully considered how to continue his legacy. Nell created Montgomery Botanical Center in 1959, dedicating her land, plants, and funds as a botanic garden to advance science, conservation, and education. Nell led this garden until she passed away in 1990. Her vision inspires our generation to go even further afield!

Collections are the foundation

Living plant collections are the foundation and center of Montgomery's work: this focus is codified in the mission, informs strategic planning and policy, and guides landscape development. All programmatic efforts – research, conservation and education – are based on and depend upon collections. This sharp focus from Nell makes perfect strategic sense; in a crowded field of NGOs, universities, and think tanks, botanic gardens have a unique, authentic niche – we excel at growing plants! Montgomery's leadership keeps collections central to our work. And with good reason: without plants, no garden can move forward.

Research

From Nell, Montgomery received great wisdom on pursuing research. Nell advocated radical colleagueship: "*A fundamental policy is that other botanical institutions and their staffs are not competitors; they are colleagues*." Nell made her collections available to any scientist. Since 2005, the Kelly Botanical Research Fellows Program has also funded scholars' travel to visit and study the collection, bringing experts from as far as Brazil, Switzerland and Australia. Montgomery's own staff participate in many engaging collaborative projects with experts worldwide.

One exciting initiative is the Collections Genetics Project which studies how best to conserve genetic diversity in living collections. This scientific pursuit follows Montgomery principles closely: it is absolutely focused on the collection, and involves a large number of collaborating institutions! Other research areas include systematics, phytogeography, and conservation horticulture, all leveraging the living plants on-site for insight.

Pre-Kindergarten students plant Pseudophoenix sargentii *palms as part of a fieldtrip. These students learned how to care for palms, and why growing this Florida native species is important for conservation.*

Education

Learners at every level use the Montgomery collections to study natural history, botany, and the environment. Graduate and undergraduate courses include Montgomery tours on their syllabi. We are fortunate to share a fenceline with a school; a purpose built gate allows abundant botanical field trips and learning opportunities. Students from further afield arrive by bus or van; examining palms and cycads, or even rocks, landscapes, lizards and art – it is up to their teachers!

Montgomery has increasing training opportunities for early-career horticulturists and botanists through internships, fellowships and service learning. A solid relationship with Miami Dade College and generous funds from the Batchelor Foundation and Christiane Tyson created our Fellowship in Conservation Horticulture, hiring horticulture students for a year-long work-study focused on green practices and rare species. Two new endowments – the Peter R. and Stuart Y. Jennings Fund and the Robert K. Zuck and Peter R. Jennings Fund – provide summer research opportunities for undergraduate botanists, who performed palm conservation fieldwork, GIS modeling of collection changes, and anatomical and developmental studies of palm flowers. Alumni of these programmes have moved forward into horticulture careers and graduate schools, and co-authored scientific papers from their studies – all very successful outcomes!

Provenance of all living collections at Montgomery shows a global focus on the tropics and subtropics, but with specific emphasis on the Western Hemisphere, especially in recent years. Each of these points also represent international collaborations, great friendships, and shared botanical outcomes!

Conservation

Conservation motivates all areas of our work: developing broad and deep collections, learning about their biology, and reaching audiences with their stories. Montgomery approaches conservation from a collections-based perspective, seeking to capture and steward genetic diversity for safeguarding. Our Collections Genetics Project has made important contributions to this field and tailored our own protocols. Detailed assessments from our fieldwork have led to refined red listing for many palms and cycads. Montgomery is also the very first botanic garden to host an IUCN SSC Specialist Group, as the official Programme Office for Cycads. This leadership role supports cycad conservation by networking worldwide expertise to help prevent extinctions.

In April 2019, Montgomery was among the first gardens to receive Advanced Conservation Practitioner Accreditation from BGCI. Thorough review of policy, collections, outputs and work helped us to view our conservation contributions in a global context. This important Accreditation fully validates the vital conservation efforts to which Montgomery is so committed, and shows the wider importance of our work with plants.

Plant exploration

Exploration is the critical, vital first step of the botanic garden life cycle – recall the old adage, the garden exists between the expedition and the mulch pile! That theme – on these pages of *BGjournal* – is held in high esteem by Montgomery, and we carry forward Robert and Nell's tradition in bringing new discoveries and treasured plants to horticulture. The plant exploration endeavor impacts all resources and programming here: many research discoveries are made in the field; education and interpretation tell the stories of these wild plants; conservation assessments result from these field inventories; and the collections themselves are the most tangible and treasured outcome of these journeys – further allowing deeper research, immersive education, and contributing directly to conservation!

Central to the success of our explorations are the cherished relationships built with colleagues worldwide, with whom we share the resources, work, outcomes, authorship and credit for these discoveries – exactly as Nell wished! Highlights from recent collaborations include new species of palms and cycads from Belize, Brazil, Bonaire, Colombia, Curacao, Panama and Paraguay, or broader-based long term studies such as an exhaustive monograph of *Syagrus* and a detailed phylogeny of *Zamia* – all of which absolutely depend on getting to where the plants grow wild.

Montgomery's current Strategic Plan is in fact titled Plant Exploration to highlight just how far afield these living treasures call us! Geographic, taxonomic and conservation criteria guide our research and exploration plans for the coming years.

The Plant Exploration Fund

Through the generosity of a visionary donor, a new fund at Montgomery sets our horizons even further. Dr. Lin Lougheed, a Miami Beach author and explorer, was inspired by our collaborative, integrated approach to international botanical research and established the Plant Exploration Fund with a generous matching gift, which inspired broad support from Montgomery's donors.

In just one single year, the Fund has already fielded 12 projects in 8 countries on 4 continents, supported 9 students from 6 universities, described 2 new species, and published 3 scientific studies – a tremendous reach! Plans, permits and schedules currently develop for more exciting work. See further detail about the Plant Exploration Fund at www.montgomerybotanical.org!

New discoveries await!

Montgomery is thrilled to move botany forward through plant exploration, to steward beloved collections, and to tell the great stories of this work. Many new discoveries are yet to be found – with our friends around the world we diligently pursue these green treasures!

M. Patrick Griffith
Montgomery Botanical Center
Coral Gables, Florida, USA

International Plant Exploration in Senegal, 2019; Conservatoire et Jardin Botaniques Genève, Université Cheikh Anta Diop, and Montgomery studied and collected palms (such as this Borassus aethiopum*) in Casamance. Supported by the Plant Exploration Fund, this project brought a new palm species into cultivation:* Calamus deeratus *was known in zero collections according to BGCI PlantSearch, but is now germinating at Montgomery. Keeping the tradition and spirit of our founders, Montgomery took more seeds to Senegalese gardens than it brought home!*

INTERVIEW
TALKING PLANTS

For this issue of *BGjournal*, we caught up with **Colin Clubbe**, Head of the Conservation Science Department at the Royal Botanic Gardens, Kew.

Colin, you presently lead the Conservation Science Department at Kew and have been involved in plant conservation for many years. Can you tell us what first stimulated your interest in plants and in plant conservation?

I was a very lucky child and roamed the countryside with my brother exploring nature. My father was in the RAF and we spent time overseas and across the UK which provided ample opportunities to investigate interesting habitats, whether rice in the tropics or the heathlands of the North Yorkshire moors. I was, and remain, curious about plants and find them endlessly fascinating. My deep interest in conservation really developed whilst living in Trinidad where I was a lecture at the University of the West Indies and working regionally across the Caribbean. An immersive 3.5 years in tropical environments with their amazing plant diversity, plus seeing the day-to-day threats and challenges plants face, helped shape my thinking and made me want to dedicate my life to plant conservation. It also taught me that people must be at the heart of conservation solutions. I still draw on that experience today.

You have travelled widely and have a particular interest in island floras. Do you have a favourite island with respect to plant diversity, and if so, why?

I have been very fortunate to visit some of the world's most amazing and remote islands. But for plant diversity it must be St Helena sitting in the middle of the South Atlantic Ocean. I first visited before the airport opened. The journey there took 3 days on the last working UK mail ship, RMS St Helena, so there was great anticipation and time to read before arrival. The flora has evolved in isolation over millennia and comprises many odd and fascinating species. Nearly 50% of the flora is unique to St Helena and many of them are on the edge of extinction, ravaged by goats and other invasive species introduced when the Portuguese discovered St Helena in 1502. Today, St Helena is a classic conservation case study with many secrets still to reveal.

Continuing on the topic of islands, what do you see as the main role Kew can play in conserving threatened island plants.

We are in the very fortunate position that we have the full conservation tool kit available to support island conservationists. The reference collections and specialists we have mean we can quickly identify material and help shape an action plan. We are keen to share this expertise and can provide facilities for conservationists to spend time learning and sharing at Kew and for our staff to visit countries to review challenges in situ and help develop solutions. We have facilities to store vital germplasm which can be used as part of recovery and restoration programmes, including for seeds and spores at the Millennium Seed Bank and living plants in our various glasshouses or outdoor spaces. Our labs and skilled conservation geneticists can help analyse and advise on species management plans based on sound genetic knowledge. We have a Plant Assessment Unit which can support red listing providing a conservation assessment of species to help planning and prioritisation.

This issue of BGjournal is themed on plant collecting and I am sure you have been involved in many collecting missions. Can you tell us a bit about your most challenging plant collecting trip.

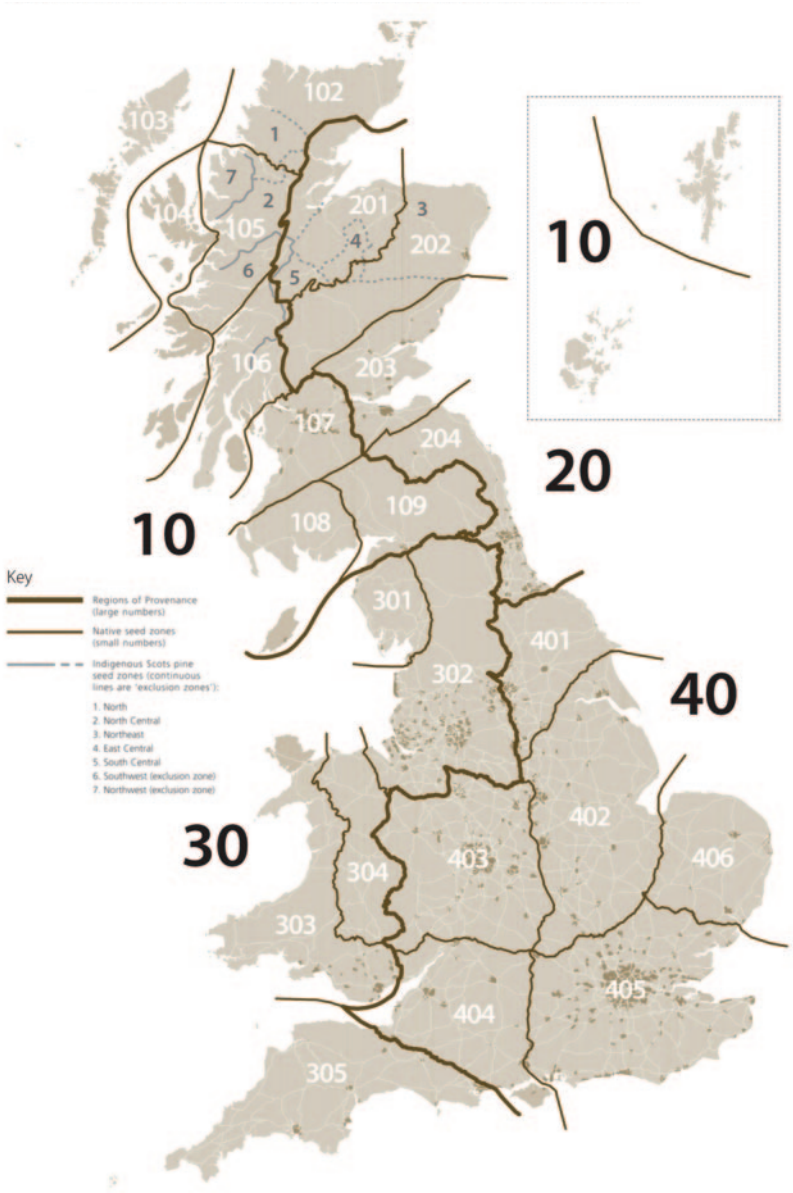
A couple of contrasting situations come to mind. Collecting seeds on a windswept coastal dune system in the Falkland Islands down on my hands and knees trying to find a beautiful tiny cushion plant, *Colobanthus quitensis* (Andean pearlwort) amongst the much larger dominant vegetation. When we eventually found the plants, the real challenge began - trying to find and extract the 0.5mm ripe seeds and get them into a small cloth bag for transport back to the Millennium Seed Bank at Wakehurst. It took an awfully long time to make the seed collection and I don't think my back has ever truly recovered! In contrast, I was led along some incredibly precipitous ledges on sheer cliffs on St Helena to do an assessment of *Wahlenbergia linifolia* (large bellflower) and decide whether we could collect seeds and/or cutting material for the endemic nursery on St Helena. With less than 50 mature individuals of the species left in the wild, we decided it was not advisable to disturb the plants so had to make the return journey empty handed. Sadly, the species is still is a perilous state.

Finally, I know you also have a keen interest in training and capacity building. What do you think we can do to encourage more young people to get involved in plant conservation?

Training and capacity building have always been at the heart of everything I do. My first role at Kew was helping establish and run a series of international summer schools in collaboration with BGCI and we have a huge alumnus network across the world which is a real force for conservation action. It's such a great privilege when I travel for Kew to meet up with these alumni many of whom are in very influential positions and doing great things for plant conservation. Young people are curious, and we need to encourage and feed that curiosity. I recently went back to give a talk in my secondary school and realised that young people don't get exposed to how exciting and important plants are. Sharing experience gained through field work opens a door to the excitement and value of working with plants. We've recently started running an annual Science Festival at Kew and at Wakehurst and it's wonderful to hear the constant questions about plants and enthusiasm of the families attending.

ARTICLES

Author: Alice Hudson



Forestry Commission Seed Zone map of Great Britain. (Forestry Commission)

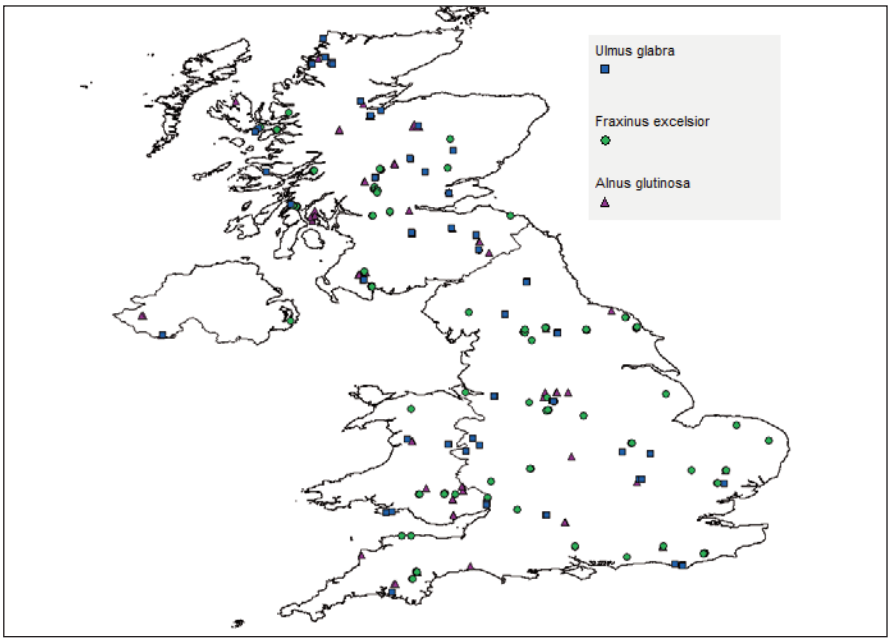
CAPTURING REPRESENTATIVE GENETIC DIVERSITY WITHIN A SEED COLLECTION: LESSONS LEARNT THROUGH THE UK NATIONAL TREE SEED PROJECT

The Convention on Biological Diversity (CBD) recognises the need to conserve biodiversity at three levels: ecosystem, species and genetic. Genetic diversity within a species can underpin the ability to cope with climate change, provide some individuals with resistance to a plant health threat or be the basis of traits potentially useful to humans. Given that seed banks (as a method for *ex situ* conservation) are often seen as a back-up in the event of a worst-case scenario, as well as a complementary method to *in situ* conservation and a potential resource for scientific research and species re-introductions/restoration programmes, it is important that as much of the genetic diversity of the population or species as possible is captured within a seed collection. For example, for re-introduction or restoration purposes, maximising the genetic diversity within seed collections can reduce the risk of inbreeding, genetic bottlenecks or negative founder effects in the new population, and also increase the chance that there will be individuals able to cope with the environmental conditions they may experience.

For many species, the distribution of genetic diversity, be it at a landscape or population scale, is unknown. When genetic studies have been undertaken, it likely only represents one aspect, such as neutral rather than adaptive genetic diversity. In addition, it is not known what genetic traits certain individuals within a population might have that could be useful in 100 years' time, either for us or for the survival of the species. This leaves the question of how to optimally sample across a species range or within a defined geographic area to capture as much genetic diversity as possible without knowing how that diversity is distributed or what potential future traits might be needed?

When the UK National Tree Seed Project (UKNTSP) was established in 2013 thanks to funding from the People's Postcode Lottery, this was one of the main challenges. The project was partially set up in response to the increase in pests and diseases threatening the UK woody flora, such as ash dieback. One of the projects intended outputs was the "*establishment of an accessible, genetically representative, national seed collection of United Kingdom trees and shrubs*". The initial species list for Phase 1 of the project consisted of 61 native woody species (a further 17 were added in 2018), including species such as ash (*Fraxinus excelsior*), holly (*Ilex aquifolium*), field maple (*Acer campestre*) and rowan (*Sorbus aucuparia*).

Within the UK, there have been studies on the neutral genetic diversity for some of the target species such as the limes (*Tilia cordata* and *T. platyphyllos* – Logan *et al*., 2015), ash (*Fraxinus excelsior* – Sutherland *et al*., 2010) and alder (*Alnus glutinosa* – Beatty *et al*., 2015) amongst others, but generally very little is known for most of our target species. For the UKNTSP we used a three-level approach to designing the sampling strategy aimed at capturing as much of the genetic diversity of each species as possible: at national, regional and population levels.



Distribution map of three species collections made through Phase 1 of the project. (RBG Kew)

UK wide sampling

The Forestry Commission has divided Great Britain into 24 seed zones (SZ) based on geoclimatic factors as well as geology and landform boundaries such as watersheds and fault lines, outlined in *Practice Note 8* (Herbert *et al*., 1999). These are factors with the potential to result in different, locally adapted populations, for example by creating gene flow barriers or different conditions for growth. These SZ were originally created to assist with the trade in planting stock to help make sure material used was suited to the area in which it was being planted. We used these SZ as the basis of our multi-provenance sampling strategy, with Northern Ireland as an additional seed zone. Overall, the project aimed to make a seed collection for each of our target species in each of the SZ where a native population existed. In addition, we also made the decision to sample each species above and below 300m above sea level in each SZ where possible. The only exception to this 'one size fits all' approach was Scots pine, *Pinus sylvestris*, for which seven distinct SZ exist based on biochemical analysis (Herbert *et al*., 1999).

Regional provenance

The second aspect of the sampling strategy focused on ensuring that the seeds collected from each SZ were likely to contain any locally adapted traits specific to the conditions within that SZ. In other words, making sure that the maternal trees sampled are autochthonous. We recommended that where possible collections were made within ancient woodland. Within the UK, ancient woodland is classified as woodland that has existed since 1600 AD (1750 AD for Scotland). Whilst this controls for the maternal plant, controlling for the paternal parent is less feasible, particularly given that within the UK a lot of planting has been carried out using non-native stock.


A yew seed collection pre-processing. (RBG Kew)

Population level sampling

The final aspect was to determine how many individual maternal trees to sample from, and how many seeds from each maternal tree within a population are required to have the best chance of capturing as much of the genetic diversity as possible. In many ways this is a trade-off between resource use efficiency, capturing genetic diversity and sustainable seed collecting procedures. In addition, species-specific factors also influence the answer. What is the breeding mechanism of the plant? How is it pollinated? How do the seeds disperse?

There are many different broad suggestions for the optimal number of maternal plants to sample for trees, varying from 15 in Brown and Hardner (2000), 20-30 in the Forestry Commission Guidance Note (Herbert *et al*., 1999), and 50 in Brown and Marshall (1995).

A wych elm collection being organised (RBG Kew)

For the UKNTSP, we recommended sampling 15 maternal plants per population and a total of 10,000 seeds where possible, in line with standard Millennium Seed Bank Partnership (MSBP) collecting guidelines, whilst also accounting for how many trees could realistically be sampled within a day by a team of four collectors. In addition, we specified each maternal tree should ideally be 50m apart (to minimise the chance of collecting from half-siblings and progeny) and that seed collections should be made from all over the crown of a tree to maximise the chance of seeds having different paternal parents. Standard MSBP procedures for sustainable seed collecting also applied (not collecting more than 20% of the available mature seed on the day of collection).

All these guidance steps were outlined during training days with partners and also provided in a manual to partners, available online.

Project achievements

During the first phase of the project over 10 million seeds were collected across the 61 target species from over 7,500 maternal trees. This was achieved with the help of more than 30 partner/ donor organisations and their volunteers, along with continued funding from players of People's Postcode Lottery. For example, for ash (*Fraxinus excelsior*), 60 collections were made totalling over 2 million seeds from 674 maternal trees. For alder (*Alnus glutinosa*), 49 seed collections were made totalling more than 790,000 seeds from 424 maternal plants, and for wych elm (*Ulmus glabra*) 44 collections were made totalling over 290,000 seeds from 338 maternal plants.

Research – testing the theory

The important question is whether the sampling strategy we implemented for the UKNTSP successfully captured the genetic diversity of the species we targeted? Two studies have been done on the UKNTSP collections to try to answer this question. One was a modelling study focusing on ash (Hoban *et al*. 2018) whilst the other was an empirical genetic study focusing on yew (*Taxus baccata* – Garguilo *et al*., 2019).

Hoban *et al*. (2018), using a modelling approach, estimated that approximately 91% of ash alleles present in Great Britain could have been captured in the UKNTSP collections. The only group of alleles estimated to be poorly represented in the UKNTSP collections were locally rare ones, of which only 52% are estimated to have been captured. They only identified one other sampling strategy that could have captured more alleles by making fewer seed collections and that was a random approach. However, from a practical view point a truly random sampling approach would be very difficult to implement at this scale.

Garguilo *et al*. (2019) used microsatellite markers to compare the genetic diversity of the maternal yew populations sampled by the UKNTSP with that of the resulting seed collections. They found that 86% of the alleles found in the maternal populations were also represented in the seed collections, but that there were 20 alleles present in the seed collections not found in the maternal populations (likely from paternal genetic contributions outside of the sampled maternal populations).

Both studies also looked at the question of whether it is better to sample fewer seeds per plant but from more maternal plants or to sample fewer maternal plants but more seeds per plant to maximise the capture of genetic diversity. Both papers found that to increase the genetic diversity within your seed collection, it is preferable to collect from more maternal plants, rather than taking more seeds from the same maternal trees.

UKNTSP tree tag (RBG Kew)

Conclusions

The UKNTSP began in 2013 with little evidence for how best to capture the genetic diversity of our target trees, so developed a practicable 'one size fits all' approach to sampling. Research undertaken since seems to indicate, that at least from a neutral genetic diversity perspective and for the species studied, we have been successful in our goal. The techniques and framework applied when designing the sampling strategy for this project can be applied to other such projects where detailed genetic information is not available.

The UKNTSP collections are available for research and conservation purposes, and hopefully as the collections are used, we will be able to understand in more detail how successful the UKNTSP has been at capturing other aspects of genetic diversity for our target species. For example, sampling considerations increasingly focus on not only capturing as much genetic diversity as possible within a seed collection, but also how many times you capture each allele within the collection (for example, Hoban *et al*., 2018, Hoban, 2019). With all the processes, both natural and human induced, that seed collections go through in terms of processing, banking, testing and end use, this inevitably leads to the loss of some of the genetic diversity within the collections. Having more than one copy of each allele therefore minimises the chance of losing that allele completely from the collection.

Interestingly, in the Hoban *et al*. (2018) analysis of the UKNTSP ash collections, they estimated the sampling effort needed to capture 50 copies of each allele. This was found to be between 150-250 populations, 15-25 trees per population and approximately 1,000 seeds per tree totalling between 2.3 million and 6.3 million seeds. Although we have not sampled as many populations or trees per population, we have collected over 2 million ash seeds.

An ash collection being made (RBG Kew)

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AN ANSWER TO THE COFFEE CHALLENGE: FROM HERBARIUM TO COFFEE GENETIC RESOURCE COLLECTIONS IN THE DEMOCRATIC REPUBLIC OF CONGO

The uncertain future of coffee

About 99% of the world coffee production is based on two species, *Coffea arabica* ('Arabica coffee') and *C. canephora* ('Robusta coffee'). Although the exact impact of global change on coffee production is still under debate (DaMatta *et al*., 2019), severe impact on coffee yield and quality can be expected if no adaptation takes place (Läderach *et al*., 2017; Ovalle-Rivera *et al*., 2015). In general, climatic suitability for Arabica coffee is predicted to decrease in Meso-America and East Africa, while Robusta coffee will compensate this decline by an increase in productivity, particularly in Meso- and South America, Indonesia, and Africa (Magrach and Ghazoul, 2015; Ovalle-Rivera *et al*., 2015). On the other hand, new consumer behavior, new processing technologies and the quest for new culinary experiences will change the requested 'traits' of the raw material, namely the green coffee bean. In this context, wild coffee diversity is an important source of traits for breeding, or can even serve directly as alternative species for the production of coffee. The introduction of Robusta coffee in the early 20th century, in response to the 19th century coffee leaf rust crisis, is a good example of a successful introduction of a new crop species that came directly from the wild.

Above: Nursery in Yangambi
Top: Rehabilitation of the coffee propagation batteries in Yangambi

Quest for wild coffee plants: the Yangambi Biosphere Reserve

Coffee diversity in (Central) Africa: important but overlooked

Coffea arabica is a montane rainforest species from southern Ethiopia, with isolated populations in southern South Sudan and northern Kenya. This tetraploid species is the result of a hybridization event between the ancestors of two diploid species, *C. canephora* and *C. eugenioides*. *C. canephora* has a broad distribution area, occurring in the lowland rainforest of West and Central Africa with some offshoots in the mid to high altitude rainforest in eastern parts of DR Congo and in Uganda. *Coffea eugenioides* plants generally grow at mid to high altitudes in the Great Rift, with some populations also growing in the lowland/mid-altitude rainforest of DR Congo. A recently published genome-based sequencing phylogeny highlighted that the close relatives of both species, and thus of *C. arabica* as well, are species from high altitude areas in East Africa (including eastern DR Congo) and low and mid-altitude areas in West and Central Africa (Hamon *et al*., 2017).

A study by Merot-l'Anthoene *et al*. (2019) illustrates that DR Congo is an important region for *C. canephora* with a high intraspecific diversity. Unfortunately, existing *ex situ* collections of coffee genetic resources (CGRs) poorly cover genetic diversity of the *Coffea* genus, despite the importance of such collections for conservation, research and breeding. Particularly, accessions of *C. canephora* and other coffee species with documented origin from DR Congo are mostly lacking (Bramel *et al*., 2017; Piet Stoffelen, pers. obs.). In addition, the few existing *ex situ* collections of coffee in DR Congo are lacking adequate resources for proper collection management.

The Global Strategy for Conservation of Coffee Genetic Resources and the DR Congo

In 2017, Bramel *et al*., published the *Global Strategy for Conservation of Coffee Genetic Resources*. Their survey of *ex situ* collections reveals that

(1) ca. 37% of the wild coffee species diversity is not represented in *ex situ* collections,
(2) most of the species are only represented by one or a few accessions, and
(3) the genetic resources of DR Congo, an important part of the natural distribution area of *C. canephora* and *C. eugenioides*, are only poorly represented in *ex situ* collections.

New collecting efforts of wild coffee genetic resources (CGRs) are therefore needed, particularly in the DR Congo.

The *Global Strategy* proposes to focus on the eight selected 'key collections', of which only four are situated in countries with wild coffee. In the light of the Convention on Biodiversity, it is important to involve coffee diversity rich countries in an international framework of coffee research. Given the importance of the coffee genetic resources (CGRs) of DR Congo, Cameroon and Tanzania, we propose to extend the list of key collections of CGRs to these countries.

In the same report, six priority actions to secure conservation and sustainable use of CGRs are formulated[1]. As these priority actions depend on structural international funding and multilateral agreements between institutions and countries, we do not expect that these priorities to be implemented soon. Therefore, Meise Botanic Garden (Meise BG) decided not to wait for this international framework and took the initiative to rehabilitate existing CGRs collections, to locate new CGRs in the wild and to enrich local CGRs collections in DR Congo.

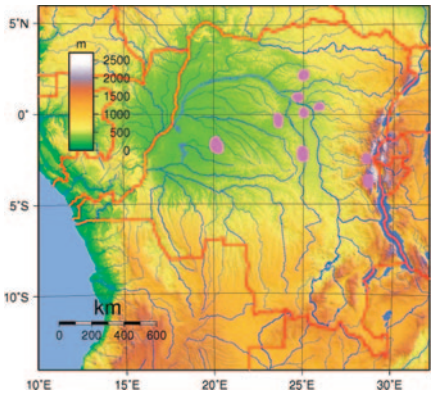
Coffee: from the herbarium to the field

Meise BG has been studying the wild diversity of *Coffea* in Central and West Africa for almost 25 years and has become a reference for wild coffee diversity research in the region (Stoffelen, 1998; Davis *et al*., 2006). This research has mainly focused on exhaustive studies of herbarium specimens maintained in herbaria worldwide. Distribution of wild coffee species in Central and West Africa was revealed and eight new species were described (Stoffelen *et al*., 1996, 1997a & b; 1998; 2008; 2009; Sonké *et al*., 2004). In addition, collaborations with other research groups on coffee were established which resulted in contributions to (phylo)genetic and chemical research (Noirot *et al*., 2016; Hamon *et al*., 2017; Souard *et al*., 2018; Merot-l'Anthoene *et al*., 2019) .

Coffea dactylifera: *an enigmatic species recently rediscovered in Bas Uele*

New undescribed coffee species discovered in the Biosphere Reserve Yangambi

[1]1. Stable funding for collections; 2. Upgraded facilities and capacity; 3. ABS for germplasm exchange; 4. Partnerships and information sharing; 5. Safety duplication; 6. Complementary *in situ* conservation.



Localities where wild coffee trees were observed during the last decade

From 2009 onwards, a network of local botanists has been established and trained by Meise BG staff in DR Congo. During their fieldwork and inventories in Congo, these botanists have located multiple wild coffee populations in the country. Recently, an additional new coffee species was discovered as well as several other poorly known endemic Congolese *Coffea* species (*C. dactylifera, C. kivuensis, C. lebruniana* and *C. aff. mayumbensis*).

Towards documented and well-organized Coffee Germplasm Collections in the D.R. Congo

Over the last decade Meise BG expanded its expertise in multiple domains such as:

(1) the rehabilitation of botanic gardens and herbaria in DR Congo;
(2) *Coffea* diversity research and collection; and
(3) biodiversity data management.

Given this expertise, the network of local botanists, the importance of the CGRs in DR Congo and our aim to contribute to the Aichi Target 13[2], Meise BG initiated two projects on the *ex situ* conservation of CGRs in DR Congo. Although both projects have the same overall goal, their starting point was different, aiming to tackle coffee related issues in the country from a different angle. Whereas the 'Yangambi project' is starting from an existing CGRs collection, the 'Kivu project' is focusing on the conservation and evaluation of one endemic coffee species not present in any *ex situ* collection.

The Yangambi project

The former National Institute for Agronomic Study of the Belgian Congo (INEAC) in Yangambi, nowadays *Institut National d'Études et de Recherches Agronomiques* (INERA), was one of the leading research stations for tropical agronomy in the mid twentieth century, and coffee research was one of their main research topics. However, this once very rich collection did not escape the many difficulties the country has gone through during the last decades and was unfortunately decimated due to lack of appropriate care and funding.

In 2017, Meise BG started to assist and train INERA staff to evaluate, document and rehabilitate the remaining coffee collection of INERA Yangambi. Two years later, and the CGRs accessions are fully labelled, with all passport data being encoded in a database. Additionally, the coffee collections of INERA have been enriched with 'new' genetic diversity collected in the wild and in backyard gardens in and around Yangambi.

Coffee cherries in Nord Kivu, DR Congo. (Adelard Palata)

[2]The genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity.

Small nursery in Lwiro: first cuttings of Coffea kivuensis *in an* ex-situ *collection*

A first preliminary evaluation of the genetic diversity of the Yangambi collections has also been made (Vanden Abeele *et al*., in prep.). This study revealed that backyard coffee plants almost always come from the INERA collections and that the local wild diversity of Robusta coffee, sometimes separated by just a few hundred meters from the backyards, was not represented in the INERA collection nor cultivated locally.

In 2019, the project was extended with the aim of enriching the *ex situ* collections with new genetic resources from different regions in the DR Congo (Yoko, Kahuzi-Biega, Salonga, Lomani, Itombwe etc.). This will allow us to collect important new CGRs of Robusta coffee and endemic coffee species only known from a few historic herbarium specimens. More detailed analyses of pollination, seed-dispersal and introgression of *Coffea canephora* in the Yangambi and Salonga regions are underway thanks to a recently financed FWO[3] project that brings together research teams from Meise BG, the Royal Museum for Central Africa (RMCA), K.U.Leuven, ILVO[4] and the University of Kinsangani (UNIKIS). This project will provide more insight into the geneflow and population structure of wild coffee, which will enable us to further optimize coffee sampling efforts in the wild. The genetic and (bio)chemical diversity of Robusta coffee will be assessed and evaluated, and the creation of a well-documented collection of CGRs for DR Congo, that is accessible for the international research community, will be the ultimate aim.

The Kivu Coffee Project

In a second project, we are targeting wild coffee species growing in the mid- and high-altitude rainforests of the Kivu region, with a special focus on the endemic species *C. kivuensis*. Although first collected in 1932, this species was only poorly documented and not present in any CGRs collection. In fact, the species was only known from historic herbarium specimens. As the species is closely related to *C. eugenioides*, one of the two parent species of the allotetraploid *C. arabica*, this species could be of particular interest for coffee breeding or even as a new crop species. Recently, this species was rediscovered by Congolese botanists, Ithe Mwanga Mwanga, Céphas Masumbuko and Chantal Shalukoma, during their field work near Mount Kahuzi (Shalukoma *et al*., 2015). In 2018, we started to study the natural habitat of the species, while cuttings and seeds of this species were brought into an *ex situ* collection in order to make them available for research, testing and breeding. The organoleptic and the agronomic characteristics will be evaluated as well.

Conclusion

These two cases illustrate that in a diversity rich country facing instability, weak implementation of ABS regulations, insufficient infrastructure and very limited resources, genetic resources can be conserved and local capacity can be built up if the different stakeholders collaborate on the basis of sound scientific knowledge, longstanding relations and a good network. As such, the training of dedicated and enthusiastic local partners is a key to success.

The discussed projects generate a strong baseline for future fundamental and applied research on coffee by collecting and conserving new genetic diversity of coffee in the *ex situ* collections, by generating new data on wild coffee diversity, by training local technical and scientific staff and by exchanging knowledge on coffee. In the long term, the projects can also illustrate the importance of protected areas as a source of Crop Wild Relatives and help to guarantee income for millions of households worldwide. However, long term sustainable funding for *ex situ* and *in situ* conservation is a crucial key to success.

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Nursery in Yangambi

[3]FWO-Flanders= Fonds wetenschappelijk onderzoek
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EYES IN THE SKY: **DRONES PROVING THEIR VALUE IN PLANT CONSERVATION**

The National Tropical Botanical Garden in Hawaii is implementing new technologies to support its important plant conservation work

Introduction:

Drone; Unmanned Aerial Vehicle (UAV); Small Unmanned Aircraft System (sUAS). Whatever you may decide to call them, they have an undeniable presence. While there are many instances of drones causing problems, this article is aimed at highlighting the positive effects the technology can have in plant conservation. As with many other emerging technologies, drone technology is progressing at a startling rate. This has led to drones with increased functionality at a reduced cost. These changes are creating excellent opportunities for both small and large organizations to apply UAV tools to complex conservation problems. The National Tropical Botanical Garden (NTBG) has been doing extensive testing and development to implement these new technologies.

Discovery: *Hibiscadelpus woodii*

Originally discovered in 1991 by NTBG Research Biologist Ken Wood, the amazing *Hibiscadelphus woodii* (Malvacae) was known from only four individuals. The species was described by Dr. David Lorence and Dr. Warren Wagner in 1995 and given the name *Hibiscadelphus woodii*, in honor of its discoverer. Over the next two decades, scientists at NTBG would give their all to protect this species.

Kalalau Valley is known to be the most floristically diverse valley in the entire Hawaiian archipelago, and the *H. woodii's* extreme habitat along the rim meant it was only accessible via rappelling on ropes. Three of the individuals were killed in 1998 when the highly-eroded landscape around them came tumbling down. The lone remaining plant survived until it was found deceased in 2011. The species was lost. In fact, the entire genus was almost extinct, with only one of seven known *Hibiscadelphus* still extant.

In early 2018, NTBG submitted a proposal to the Mohamed bin Zayed Species Conservation Fund specifically aimed at finding the "thought-to-be-extinct" *Hibiscadelphus woodii*. This species was selected because the steep habitat had been nearly impossible to survey and drones were unlocking these hard to reach areas. Thankfully the application was accepted, and with the new funding we expanded our drone toolkit.

Above: Using drones for inventory - Wilkesia hobdyi *(Ben Nyberg)*
Top: Drones for discovery – looking for Hibiscadelphus *in the Kalalau valley (Ben Nyberg)*

Field surveys commenced during the extremely wet summer of 2018, which led to many challenges. Misty and rainy conditions severely limited our survey days and damaged the equipment. In January of 2019, the weather started improving and our work resumed. A steep, long downhill hike leads to the very edge of the Kalalau cliffs where we launch the drone. From that location, the quadcopter descended an additional 250-350 meters. One drone battery provides approximately 25 minutes of flight, which allows collection of 40-50 photographs. After multiple flights, we had checked the main area of interest with no apparent *H. woodii*.

Binoculars aided in the selection of a secondary survey area, one valley over and much further down the surface. Indicator species, such as the silvery *Nototrichium sandwicense* hinted at an intact native cliff system. The drone descended into position but windy, misty conditions made plant identification difficult. I collected many photos hoping to catch a glimpse of the small yellow flower.

Post-processing of the imagery was underway back in the computer lab at NTBG's Botanical Research Center. As I slowly checked through the images without a sighting, disappointment was setting in. The process is extremely time consuming and tedious, but occasionally there are sparks of excitement. That spark came when I saw an interesting plant in the lower right corner of photo #228. I had never seen the *Hibiscadelphus* in person, so I quickly contacted Ken to ask for his help in identification.

We examined herbarium specimens and historic photos from the original discovery. When we revisited the drone photo on my computer, the mood soon became joyous. We had rediscovered *Hibiscadelphus woodii*!

Excitement and energy gave way to focus and determination. Additional surveys were needed to confirm the identification. Three consecutive days were rained out, but the on fourth day, the drone assisted in relocating the individual we had originally sighted plus an additional two individuals. High-resolution video was captured to assess potential access routes, but the cliffs are simply too sheer and dangerous for humans to reach the plants. Future work is planned with the goal of finding additional populations in more accessible locations so the plant material can be collected and brought into *ex situ* conservation.

Discovery: Limahuli Valley

Due to difficulty with regulations and permitting, our initial drone testing began in NTBG's Limahuli Garden and Preserve. This valley is over 1,000 acres and is managed almost exclusively by our staff. It provided a location on private property with limited air traffic and wide variety of rare plants. While Kalalau may be the most-biodiverse valley in the state, Limahuli is a close second. A series of vertical rock spires are a distinguishing feature of the area, that until recently had never been surveyed. As the surveys commenced, we immediately started uncovering rare plant populations. The Plant Extinction Prevention Program (PEPP) manages species with fewer than 50 individuals remaining and drones aided in the discovery of three species they work on. We were able to identify and map 75 *Plantago princeps* var *anomala* (Plantaginaceae, previously known from only 25 individuals) and over 200 *Euphorbia eleanoriae* (Euphorbiaceae, previously known from 40 individuals). These Kauai endemics were both new records for the valley and the findings significantly expanded their known habitat.

Hibiscadelphus woodii *(Ken Wood)*

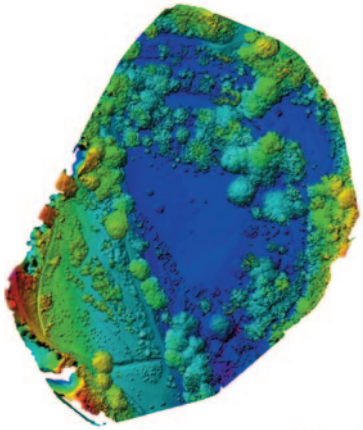
In the Garden- imagery and mapping:

Botanical gardens may vary in size or location, but almost all gardens rely on accurate and up-to-date maps. A common and extremely valuable application of remote flying aircrafts is the high-resolution on-demand imagery they produce. Prior to drones, comparable data sets would be expensive and time-consuming to create. This new technology can provide hundreds of acres of imagery and digital elevation models in a matter of hours. NTBG has found the output products helpful in mapping living collections, surveying damage from natural disasters, analysis of terrain for garden expansion, digitizing garden features and producing high quality paper maps.

Inventory and monitoring: *Wilkesia hobdyi*

Wilkesia hobdyi (Asteraceae) offers another intriguing case for the use of drones. This species grows in dry coastal cliff habitat and is distinctive in its size and color. The IUCN Red List for *W. hobdyi* estimated a total population of 750-809 individuals, which placed it in the Critically Endangered category. A concerted effort has been made to visit each known population and early results have been staggering. In-depth survey and counting has revealed at least 6,000 individuals. New populations have been documented in three locations, two of which are areas where it has not been found before; directly ocean-facing and on dry south facing slopes.

Imagery



Digital Elevation Model

Left: Ken Wood surveying with binoculars (Ben Nyberg)
Below left: Drones for discovery – Limahuli Valley (Ben Nyberg)

The Future:

NTBG is prioritizing the further development of drone technology to create a comprehensive plant conservation toolkit.

- Ongoing research with the University of Sherbrooke is aimed at customizing sampling mechanisms to remotely collect plant material such as seeds or cuttings. This setup will allow us to reach unreachable plants.
- AI and machine-learning have the potential to significantly reduce the time spent in the lab. post-processing photographic data. With proper training, these complex software solutions can identify individual plants and tabulate the information.
- Drones rely on a solid satellite lock to maintain their spatial awareness. Many locations that we survey have limited GPS reception, meaning the flights can be difficult, inaccurate and dangerous. There is work underway to find navigation systems that will function in these challenging environments.

While drones are currently proving to be effective tools, evolution of the technology has the potential to provide ground-breaking results for botanical conservation.

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As part of these counts we have employed a new system in which a pilot and observer (with spotting scope) position themselves across the valley from the plants. With an improved vantage point, the observer directs the UAV into areas where plants occur to collect photos and GPS points. Once the photos are post-processed and mapped, the data can be used to guide seed collection of the species. Specific seed-bearing plants are selected and tie-in locations identified from the photos. The collector can then rappel directly down to the individual, effectively taking all guesswork out of the equation, while increasing both efficiency and safety.

Inventory and monitoring: *Pritchardia flynnii*

Drones allow botanists to cover large areas in limited time. A great example of this is our surveys for *Pritchardia flynnii* (Arecaceae, Loulu palm). *Pritchardia* is a genus of fan palms endemic to tropical Pacific islands with an extremely diverse group in the Hawaiian Islands. Due to its distinct look and size in the canopy, it makes a great candidate for mapping with drones. I highlight this species to illustrate the expansive area that can be surveyed in just one day. On August 8, 2018, NTBG staff were able to cover two square kilometers (500 acres) of steep and challenging terrain while mapping 158 *Pritchardia flynnii* trees. All photos that are collected include high-resolution GPS points allowing for mapping and navigation to specific individuals. Traditional field survey would have taken much longer with less complete results.

Drones for inventory - Pritchardia flynnii *(Ben Nyberg)*

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CONSERVING ENDEMIC SPECIES IN MALAYSIA

The Tropical Rainforest Conservation and Research Centre (TRCRC) is partnering with YTL Cement to protect *Vatica kanthanensis*

Driving north from the capital of Kuala Lumpur, visitors are likely to encounter the numerous picturesque limestone hills that are iconic in towns like Ipoh in the state of Perak. Adjacent to the Titiwangsa Range that divides peninsular Malaysia in half, many small limestone hills with steep flanks stand out from the flat surrounding plains. These hills range from tens to hundreds of meters in height, and are littered with caves and caverns, some of which are occupied by Buddhist or Hindu temples. Tourists also frequent these sites to see the natural formations of stalactites and stalagmites, with the more intrepid travellers spelunking in some of the longer caves.

There are approximately 26,000 hectares of limestone forest areas in Peninsular Malaysia and these are extremely rich in flora. They occupy only 0.4% of the country's land, yet harbour 1,216 (14%) of Peninsular Malaysia's 8,500 plant species . These biodiversity hotspots are highly vulnerable as they are being used for one of the raw materials for the cement industry (Choong *et al*., 2014).

Discovering *Vatica kanthanensis*

In 2013 researchers from the Forest Research Institute Malaysia (FRIM) made an exciting new discovery when they found *Vatica kanthanensis*, a plant from the dipterocarp family on Gunung Kanthan, a limestone hill just north of Chemor, Perak (Tan *et al*., 2014). An additional survey in 2014 showed fewer than 50 adult trees in the wild in the same area, but another survey in 2016 at Gunung Kuang, a nearby limestone hill, resulted in the identification of at least 30 individuals through visual counting.

Vatica kanthanensis is endemic to Kanthan, and is assessed as critically endangered (CR) on the IUCN Red List. Gunung Kanthan is considered a high conservation value area because of the presence of rare and endangered plant and animal species, its cave systems and fossils. The site has high levels of endemism from various taxonomic groups of plants which are uniquely adapted to the limestone habitat. Some examples of these endemic species are *Gymnostachyum kanthanese, Meiogyne kanthanensis*, in addition to *Vatica kanthanensis*. Cement quarrying has been in operation in the area since the 1960's.

Above: Setting up YTL Cement's conservation nursery (TRCRC)
Top: Vatica kanthanensis *seedlings in a seedplot at YTL Cement's conservation site (TRCRC)*

Aerial view of YTL Cement's quarry at Gunung Kanthan, Perak (TRCRC)

Since 2017, the Tropical Rainforest Conservation and Research Centre (TRCRC), a Malaysian NGO, in collaboration with the site operator, YTL Cement have helped enact a combination of *in situ* and *ex situ* conservation plans and will assist in conserving this species and its habitat.

TRCRC and Botanic Gardens Conservation International (BGCI) worked together with The Global Tree Assessment to train the TRCRC research team with expertise in tree conservation. Using information gathered on-site and from the scientific literature, species assessments were made under the IUCN Red List Criteria. TRCRC listed *Vatica kanthanensis* as Critically Endangered due to its small extent of occupancy and low population size.

Restoring Gunung Kanthan

The Kanthan quarry is a heavily modified ecosystem, and the restoration and rehabilitation of the degraded sites within the quarry will be based on a nearby intact reference ecosystem. The goal is to establish a long-term plan to create a self-sustainable system that resembles the reference forest and to promote natural regeneration. The restoration process will face challenges such as collecting species from the unpredictable and hazardous karst forest and establishing vegetation on barren rock. In addition, it is expected to be cost-intensive and will require multidisciplinary collaborations.

Limestone forest areas are biodiversity hotpots which harbour 14% of Peninsular Malaysia's plant species (TRCRC)

Collaboration for conservation

In close collaboration with YTL Cement, TRCRC was tasked to conduct an assessment of the area and help develop a strategy to conserve the threatened species. TRCRC is dedicated to the conservation and preservation of tropical rainforest plant species and to helping enhance efforts to cultivate and maintain stable forest ecosystems.

TRCRC developed two *ex situ* conservation programmes to collect, germinate, and propagate *Vatica kanthanensis* for eventual reintroduction into its natural habitat. YTL Cement's conservation programme is focused on species that have been collected on Gunung Kanthan and are now stored in a conservation nursery within the compound of the quarry, to create planting material to support the long-term restoration and rehabilitation of the site once the limestone quarrying is completed.

Ex-situ conservation of slightly over 500 *Vatica kanthanensis* seedlings collected from two mother trees is also being carried out at TRCRC's Tropical Rainforest Living Collection (TRLC) at Banun, Perak. The nursery team follows protocols established by TRCRC to ensure germination and survival of these precious trees. TRLC Banun is also home to other ecologically important rainforest species and is tied closely to the state of Perak's conservation goals. The prime directive of TRLC Banun is to conserve a representation of the species and the genetic diversity of trees from various forest reserves in Perak.

The team at TRLC Banun transplanting Vatica kanthanensis *into polybags (TRCRC)*

Eventually, TRLC Banun will be able to be the source of restoration for native Perak Dipterocarpaceae trees. This effort is aligned with Malaysia's Central Forest Spine (CFS) initiative; restoring connectivity between existing forest fragments to conserve biodiversity.

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COLLABORATION ACROSS CONTINENTS AND CULTURES

The North America-China Plant Exploration Consortium

For nearly 30 years, the North America-China Plant Exploration Consortium (NACPEC) has worked to foster partnerships and undertake plant exploration to study and conserve the flora of China. Although NACPEC membership has grown slightly over the decades and the individuals involved have transitioned, the goals of this unique collaboration remain consistent: to establish relationships and information sharing among North American and Chinese gardens and the representative horticulturists and botanists, increase cultural awareness, and ultimately, provide a framework for plant research, conservation, and introduction.

On the heels of successful collaborations in South Korea during the 1980s, NACPEC started in the early 1990s as a group of American arboreta planning for extensive plant exploration across northern and central China. In 1991, an initial feasibility expedition included a series of meetings and introductory events at several Chinese botanical and forestry institutions that then led to the formation of the Consortium. Using climate information, the Consortium developed a plan to explore across a broad arc of China, ranging from where the Qinling mountain range forms the continental divide separating north from south, to the mountain ranges west of Beijing, and to the far north and northeast provinces bordering Russia and North Korea. Including the initial 1991 trip, NACPEC has conducted a total of 18 expeditions to China that represent a concerted effort to explore and investigate systematically varying climatic areas, habitats, and ecosystems across a wide geographic range (see Table 1 & Figure 1).

Above: (Left to Right) Kevin Conrad, Riming Hao, Peter Del Tredici, a Chinese official, Yi Lu, and Cailaing Mao on the 1994 NACPEC expedition in Hubei, China. The assigned official helped insure the safe travel of the group (Peter Del Tredici)
Top: Sunrise in Xia Ban Xi (Cloud Sea), Shaanxi, China at 9,000 feet (2,743 meters), the highest point reached on the 2008 NACPEC expedition (Anthony Aiello)

NACPEC goals

Since its inception, NACPEC goals have been to:

- Develop long-term collaborative relationships with the international botanical community
- Increase the understanding of botanical diversity throughout China
- Conserve rare and threatened species
- Evaluate and introduce appropriate new species into cultivation
- Broaden the genetic representation of species already in cultivation and potential for improvement in horticultural traits such as cold hardiness and heat tolerance, plant vigor, urban adaptability, insect and disease resistance, and novel forms

Of utmost importance to NACPEC has been collaboration in collecting, documenting, and growing plants across member institutions and Chinese partners. This collaboration, if not unique, is certainly rare. In achieving these goals, NACPEC has strengthened the relationships among its members and, more importantly, built bridges and lasting relationships with our Chinese colleagues. The group of collaborating North American gardens was consistent through the 1990s and early 2000s, with three members added in recent years, including the Consortium's first official Chinese institution in 2019. Today, NACPEC consists of these eleven organizations:

- The Arnold Arboretum of Harvard University, Boston, MA
- Beijing Botanical Garden, China
- Chicago Botanic Garden, Glencoe, IL
- The Dawes Arboretum, Newark, OH
- The Holden Arboretum, Kirtland, OH
- Longwood Gardens, Kennett Square, PA
- The Morris Arboretum of the University of Pennsylvania, Philadelphia, PA
- The Morton Arboretum, Lisle IL
- U.S. National Arboretum, Washington, D.C.
- USDA-ARS Germplasm Repository, Beltsville, MD
- University of British Columbia Botanical Garden, Vancouver, BC

Collecting trips

Although very comparable in land mass, China has a much greater vascular plant diversity (31,000 species) than the United States (17,000 species). With NACPEC institutions located within USDA Plant Hardiness Zones 5 (where average annual extreme minimum temperatures range from -20 to -10°F, or -28.9 to -23.3°C) through 7, (0 to 10°F, or-17.8 to -12.2°C), the locality focus has been at the intersection of maximizing species diversity and potential for plant hardiness. As can be seen on the expedition map (Figure 1), this has led to trips to northeast China (Heilongjiang, Jilin, Beijing, Hebei, and Shanxi provinces) and the Qinling Mountains of central China (Hubei, Shaanxi, and Gansu provinces), with forays into south-central China (including northern Sichuan province and Chongqing municipality).

Table 1: List of NACPEC expeditions, abbreviations, participants.

Trip Name	Abbreviation	Participants
1991 Initial Feasibility Expedition (Beijing, Heilongjiang, Jilin, Shaanxi, Jiangsu)	LL	Bristol, Peter; Holden Arboretum Lee, Lawrence; U.S. National Arboretum Meyer, Paul; Morris Arboretum
1993 Expedition to Heilongjiang	HLJ	Bachtell, Kris; Morton Arboretum Bristol, Peter; Holden Arboretum Meyer, Paul; Morris Arboretum Gao, Shi Xin; Heilongjiang Academy of Forestry Jin, Tae Shan; Heilongjiang Academy of Forestry Liu, Jun; Heilongjiang Academy of Forestry
1994 Expedition to Beijing	BJG	Bachtell, Kris; ; Morton Arboretum Lewandowski, Rick; Morris Arboretum Garvey, Edward; U.S. National Arboretum Tubesing, Charles; Holden Arboretum Liu Mingwang; Beijing Botanical Garden IBCAS
1994 Expedition to Hubei	WD	Conrad, Kevin; U.S. National Arboretum Del Tredici, Peter; Arnold Arboretum Meyer, Paul W.; Morris Arboretum Thomas, R. William; Longwood Gardens Hao, Riming; Nanjing Botanic Garden Mao, Cailaing; Nanjing Botanic Garden
1995 Expedition to Shaanxi	SHX	Garvey, Edward; U.S. National Arboretum Lewandowski, Rick; Morris Arboretum Cui, Tiecheng; Xi'an Botanic Garden
1996 Expedition to Shaanxi & Gansu (Qinling Mountains)	QLG	Ault, James; Longwood Gardens Conrad, Kevin; U.S. National Arboretum Lewandowski, Rick; Morris Arboretum Kim, Kunso; Norfolk Botanical Gardens Cui, Tiecheng; Xi'an Botanic Garden
1997 Expedition to Changbai Shan (Jilin)	NACPEC97 (CBS)	Bachtell, Kris; Morton Arboretum Del Tredici, Peter; Arnold Arboretum Lynch, Jeffrey; Longwood Gardens Meyer, Paul W.; Morris Arboretum Tubesing, Charles; Holden Arboretum Wang Xian Li; Shenyang Institute of Applied Ecology Cao Wei; Shenyang Institute of Applied Ecology Sheng Ning; Nanjing Botanical Garden
1998 Expedition to E. & SE. China (Anhui, Guangxi, Jiangxi)	NACPEC98 (TS98)	Lewandowski, Rick; Morris Arboretum Garvey, Edward; U.S. National Arboretum Li, Weilin; Nanjing Botanical Garden Wang, Qing; Nanjing Botanical Garden
1999 Expedition to Sichuan	NACPEC99 (TS99)	Belt, Shawn; U.S. National Arboretum Garvey, Edward; U.S. National Arboretum Stites, Jerry; Longwood Gardens Wang, Qing; Nanjing Botanical Garden
2002 Expedition to Shanxi	NACPEC02	Aiello, Anthony; Morris Arboretum Bachtell, Kris; Morton Arboretum Bordelon, Carole; U.S. National Arboretum Bristol, Peter; Holden Arboretum (Chicago Botanic Garden) Tang, Yudan; Beijing Botanical Garden IBCAS
2005 Expedition to Gansu	NACPEC05	Aiello, Anthony; Morris Arboretum Bachtell, Kris; Morton Arboretum Scanlon, Martin; U.S. National Arboretum Wang, Kang; Beijing Botanical Garden Sun, Xue-gang; Forestry College of Gansu Agricultural University
2008 Expedition to Shaanxi	NACPEC08	Aiello, Anthony; Morris Arboretum Bachtell, Kris; Morton Arboretum Carley, Chris; U.S. National Arboretum Wang, Kang; Beijing Botanical Garden
2010 Expedition to Shaanxi, Hebei, Beijing	NACPEC10	Aiello, Anthony; Morris Arboretum Bachtell, Kris; Morton Arboretum Dosmann, Michael; Arnold Arboretum Wang, Kang; Beijing Botanical Garden
2011 Expedition to Shaanxi & Gansu	NACPEC11	Meyer, Paul; Morris Arboretum Kim, Kunso; Morton Arboretum Dosmann, Michael; Arnold Arboretum Wang, Kang; Beijing Botanical Garden
2015 China *Acer griseum* Expedition	NACPEC15	Aiello, Anthony; Morris Arboretum Bachtell, Kris; Morton Arboretum Dosmann, Michael; Arnold Arboretum Wang, Kang; Beijing Botanical Garden
2016 Expedition to Sichuan	NACPEC16	Aiello, Anthony; Morris Arboretum Dosmann, Michael; Arnold Arboretum Gao, Yundong; Chengdu Institute of Biology Tian, Changbao; Huanglong Nature Preserve Wang, Kang; Beijing Botanical Garden
2017 Expedition to Sichuan	NACPEC17	Dosmann, Michael; Arnold Arboretum Gapinski, Andrew; Arnold Arboretum Li Huaicheng; Chengdu Institute of Biology Wang, Kang; Beijing Botanical Garden
2018 Expedition to Hubei	NACPEC18	Gapinski, Andrew; Arnold Arboretum Lobdell, Matt; Morton Arboretum Quan, Jian; Beijing Botanical Garden Wang, Kang; Beijing Botanical Garden Zale, Peter; Longwood Gardens Zhang, Daigui; Jishou University, Hunan

Field guide, Mr. Diao, holding collection of Pyrus ussuriensis*, Ussurian pear, obtained on the 1993 NACPEC expedition in Heilongjiang, China (Kris Bachtell)*

Areas not targeted are the southernmost tier of provinces, such as southern Sichuan, Yunnan, Guangxi, and Guizhou, because of the inherent lack of cold-hardiness among plants with restricted distributions to these areas. (Exceptions were the 1998 and 1999 expeditions that were specifically targeting southern populations of *Tsuga chinensis*). Expeditions have also targeted areas not frequented by other modern plant collectors, such as Beijing, Hebei, and Shanxi. Although lower in plant diversity, these areas have yielded collections well-suited to the climates of the member gardens.

Through the 1990s and early 2000s, participation in expeditions rotated among the North American organizations working in conjunction with a number of Chinese collaborators, including the Heilongjiang Academy of Forestry (1993), Beijing Botanical Garden, Institute of Botany, Chinese Academy of Sciences (1994 & 2002), Nanjing Botanical Garden (1994, 1997, 1998, & 1999), and Xi'an Botanic Garden (1995 & 1996). Since 2005, NACPEC has collaborated closely with the Beijing Botanical Garden on numerous expeditions and other collaborative studies. This relationship continues today alongside other Chinese partners such as Chengdu Institute of Biology (2016 & 2017) and the Kunming Institute of Botany (2018).

While the member organizations have remained relatively constant, the individuals from those institutions have changed over time. While Paul Meyer and Rick Lewandowski represented the Morris Arboretum on many NACPEC trips in the 1990s, for example, Tony Aiello has been the primary representative since 2002. Similarly, in the last decade, Michael Dosmann and Andrew Gapinski have replaced Peter Del Tredici as the Arnold Arboretum's primary NACPEC representatives.

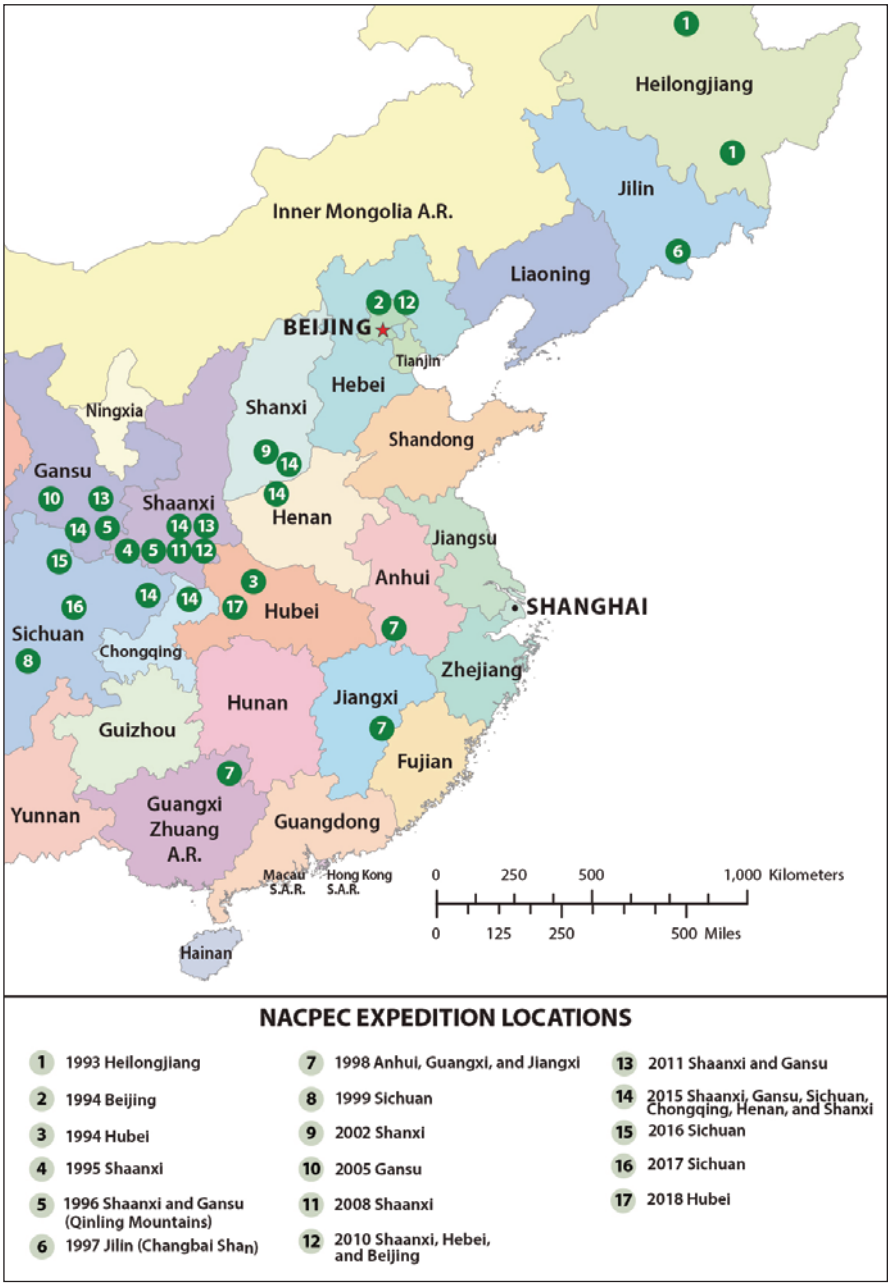


Figure 1: Map of NACPEC expedition locations

*Chinese hemlock (*Tsuga chinensis*) observed in its native habitat on the 2005 NACPEC expedition to Gansu, China (Kris Bachtell)*

Kevin Conrad reviews NACPEC accessions held in long-term seed storage at the USDA-ARS Woody Landscape Plant Germplasm Repository of the U.S. National Arboretum. The facility contains seed from 96 of the Consortium's collections, representing a vital component in conserving this genetic resource. (Young Choe)

The specific collecting goals of each trip have varied. Many expeditions worked from a large list of target taxa and included collections of a wide diversity of plants opportunistically encountered, while other trips focused on pointed taxa (e.g. *Tsuga* in 1998 and 1999, *Fraxinus* in 2008 and 2010, and *Acer griseum* in 2015). With greater knowledge of the flora of China in hand and limited space in living collections, the work of NACPEC today uses gap analyses of current holdings and conservation assessments to maximize limited resources for future, more targeted, collection development.

Building knowledge and collections

Not surprisingly, 18 expeditions over 28 years have resulted in significant additions to NACPEC member herbaria and living collections, as well as a wealth of knowledge about the characteristics and natural growing conditions of Chinese plants. In total, there have been 1,687 field collections, with 1,561 obtained as living material (primarily seed), 18 as dried tissue for DNA analysis, and the remainder as herbarium specimens only. Of the living collections, 835 (53%) are represented by specimens growing at member institutions (not including 2018 collections still in member production facilities), while 4,975 herbarium specimens, representing a significant permanent record of the taxa collected and their associated species, exist in herbaria in China and the U.S. After each trip, a top priority is to place a complete set of herbarium vouchers at the U.S. National Arboretum, and when possible, to deposit a quantity of seed from select collections at the USDA-ARS Woody Landscape Plant Germplasm Repository in Beltsville, MD for long-term storage. Each year, the member institutions contribute to an annual inventory accounting for the status of these propagule and herbaria collections.

Furthermore, participants in NACPEC collection trips summarize their expeditions in trip reports housed in the libraries of the participating institutions. These generally consist of two parts: the trip journal and field notes. The journal recounts the daily activities of the trip and sets the context for the various plant collections, while the detailed field notes provide extensive information on all of the collections obtained during an expedition. These trip accounts, alongside herbarium vouchers, provide a resource for current and future exploration efforts.

Among these many collections, some case studies stand out for significant contributions to research or for their horticultural merit. In the early 1990s American horticulturists and botanists became aware that Chinese hemlock (*Tsuga chinensis*) was resistant to hemlock wooly adelgid (*Adelges tsugae*), a pest introduced to North America from Asia. In response to the limited number of collections of Chinese hemlock in the U.S., NACPEC began a concerted effort in the mid-1990s to make collections throughout Chinese hemlock's native range in China.

Acer griseum *scions were collected from two populations located in Chengkou County, Chongqing Municipality and Xixia County, Henan Province (Kang Wang)*

These collections have ultimately led to an infusion of new genetic material (19 collections held at member institutions as of 2018) that allows partner gardens to evaluate trees in a range of climactic conditions, while also providing the basis for a breeding program at the U.S. National Arboretum.

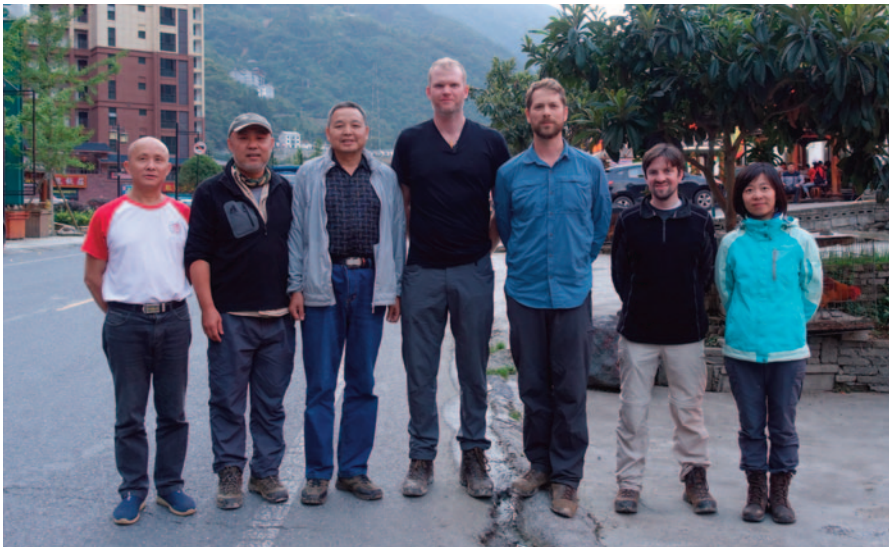
More recently, NACPEC launched a project to compare the genetic diversity of paperbark maple (*Acer griseum*) in cultivation and in the wild. Although it is a widely grown, highly ornamental tree, *A. griseum* is endangered in its native habitat in central China. By comparing the diversity of plants in cultivation across the U.S. and the United Kingdom to those of native populations, it was determined, that nearly all material in cultivation resulted from a single introduction in 1901 by Ernest H. Wilson. Visiting and sampling *A. griseum* populations in China allows for identification of populations that are on protected land (such as national parks or nature preserves) and those existing in unprotected areas. NACPEC is targeting unprotected populations for propagation and working to develop *ex-situ* conservation sites in China, the U.S., and possibly Europe. Our goal is not only to ensure the stability of this species but also to develop a model that can be applied to equally threatened temperate tree species.

Sharing benefits

Since its inception, NACPEC has strived to make our relationships with our Chinese colleagues full partnerships and

(Left to Right) Anthony Aiello, Michael Dosmann, Kang Wang, and Kris Bachtell in Shaanxi, China with a specimen of Acer griseum *sampled for DNA analysis during the 2015 NACPEC expedition (Anthony Aiello)*

to abide by the goals of access and benefit sharing. These partnerships have included collaboration on fieldwork, sharing of germplasm and herbarium collections, staff exchanges, technology transfers, and training of junior staff members. NACPEC's role in the study and conservation of the flora of China is only possible through the support of the Chinese Academy of Sciences, Beijing Botanical Garden, and the dedicated individuals involved. To this end and for the first time, a group of NACPEC's Chinese partners–Beijing Botanical Garden, Chengdu Institute of Biology, and Kunming Institute of Botany–will be visiting the U.S. for NACPEC's first North American expedition to the Appalachian Mountains, further cementing the one-of-a-kind collaboration.



NACPEC 2018 expedition team to western Hubei, China. (Left to Right) Chengyuan Liang, Kang Wang, Daigui Zhang, Andrew Gapinski, Peter Zale, Matt Lobdell, and Jian Quan (Andrew Gapinski)

Germinating seedlings of Magnolia biondii *at the Arnold Arboretum, collected on the 2018 NACPEC expedition to western Hubei (Andrew Gapinski)*

With nearly 30 years of plant exploration and collections development, the loose confederation of gardens known as NACPEC is likely one of the longest-running collaborations of its kind, and one that is committed to documentation and curation of valuable germplasm alongside our Chinese partners. We are working to ensure that these relationships continue long into the future with a new generation of participants and partnerships.

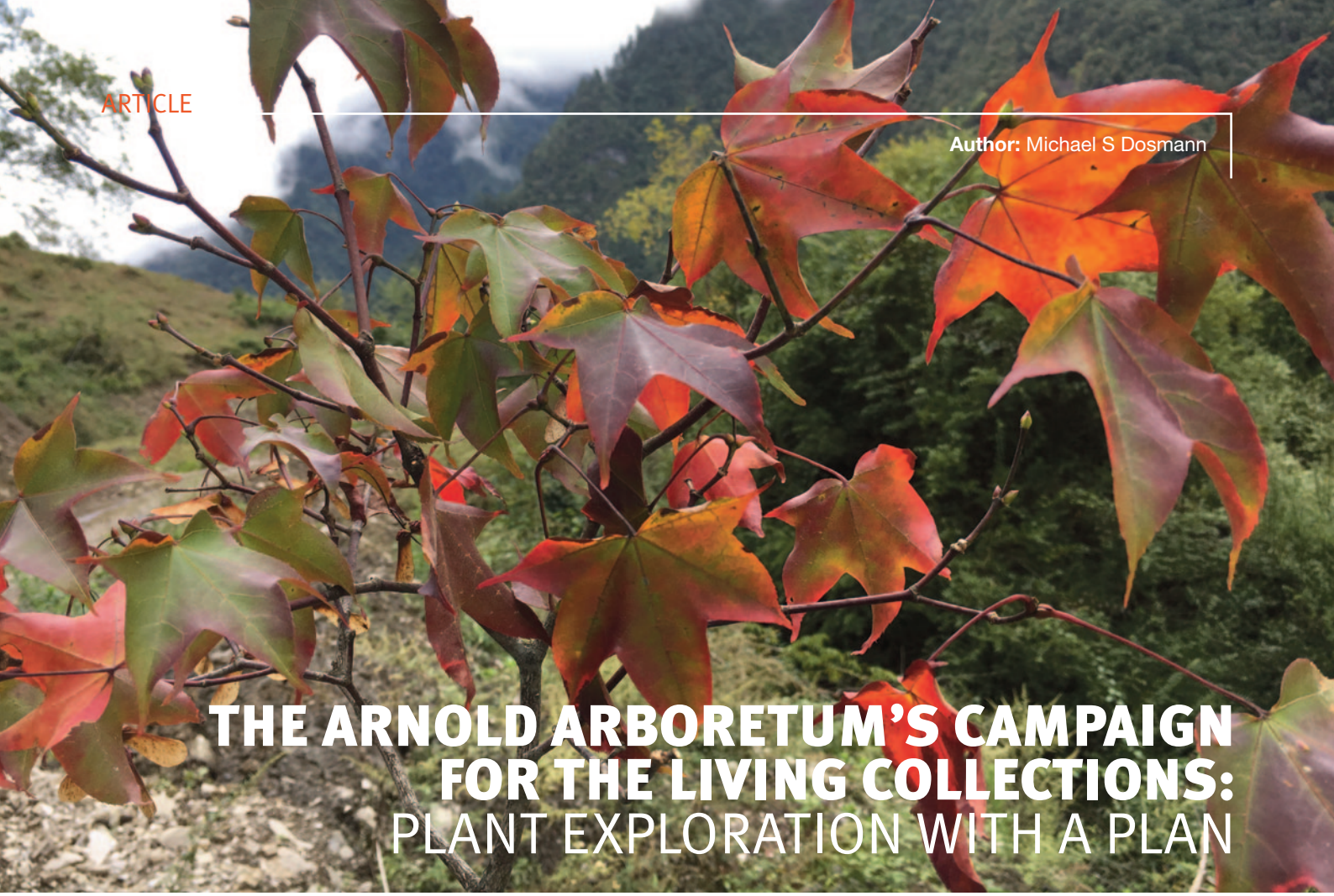
For more information on the history of NACPEC and its expeditions refer to Arnoldia, Volume 68 Number 2 2010, http://arnoldia.arboretum.harvard.edu/issues/247.

Anthony S. Aiello, The Gayle E. Maloney Director of Horticulture and Curator, Morris Arboretum of the University of Pennsylvania

Andrew T. Gapinski, Head of Horticulture, The Arnold Arboretum of Harvard University

Kang Wang, Research Horticulturist and Director of Education, Beijing Botanical Garden

Author: Michael S Dosmann



THE ARNOLD ARBORETUM'S CAMPAIGN FOR THE LIVING COLLECTIONS: PLANT EXPLORATION WITH A PLAN

The Arnold Arboretum has become a leading center for living collections-based scholarship – supported by its strategic approach to collection development.

Conserving biodiversity under threat

Pinkish-tan samaras whirled past me as I stood among the maple trees as they jostled in the spring breeze. Deft hands could snatch the winged seeds as they spun in the air, but it was easier to simply pluck them from the leaves of the rich herbaceous understory below. Who knew that fern fronds made such wonderful seed traps?! It was this past May, and I was in Japan's Nagano Prefecture with Professor Mineaki Aizawa and his graduate student Tatsuhiko Shibano, my friends and colleagues from Utsunomiya University. Our muse was *Acer pycnanthum*, a vulnerable species represented by only 1,500 trees in central Honshu. In cultivation the species is just as uncommon, found in just 33 botanical gardens and arboreta worldwide, according to BGCI's PlantSearch database. While documenting several populations, we collected herbarium vouchers and acquired germplasm (seed) to germinate and integrate not only into Arnold Arboretum's living collection, but other *ex situ* repositories following distribution. This experience epitomizes modern-day plant exploration, underscoring the essential work we all must do to describe and conserve biodiversity under threat, and share the experiences with others.

Thankfully, the past few decades have experienced a resurgence in botanical garden exploration, and this issue of *BGjournal* is replete with wonderful examples from throughout our diverse community. The Arnold Arboretum has a long-established history in plant exploration, having conducted nearly 175 expeditions since our founding in 1872. As a result, our archives, herbarium cabinets, and living collections abound with records of Earth's biodiversity. Presently, our living collections boast some 16,000 temperate trees, shrubs, and vines that represent significant taxonomic diversity as well as documented provenance. Exhibited within a historic landscape designed by Frederic Law Olmsted in collaboration with founding Arboretum director Charles Sprague Sargent, these plants are a haven for visitors, an inspiration for educators, and a bounty for scholars who come from around the world to study them.

Above: The author with an old, coppiced Acer griseum *in China during the 2015 NACPEC expedition to survey the rare species (Tony Aiello)*
Top: When collecting seed in the autumn in temperate regions, an explorer often gets the chance to witness striking leaf colour, as on Acer oliverianum *in Northern Sichuan in 2017 (Michael Dosmann)*

The expedition is a minor investment compared to the efforts of propagation staff to coax seeds (like this Fagus japonica*) to germinate, and then transition the young plants into the permanent collections (Michael Dosmann)*

Curation for research and conservation

Not long after my arrival in 2007, the Arboretum embarked on several collections management and curation initiatives. A new living collections policy solidified priorities, and within a year, collections development needs triggered annual plant collecting expeditions. Gone were the days of broad, general collecting trips where anything bearing fruit was collected (a process sometimes referred to as 'baling hay'). Our new paradigm would focus upon taxa that met specific collections goals. We also took stock of our existing conservation efforts. Abby Meyer (then a Putnam research fellow at the Arnold; now Executive Director of BGCI-US) and I delved into how gardens – and the Arboretum specifically – could better 'curate for conservation'. Among the actions put into play was a firmer consideration of a species' conservation status across levels of curation and collections management, including acquisition.

A bag of pinkish samaras of Acer pycnanthum*, a rare maple in Japan (Michael Dosmann)*

I've long had an interest in the research use of living collections, so around the same time, the Arboretum launched an initiative to better engage scholars. By adopting a customer service approach and an open mind, we have become a leading center for living collections-based scholarship, seeing a rampant expansion and diversification of projects. We now annually shepherd 75 to 100 distinct research projects in the living collections, across a myriad of disciplines, accessing 1,000s of accessions. Such demand underscores the intrinsic value of living organisms, curated and made available for study. For certain, herbarium vouchers are precious, and *ex situ* repositories of seeds essential for preservation and potential restoration. But, a scholar can use neither resource to observe the essence of a living tree at maturity, be inspired by its beauty, or collect the data essential to their research. While fieldwork remains an option (assuming a researcher can access natural populations), there is something special that an *ex situ* repository of living plants provides, particularly when it comes to studying their comparative biology.

The Arboretum's Tiffany Enzenbacher uses a pole pruner (essential when collecting from trees) to collect Quercus stellata *in Arkansas in 2018 (Kea Woodruff)*

The Campaign for the Living Collections

With these key components underway, the Arboretum was able to launch one of its most ambitious endeavors in a century: *The Campaign for the Living Collections*. Kicked off in the autumn of 2015, the Campaign followed several years of strategic planning conducted by Arboretum director William 'Ned' Friedman and I, along with our living collections advisory board (see Friedman *et al*., 2016). We infused the principles outlined above (prioritization, conservation, collections-based scholarship) with a daring vision to simultaneously preserve the Arboretum's rich, singular legacy while also securing an even bolder future. We wanted to enact an ambitious 10-year collections development and acquisitions plan whose impact would resonate for the next century. This meant creating a compelling narrative that not only put forth a thematic agenda but justified our plant exploration efforts with a sense of urgency.

However robust and glossy our themes and vision, we still needed specific goals to create a functional plan. I compiled a list of nearly 400 desiderata to acquire from documented sources, almost exclusively of wild provenance. That number could easily have been twice or even three-times the size. However, the Arboretum no longer abides by a mantra to cultivate everything under the sun, to somehow 'complete' the collection (neither of which is achievable). As a mature collection, with fixed spatial and other resources, we must be prudent in our approach to development. The plan would renew the living collections by considering synoptic breadth, as well as depth. For instance, from a breadth perspective, by adding just a few taxa (even those that are herbaceous or otherwise considered anathema in our traditional arboretum of woody plants), we achieve greater phylogenetic representation. A great example of this is *Opuntia humifusa*. With just one accession of this North American species (which is actually winter hardy in Boston), we can add an entirely new family (Cactaceae) to our holdings.

Adding depth to our collections requires a different approach. Some genera are core in our living collections policy, particularly those eight (*Acer, Carya, Fagus, Forsythia, Ginkgo, Stewartia, Syringa*, and *Tsuga*) that are Nationally Accredited through the Plant Collections Network. These already represent some of the most species-rich and well-documented of their kind in cultivation. However great they may be, we knew that further improvement could make them truly exemplary. For these, the goal was to maximize species diversity within each (requiring the collection of taxa which had previously been a challenge to acquire and grow), and to have each represented by multiple, disparate provenances of wild origin. (Monotypic *Ginkgo* is a special case – our goals here are to append our current collection of wild-origin accessions with those from other populations in nature, as well as a few distinct cultigens.)

From its early days, the Arnold's collection has been used to tell the story of biogeography, particularly that chapter pertaining to Eastern Asia-Eastern North

Fruit and seed cleaning are essential parts of the expeditions, particularly those conducted internationally. Shown are cleaned seeds from China, waiting to be inspected (Michael Dosmann)

Partnering with colleagues leads to successful expeditions and lasting friendships, as experienced by Utsunomiya University's Tatsuhiko Shibano (l) and Mineaki Aizawa (r), and the Arboretum's Steve Schneider in Japan (Michael Dosmann)

America disjuncts. Thus there was another theme, with eight additional priority genera including *Cornus, Magnolia* and *Viburnum*. The Arboretum cannot grow every species within each, but it is possible to maximize phylogenetic breadth within each and have as diverse – from an evolutionary point of view – a collection as possible. Using recent phylogenetic literature, I identified clades or well-supported sections within each genus and selected one or two target species of any clades not currently represented in our collections.

Being in a cold, temperate part of the world limits what we can cultivate, but it doesn't temper our ambitions (some call this 'zone denial'). It was important to target species that heretofore evaded our grasp, just in case we can coax them into cultivation now. This means identifying discrete ecotypes that might enjoy living in Boston, as well as specific microsites within which to plant them. And, in a worst-case scenario, a few species (collected as wild germplasm) are integrated into our bonsai and penjing collection – such specimens yield leaves for molecular analyses as easily as those growing in the permanent collections. Lastly, with one out of every five plant species threatened with extinction, conservation was a prominent layer that factored into our planning.

Seed collections are accompanied by herbarium vouchers to document the species in its wild state. Here, the Arboretum's Kyle Port presses a Larix laricina *collected in Wisconsin (Tiffany Enzenbacher)*

Not only were species selected exclusively for their conservation value, but conservation became a leitmotif when prioritizing taxa in other categories (e.g., selecting rare species over secure ones to represent particular clades). We also know that species we collect today, seemingly secure from threat, may become rare in the coming decades due to the litany of stressors that range from climate change to the introduction of novel pests or pathogens.

With the help of two living collections fellows (Robert Dowell and Terry Huang) to help plan the decade-long endeavor and support from the Franklinia Fondation, the Campaign is well under way. In four years, we have embarked upon 18 expeditions that extend from the Republic of Georgia, China, and Japan, to swaths of the United States from the Pacific Northwest to the Coastal Southeast. These expeditions have included ten members of the Arnold Arboretum staff, providing excellent opportunities for professional and personal growth at all levels. Our collaborations with sister gardens and consortia (including the North America-China Plant Exploration Consortium, profiled in this issue) as well as colleagues from universities, land stewards, and governmental agencies have also contributed to our successes.

To date, we have acquired 200 of our targets, putting us just ahead of the benchmark we set for this stage in the venture. Of course, much work remains, and some species on the list may evade us until the end. But, already, the infusion of new germplasm is transforming the character of our living collections.

It is poignant that the most recent acquisition was *Acer pycnanthum*, a rare maple from Japan whose closest relatives occur in eastern North America. It cuts across so many of the Campaign's themes. Collecting it reminded this plant explorer of *ex situ* conservation's importance, to cultivate species so they may be preserved and studied. And yet, there is something else I realize in earnest. It is the important role that plant explorers must play in inspiring others, inspiring them not only to see plants locally and beyond, but to recognize their value and to join in their advocacy. Our articles and lectures can still show the requisite photos of exotic foods eaten and cliffs scaled, but they should always end with a call-to-arms about conservation, and opportunities for people to engage as part of the solution.

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The Arnold Arboretum of Harvard University
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These Opuntia humifusa *collected from Virginia in 2016 were some of the first Campaign acquisitions to be planted into the living collections (Michael Dosmann)*

Author: Barbara Knickman

SEED COLLECTING EXPERIENCES TO FULFILL TARGET 8 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION

Seed collecting by the Botanical Garden of the University of Vienna

At the Botanical Garden (BG) of the University of Vienna, seed collecting has a long tradition, particularly in the context of the annual production of the *Index Seminum* (Seed List), which contains, besides seeds from garden accessions, also seeds of plants collected in the wild. Since the so called "Pannonische Gruppe" in the garden was created, collecting activities were intensified, as nearly all the plants in this display group have been raised from seeds collected by the staff of the garden in eastern Austria. With the launch of the Global Strategy for Plant Conservation (GSPC) of the Convention on Biological Diversity in 2002, efforts to collect seed to reach Target 8 of the GSPC were started, accompanied by gap analyses and strategic plans of botanic gardens at the Austrian level to reach Target 8 by 2010 (and 2020). Every seed collection is well documented in the garden database and accompanied by voucher specimens. The collections in the wild have been, and are, carried out by experienced gardeners and the collection management teams respectively and all collections are based on collection permits. So, based on long experience, a scientifically sound framework for seed collecting has been established in the garden for many years.

Cooperation with the Millennium Seed Bank

As a member of the European Native Seed Conservation Network (ENSCONET)-Consortium, the call to participate in joint collecting trips in Spain or Slovakia reached the BG of the University of Vienna in 2011. The author took part in the collecting tour through Asturias and Cantabria/Spain. Having returned from that inspiring trip, the experiences under the brilliant leadership of the BG Gijon boosted the initiative to collect for the Millennium Seed Bank (MSB) and to connect this with GSPC Target 8-related activities in Austria.

Above: Agropyron pectiniforme*, under threat of extinction in Austria; seeds are stored at the MSB. From the same collection, plants are now growing at the BG of the University of Vienna*
Top: Pulsatilla alpina *in the Alps, southern Carinthia*

Dipsacus pilosus *in the Danube plains, ready to be collected*

In 2012, cooperation with the MSB started with a joint workshop. Several botanical institutions from Austria and Slovenia participated in the workshop, which comprised one day of theory and three days of fieldwork. Over the following years, collecting for the MSB continued, culminating in a two-year project carried out by the Botanical Garden of the University of Vienna in 2017 / 2018. It was entitled "*Conserving the rare and endangered plants of Austria*". The project aimed to fill gaps in the collections held by the MSB (number of species to be collected: 100, of which 60 new to the MSB), and to further add to the achievement of GSPC Target 8 in Austria.

Collecting in the National Park "Neusiedler See - Seewinkel", Burgenland

Legal framework for collecting seeds in Austria

In Austria, collection permits are needed for the collection of protected species (both national and regional levels of Red Lists). Permits are also needed if collections are carried out in protected areas (nature conservation areas, national parks). In general, the permits have to be requested from the responsible nature conservation authority that is based in the province. Thus, for each species a permit is needed from every province where collection is intended. In the province of Carinthia, the situation is even more diverse: every single district needs to be asked for a permit. A good knowledge of administrative boundaries is therefore needed to create a list of target species and to summarize the report at the end of the collecting season.

There is no standard permit; every permit has its own individual format. The only features they have in common are: the collectors are authorized by name, the collection must not harm the population, and a report has to be submitted at the end of the collecting season. Permits may be valid for different periods: some permits need to be requested every year, for other provinces, there is no time limit at all. In some of the provinces you have to pay for the permit, in others collection for research reasons is free, as long as no species on the FFH-appendices[1] are concerned. Obtaining permits must be done long before fieldwork is carried out, and even months might not provide a long enough time to get a permit.

Further challenges of planning seed collections

The more information that is gathered in advance, the more successful collecting will be – information concerning taxa, local experts, and the practicalities of reaching certain areas.

Searching herbarium databases for the distribution of taxa and the fruiting period is an excellent source of information. Another important, more recent source is a masters thesis with the title "Die Global Strategy for Plant Conservation in Österreich: Überlegungen und Strategien zur Umsetzung des Zieles 8". In the context of this thesis, a survey was carried out throughout institutions in Austria that hold *ex situ* collections. Thus, target taxa (especially endemic taxa and taxa listed on the red list) to be collected were filtered out.

Within the framework of a big institution like a University, planning needs to be done a long time in advance (e.g., to apply for official approval for collecting trips, to reserve the official vehicles …). However, in the "seed collecting-business", short-term decisions are sometimes indispensable (e.g., in response to specific weather conditions).

The perfect collecting team – you need experts!

Seed collection requires a lot of experts. Our team is usually made up of a "lead organizer", taxonomic experts, experienced gardeners and sometimes experts from specific areas. You need taxonomic experts, especially if you want to collect seeds of "difficult" taxa. Absolutely crucial is the knowledge of when the seeds are really ready to be collected. We also need to know if they should be cleaned right away because they might be infested by insects (as is the case for many Fabaceae and many taxa out of the thistle-group). In this case, people who work with seeds every day should be involved – this is where the experienced gardener is needed! A "general secretary" responsible for the documentation (collecting lists, herbarium vouchers, photo-documentation …) is also indispensable in the team. Sometimes some of these tasks can be taken over by the same person.

[1]FFH = Fauna-Flora-Habitat

You also need experts for specific geographical areas. Usually there are local botanists that know "their" area like no one else. Local experts also know other people that might be important to make the collection a success: our local botanist knew of a population of *Pulsatilla* within a public green space, mown by lawn mower on a regular basis. The first year the amount of seeds gathered there was poor. The next year, the local botanist contacted the local authorities and asked to wait with the mowing until the seeds were ripe. He even set up an information board explaining why the area was not mowed. Local experts help to define the right collection period as they are usually out in the field on a very regular basis. Some species are really tricky to collect (like members of the genus *Euphorbia*). You need to come and collect "on the spot"; otherwise, the seeds are off and away.

Last but not least: It is very helpful to ask locals to get permission to drive into areas where driving is usually not allowed. This saves a lot of time, walking and carrying equipment.

Competitors in the collecting business: Beware of grazing animals!

In Austria, especially in alpine areas, this turned out to be of enormous importance: Try to find out where grazing takes place! In the Alps, grazing is a big problem for seed collectors. There are opposing interests between grazing animals and seed collecting botanists. As regards effects of grazing, horses are the worst. Where they have been, the area looks like a golf course! The only species that are left are either indigestible or toxic, e.g., *Gentiana* spp. In one case of frustration about grazing effects, we decided to concentrate on water plants that we had spotted while passing a small alpine lake on our way to another collecting site. Coming back to that lake, we realized that cattle were just swimming through it – thus no seeds there either!

Competitors in the field with surprising skills

The longest list of successful collecting in Carinthia came from an area which is famous for its hay meadows. As there is no water up there (neither ponds nor wells in the area), it is not possible to keep animals there. So there was a long tradition to cut the grass and transport the hay down to the valley. Paradise for seed collectors! Look out for such areas!

In summer 2017 and 2018, we visited the collecting areas twice. This may sound unnecessary, but it was worth the effort: if you want to make sure to find specific species, it is highly recommended to visit the site in flowering time to spot the plants while flowering, and then once again at fruiting time. The result is much more satisfying.

Seeds, data and herbarium vouchers sent to the MSB

Between 2012 and 2018, seeds of more than 400 species were collected by the staff of the Botanical Garden of the University of Vienna for storage at the MSB. Nearly all of them were collected in the wild, with just a few being collected from *ex situ* populations in the garden or donated by private people. Of these, about 180 species are listed in the national Red List of threatened species. So these collections stored at the MSB are considered as a substantial contribution to achieve GSPC Target 8:

At least 75 per cent of threatened plant species in ex situ *collections, preferably in the country of origin, and at least 20 per cent available for recovery and restoration programmes.*

All the collections are documented in the database of the Botanical Garden (JACQ for living collections) and a comprehensive data sheet required by the MSB has been sent to them. There is a photo documentation of seeds (macro-photography, pictures taken through the microscope) and of the plants from which the seeds have been collected. There are usually two herbarium vouchers of every taxon (one stored at the MSB, one at the herbarium WU).

Onosma helvetica *ssp.* austriaca*, threatened with extinction at the national level, growing high above the Danube river; seeds are now stored at the MSB*

The collection activities of 2012 and 2013 were funded by the MSB, as well as those of the years 2017/2018. In the years in between, the Botanical Garden collected at its own expense, but combined the collections for the MSB with the interests of the Garden itself (*Index Seminum*, new species for the Alpinum / Pannonian display group).

Conclusions

Seed collecting is fun! The cooperation with the MSB can be considered as a real win-win-situation. The collections are of international and national importance. We filled the gaps in the MSB collections, and contributed to achieving GSPC Target 8 for Austria. We gained a lot of plant knowledge, concerning the sites where they grow, the way they behave, how to collect seeds and how to deal with them. And we made contact with many other keen seed collectors.

All images credited to Barbara Knickman

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THE COLLECTION POLICY OF THE BALKAN BOTANIC GARDEN OF KROUSSIA: ALMOST 20 YEARS OF DOCUMENTATION AND *EX SITU* CONSERVATION OF THE GREEK FLORA

Collection of wild propagation material in Greece by the BBGK.

Natural context, richness and uniqueness of the Greek flora

Greece has an exceptionally rich flora with >6,620 native taxa (species and subspecies), of which 22% are unique i.e. found nowhere else in the world (Greek endemic taxa); compared to its area, Greece presents the highest degree of endemism in Europe and the Mediterranean region (Dimopoulos *et al*., 2013, 2016). Although small in size, Greece has a complex topography and one of the longest coastlines of Europe (>15,000 km) due to thousands of islands. More than 40% of the country is above 500m, with hundreds of high mountains and there are over 400 wetlands. Climatic conditions range from subtropical to subalpine in different areas (Dimopoulos *et al*., 2013).

The national territory can be divided into 13 different floristic regions, mostly defined by natural geographic features such as archipelagos, rivers, mountain ranges and lowland areas between mountains. In this context, effective conservation efforts are needed as many species are under increasing threat/risk due to climate change, fires, land reclamation, over-grazing, changes in land uses and management practices, urban and tourist development (Krigas *et al*., 2014).

The policy of the Balkan Botanic Garden of Kroussia and current outcomes

The Balkan Botanic Garden of Kroussia (BBGK) has formulated a clear conservation strategy with specific policies (Krigas & Maloupa, 2008) and has adopted the mission to "*support research, maintenance, propagation, evaluation, conservation and sustainable use of the native plants of Greece and the Balkans, combined with raising the environmental awareness of the public*" (Maloupa *et al*., 2008).

Single-island local endemics of Crete, southern Greece - Tulipa doerfleri *(Ghious Kampos)*

The BBGK is situated at two different localities in northern Greece. The first one is the Garden of the Senses with an extended conservation area (31 ha) within a traditionally managed deciduous oak forest at 600 m a.s.l., close to Pontokerasia village (Prefecture of Kilkis); this area is close to the borders with Northern Macedonia and Bulgaria, lying between two important conservation sites of the Natura 2000 network (GR1260001, GR1230002). The second area includes the basic research infrastructure (well-equipped nurseries, mother plantations, seed bank, *in vitro* facilities and laboratories) as well as a smaller botanic garden (Garden of Environmental Awareness, 10 ha), all located at sea level in Thermi, metropolitan Thessaloniki. The first site is dedicated to the combined *ex situ* and *in situ* conservation of native plants ('*Combined* ex situ *and* in situ' *policy*) and the second one focuses on the *ex situ* conservation of prioritised native plants of Greece and the Balkans; both facilitate the raising of environmental awareness of citizens and schools ('*Environmental awareness in native plants*' policy).

The BBGK focuses on the conservation and the sustainable use of the native plants of Greece and the Balkans ('*Only native plants*' policy), leaving aside exotic ornamental plants. In this way, all plant displays in BBGK (n=40) have been created using plant material originating in the wild that has been sustainably managed and put through a 'domestication procedure' in the man-made environment of the botanic gardens. In the first place, all plant material is collected under a special permit from the Greek Ministry of Environment and Energy, which is issued upon request on an annual basis, and reports are given back to the national authorities regarding the plant material collected and maintained. Prior to collections in the wild, the regional forest agencies are informed and they report back to the Greek ministry. With this permit, the BBGK's scientific staff is able to collect plant material for *ex situ* conservation from threatened or common species, even from protected areas, Natura 2000 sites and nature reserves. The collected plant material is associated with explicit information i.e. geographical coordinates and site description (specific location, region, prefecture and country). No accession number is given to plant collections with poor documentation. Habitat information is also documented *in situ* for each accession collected (substrate, soil type, forest zone, habitat type, slope, altitude). Additionally, in many cases GIS is used to unveil the natural species-specific ecological preferences of conservation priority plants (Krigas *et al*., 2012). This procedure represents the BBGK's '*explicit plant documentation*' policy.

To document the genetic identity of different accession numbers and to facilitate identification of the uniqueness of specimens, possible sustainable exploitation of selected accessions, accurate plant documentation, traceability, access and benefit sharing policies, the '*DNA barcoding policy*' is applied with selected molecular markers (Tsoktouridis *et al*., 2009, 2019).

To date, more than 130 plant collecting expeditions have been organized in all phytogeographical regions of Greece and over 2,800 accessions of propagation material (seeds, bulbs, rhizomes, cuttings, living individuals) have been collected from the wild. This corresponds to 1,470 taxa (> 22% of the Greek flora).

Not the entire Greek and Balkan native flora is a key priority of BBGK; taking into account the *International Agenda of Botanic Gardens in Conservation* (Wyse-Jackson & Sutherland, 2000), five principal plant categories have been prioritised for action ('*Important Plant Species* (IPS)' policy, (Krigas *et al*. 2012)); these are:

(1) Greek endemic plants (range-restricted) such as single-island or single-mountain or single-area endemics and Greek regional (restricted to few phytogeographical regions of Greece) or national endemics (restricted to several regions of Greece);

(2) Balkan endemics of narrow distribution (range-restricted), including native plants occurring around the boundaries of Greece with neighbouring Balkan countries and/or Turkey;

(3) Balkan (sub-) endemics, including taxa found exclusively in the Balkan countries and/or extending to western Turkey and/or parts of Italy;

(4) Other rare plant taxa found in Greece, including native plant species of wider distribution than (i), (ii) or (iv), with one or only a few scattered and/or isolated populations nationally;

(5) Plants with aromatic-medicinal properties, agro-alimentary interest, ornamental-floricultural or breeding potential (e.g. crop wild relatives), or socioeconomic value ('*Evaluation for sustainable exploitation*' policy).

The BBGK prioritises the propagation and *ex situ* conservation of the important plant species ('*IPS first*' policy) and several species-specific propagation protocols have been produced (e.g. Gkika *et al*., 2013; Grigoriadou *et al*., 2011, 2014; Krigas *et al*., 2010; Sarropoulou *et al*., 2018). During the last 15 years, about 112 Greek endemics have been successfully propagated (Krigas *et al*., 2016), but progressively during the last years efforts have been intensified and more than 300 taxa (20% of all Greek endemics) are currently found under *ex situ* conservation.

Collection of wild propagation material from the high altitudes of Mt Voras, northern Greece

Any plant material shared with other institutions for research purposes, citizens or stakeholders is provided with a Material Transfer Agreement and passport data with International Plant Exchange Network (IPEN) numbering and in compliance with the EU Regulation 511/2014 implementing the Nagoya Protocol and the Greek National Law 4617, Issue A' 88/10.6.2019 ('Access and benefit sharing' policy).

After collection, the selected plant material is subsequently transferred to the Balkan Botanic Garden for propagation and ex situ *conservation*

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INVESTIGATION AND COLLECTION OF *ROSA CHINENSIS* VAR. *SPONTANEA* IN THE PART DISTRICT OF NORTHERN SICHUAN

Introduction

China rose (*Rosa chinensis* Jacq.), which was introduced into Europe in the late 18th century, is one of the important parents of modern roses. *Rosa chinensis* var. *spontanea* was first found by the Western plant collector Dr. Augustine Henry (1857-1930) near a gorge "San-yu-tung" in Yichang, Hubei Province of China in 1902. In 1914, *Rosa chinensis* var. *spontanea* was described as a variety. Although in the early 20th century *Rosa chinensis* var. *spontanea* was collected many times, there was then a significant gap in collecting until 1983, when the Japanese botanist Mikinori Ogisu found and collected it again in Leibo in Southwest Sichuan at the altitude of 1,700m. Its discovery aroused the attention of many botanists and many research institutes began to collect and conserve it as an important species. However, investigation and collection of *Rosa chinensis* var. *spontanea* in the wild in China, was still limited. Further investigation of this species will be of a great importance, providing more accurate information on the distribution of this species in the wild, and allowing a better understanding of the current survival status of the species.

Collection times and places:

The first collecting mission was organized in mid-September 2012, in Sichuan Province's Pingwu and Beichuan Counties; the second was in late April 2014, in Tongjiang Village, Nanba Town of Pingwu County. The third was in early April 2015, in Maowan, Nanba Town of Pingwu County (located 36 kilometers away in the southeast of Pingwu County) (see satellite positioning picture, Fig. 1). The main collection goal was pollen.

Specimen collection methods:

Two- to three-year old robust plants are selected, and data, including GPS location coordinates, growth conditions, locations, habitats and associated plants are all recorded. The plants are tagged and photographed. The branches above the ground are then cut and bound and placed in pre-prepared packaging. The sampled branches, leaves and prickle traits are all recorded and photographed. Attention is paid to the ripe hips during the autumn collection.

Above: Leaf morphology of Rosa chinensis *var.* spontanea
Left: Fig. 1: the Survey route in 2015

The habitat of Rosa chinensis *var.* spontanea

If hips are present, they are collected and placed in closed and labelled plastic bags. The tender leaves on the branches are also picked and dried in bags containing silica gel.

Trimmed down branches with good lignification are selected, the leaves removed and they are cut into small sections, and bound up with moisturizing bandage material. After that, they are tagged and brought back for cutting propagation. Collecting missions that are carried out during the period of flowering allow flowering and growth to be photographed and recorded, and pollen to be collected from different collection locations.

Survey results

During the survey in 2012, *Rosa chinensis* var. *spontanea* was found mainly in the mountains along the river of Nanba Town, Pingwu County, Sichuan at an altitude of 500-1,000m. It likes calcareous soil, which is as described by Martyn Rix (2005). The habitats for the plants collected in the survey were lower level dense woods, hillsides or cliffs with plenty of light. Most of the plants were upright with sprawling branches and plant height of about 2-4m. This first collection was carried out in September, therefore the flowers were not seen. But on some older plants, there were rose hips which had become yellow, including seeds of different maturity.

To further determine the identity of the species collected, in April 2014, we entered Nanba Town of Pingwu County again for a second survey. It was already at the end of flowering season at that time. So once again, we carried out the survey in 2015 and collected pollen of *Rosa chinensis* var.*spontanea* to further investigate its intraspecific diversity. Indeed, as described in the literature, the wild *Rosa chinensis* var. *spontanea* often has plants with different flower colors with significant differences between one another. It is worth noting that the distribution of *Rosa chinensis* var. *spontanea* is not concentrated in one place, but it is found growing together with other local species. In the distribution area of *Rosa chinensis* var. *spontanea*, we also found two other widely-distributed rose species: *Rosa rubus* and *Rosa cymosa*.

Introduction, cultivation and breeding

Rosa chinensis var.*spontanea* is easy to cultivate and can be propagated by cuttings. It thrives near a warm wall or in an open garden. Introduced in 2012, it lived through the winter in 2013 in the greenhouse, and then it was planted in an open field the next year. With conventional earthing and film mulching, the plant was protected to live through the winter. And finally in 2015, the 3rd year after its introduction, it bloomed and bore hips. Compared with the introduction region, the difference of flowering phase is 20-30 days. In the introduction region, its flowering phase starts in early April while in Beijing, the flowering stage starts in late April. According to the literature, flowers of *Rosa chinensis* var. *spontanea* usually grow from branches at least 2 years old, so it is important that it is not pruned until it has flowered or grown for at least three years. According to the tests and observation after the introduction, indeed there were no buds on the 1st year or two-year branches of *Rosa chinensis* var. *spontanea*.

Different flower forms are found in the wild.

After being kept in the deep freeze for 6 months, the seeds may lose their dormancy and germinate. It is not as reported by Rix (2005) that the seeds need 3 years or more to germinate. It is noteworthy that the survival percent of seed propagation is about 30%, while that of cuttings can be up to 80%. It can be seen that the flower color of this species is variable. This has been confirmed and proved by the Japanese botanist Mikinori Ogisu through his multiple acquisitions. During the introduction of collections from Pingwu County in 2012, two types of sample plants were obtained. The flowering of these are pale pink and white to dark pink.

Plant morphology of Rosa chinensis *var.* spontanea

Discussion and prospects

Rosa chinensis var. *spontanea*, as a native species, was found in China more than a hundred years ago. In the last decade, people have become increasingly interested in it and some botanical gardens and research institutes have begun to search for the species in the wild. Domestic and foreign scholars have used it for some valuable research work, such as analysis and identification of the flavor components of roses, analysis of genetic relationships between different varieties, China tea rose's hybrid origin, etc. However, few people focus on its living conditions, and the status of the wild populations is still not clear. With the increasing natural changes and human intervention, a survey of it's natural populations is urgently needed. The site visits and introduction of *Rosa chinensis* var. *spontanea* in Beichuan area provides some information on the current distribution of this species, as well as laying the foundation for carrying out further basic rose research. There is a need to further expand the survey areas around Hubei and other southwest provinces where this species has been collected. In this way, its habitat, conservation status, intraspecific diversity and other aspects can be evaluated scientifically and conservation strategies and plans developed, for the protection of this endemic species.

Left: Fruit of Rosa chinensis *var.* spontanea

White - dark pink flowers of Rosa chinensis *var.* spontanea *introduced form Beichuan, Sichuan in April 2015*

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PLANT COLLECTING FOR CONSERVATION IN ETHIOPIA

The Gullele Botanic Garden has a vision of developing into a world-class botanic garden serving the purposes of conservation, research, education and ecotourism

Environmental education for sustainable development

Introduction

The forest in Ethiopia is currently decreasing at an alarming rate, mainly due to unprecedented human population growth, which puts a great demand on natural resources. This is compounded by climate change and associated problems, including drought, erratic rainfall and soil erosion, to such an extent that the possibility of living sustainably in the future is under threat.

To address these issues, and to make some contribution towards addressing the need for protection and conservation of natural resources, Gullele Botanic Garden was established with a focus on collection, conservation, research, display, education and nature-based tourism. Gullele Botanic Garden was established as a joint venture between Addis Ababa University and Addis Ababa City Administration in 2009. It covers about 705 hectares of land in the North Western part of Addis Ababa (the capital city of Ethiopia) and is situated at an elevation range of 2,600 to 3,000 meters. Its elevation range makes it uniquely able to grow plants from all agro-ecological zones of the country and therefore create a miniature Ethiopia.

The Gullele Botanic Garden is an infant institution compared with other botanic gardens in the USA and Europe but it has a vision of developing into a world-class botanic garden serving the purposes of Conservation, Research, Education and Ecotourism.

Conservation

Enhanced biodiversity conservation can be achieved through offering a refuge and better security for threatened species and developing model ecosystems that support genetic and species diversity.

Research

The garden can conduct research on different plant species, species interactions ecological dynamics, vegetation-climate change relationships and assist in local, regional and national socio-economic development.

Recreation and ecotourism

This can be achieved by developing nature-based, world-class model eco-friendly recreational facilities that constitute one of the tourist attractions of our capital city

Education

The garden's programme of environmental education for sustainable development pays special attention to nature as well as providing training on sustainable gardening, horticulture, floriculture, urban agriculture and urban forestry.

Plant collecting at Gullele Botanic Garden

Collaborators and stakeholders during collection

Gullele Botanic Garden does not need any special permission to collect in Ethiopia as it is mandated to collect plant diversity across the country. However, the contribution of certain stakeholders plays an important role in plant collection as letters of support from these people can help to ensure access to various collection sites where the garden has a focus.

According to the current political administration in Ethiopia, structure and power is decentralized and the administrative regions are delegated to make certain decisions on their own. Thus, collecting permission is required at different levels including from the lower administrative structures such as Woreda and Kebele Administrations.

However, even if permission is granted by the relevant administrative body, local people may still stop the collectors and/or the researchers if they are concerned about the possible misappropriation of the resources under collection. So, in addition to the official letters from the relevant administration and/or any other concerned body, it is important to ensure the consent of the local community. They need to know about the objectives of the collection trip in order to give their support and to be prepared to act as local guides.

The following have been identified as the main collaborators and stakeholders to consider when planning a collection trip (but not limited to this):

- The Federal Democratic Republic of Ethiopia, Ethiopian Biodiversity institute (EBI);
- The Federal Democratic Republic of Ethiopia, Environment, Forest and Climate change Commission;
- Addis Ababa Environmental Protection and Green Development Agency;
- Addis Ababa City Government River Basins and Green areas Development and Administration Agency;
- Ethiopian, Forest Research Center;
- Addis Ababa University, College of Natural Science, Department of Plant Biology and Biodiversity Development;
- Ethiopian Wildlife Conservation Authority;

Enhanced biodiversity conservation for prioritized species

- Regional Environmental Authorities (Amhara, Oromia and others);
- Local communities.

Team composition and trip schedule

Before field collecting starts, desk research is carried out to answer the following questions:

- Is the plant on our priority list?
- Where and when will the required plant material be available (with reference to the Flora of Ethiopia and Eritrea (FEE) and using label information on the plant material in the Addis Ababa University National Herbarium and other supporting materials)?
- What is the security situation in the areas where the proposed plant is to be collected?
- Are the species available in the Ethiopian Biodiversity Institute collections (e.g. seed bank) to avoid duplicated effort?

Nature based ecotourism and recreation in the garden

Once these and other issues have been double-checked, the actual field trip will be planned.

The collecting team is mainly composed of botanists and horticulturists. Sometimes forester and natural resource management experts will join the team when needed.

In order to access the plant material and the related knowledge, the team must hire local people as field guides. If local people are not included, the team will be considered as outsiders and will not be allowed to access the plant material. Sometimes the team may even be forced to leave that area.

The timing of collecting trips is dependent on the type of plant material to be collected (seed, herbarium specimen, live specimen, succulent); weather conditions; proposed collection area and other factors. For accessing seedlings and young plants, collecting trips are mainly scheduled during the rainy season from June to September, while the dry season is preferable for collecting the seeds, as most of the plants start fruiting after the rainy season. However, due to its varied topography, Ethiopia has very varied climatic and weather conditions – and these can also limit the trip schedule.

Collecting priorities

According to the Flora of Ethiopia and Eritrea, Ethiopia has about 6,500 vascular plant species distributed in various part of the country, ranging from 4,620 meters above sea level to 148 meters below sea level represented by Ras Dashen and the Dallol depression respectively. As it is not possible to collect all these species in a short period of time, the garden gives priority to indigenous, endemic, medicinal, endangered and economically important species.

Amongst these, the garden gives particular priority to those species which are listed as Critically Endangered and Endangered on the IUCN Red List.

Materials to be collected and the trend to exchange plant material

In addition to developing various thematic gardens based on plant use category and evolutionary relationships, Gullele Botanic Garden has a plan to establish both a herbarium and a seed bank. Hence, materials to be collected include seedlings, herbarium materials and seeds. In order to conduct mass propagation in the nursery, the garden mainly gives priority to collecting seed instead of seedlings (living materials) – particularly for those plant species with very few individuals. On the other hand, for those species without seed or with seed that is difficult to collect, seedlings and other plants materials will be collected from the wild and used to establish propagation protocols other than sexual propagation.

Any form of the collected plant material can be transferred to other parties, such as researchers, research institutions and universities for the purpose of research, education, display and conservation either by signing an MoU or official letter to approve the consent of the two parties.

Since its establishment, the garden has achieved numerous successes in collecting plants from various parts of the country, and has developed nurseries and thematic gardens where prioritized plants are grown based on their use category and evolutionary relationships.

Facilities for conducting research on different plant species

Major challenges during collection

- **Lack of local contacts and continuity:** The team from the garden have visited many parts of the country – but only for short periods, so they have been unable to build local contacts and are often seen as 'strangers' by the local community. This has limited cooperation by local people, with a reluctance to share information about local plants – a particular problem if none of the team speaks the local language.

- **Misunderstanding of interests:** As the current political system is ethnically based, the local people and the corresponding political leaders and administrators may question why the team wants to visit certain areas, undermining the confidence of the collecting team.

- **Limitation of equipment:** The lack of certain equipment (e.g. tree climbing gear, suitable vehicles, drier for herbarium specimens…) can limit the quality and quantity of material collected.

- **Development of collections database:** The garden is still in the process of establishing a dedicated database to fully document and manage data and associated information on its collections.

- **Lack of national collection policy:** Ethiopia has no policy in place for the conservation of threatened plant species, especially those with very few individuals remaining in the wild. Gullele Botanic Garden has a plan to develop its own collection policy or protocol.

- **Lack of capacity:** The garden staff require further training on how to collect plant materials, accessioning, labeling, record keeping and green house management.

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Different thematic areas of the garden: A= Juniperus dominant vegetation, B = succulent garden C = wetland

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C	Institution Member (budget USD 1,500,000 - 2,250,000)	£ 675	$ 900	€ 800
B	Institution Member (budget more than USD 2,250,000)	£ 1,250	$ 1,500	€ 1,375
Patron	Patron Garden Institutional Membership	£ 6,000	$ 7,750	€ 6,750

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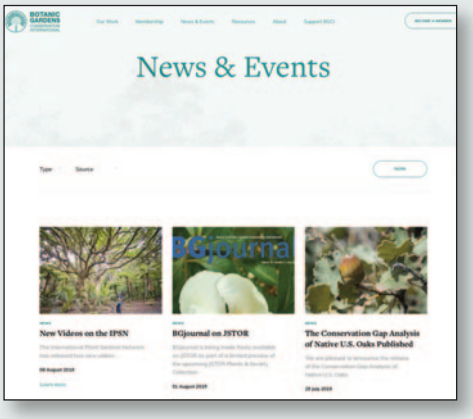
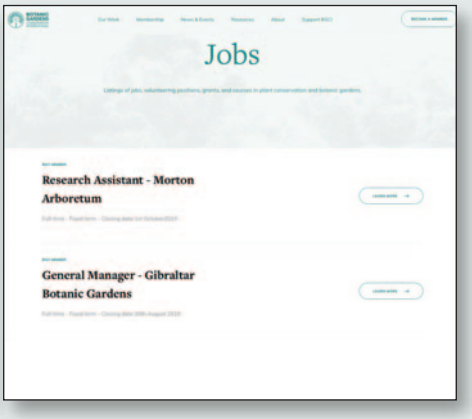
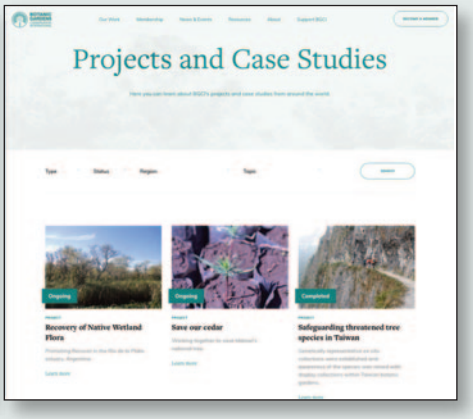
The New BGCI Website: www.bgci.org

In June, BGCI launched a revamped and upgraded website to better advocate BGCI's Members and all of our work in plant conservation at botanic gardens.

BGCI Members and supporters can now access our incredible resources in our updated Tools and Resources Centre.







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